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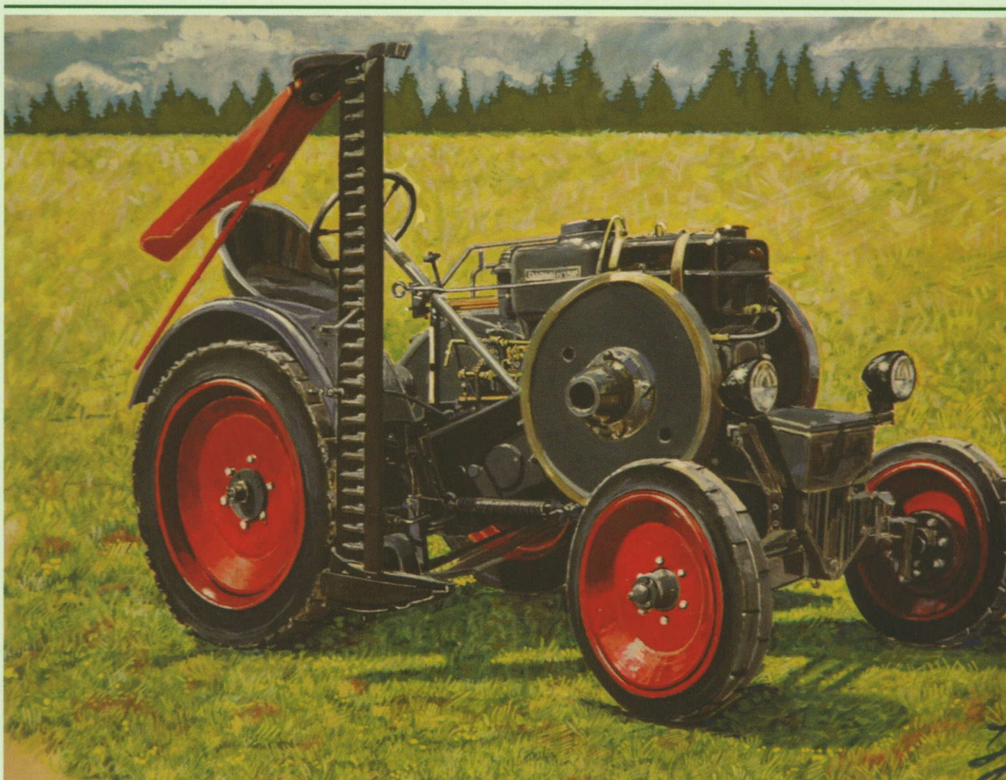
35. INTERNATIONAL SYMPOSIUM ON
AGRICULTURAL ENGINEERING

Actual Tasks on Agricultural Engineering



OPATIJA, CROATIA, 19. - 23. FEBRUARY 2007

AGRONOMSKI FAKULTET SVEUČILIŠTA U ZAGREBU
ZAVOD ZA MEHANIZACIJU POLJOPRIVREDE
POLJOPRIVREDNI FAKULTET SVEUČILIŠTA U OSIJEKU
FAKULTETA ZA KMETIJSTVO UNIVERZE V MARIBORU
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AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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PRIČA O TRAKTORU S NASLOVNICE

FENDT DIESELROSS F 18

Povijest Fendt-a, poznatog proizvođača traktora, započela je malim traktorom jednostavne konstrukcije. Prema nekim poznavateljima povijesnog razvoja traktora, prvi primjerak traktora Fendt Dieselross ujedno je prvi mali traktor s dizelskim motorom u Europi. Počeci bavarske tvornice Fendt, danas jedne od vodećih na području traktorske tehnike, seže u kraj dvadesetih godina prošlog stoljeća i bili su vrlo skromni.

Prvi fendtov proizvod bila je motorna kosilica izrađena u kovačnici obitelji Fendt 1928. godine. Motorna kosilica s benzinskim motorom poslužila je 1930. godine kao osnova za prvi fendtov traktor, oblikom sličan kosilici. Osim za spremanje sijena, traktor je korišten za obradu tla, transport i pogon stacionarnih strojeva. Konstrukcija traktora bila je vrlo jednostavna, na željezni okvir prigrađen je stabilni dizelski Deutz motor snage 9 KS sa sustavom hlađenja otparivanjem vode. Od 1936. godine ugrađivan je snažniji deutzov motor od 12 KS. Pogon s motora na jednostavni mjenjač ostvaren je lančanim prijenosom. Traktor je bio namijenjen malim njemačkim gospodarstvima kojima su bili nedostupni veći i tehnički dorađeniji traktori na tadašnjem tržištu. Koncepcijski jednak fendtovom traktoru bio je i traktor njemačkog proizvođača Kramera tridesetih godina prošlog stoljeća, te austrijskog Lindnera krajem četrdesetih.

Tijekom 1933. godine pet je radnika u fendtovoj radionici proizvelo tri traktora. Dvije godine kasnije iz fendtove tvornice već je izašao stoti traktor. Godine 1936. tvrtka seli na današnju lokaciju u Marktsoberdorfu i od tada možemo govoriti o tvornici traktora Fendt. Već slijedeće godine počinje proizvodnja modela F 18, opremljenog pneumaticima i Deutz motorom snage 16 KS. Tisućiti Dieselross proizvodnu je traku napustio 1938. godine.

Godine 1940. predstavljen je model s motorom s dva cilindra i taj je traktor predstavljao osnovu za modele koji su se proizvodili četrdesetih i početkom pedesetih godina prošlog stoljeća. Te je godine proizvodna već narasla na 1000 traktora godišnje. Zbog racioniranog goriva za civilnu upotrebu (velike potrebe njemačke vojske za tekućim gorivima) započela je proizvodnja modificiranih Dieselross motora na drvni plin, te je od 1942. do 1946. godine proizvedeno 1497 spomenutih primjeraka. Na te je traktore bio prigrađen posebni kotao za proizvodnju drvnoga plina, izrađen od željeza i obložen šamotom na mjestu gdje su se razvijale visoke temperature. U motoru je drvni plin sagorijevao jednako kao benzinsko ili dizelsko gorivo. Snaga motora smanjila se oko 20-30%, a masa traktora znatno povećala. Drvni je plin bio problematičan zbog toga što se u motoru skupljala čađa pa ga je često bilo potrebno čistiti.

U teškim poslijeratnim vremenima Fendt je 1949. ponudio više modela Dieselrossa s motorima snage 15-25 KS. Na slici je model F 18 koji se proizvodio od 1937. do 1942. godine i s njime se Fendt uvrstio među prave proizvođače traktora (proizvedeno je ukupno 3212 primjeraka modela F 18). Jednocilindrični deutzov dizel motor zapremine 1797 cm^3 razvijao je 16 KS pri 1400 min^{-1}, kratkotrajno čak 18 KS. Mjenjač je imao četiri stupnja prijenosa za vožnju naprijed i jedan nazad. Najveća brzina kretanja iznosila je 15 km/h, a masa traktora 1500 kg. Za razliku od prvih fendtovih traktora bez električne instalacije, F 18 je imao dinamo, električna svjetla i elektropokretač.

Tekst: Viktor Jejčič Slika: Dušan Jejčič

PREDGOVOR - PREFACE

Sustavnim radom organizacijskog tima, a uz stalnu potporu kolega iz struke, strukovnih udruga (HUPT i HAD), trgovačkih kuća-predstavnika svjetskih proizvođača poljoprivrednih strojeva i opreme, Ministarstva znanosti obrazovanja i športa i Ministarstva poljoprivrede, šumarstva i vodnog gospodarstva, te međunarodnih udruga Poljoprivredne tehnike (EurAgEng, CIGR, AAAE i AAESEE) dospjeli smo do 35. Simpozija "Aktualni zadaci mehanizacije poljoprivrede". Tijekom proteklih godina obišli smo slijedeće gradove, domaćine simpozija: Zagreb ('70, '82), Zadar ('75, '87), Poreč ('77, '81), Split ('78, '85), Opatija ('79, '83, '84, '88, '90, '94 – '07), Šibenik ('80), Rovinj ('86), Trogir ('89), Stubičke toplice ('92) Pula ('91, '93) . Dakle, najveći broj godina, ukupno 18, grad domaćin bila je Opatija. Ukupan broj radova od 1.425, varirao je 20 – 83, prosječno 44.5 radova, a ukupan broj stranica svih Zbornika je 13.432 s variranjem 58 – 900, prosječno 419.8. Ovaj 35. po redu Zbornik sadrži 52 rada sa slijedećim učešćem: Estonija, Litva, Portugal i Turska (1), Bugarska i Grčka (2), Italija, Mađarska, N.R. Kina i Njemačka (3), Bosna – Hercegovina i Srbija (4), Slovenija (7), Hrvatska (8) Rumunjska (11). Zahvaljujemo se svim sponzorima koji su svojom potporom omogućili održavanje ovakvog skupa, autorima referata, kao i svim učesnicima na interesu. Posebno se zahvaljujemo Ministarstvu znanosti i tehnologije Republike Hrvatske na stalnoj potpori. Svim sudionicima želimo ugodan boravak u Opatiji za vrijeme održavanja Simpozija.

Continuous work of organizing team with long-term support of our colleagues, our associations (CAES, CSA), commercial representatives of the world famous agricultural machinery and equipment producers, Ministry of sciences, education and sport, Ministry of agriculture, forestry and water management and finally world known associations for agricultural engineering (EurAgEng, CIGR, AAAE and AAESEE) has brought us to the 35th symposium "Actual tasks on Agricultural Engineering". During all that years host towns were as follows: Zagreb ('70, '82), Zadar ('75, '87), Poreč ('77, '81), Split ('78, '85), Opatija ('79, '83, '84, '88, '90, '94 – '07), Šibenik ('80), Rovinj ('86), Trogir ('89), Stubičke toplice ('92) Pula ('91, '93) . So, Opatija was our favourite town with 18 years in total. Total number of published papers was 1,425 with variations 20 to 83 per proceedings, in average 44.5 papers. Total number of pages was 13,432 with variations of 58 to 900 per proceedings, in average 419.8 pages. This proceedings contains 52 papers among them are: Estonia, Lithuania, Portugal and Turkey with 1, Bulgaria and Greece with 2, Italy, Hungary, P.R. China and Germany with 3, Bosnia – Herzegovina and Serbia with 4, Slovenia with 7, Croatia with 8 and Romania with 11 papers. We would like to thank authors, reviewers, participants and especially sponsors for their contribution to organise the symposium. We especially emphasize sponsoring of Ministry of Sciences education and sport of Republic of Croatia who support us for 13 years. Finally we wish all participants, our colleagues pleasant time and company during symposium.

Chief Editor

Zagreb, siječanj-January 2007. Prof.dr. Silvio Košutić

SADRŽAJ – CONTENTS

35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Review paper

AGRICULTURAL ENGINEERING CURRICULA: PAST, PRESENT AND FUTURE

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SUMMARY

This paper chronologically unveiled events and principal ideas of the creation of academic harmonisation, in view of the Unique Market in order to facilitate the free exchange of University graduates in Agriculture and Agricultural Engineering throughout the EC, continuing with present situation and marking possible future.

***Key words**: University curricula, Bologna Declaration, University Studies of Agricultural Engineering-USAEE, Agricultural engineering, European Federation of National Associations of Engineers-FEANI*

AGRICULTURAL ENGINEERING CURRICULA: THE PAST

At the end of 1989 the International Commission of Agricultural Engineering (CIGR), under the chairmanship of Prof. Giuseppe Pellizzi, with the cooperation of the former Italian Association of Agricultural Engineering (AIGR, now AIIA) and the University of Milan, sponsored a project designed to compare University curricula in Agricultural Engineering in the 12 Countries of the former European Community. The aim of this project was to facilitate the creation of academic harmonisation, in view of the Unique Market beginning in 1993 and in order to facilitate the free exchange of University graduates in Agriculture and Agricultural Engineering throughout the EC.

Moreover, other Countries (e.g.: Japan, U.S.A.) felt the need of updating their academic curricula, so that they would better correspond to market demands and expected developments in the agro-industrial sector.

This feeling determined the following events: two study seminars, attended by representatives of the various Countries, were held at Gargnano (Italy) in May 1991 and at

Silsoe (UK) in May 1992; several papers were presented at conferences or published in Italian or international journals [4, 5, 7, 8, 9, 11]; two Working Groups were created, of which one, called W.G. 1, within CIGR, and the other, called S.I.G. 12 "Education and Communication", within the European Association of Agricultural Engineers (EurAgEng).

From 1990 to 1994 various surveys were carried out in several Countries, in order to investigate the organisation of the University structures and academic degrees, with special regard to Agricultural Engineering degree courses or specialisations [1, 2, 3, 6].

From 1996 to 1999 the previous surveys were updated and extended to other Countries and Universities [10, 12].

In June 2000 the results of the last survey about the courses of Agricultural Engineering degree study programmes were presented in the report "The University Structure and Curricula on Agricultural Engineering. An overview of 36 Countries", issued by FAO; this work was presented in July 2000, during the EurAgEng Conference held in Warwick (UK) [13].

In 2001 the Working Package 3 of AFANet (EU SOCRATES Thematic Network for Agriculture, Forestry, Aquaculture and the Environment) issued the report "Towards a European Standard for Agricultural Engineering Curricula", which outlines the basis for four European core curricula:

- a 5-year diploma degree, more scientifically oriented;
- a 3-year Bachelor degree, more application-oriented;
- a Master's degree, corresponding to the long term 5-year diploma degree;
- a Master's degree, corresponding to the short term 3-year Bachelor degree.

Further, in this report an accreditation system is proposed and the European University faculties and departments offering diplomas in Agricultural Engineering, in Agriculture with specialisation in Agricultural Engineering and in Engineering (agricultural engineering courses) are, respectively, listed [14].

Sadly the beginning of the third millennium brings a crisis in the Agricultural Engineering sector. Several Institutes, Departments and Research Centres of Agricultural Engineering were closed or had their staff significantly reduced.

In the mean time, with the advent of new topics (e.g. Precision Agriculture, Robotics, Information Systems for Agriculture) in several Universities the Department of Agricultural Engineering and the related degree study programmes changed their name, course contents and research topics towards Applied Biology. This trend also implied the progressive substitution of the name "Agricultural Engineering" with "Bio-Engineering" or "Biosystems Engineering". In order to take into account this trend, since 2002 EurAgEng changed the name of its official journal from "Journal of Agricultural Engineering Research" into "Biosystems Engineering".

In Agricultural Engineering study programmes the learning outcomes (knowledge, competencies and skills) of a lot of courses are integrated among each other, so that graduates can:

- develop new technologies and materials, in order to improve the quality and reliability of agricultural products;
- plan field operations with high energy efficiency;
- control electronically agricultural productions;
- design environmental structures and systems;
- develop efficient technologies for transforming agricultural products.

In most European Countries the University study programmes in Agricultural Engineering are very different among each other; often they are a specialisation of a degree in Agricultural Sciences rather than a specific study programme in Agricultural Engineering, so that the Engineering learning outcomes are limited and, therefore, the graduates are Agronomists rather than Agricultural Engineers.

Moreover, the millennium brought also the new structure of the degrees (3+2) (1^{st} level or Bachelor of 3 years, 2^{nd} level or Master of 2 years) according to the Bologna Declaration of 1999; several EU Countries felt the need of updating all the University study programmes, including those in Agricultural Engineering, in order to satisfy the general economical conditions, the scientific and technological development and the need of developing competitive study programmes.

From this background the need of establishing an European thematic network on Agricultural Engineering was felt, as it is described in the report of AFANet - Working Package 3.

Therefore, the idea of carrying out, at European level, a project aimed at developing basic core curricula to be used as benchmarks for the local developments of Agricultural Engineering and for training the future agricultural engineers, was born.

Thus, in 2003 the thematic network USAEE (University Studies of Agricultural Engineering in Europe), coordinated by Prof. Demetres Briassoulis (Greece), was established with the aim of developing this project, approved and supported by EurAgEng and the 35 members of the thematic network itself (Tab. 1).

The main objectives of USAEE-TN are to:

- define and develop core curricula, to be used as benchmarks for Agricultural Engineering studies in Europe;
- determine a set of minimum criteria/requirements, against which any curriculum can be tested, in order to decide whether or not it meets the criteria/requisites and, therefore, can be recognised or not as a programme of Agricultural Engineering;
- define common accreditation strategies and procedures, also in terms of ECTS (European Credit Transfer System) credits and establish the bodies/committees for carrying out the accreditation of study programmes.

In order to be recognised, a core curriculum must meet the criteria of FEANI (European Federation of the National Associations of Engineers) for being an Engineering study programme, concerning the basic Engineering course contents and the related ECTS, and the criteria of EurAgEng, concerning the Agricultural and Biological course contents and the related ECTS [15].

In 2005 the USAEE Thematic Network produced the draft report "Core Curricula of Agricultural/Biosystems Engineering for the First Cycle Pivot Point Degrees of the Integrated M.Sc. or Long Cycle Academic Orientation Programs of Studies".

The main conclusions of the USAEE report are summarised as follows.

It is recognised that the weak part of the current Agricultural Engineering studies in Europe is the inadequate Engineering foundation of the corresponding curricula. Therefore, the main challenges are to:

- enhance the Engineering part of the European core curricula, so that they can meet the FEANI criteria for being Engineering study programmes;
- significantly reduce the Agricultural and/or Biological Sciences part of the core curricula.

In several European Countries intermediate 3-year degree study programmes, named "pivot point", were established, in order to facilitate the exchange of students between Universities and Countries. These degree study programmes are different from those "relevant for the job market", defined by Bologna Declaration.

The degree study programmes should be fitted to Bologna Declaration Scheme and coexist with the new intermediate 3-year "pivot point" degree study programmes (Bachelor's Science), according to the history, the industrial and social conditions and the traditions of any Country.

The main challenge is to agree on certain minimum standards of core curricula and describe, in a commonly understood way, the various competencies to be used for professional and academic applications. In this perspective the work done by the Thematic Network E4 (Enhancing Engineering Education in Europe), run by the University of Florence in cooperation with SEFI (European Society for Engineering Education) and other organisations, is relevant. Therefore, from the beginning the USAEE Thematic Network established strong synergies with both SEFI and E4 TN towards common objectives.

The core curricula structure should aim at developing the foundation for Agricultural Engineering studies, specialising in designing solutions to problems in systems involving (all or combination of):

- plants (agricultural production, including power and machinery);
- animals (animal production, including structures and environment);
- humans (health, safety and biomedical engineering);
- environment (bio-environmental engineering, including soil and water engineering, waste management, etc.).

All of these areas require proficiencies in instrumentation, information technology and many other disciplines.

In the first step of the development of Agricultural Engineering core curricula the 1st study level was examined and two different schemes were defined.

Scheme A, with academic orientation, is distinguished in:

- core curricula of integrated 5-year degree study programmes (M.Sc.);
- core curricula of "pivot-point" 1st level 3-year degree study programmes (B.Sc.).

Scheme B, with applications-technological orientation, is represented by the core curricula of professional 1st level (mostly 3-year) degree study programmes.

The above report contains not only the core curricula (Fig. 1) but also seven modules or specialisations in Agricultural Engineering topics:

- Water Resources Engineering;
- Mechanical Systems and Mechanisms used in Agricultural and Bioprocess Engineering (Figg. 2 and 3);
- Structural Systems and Materials in Agricultural and Bioprocess Engineering;
- Waste Management in Agricultural and Bioprocess Engineering;
- Bioprocessing;
- Energy Supply and Management in Agricultural and Bioprocess Engineering;
- Information Technology and Automation in Agricultural and Bioprocess Engineering.

In September 2004 this draft report was distributed to the Executive Committees of FEANI and EurAgEng for evaluation and comments; only after April 2005 FEANI started to evaluate this draft.

At the end of 2005 the European Monitoring Committee (EMC) of FEANI assessed this draft and, then, required some modifications:

- to explain the contents of "general" within Basic Sciences;
- to specify the number of ECTS of Mathematics (which must be at least 24);
- to specify the percent of Engineering Basic Sciences (which must be at least 20% and 36 ECTS) of the study programme;
- to provide all the seven specialisations with at least 60% of Engineering subjects;
- to specify the percent of non technical subjects (which must represent at least 10% of the study programme).

Moreover, the EMC of FEANI implicitly required an accreditation process for Agricultural/Biosystems Engineering curricula, such as a view of academic and professional qualification of the teaching staff and laboratories facilities.

EurAgEng agreed to undertake the task of establishing the recognition process of the core curricula.

Tab. 1 Participants of USAEE Thematic Network.

Contact persons	Partners
Prof. BRIASSOULIS Demetres	Coordinator, Agricultural University of Athens
Prof. AHOKAS Jukka	University of Helsinki
Prof. AYUGA Francisco	Polytechnic University of Madrid
Prof. BIRZIETIS Gints	Latvia University of Agriculture
Prof. CRUZ Vasco	University of Evora
Prof. DOUZALS Jean Paul	National School of Higher Agronomy Studies in Dijon
Prof. FARKAS Istvan	Szent Istvan University of Godollo
Prof. FEBO Pierluigi	University of Palermo
Prof. HEATH Simon	Coordinator of AFANET - TN
Prof. HOFSTEE Jan Willem	Wageningen University
Prof. KIC Pavel	Czech University of Agriculture Prague
Prof. KUTZBACH Heinz	University of Hohenheim
Prof. LAKOTA Miran	University of Maribor
Prof. MINVYDAS Liegus	Lithuanian University of Agriculture
Prof. MITEV Georgi	University of Rousse, Bulgaria
Prof. MUSY Andre	EPFL, ENAC, ISTE – HYDRAM
Prof. NAVICKAS Kestutis	Lithuanian University of Agriculture
Prof. NILSSON Christer	Swedish University of Agricultural Sciences
Prof. PANAGAKIS Panos	Agricultural University of Athens
Prof. PERREIRA Estella	TUNING counselor
Prof. RAMON Herman	K.U. Leuven
Prof. ROWINSKI Robert	Warmia and Masuria University in Olsztyn
Prof. SCARASCIA-MUGNOZZA Giacomo	University of Bari
Dr. FEHRMANN Jens	Dresden University of Technology
Mrs. NIKOPOULOS Effie	Agricultural University of Athens
Mr. BONDE Poul	Danish representative of ECTS in E.U.
Mr. SEVERIN Holde Christian	The Royal Veterinary and Agricultural University

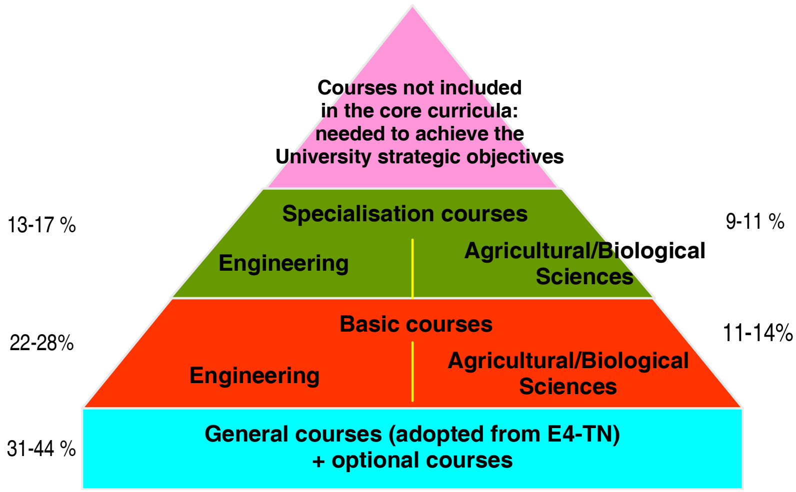

Fig. 1. Agricultural Engineering core curricula of 1st level "pivot point" integrated degree study programmes (3+2) and 5-year ones with academic orientation.

ENGINEERING PART OF THE CORE CURRICULA: OPTIONAL COURSES	AGRICULTURAL / BIOLOGICAL SCIENCES PART OF THE CORE CURRICULA: OPTIONAL COURSES
24-30 ECTS CREDITS: **equal to** 13-17% **of total** 180 ECTS CREDITS	(16-20 ECTS CREDITS: **equal to** 9-11% **of total** 180 ECTS CREDITS
Learning outcomes and contents follow this table	***Learning outcomes and contents follow this table***
Assuming 6 course units with 4 or 5 ECTS credits per unit, respectively, or equivalent, the learning outcomes that follow may be delivered through the following structured coursework:	***Assuming 4 course units with 4 or 5 ECTS credits per unit, respectively, or equivalent, the learning outcomes that follow may be delivered through the following structured coursework:***
1. Kinematics of Mechanisms 2. Power Generation Engines 3. Mechatronics 4. Soil Mechanics 5. Electrotechnics 6. Electronic Circuits 7. Instrumentation and Measurements 8. Engineering Surveying - GIS	1. Crop Science and Management 2. Crop Protection 3. Agro-chemicals 4. Animal Science and Management 5. Environmental Impact Assessment

Fig. 2 Proposed module or specialisation in "Mechanical Systems and Mechanisms used in Agricultural and Bioprocess Engineering" within the 1st level "pivot point" degree study programmes.

Mechanical systems and mechanisms used in agricultural and bioprocess engineering

1. Agricultural Machinery Design
2. Farm Power Units
3. Farmstead Equipment
4. Analysis and Design of Biomachinery
5. Techniques in Precision Agriculture
6. Automatic Controls
7. Computer Control of Machines and Processes
8. Ergonomics, Health and Safety
9. Design Methods for Machines for Biosystems
10. Remote Sensing
11. Soil Erosion
12. Landscape Planning
13. Free Technical or Agricultural / Biological Electives

Fig. 3 Indicative list of Agricultural Engineering courses included in the proposed module or specialisation in "Mechanical Systems and Mechanisms used in Agricultural and Bioprocess Engineering". In fact, Agricultural Engineering courses are to be developed by each University according to the orientation of the study programmes offered and the institution's strategic goals.

AGRICULTURAL ENGINEERING CURRICULA: THE PRESENT

Since the results of the USAEE-TN project needed to be widely disseminated and promoted, by March 2005 a dissemination proposal was submitted to the DG for Education and Culture of the EU.

By August 2005 the above DG selected this proposal, so that on the 1st October 2005 the 4th and last year of the USAEE-TN project, mainly aimed at the dissemination of its results, started.

The outputs envisaged to be achieved during the USAEE Dissemination Year are the following:

- development of a web-based database, where the USAEE-TN project results will be continuously updated and made available using a specific authorisation; this database will contain the courses or modules (set of courses) of the study programmes, including also the course ECTS value, in order to facilitate the recognition of the core curricula and, therefore, promote the student mobility throughout the EU;
- enhancement of the USAEE web-site (www.eurageng.net), by creating links with organisations, other related thematic networks and projects (ICA, TREE, ARCHIPELAGOS and TUNING, etc.);
- dissemination and promotion of the USAEE-TN results to the wider area of Higher Engineering Education in Europe, through synergic activities with TECHNO/ARCHIPELAGOS on issues concerning ECTS, quality assessment and employability;

- dissemination and promotion of the USAEE-TN results to the wider international Agricultural/Biosystems Engineering community outside Europe, through the TUNING III web-site and synergic activities with TUNING III;
- dissemination of the USAEE-TN results, through contacts with student associations (in order to promote student mobility and participation), alumni associations (in order to promote alumni involvement), Deans, Rectors, ERASMUS officials, policy makers and other academic bodies, representatives of enterprises, companies and industries involved in Agricultural Engineering;
- synergy and interaction with FEANI and, through FEANI, with the major professional non-academic stakeholders in Europe, aimed at the final approval of the USAEE-TN project results; this synergy will promote the core curricula developed by USAEE-TN;
- synergy with EUR-ACE towards a common accreditation system for the Higher Engineering Education in Europe, according to the current developments of Bologna process;
- organisation of dissemination events, at national level, where the national professional societies of Agricultural Engineers, also representing strong national contact and dissemination points towards the students and the industrial and the broader non-academic sector of Agricultural Engineering;
- presenting and reporting comparative analyses from case studies about the implementation of the USAEE-TN project results;
- organisation of two regional workshops concerning USAEE tasks, called respectively "Restructuring Agricultural/Biosystems Engineering studies and employability in Europe" and "Tools for Quality Assurance and Assessment Assurance of Agricultural/Biosystems Engineering in Europe"; a special session of one of these workshops will be devoted to disappearing rare knowledge on traditional environmental friendly agricultural engineering practices towards biological agriculture (eventually, in synergy with UNESCO and FAO-AGSE);
- organisation of a plenary session in the framework of the combined EurAgEng Conference AgEng2006 - XVI CIGR World Congress, to be held in Bonn (Germany) in September 2006, where the USAEE-TN results will be presented to academic and non-academic (e.g. industries, students) communities;
- synergic activities (together with ICA, SEFI, TREE, etc.) for promoting the USAEE-TN results to academic and non-academic communities and targeted groups, including industries and professional societies;
- support of short-term student mobility, through the participation of student associations (e.g. IAAS, BEST) to the workshops with contribution to presentations and proceedings and also to the dissemination activities addressed to them, the European market and the students of Agricultural/Biosystems Engineering University studies in Europe (in synergy with IROICA and, eventually, with the development of a summer school);

- investigation about the possible cooperation of education with research, in the framework of Euro PhD schemes or ERASMUS Mundus.

AGRICULTURAL ENGINEERING CURRICULA: THE FUTURE

In November 2005 the same members of USAEE-TN proposed a new ERASMUS Thematic Network called ERBEE (Education and Research in Biosystems Engineering in Europe) to the DG for Education and Culture of the EU.

The ERBEE-TN intends to carry out a new project, aiming at achieving the following objectives:

- establishment of the recognition procedures of the new European study programmes in Biosystems Engineering by FEANI and EurAgEng, based on the core curricula of the first two cycles developed by the USAEE-TN;
- promotion of the accreditation of new European study programmes in Biosystems Engineering, in synergy with EUR-ACE and in support of the establishment of European Quality Labels in Bio-Engineering;
- organisation of case studies about the implementation of new European study programmes in Biosystems Engineering, based on the core curricula of the first two cycles developed by the USAEE-TN, aimed at recognition by FEANI and EurAgEng;
- “mapping” and promotion of the 3rd cycle University study level and the European Doctorate in Biosystems Engineering, following the recognition by FEANI and EurAgEng, through the implementation of the core curricula of the first two cycles developed by the USAEE-TN;
- development of synergies and schemes of cooperation for strengthening the interaction between research and education at all three cycles/levels of the University studies in Biosystems Engineering in Europe;
- promotion of the adoption of the European Standards on quality assessment and assurance of European study programmes in Biosystems Engineering, in accordance with the emerging European Qualifications Framework (EQF);
- enhancement of the attractiveness of European study programmes in Biosystems Engineering, both within and outside Europe;
- implementation of the main lines of TUNING, based on the outcomes of USAEE-TN and any further development in the field of Biosystems Engineering University studies in Europe;
- promotion of the sustainability, through the interaction with non-academic stakeholders and third party organisations.

The beneficiary target groups of ERBEE-TN project are the following:

- the Universities offering Biosystems Engineering graduate and postgraduate-level studies;

- the groups benefiting directly from teaching and research, namely graduate students in Biosystems Engineering, professional societies, companies and enterprises involved in agricultural production and processing, the industry and market in the field of the technical support of agriculture, etc.;
- the European and national accreditation bodies for the corresponding output on accreditation, policy makers, ministries of education and the academic society of higher education in Europe;
- students, scholars and researchers from regions outside Europe;
- other related disciplines, associations and thematic networks in synergy with ERBEE-TN.

In January 2006 the pre-proposal of the ERBEE-TN project was selected by the DG for Education and Culture of the EU, so that all the partners of this thematic network are now invited to submit a full proposal by March 2006.

ABBREVIATIONS

CIGR = International Commission of Agricultural Engineering

AIIA (former AIGR) = Italian Association of Agricultural Engineering

SIG = Special Interest Group

EurAgEng = European Association of Agricultural Engineers

FAO = Food and Agriculture Organization of the United Nations

AFANet = EU SOCRATES Thematic Network for Agriculture, Forestry, Aquaculture and the Environment)

USAEE-TN = University Studies of Agricultural Engineering in Europe - A Thematic Network

ECTS = European Credit Transfer System

FEANI = European Federation of the National Associations of Engineers

Thematic Network E4 = Enhancing Engineering Education in Europe

SEFI = European Society for Engineering Education

EMC = European Monitoring Committee of FEANI

DG = Directorates General

ICA = Interuniversity Conference of Agriculture and Related Sciences

TREE = Training & Resources in Early Education

EUR-ACE = Accreditation of European Engineering Programmes and Graduates

UNESCO = United Nations Educational, Scientific and Cultural Organization

AGSE =Agricultural Engineering Branch

IAAS = International Association of Students in Agricultural and related sciences

BEST = Board of European Students of Technology

IROICA = European Network of International Relations Officers at Higher Education Institutes for Agricultural and Related Sciences

ERBEE-TN = Education and Research in Biosystems Engineering in Europe – A Thematic Network

EQF = European Qualifications Framework

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Review paper

[1]AGRICULTURAL ENGINEERING IN SOUTH EAST EUROPE, STATUS AND PROSPECTS

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SUMMARY

The paper describes past, present and future status of Agricultural Engineering according to their social, economic and scientific role in the countries of South East Europe. Besides mentioned, the paper has clearly defined role, objectives and future activities for Bio - systems Engineering Societies.

Key words*: Agricultural engineering, bio systems engineering, education, economy*

[1] The paper is based on survey done as preparatory for Full Session of Club of Bologna 2006 presentation, which has been supported by UNACOMA. Draft of presentation is available on www.clubofbologna.org.

INTRODUCTION

Being witnesses of huge changes that had occurred during last 15 years within the field of Agricultural Engineering, some enthusiasts, founder members of Association of Agricultural Engineers of South-East Europe have started to taking care and thinking about changes and their influence on present and future status of Agricultural Engineering parts as: education, market of agriculture machines, their production etc. in South-East Countries. Here it has to be emphasized that this paper includes reports from Bosnia and Herzegovina, Bulgaria, Croatia, Romania, Serbia and Turkey. Macedonia and Monte Negro weren't included only due to problems finding colleagues whom would be willing to make such kind of survey within very limited time period but colleagues from mentioned countries are always welcome for further cooperation. So, the essential idea for the survey had arisen due to the fact that a brief cross-section view of Agriculture and Agricultural Engineering in South-East European countries no one in the recent past hadn't even try to make. According to that fact and fact that such survey would help us to face up with present state and possible prospects this group had started mentioned task and finished the job but authors accepted it only as the beginning. It should be also known that showed data describe status of single country are partly based on official statistical sources and partly on expert's opinion. Objectives of this paper could be described with single mind that authors finally wanted to put down the bottom line at the past and raised his view to the new horizon.

STATUS

The following tables 1 and 2 give preview of general, economic and agriculture regarding data for covered countries:

Table 1 General and economic data

	Bosnia and Herzegovina	Bulgaria	Croatia	Romania	Serbia	Turkey
GENERAL DATA						
Country surface in km^2	**51.209**	**111.002**	**56.594**	**237.500**	**88.361**	**769.604**
Population	**3.843.000**	**7.761.000**	**4.437.460**	**21.680.974**	**10.100.000**	**72.070.000**
Agricultural land in million of ha	**2,53**	**5,73**	**3,14**	**14,72**	**4,20**	**26,58**
Share of agricultural land	**49,4%**	**51,6%**	**55,4%**	**61,7%**	**48,0%**	**34,5%**
Agricultural land in ha per capita	**0,66**	**0,74**	**0,71**	**0,68**	**0,42**	**0,37**
ECONOMICAL DATA						
GDP per capita EUR/a	**2.100**	**2.400**	**6.900**	**2.800**	**2.200**	**3.700**
GDP in agriculture	**10,1%**	**10,9%**	**7,6%**	**12,8%**	**16,0%**	**11,9%**

Table 2 Agriculture data

	Bosnia and Herzegovina	Bulgaria	Croatia	Romania	Serbia	Turkey
AGRICULTURE **Main crops**						
Cereals:	**321,000 ha**	**1,811,039 ha**	**700,000 ha**	**5,541,000 ha**	**2,000,000 ha**	***over 13,500,000 ha***
Maize	**196,884 ha**	**415,971 ha**	**406,000 ha**	**3,199,600 ha**	**1,220,000 ha**	**545,000 ha**
Wheat	**73,184 ha**	**1,044,006 ha**	**227,000 ha**	**1,748,000 ha** *including rye*	**612,000 ha**	**9,300,000 ha**
Barley		**333,484 ha**				**3,600,000 ha**
Industrial plants	**9,000 ha**	**694,281 ha**	**117,000 ha**	**1¸448,300 ha**	**420,000 ha**	***over 1,700,000 ha***
				Individual farms:		
Average size of farm	**3.2 ha**	**5.2 ha**	**3.0 ha**	**2.28 ha**	**3.0 ha**	**5.9 ha**
			2.4 ha (UAL) *Utilised agr. Land*	*Familial assoc.:* 139 ha *Juri. personality:* 435 ha		
under 5 ha	**83,3%**		**85,7%**	**61,4%**	**39,0%**	**67,0%**
5 - 10 ha	**13,7%**		**9,5%**	**20,3%**	**35,0%**	**18,0%**
10 - 100 ha	**2,9%**		**4,7%**	**12,8%**	**14,0%**	**14,1%**
over 100 ha	**0,1%**		**0,1%**	**5,5%**	**12,0%**	**0,9%**

COUNTRY REPORTS

The country reports of most of South East European countries have been are presented below in alphabetic order of country names.

Bosnia and Herzegovina

Agriculture

In B&H arable land and gardens cover approximately 1,028 thousand ha (2005), out of approximately 992 ha (96.5%) are privately and 36 thousand ha (3.5%) are state-owned. Average size of a farm is 3.2 ha. According to statistic data from 2005, cultivated land comprised 553,000 ha out of the overall 1,028,000 ha of arable land. It is assumed that the low utilization of arable land is a result of the size of farms, poor organization, insufficient adaptation to market economy and migration of population during and after the war in BiH. In 2005 the agriculture production structure was as follows: cereals 31.2%, feed crops 13.4%, vegetables 8.3%, industrial plants 0.9%, nurseries, osier and aspen beds 0,3% and fallows and uncultivated arable lend 45.9%.

Agricultural mechanization

Number of tractors in B&H decreased from 92,117 units in 1992 to 54,140 units in 2005, out of which 33,536 are double-axle tractors and 20,604 single-axle tractors. Agriculture tractors are rather old. The estimated age is 25 years for tractors and over 30 years for implements. The classification of agriculture tractors reflects the B&H breakdown of farms by size. Tractors up to 11 kW (38.1%) constitute the biggest category of tractors in B&H, and the second biggest category are two-axle tractors of 27-37kW. The tractor power in comparison to the type of land varies from 0.4 kW/ha for agriculture land to 2.0 kW/ha for arable land. Annual requirements for agriculture machinery are assessed to 1,200 single axle tractors, 1,030 double axle tractors, 70 harvesters and 8,300 implements.

Industry of farm machinery

Domestic production of agricultural machinery and equipment is relatively small, precisely it includes 500 units of motor-cultivators, assembly of 300 units of two-axle tractors, 500 trailers, 100 cabs for two-axle tractors, 50 fertilizer spreaders, 300 rotor cultivators for single-axle tractors, 200 ploughs and as production of components and spear parts about 1,000 pumps and 50,000 filters. Value of production of tractors is 2.3 million € and of motor-cultivators 1.7 million €. Assembly program includes two categories of two-axle tractors: light, 18-26 kW, and medium heavy, 27-37 kW, and four categories of motor cultivators: 3.7 kW, 5 kW, 9 kW and 12 kW.

Visions and missions

The B&H agriculture machinery market is relatively small and characterized by the transition from socialist concept to market concept of economy. Domestic production and export of agriculture machinery, together with the above-mentioned two restricting factors, is limited. Manufacturers in B&H should develop cooperation or joint ventures with renowned international manufacturers, and capitalize on the availability of cheap and highly-qualified working force, and availability and proximity of raw materials (iron, steel, aluminum, etc.). One of the main goals of foreign policy of Bosnia and Herzegovina is membership in the EU and other Euro-Atlantic integration processes. B&H is currently in the process of negotiations of the Stabilization and Association agreement with EU. Estimates are that B&H will hopefully sign the Agreement in 2007.

Bulgaria

Agriculture

The agricultural sector creates a significant part of the GDP –about 10-13%. It determines the life standard of the population and influences other important branches of the industry like energetic, transport, food production, etc.

Agriculture employs more than 1 million full time and more than 300 thousands part time workers. The tendency is to decrease the agricultural working places, which creates other problems related to unemployment.

Since 2007, Bulgaria joined the European Union and this will influence the future growth of the agricultural sector, at least because of the very sharp competition and strict regulations for production and ecology requirements.

The 3 main agricultural groups involved in the economy are:

1. About one third of the agriculture land is owned by big landowners (more than 1,000 ha farms).
2. The best part of the lands though (over 40%) is owned by middle sized landowners.
3. The remaining ¼ of the agricultural land belongs to small family farms. There is a tendency toward increasing the percentage of big landowners, causing reduction of second group.

Agricultural mechanization

The level of mechanization could be estimated by the number, the type and the power of the used machinery. The 3 main groups of used machinery are tractors (25%), harvesters (8%) and soil tillage machinery (24%).

The distribution of the type of machinery used by the three groups is as follows: the big landowners use mainly high and intermediate power machinery (40–60 kW and more). The most machinery are owned by the second group and with mainly intermediate and low power (less than 60 kW). The 3rd group which is also the largest, also prefers low and intermediate powered machinery.

There are opportunities for subsidies in the sector. Only for 2005 under the Agricultural machinery program SAPARD, 272 investment projects have been financed at approximately 22 million €.

Industry of farm machinery

The domestic agricultural machinery industry has almost disappeared after 1989. This situation causes new specific problems like realization of machinery engineers, involved in design and production of agricultural machinery, the need for university specialties in this area, etc.

The necessary agricultural machinery are mainly imported. Today the domestic industry consists mainly of companies specializing in smaller agricultural equipment and machinery as well as spare parts. Their production is oriented to ploughs, disks, harrows, seeders, fertilizer distributors, etc.

Visions and missions

In the future the agricultural production will play a major role for the feeding of the population and ensuring a raw material basis for other industrial sectors. Other than the traditional introduction of modern science achievements in the agricultural machinery, ecology, improvement of the working conditions and quality of the production, following areas will also be developed:

- production of different types of renewable energies;
- information technologies.

The access of Bulgaria to the huge European market, suggests new opportunities for development of the agricultural trade. This will force the introduction of more modern technologies and agricultural machinery, to make the domestic products competitive. The expected EU subsidies will contribute for that.

Croatia

Agriculture

Agriculture, forestry and fishery account for about 8% of the GDP. The diversity of climate, landscape and soil enables a varied agricultural product range and ecosystems are well preserved. In accordance with Agricultural Census and data for 2003, there were 3.14 million hectares of agricultural land (55.4% of land area), and 1.08 million hectares of that is utilized agricultural land. Two thirds of agricultural land belongs to family farms (about 80% of plough-fields (arable land), gardens, orchards, olive groves, vineyards, and meadows, and about 40% of pastures). The whole territory consists of 42% of forests and forest woodlands (about 80% state-owned). The statistics on agricultural land use in Croatia are the most problematic of all agricultural data due to different reference basis.

The plant production, preceded by cereals, dominates in the value structure of the agricultural production. Livestock production contributes with approximately 50% of the total value of agricultural production.

Croatian agriculture has been characterized by the dual structure of ownership. Agricultural resources were directed to a small number of large socially-owned agricultural holdings and small family agricultural holdings, restricted in size. This resulted with a majority of very small agricultural holdings, unable to generate a profit sufficient for the necessary investment for improved production. Today, the majority of the Croatian agricultural holdings are characterized by small, fragmented parcels, which is the major limiting factor to improve their competitiveness. Also, problems are over-aged agricultural population and low degree of qualification and skills of the population occupied in agriculture as compared to other branches.

Reform of the agricultural subsidy system comprises 4 support schemes: Production support scheme (direct payments), Capital investment scheme, Income support scheme and rural development scheme. The aim of the reform is distinguishing differences between commercial or potentially commercial farms, and that non-commercial farms which have weak potentials for profitable production.

The process of privatization of companies dealing with the agricultural and food processing industry has been carried out since 1993, to date, more than 400 companies from the sector of agriculture and food-processing industry were privatized.

Agricultural mechanization

According to Agricultural Census 2003 data total number of two-axle tractors is about 190,000 pieces. (similar figures were for 1991) and average engine power per tractor is approx. 36 kW. Engine power distribution shows that 75.1% of tractors are in category up to 40 kW and 20.9% are in 41-60 kW category. Only 3.2% of tractors are in 61-100 kW category and 0.9% in over 100 kW category. Since the last usual renewal of mechanization had occurred at the end of 80's, rough estimation could be taken that 75% of the machinery starting with tractors, combine harvesters, tillage implements, fertilizers, plant protection equipment and other equipment are now at least 18 and over 18 years old. Dominant used mechanization are: tractors (up to 35 kW), with attachments for maize and wheat production (conventional soil tillage), haymaking machinery (mowers, tedders, rakes and forage wagon), tractor attached/trailed harvesters for maize (corncob picker or for silage).

In 2005 new and used tractors were mainly imported from EU countries (not necessary produced in EU). Main engine power category of imported tractors in 2005 was 55-80 kW, about 40% of new imported tractors and about 60% of used imported tractors were in that category. Used tractors represent about 33% of tractor's import market.

Capital investment scheme (subsidy), takes a part in financing investment for which a financial institution has approved credit, also specialized pre-accession EU funds for candidate countries are intended for investments in agricultural. High investment costs are necessary for modern mechanization and production technologies for increased productivity and quality primary products, but poor solvency and indebtedness of farm resulting in low investment capacity and lack of interest of banks to become engaged in family farm lending. Also, problems are high risk aversion of farmers and fear of applying for bank credit, and lack of collaterals of smallholders for bank lending.

Industry of farm machinery

Main activities in industry of agricultural mechanization are in production of walking tractors, combine harvesters including machines and devices for harvesting and threshing. During the 90's many producers with tradition and reputation bankrupted and vanished, but some producers in metal industry are still able to be manufacturer for reputable world producers of farm machinery.

Visions and missions

Introduction of high EU environmental, hygiene and animal welfare standards increases costs and requires additional investments for upgrading of technologies, premises and management practices.

Romania

Agriculture

Romania has proper natural condition for a high efficient agriculture. The main relief forms in Romania (plains – 33%, hills – 36%, mountains – 31%), determine a wide range of vegetal and animal production. Romania has a transitional temperate-continental climate, with oceanic influences to the west, Mediterranean influences to the southwest and continental-excessive to the northeast. The annual average rainfall is variable, depending on altitude: 500 mm in the plains, 700 mm in the hills and 1200 mm in the mountains.

With its 14.72 million hectares of agricultural area, of which 9.4 millions is arable land, Romania has the potential to became a large and diversified market for farming equipment. As a new member of EU, Romania will feature among the four to five important farming countries in Europe.

The structural changes in the Romanian agriculture led to the formation of small or average farms. The main type of farm is the small household, with an average area of 2.28 hectares of farming land, representing 53% of the total of farming land. Farming companies have an average area of 282 ha and account for 43% of farming land. From the total of 4,462,221 individual farms which have the surface of agriculture land of 7.71 millions ha, 52.4% have the surface of agriculture land smaller than 1 ha, and 42.1% have the area of agriculture land between 1-5 ha, represent subsistence farms and semi-subsistence farms. The farm structure will be changed, in the future according to the INMA evaluation, as follows: 1-5 ha (10%); 5-10 ha (10%), 10-20 ha (10%), 20-50 ha (30%) and over 50 ha (40%).

Agricultural mechanization

Related to Romanian agricultural land, the level of mechanization is low. A tractor is allocated to 57 ha arable land. Only 30.6 % of necessary tractors exist and about 70 % is necessary for the normal load.

Domestic output of agricultural equipment is far from meeting, either quantity or adequacy requirements. In analogy with EU situation, the experts estimated a need for about 720,000 tractors, 400,000 new cultivators and 60,000 new harvesters over the next five years, compared to only 170,000 tractors, 132,000 cultivators (including ploughs) and 26,000 self-propelled harvesters. About 60% of tractors and farm machinery have more than 10 years in use.

Industry of farm machinery

Most of the tractors and agricultural machinery were produced in Romania before 1989. There were about 25 agricultural machinery and tractor factories. The main tractors type was: 45 HP, 65 HP and 100 HP wheel tractors and 150-180 caterpillar tractors. They were produced for domestic needs and for export. Some of the farm machinery and tractors factory drastically reduced their production and some changed the production nomenclatures.

The newly established family farms, due to their smaller size and different production structure, need tractors and agricultural machinery adapted to their own needs. While straight import for the sector is limited for the Romanian's shortage of hard currency, accessing the market via licensing agreements and joint ventures with the local industry, which has good basic technologies, skilled labor, and low labor costs could be a rewarding option for EU and others manufacturers of tractors and agricultural equipments.

Visions and missions

Agriculture is the vital part for the living resources, is strongly related to the rural area and to the environment. Consequently, each action and steps towards "better" have to take into account these three figures.

Romania, as a new member of EU, has to take adequate actions in accordance with the real situation in the agriculture and rural area and in harmony with EU regulations. In this respect the main missions of the government and of us may be defined as follows: Temporary support for semi-subsistence farms and encouraging of association of farmers; Modernizing of technology and agricultural infrastructure; Modernizing the processing units and encouraging and promoting innovation and access to research and development; Diversifying production and activities in rural areas through non-agricultural economic activities by promotion of new technologies; Training human resources to create/improve local technical potential; development of sustainable agricultural systems.

Serbia

Agriculture

Agriculture has a good status and is politically supported, not only due to economic importance, food security and exports, but also due to social effects, support of rural areas, and vision of future chances in the sector. Only limited subsidies for commodities and acreage are practiced. On the other hand there is a program for support of purchase of mechanization and equipment offering allowance and very convenient loans.

There are three significant groups involved in agricultural production: 1. big company farms, farming over 1,000 ha; 2. advanced young farmers and well organized cooperatives; 3. small family farms including also these owned by old farmers. The farming technology and economic status are significantly different between the groups. Unfortunately, the third one is the biggest.

It is typical that processors of agricultural products dictate the prices and mange to have benefits of almost all supporting measures. That is why medium and small farms try to set up some kind of post harvest processing, up to level of getting shelf ready products.

The economic regression of rural areas is significant.

Agricultural mechanization

The obsolescence of machinery is critical, but last five years this has been significantly improved. Renovation of machinery was until now reduced due to intention of farmers to buy as much as possible land. The machinery market, including equipment for primary post harvesting, is estimated to be round 1.5 billion of euro per annum. Farms belonging to first and second mentioned group mange, in most of the cases, purchasing of contemporary machinery, with high capacity and profitability of use. The problem are farmers belonging to the third group, whose are not able to follow trends and mostly use old machines or buy out of dated ones. This makes their situation even tougher.

Industry of farm machinery

“Big” domestic industry of agricultural mechanization almost collapsed. The privatization is in progress and should be finalized up to middle of 2007. The future of it is uncertain, and best scenario will be establishing of the cooperation with reputable world producers. It will be supported by national legislation and funds. A huge number of small companies produce simpler machinery and equipment, as well as spare parts and assemblies. This group will grow and, already now, some companies are able to be sub-contract manufacturer for reputable producers of mechanization. Establishing of regional cooperation in the sector, as well as expected custom duties free trading, are remarkable visions and intentions.

Visions and missions

There are two objectives for future development of agriculture: to support agricultural production and processing for domestic market and exports and to support development of rural areas. Improvement of food safety and quality has been declared and accepted as an important task. Many activities are already in progress, introduction of HACCP, newest ISO standards and GAP, organic farming etc. The interest of farmers is creation of regional and wider cooperation in the field of agricultural production – market and agricultural mechanization.

Most of the farmers are interested in non-food production, intensive crops and processing of agricultural products. Production and use of renewable energies is expected to be important issue. Rural development and especially help of economically weak groups are objectives for government and universities.

Turkey

Agriculture

The agricultural sector, with a GDP share of 11.5% in Turkey, is not able to achieve the performance level of production that can be obtained with the existing resources. In other words, the productivity level of agriculture is very low, which is due to small (avg. 5.9 ha) and scattered (avg. 4 plots/farm) agricultural enterprises and rather high input costs. As in many parts of the world, Turkish farmers are also typically conservative and resistant to new technologies and do not accept them unless they are fully convinced of their benefits. Low level of farm income is one of the major sources of problems within the sector. The government has recently cut down all incentives, subsidies and any kind of support, but direct income support to agricultural production. Crops are the most important products with 75% of total value of agricultural production, split between field crops (46%), vegetables (26%) and fruits (28%). Within the field crops value, cereals has a 52% share, whereas industrial crops (mainly cotton, tobacco) 23.4% and root crops 13%. Wheat is the most important single crop with 7.9% of total output value. Livestock farming in Turkey is generally a small-scale family farm activity, carried out in the vast majority of cases as a sideline activity by arable farmers.

Agricultural mechanization

Tractor power use per ha and total weight of machines per tractor are approximately 1.3 kW/ha and 4.2 tones, respectively, compared to 5–7 kW/ha and 12 tones in the EU. Very few numbers and types of agricultural machinery are imported. Main importers are those marketing companies of major tractor manufacturers. They import sets of agricultural machinery especially compatible with their large size tractors. 31.5% of 3.075,515 farmers own at least one tractor. 19.7% of farmers, having land between 0-5 ha, own at least one tractor whereas 85% of farmers, having land larger than 50 ha, own at least one tractor. 74% of farmers (3.0121,190) are using tractors. 72% of farmers possessing land are cultivated by tractors. Area cultivated per tractor is 13.3 ha.

Industry of farm machinery

In Turkey almost all of the machinery and tractors used in agriculture are produced domestically and apart from those well-known and marketed brands, most of them are manufactured locally in order to meet the local market needs. There are 9 agricultural tractor manufacturing establishments in Turkey working with 58% capacity utilization.

There has been a significant development for the last 20 years in the production, use and adoption of machinery in agriculture. Turkey has always had a surplus with an important share of exports of agricultural machinery and tractors. Only some of those machines which are not feasible to produce domestically, such as combine harvesters, cotton pickers, self propelled forage harvesters and some other SP machines, large and extreme large tractors and machines required by specialized farming establishments. Import penetration rate in agricultural machinery sector is very low, which means there is not much prosperity for foreign machinery falling into ranges of machines being produced in the country.

Visions and missions

Agriculture is and will be one of the most important sectors in Turkish economy. Turkey's geographical location and diverse climatic conditions give the advantage of production of numerous diverse crops. Recent progresses towards EU membership also enable the country to harmonize with the European countries and therefore improve the competitive advantage in terms of quality of production for certain crops.

The current trend in agriculture is towards sustainable, more productive, intensive and environment friendly production in agriculture. In this respect, organic farming or ecological farming practices and the consumer demand for their products are to a large extent increasing in the country as well as all over the world. It is therefore necessary to consider the production and implementation of appropriate machinery, such as computer aided production technologies, precision farming, zero-tillage techniques, multi-farm use organizations, etc. As the awareness of public widens, environmental issues, on the other hand, are becoming vital for the government policies. Soil conservation, savings of irrigation water usage, lesser use of chemicals and fuel consumption, and more productive approaches are those issues considered within the current policies. Good agricultural practices and traceability of food products is also highly essential concerns for Turkey, especially due to the high level of fruits and vegetables production marketed mainly to the EU. On the other hand, since there is a pressure on the rural sector to move to urban areas and diminish the employment rate of agriculture, the farm sizes are becoming larger than before and this brings the consideration of larger and more productive machines in operation.

THE ROLE, OBJECTIVES AND FUTURE ACTIVITIES

The role of agricultural engineering today is much more complex than before. It should not only fulfill the goals of agriculture, but of society in general. The objectives of the profession, in addition to traditional ones, mostly related to engineering problems, should today strictly respect following issues:

Complexity and multidisciplinarity. It has to be treated not only for the main crop, but also for the influence of technology and machinery on all ecosphere, considering all possible influences, and prevent negative effects. Even more pronounced is the need of close cooperation with other professions, agronomists, breeders, food technologists etc.

Environment protection. Full respect for environment protection is a very important issue. Every technology has to be evaluated from this point of view. Typical examples are: reduction of soil compaction, environment friendly application of crop protection chemistry, and fertilizer broadcasting, energy saving, reduction of emission of pollutants, etc.

Food safety and quality. Every process in agriculture and post harvesting has to be evaluated according to its influence on food safety and also quality. The introduction of documented production, Good Agricultural and Manufacturing Practice and Traceability are contemporary societal and market demands. Here, agricultural engineering is very close to, or even overlapping with food processing industry.

Economy of production, profitability. Farmers are more than ever expected to produce without subsidies or as low as possible. Due to globalization, all domestic markets are open. All activities of agricultural engineering have to ensure sufficient income for farmers. High income, not high yield.

The country reports have presented status of industry of machinery and equipment for agriculture and food processing. Obviously this sector is of special importance for every country. It offers employment of domestic recourses and should contribute to welfare of societies. Similarities in conditions, structure of agriculture and vicinity are good prerequisites for regional cooperation in this field. Agricultural engineering should support **development of own industry of agricultural machinery and equipment** and establish cooperation with reputable world companies and regional cooperation and trading.

All country reports signalize that there exist wide and huge groups of small farms. These farmers belong to economically weak groups of the society. Their income can not ensure satisfactory living standard. It causes enormous emigration from rural to urban areas and is followed by many economic and social problems. This has been recognized also by World Commission of Agricultural Engineering, CIGR. During World Congress, called *Agricultural Engineering for a Better World* held in September 2006 in Bonn, a new Working group entitled: “Rural development and preservation of cultural heritages” was established. By this act agricultural engineers expressed their interest and willingness to help **rural development**, not only as a typical, but as a cultural problem as well. From the country reports it is obvious that rural underdevelopment is a critical point in the region of South East Europe.

Agricultural engineering today has much wider objectives, and therefore a new term “*Biosystems Engineering”* which is already widely used in the USA and also in Europe, covers this wide field better.

All country reports point out the existence of three major types of farms: big, mostly over 1,000 ha, company or privately owned, medium, mostly family farms and cooperatives and small. The last type is most numerous and also economically weakest. In the future, the agricultural engineering profession should focuses and support all types of farms, and third one should be from point of view of social progress much more focused.

Based on country reports, and discussed contemporary roles of agricultural engineering, the list of objectives of the profession has been established and presented in tab. 3.

Tab. 3 Objectives of agricultural engineering in SEE countries

No	Objectives	Type
1	Sustainable and effective agriculture, competitive on the World market, whose can contribute increase of GDP. Increase of competitiveness of domestic farmers.	Economic
2	Security of safe and quality food for domestic market and exports. Supporting farmers who are not able to follow economic restructuring. Production support.	S and Q Economic and societal
3	Support of rural development.	Rural development, societal
4	Protect environment from negative influences of agricultural production. Contribute utilization of renewable energies.	Environment protection
5	Development of own industry of agricultural machinery and equipment, establish regional, European and world wide cooperation.	Economic and societal
6	Adopt own agriculture to EU agricultural policy. Harmonize subsidies policy and trading in agriculture with WTO (World Trading Organization) rules.	Political

The objectives defined in tab. xx can be realized through following groups of research, development and demonstration (including education and training) activities:

A. Continuous study of newest achievements in the field of agricultural production, agricultural engineering, including post harvest technologies, critical evaluation from point of view of applicability in own country. Especially should be evaluated environmental influence, but also demands defined by EU. First after detailed evaluation and own testing the technology will be proposed for farmers. The beneficiary of this group of activities will be big and medium scale farms. It will cover objectives 1, 2, 4 and 6.

B. Development of new or significant improvement of existing, including traditional, indigenous, production technology with special regard to improve food safety and quality. Here can be included new measuring equipments and procedures, testing methods and certifications. It will include also demonstration and training. The target is to get high level of certified products, including organic, with final goal to get shelf ready branded food. Beneficiaries are all size of farms, and medium one are emphasized. It covers objectives 1 and 2, partially 3.

C. Support for establishing international cooperation in the field of agricultural machinery and equipment, primary with reputable world companies, but within the region as well. Research and development of new products, especially *low costs* solutions, whose will be produced by domestic small and medium companies, or realized in a frame of regional cooperation. Introduction of new solutions based on information technologies, taking into account profitability of application. This can contribute realization of objectives 1 and 5. Beneficiaries are, first of all, producers of agricultural machinery and equipment, and small and medium scale farms.

D. Improvement of existing and introduction of new technologies aimed in improvement of environment protection. Here are included all typical measures of crop protection, fertilizer broadcasting and similar. Activity includes development of new, applicable in local conditions, testing and adjustment equipment, demonstration and training of users. This activity is very important and should be performed by institutes, faculties and extension services. Beneficiaries are all farms, but society in general. It is related to almost all objectives, but especially to 2, 4 and 6.

E. Integration into European Research Area, first of all through FP7 projects. Involvement into international, regional and bilateral project. Internationalization of R&D activities. This activity will not only approved national human recourses and R&D capacities, but will contribute demonstration, training/education and certification in land. This group of activities includes also PR activities, presentation to the public, and creation of farmers' awareness related to contemporary production methods. The later will include also extension services. Beneficiaries are all farmers, and this group of activities covers all objectives.

F. Contribution to rural development is a very important future group of activities. It should be provided in cooperation with other professions. To name but a few: introduction of use of Internet, e-commerce, tending of traditional skills, including handicrafts, creation of background for production of traditional foods and beverages and development of countryside tourism etc. Improvement of infrastructure, development of other profitable activities. Beneficiaries are small farms and society. This covers objective 3.

G. According to the contemporary demands in EU and world wide development of production and utilization of renewable energies, although can be included in one of former groups, here is emphasized as a separate. The hypothesis is simple and clear: most or resources of renewable energies are available or can be produced in rural areas; the society is obligated to support utilization of renewable energy sources, and have to provide funds. The funds can used to support both: utilization of renewable energy sources and contribute rural development. Beneficiaries are rural areas and whole society. This group of activities can cover objectives 3, 4, 5 and 6.

CONCLUSIONS

In all countries of South East Europe the agriculture has important role for national economy and also high reputation. Some of the countries are already members of EU, two of them are official candidate countries and all other intend to join the Union. The conditions of agriculture in the region are similar and different than in many other EU countries. Consequently, the goals of agriculture are different. The role of agricultural engineering is to fulfill these goals. The objectives of contemporary agricultural engineering, not only in the region, but also worldwide, overcome traditional role of profession. It is expected not only to contribute in the field of engineering, but also to solve problems of environment protection, help ensure food safety and quality, enable profitable agricultural production and food processing, support environment protection and general societal welfare. The regional survey shows realistic need of supporting rural development in the region, what is also the objective of agricultural engineering. The complexity, multidisciplinarity and synergy of many professions suggest that the new term *Biosystems Engineering* instead of agricultural engineering becomes more adequate.

Following the world trends and the results of country reports, the most important objectives of agricultural engineering, i.e. bio systems engineering profession in the region of South East Europe are defined. They comply not only with the traditional rules of the profession but also with economic, environmental, societal and political ones. The seven groups of activities aimed at realization of objectives present background for future national, regional and European research, development and demonstration–training policies.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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THERMAL FLUID DYNAMICS OF WATER DROPLET IN SPRINKLER IRRIGATION: PHENOMENOLOGICAL ANALYSIS AND MODELING

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ABSTRACT

A thorough understanding of the factors affecting spray flow and evaporation losses in sprinkler irrigation is important for developing appropriate water conservation strategies. To properly tackle this problem, relevant theoretical and experimental studies have been carried out during the second half of the last century. Notwithstanding all these efforts, the phenomenon of aerial evaporation of droplets exiting from a nozzle has not been fully understood yet and something new has to be added to the description of the process to reach a better assessment of the events. To this end, a mathematical model for irrigation sprinkler droplet ballistics, based on a simplified dynamic approach to the phenomenon, has been presented. The model proves to fully match the kinematic results obtained by more complicated procedures. Moreover, field trials showed the model to reliably estimate spray evaporation losses caused by environmental conditions. Further analytical and experimental activities are needed to gain a better understanding of water flow and waste in sprinkler irrigation practice

Keywords*: thermal fluid dynamics, mathematical model, sprinkler irrigation, water droplet, travel distance, time of flight, evaporation.*

INTRODUCTION

Scientific literature concerning irrigation systems (Larry, 1988; Schultz & De Wrachien, 2002) is mainly focused on the optimisation of water distribution on the soil, generally neglecting other aspects such as aerial evaporation in sprinkler irrigation. One of the causes of this behaviour is a scarce agreement among scientists for what concerns a clear and univocal definition of the phenomenon causing water losses during irrigation and of the parameters affecting its dynamics. So, spray evaporation of water droplets in sprinkler practice - that is water loss in the aerial path covered by a droplet exiting from a nozzle before it reaches the soil surface - was quantified with values ranging from 2 % or less up to 40 % or more (James, 1996; Tarjuelo *et al.*, 2000).

Since Christiansen's (1942) now classical work, important studies (theoretical and experimental ones) have been carried out to determine sprinkler spray flow and losses under various climatic and operational conditions (Mather 1950, Frost & Schwalen, 1955; Wiser, 1959; Inoue, 1963; Kraus, 1966)

Among the different procedures now available, the heat and mass transfer approach offers a sound basis for the assessment of evaporation from falling droplets and the results are in reasonable agreement with experimental data for Reynolds numbers, generally, lower than 1000 that fall, mainly, under the laminar and/or intermediate flow laws (Edling 1985; Thompson et al. 1993).

More recently, Lorenzini (2004) and Lorenzini and De Wrachien (2003, 2004, 2005) proposed a model that accounts, mainly, the effects of air friction on droplet evaporation, which is relevant in the turbulent flow law (Reynolds numbers greater that 1000). The model proved to fully match the kinematic results obtained by more complicated procedures and to work out ready to apply formulae suitable to assess the contribution given to the droplet evaporation by the dynamic phenomena that accompany its aerial path from the sprinkler nozzle to the ground.

A NEW MODEL FOR SPRINKLING SPRAY FLOW AND EVAPORATION

Droplet dynamics

The flow of a droplet from the sprinkler nozzle down to the ground is described by means of the Second Principle of dynamics: $\vec{F} = m\vec{a}$, where $\vec{F}$ is the total force in N acting on the droplet and equal to the vector sum of the weight of the droplet of mass m in kg diminished by its buoyancy force and of the friction force acting during the flight on the droplet of acceleration $\vec{a}$ in ms^{-2}. The friction factor f used in the model is that defined by Fanning (Bird *et al.*, 1960). For a fluid flow surrounding a droplet it is given by :

a) for Reynolds number $Re < 0.1$: $f = \dfrac{24}{Re}$

b) for $2 < Re < 500$: $f = \dfrac{18.5}{Re^{0.6}}$

c) for $500 < Re < 200000$: $f = 0.44$

Case (a) expresses the conditions of the laminar flow law; case (b) of an intermediate flow law, and case (c) of the turbulent flow law. Case (a), statistically speaking, is very unlikely to occurs in sprinkler irrigation practice as, at the usual flow velocities, it would imply droplet diameters of an order of magnitude 0.1 μm, which is more typical with chemical spray application rather than with irrigation.

The hypotheses formulated are that: each droplet is generated exactly in correspondence to the nozzle outlet; the forces applied to the system are weight, buoyancy, friction; the droplet has a spherical shape; the volume of the droplet is invariant during the flight; the friction has the same direction of the droplet velocity but opposite sense for all the path; and there is no wind.

The parameters to be introduced are: the nozzle height *h* with respect to ground level; the droplet velocity *v* and the angle α, with respect to the horizontal direction, of the jet .

If *n* is the mass of the droplet accounting for its buoyancy component and the friction parameter k in kgm^{-1} (given by $k = \frac{f\rho A}{2}$ where ρ is air density, depending on temperature, and *A* is the cross section in m^2 of the droplet) is the coefficient which defines the action of the friction force, then the final equations in the horizontal and vertical directions are :

$$m\ddot{x} = -k\dot{x}^2 \quad (1)$$

$$m\ddot{y} = -k\dot{y}^2 - ng \qquad (2)$$

where $\dot{x}$, $\dot{y}$, $\ddot{x}$, $\ddot{y}$ are velocities in ms^{-1} and accelerations in ms^{-2} in the horizontal and vertical direction, respectively. The initial conditions are:

$$x(t=0) = 0 \quad (3)$$

$$\dot{x}(t=0) = v_{0x} \qquad (4)$$

for the first equation and:

$$y(t=0) = h \quad (5)$$

$$\dot{y}(t=0) = v_{0y} \qquad (6)$$

for the second one: where *t* is time; v_{0x}, v_{0y} represent the horizontal and vertical velocity components in ms^{-1}, respectively, at the entrance; and h is the nozzle height with respect to the ground in m. Integrating the system of differential equations we obtain the full analytical solution of the problem in the form of parametric equations of position (*x(t), y(t)*), velocity ($\dot{x}(t)$, $\dot{y}(t)$) and flight time.

The model, providing an exact solution, applies to every particular configuration of the system, *i. e.* for every droplet diameter, flow state, air temperature nozzle geometry, initial flow rate and velocity, in the hypotheses formulated. Attention, though, has to be drawn to the friction parameter k, as it is strongly affected by the flow state of the droplet. In fact it may happen (and it often does) that a droplet starts its path in a certain flow state modifying it along the way, so requiring a different value of k, to be inserted in the model. Lorenzini (2004) showed that, a part from the smallest diameter droplet, all the cases fall in the turbulent flow law region in which the value for f is 0.44.

Droplet evaporation

Spray evaporation is assessed on the basis of the analytical procedure previously described (Lorenzini, De Wrachien, 2003). The model accounts only the effects of air friction on the droplet evaporation and neglects all other parameters. Despite its limits, the model could improve the understanding of the sprinkler evaporation phenomenon. This approach has not been found elsewhere, probably because air friction was considered as a factor of minor relevance in the process.

Three additional assumptions have been introduced:

(1) evaporation is obtained by the total work of the resulting force (sum of weight, buoyancy and friction force) acting on the droplet along its trajectory;

(2) droplet evaporation occurs just at the end of the flight path; and

(3) the droplet is considered as a material point.

The second hypothesis entails a limitation to the results, as the final kinetic energy of the droplet is calculated by means of the initial mass: this implies that the evaporation losses are somehow over-estimated. A sort of 'upper limit' (in the proper mathematical meaning) of the 'force-induced' droplet evaporation is so worked out in the present approach. This does not, anyway, reduce the effectiveness of the model, just aimed at assessing the role of air friction in spray evaporation for sprinkler irrigation systems.

Validation of the dynamic model

The validation of the procedure needs a quantitative approach to check how reliable the predictions are: this can be done introducing other authors' data in the model. The works chosen for these comparison purposes are by Edling (1985) and Thompson *et al.* (1993). Among the case studies by these authors, only those involving a no-wind condition were considered. Results are shown in Fig 1 to 7 in terms of travel distance and in table 1 interns of time of flight.

Facing a comparative approach, it can be stated that the model here defined proves to be kinematically reliable in its predictions from a qualitative and quantitative points of view, particularly when droplets having a 'not too small' diameter are considered. This, being the model defined by neglecting most of the parameters typically introduced in the others, can be considered as a first relevant result. The comparisons performed with the Thompson *et al.(1993)* data show that when the droplet gets close to a condition of the laminar flow law the model provides less accurate results. This is the limit to the model and it somehow defines the field of acceptability of the method. The model becomes weaker when moves away from the turbulent flow law because of the approximation used to define the value of k in the other two flow patterns. The dependence of the results on the flow state criterion can easily explain the different results obtained for the smallest droplets in the present work and in Thompson *et al*. (1993).

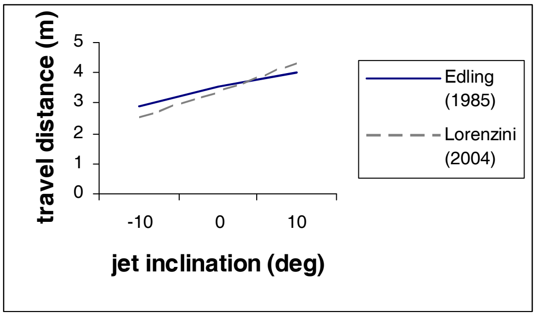

Figure 1 Travel distance of sprinkler droplets: Edling's (1985) data compared to Lorenzini's (2004): flow rate= $1.4x10^{-4}m^3s^{-1}$; nozzle diameter $3.96x10^{-3}$m; air temperature 29.4°C; nozzle height = 1.22m; droplet diameter = $1.5x10^{-3}$m.(R^2=0.997)

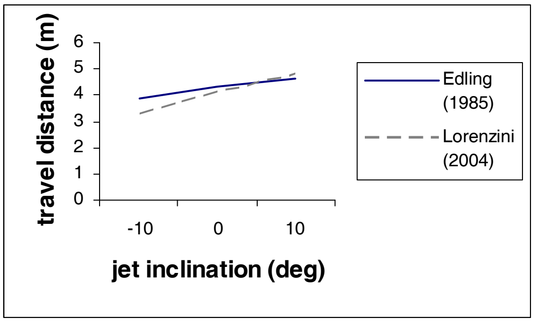

Figure 2 Travel distance of sprinkler droplets: Edling's (1985) data compared to Lorenzini's (2004): flow rate= $1.4x10^{-4}m^3s^{-1}$; nozzle diameter $3.96x10^{-3}$m; air temperature 29.4°C; nozzle height = 2.44m; droplet diameter = $1.5x10^{-3}$m.(R^2=0.997)

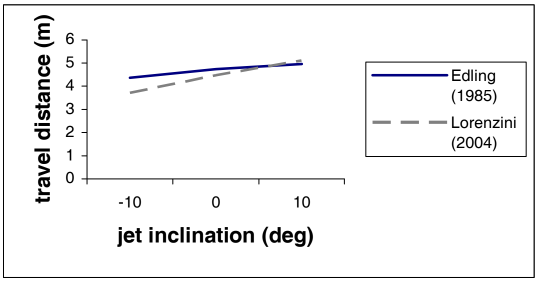

Figure 3 Travel distance of sprinkler droplets: Edling's (1985) data compared to Lorenzini's (2004): flow rate= $1.4x10^{-4}m^3s^{-1}$; nozzle diameter $3.96x10^{-3}$m; air temperature 29.4°C; nozzle height = 3.66m; droplet diameter = $1.5x10^{-3}$m. (R^2=0.995)

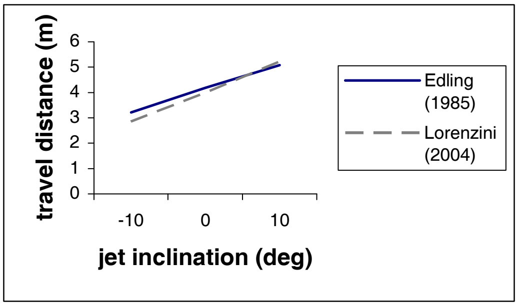

Figure 4 Travel distance of sprinkler droplets: Edling's (1985) data compared to Lorenzini's (2004): flow rate= $1.4x10^{-4}m^3s^{-1}$; nozzle diameter $3.96x10^{-3}m$; air temperature 29.4°C; nozzle height = 1.22m; droplet diameter = $2.5x10^{-3}m$. (R^2=0.999)

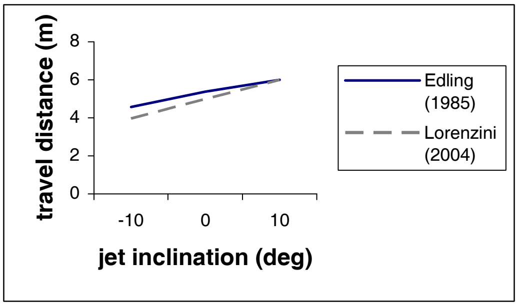

Figure 5 Travel distance of sprinkler droplets: Edling's (1985) data compared to Lorenzini's (2004): flow rate= $1.4x10^{-4}m^3s^{-1}$; nozzle diameter $3.96x10^{-3}m$; air temperature 29.4°C; nozzle height = 2.44m; droplet diameter = $2.5x10^{-3}m$. (R^2=0.998)

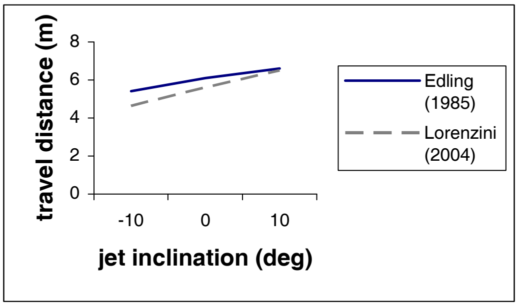

Figure 6 Travel distance of sprinkler droplets: Edling's (1985) data compared to Lorenzini's (2004): flow rate= $1.4x10^{-4}m^3s^{-1}$; nozzle diameter $3.96x10^{-3}m$; air temperature 29.4°C; nozzle height = 3.66m; droplet diameter = $2.5x10^{-3}m$. (R^2=0.998)

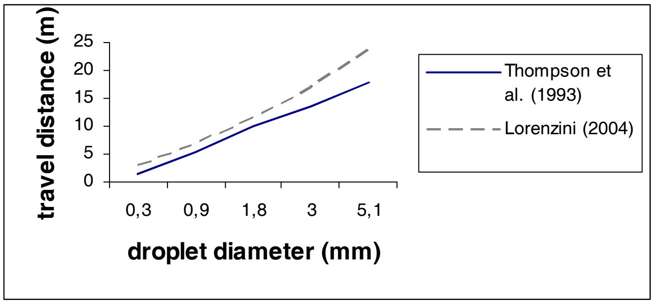

Figure 7 Travel distance of sprinkler droplets: Thompson et al (1993) data compared to Lorenzini's (2004): flow rate= $5.5x10^{-4}m^3s^{-1}$; nozzle diameter $4.76x10^{-3}$m; air temperature =38°C; jet inclination=25°; nozzle height = 4.5m. (R^2=0.994)

Table 1 Time of flight of sprinkler droplets: Thompson et al.'s (1993)data compared to that of Lorenzini(2004): flow rate = 5.5 x $10^{-4}m^3s^{-1}$; nozzle diameter = 4.76 x 10^{-3} m; air temperature = 38°C; jet inclination = 25°; nozzle height = 4.5 m.

		Droplet diameter (m)			
		0.9 x 10^{-3}	1.8 x 10^{-3}	3.0 x 10^{-3}	5.1 x 10^{-3}
Time of flight (s)	*Thompson et al. (1993)*	1.54	1.63	1.75	1.84
	Lorenzini (2004)	1.35	1.73	2.00	2.26

Validation of the droplet evaporation model

The droplet evaporation model, based on the consideration of the air friction effect only, which applies to the turbulent low, was tested on the basis of the data provided by Edling (1985) and Thompson *et al.* (1993) reported in Table 2. These authors took into account a range of conditions which fall, mainly, under the laminar and/or intermediate flow laws, so neglecting the air friction effect. This is why the evaporation results, reported in Table 3, are not directly comparable to ours, even if a check on the order of magnitude can help an analysis. Table 4 presents the upper limits of droplet evaporation obtainable by means of the model presented, starting from the reference data set. The discrepancies between the results in Table 3 and Table 4 depend on the different nature of the affecting parameters chosen. It has to be stressed, however, that the results here achieved are both qualitatively and quantitatively correct, not of course as descriptive of the whole phenomenon, but just with regard to the maximum role that air friction plays in the process. In fact, the friction force depends on the cross section area of the droplet, and so it is reasonable to expect that larger droplets undergo bigger frictional effects. This is due on the one hand to a longer time of flight, on the other hand to a more intense action of the friction forces because of the bigger cross-section. It has, also, to be underlined that in some practical applications, such as fogging systems or pesticide sprayers, equipment is made to produce very small droplets to have maximum evaporation. In this case, it is clear that droplet evaporation decreases when its diameter increases due to the fact that the parameters introduced (relative humidity, *etc.*) depend on the whole external surface of the droplet, which, augmenting the droplet diameter, has an increase smaller than that of the volume. So it clears why the trends are different.

On the whole, it is possible to underline the general reliability of the procedure. Furthermore, the model could represent the first step towards a full comprehension of an important issue; *i.e.* to assess the role played in the evaporation process by the thermo fluid dynamic phenomenon that accompanies the droplet along its trajectory.

Table 2 Droplet evaporation without allowing for air friction: Edling's (1985) and Thompson *et al.* (1993) data

	Edling	**Thompson et al.**
Flow rate exiting from the sprinkler, ls^{-1}	0.73	0.55
Nozzle diameter, mm	7.14	4.76
Jet inclination with respect to horizontal, °	0	25
Nozzle height, m	3.66	4.5
Air temperature, °C	21.11	38
Air relative humidity, %	20	20
Wind	NO	NO

Table 3 Droplet evaporation without allowing for air friction: Edling's (1985) and Thompson *et al.* (1993) results

Droplet diameter, mm	**Edling**	**Thompson et al.**
1.000	1.19	2.39
1.125	1.08	2.11
1.250	1.01	1.85
1.375	0.95	1.75
1.500	0.81	1.41

Table 4 Maximum value possible for droplet evaporation caused by the air friction: Lorenzini & De Wrachien (2003).

Droplet diameter, mm	Droplet evaporation, %	
	Lorenzini & De Wrachien with Edling's data	Lorenzini & De Wrachien with Thompson et al data
1.000	1.12	1.99
1.125	1.52	2.19
1.250	1.70	2.35
1.375	2.29	2.78
1.500	2.69	2.95

CONCLUSIONS

Irrigation water that is applied to crops is most effective if that water enters the transpiration stream and contributes directly to the matter accumulation. Unfortunately, some of the irrigation water may be lost by evaporation and never be able for transpiration or direct contribution to yield. Evaluating the losses associated with an overhead sprinkling system is challenging because evaporation can occur from droplet before they reach the canopy, from wet leaves, and wet soils. Therefore, a thorough understanding of the thermal fluid dynamic process that effects spray flow and evaporation losses in sprinkler irrigation systems represents a great help in assessing the performance of the systems and in developing appropriate water conservation strategies. The issue requires a full analytical description of how a droplet exiting from nozzles reaches a solid surface and entails both experimental and theoretical studies.

Among the analytical studies, the heat and mass transfer analogy, linked with particle ballistics, offers a well-established approach to assess jet flow and evaporation losses. The procedure describes the event of a droplet travelling from the sprinkler nozzle to the ground as a combination of environmental parameters such as pressure gradient, vapour concentration, air relative humidity, resulting in very elaborate formulae and strongly condition-dependent. The results are in reasonable agreement with experimental data for Reynolds numbers, generally, lower than 1000, that fall, mainly, under the laminar and/or intermediate flow laws. However, this range covers too small an interval of values to be of a general utility in irrigation practice. To narrow this gap, the model proposed is suitable to assess the contribution given to the droplet evaporation by friction force during the aerial flight of the droplet, within the field of the turbulent flow law.

The tool has proved to fully match the kinematic results obtained by more complicated procedures. Furthermore, the model made it possible to work out ready-to-apply formulae suitable to asses the 'upper limit' of the contribution given to the droplet evaporation by the friction force during the aerial flight of the droplet. This approach has not been found elsewhere, probably because air friction was considered as a factor of minor relevance in affecting spray evaporation. A more comprehensive analysis of this problem by means of the model here described, will allow the authors to assess the ‘actual value’ of the ‘force-induced’ droplet evaporation and further steps towards a thorough understanding of the phenomena.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

AKTUALNA SITUACIJA U POLJOPRIVREDNOJ PROIZVODNJI U DOLINI RIJEKE SPREČE U BIH

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SAŽETAK

Sliv rijeke Spreče nalazi se u sjeveroistočnom dijelu Bosne i Hercegovine, a ima veoma dobre potencijale za poljoprivrednu proizvodnju, a različite kulture voća i povrća se uzgajaju na ovome području. U zadnjih pedesetak godina, u ovom dijelu BiH, građeni su veliki industrijski kapaciteti, uključujući i rudnike uglja, te različite fabrike kao što su fabrika sode, koksa, cementa, itd., što sve skupa predstavlja veliku opasnost za tlo, voće i povrće. Pored toga, vještačko jezero Modrac, koje se također nalazi na ovom području, predstavlja veliku opasnost za poljoprivrednu proizvodnju nizvodno rijekom Sprečom. U kišnom periodu, jezero Modrac ne može da akumulira svu količinu vode sa okolnih planina, zbog toga se kao posljedica često javljaju poplave. Uzimajući to u obzir, u ovome radu, želja je da se pokaže na opasnosti koje prijete ne samo navedenom području nego i široj regiji, nizvodno rijeka Spreče, Save i Dunava. Na šest lokaliteta, gdje Spreča najčešće plavi uzimani su uzorci tla, te analizirane osnovni pokazaatelji kvaliteta, koji pokazuju da je na tim lokalitetima tlo prekiselo, pH ispod 6. Uz ove analize, rađene su i analize radi kategorizacije rijeke Spreče. Na osnovu čega se došlo zaključa da rijeka Spreča, pripada trećoj kategoriji otpadnih voda, te kao takva ima velike i nesagledive posljedice za poljoprivrednu proizvodnju, što se naravno ogleda i u velikoj kiselosti tla.

Ključne riječi*: poljoprivredna proizvodnja, voće, povrće, plavljenje*

UVOD

Razvoj industrije, i sve manja briga čovjeka za okoliš dovela je do mnogih problema od kojih je plavljenje najveći. U zadnje vrijeme na području sliva rijeke Spreče, nizvodno od jezera Modrac, skoro dva puta godišnje mnoge obradive površine budu poplavljene i mnoge kulture ostaju uništene. Do nekih biljnih kultura stigne voda, ali ih ne uništi, što može predstavljati još veće probleme zbog toga što dolazi do promjena mikroflore i mikrofaune, te narušavanja ravnoteže među živim organizmima (Van Os et al. , 1997.).

Nakon plavljenja, dolazi do određenih promjena koje imaju negativan efekat na strukturu i sastav zemljišta, jer može doći do promjena elektroprovodljivosti, dostupnosti fosfata, izmjenjivosti dostupnog kalija, itd. (Minkyeong et al., 2006.).

S geološkog aspekta, poplave su prirodne posljedice kontinuirane promjene riječnih tokova, a uzroci mogu biti prirodni i posljedica ljudskih djelovanja. Prirodni uzroci plavljenja su uglavnom obilne kiše, reljef, itd., dok su ljudski faktori različiti, što uključuje sječu šuma, slabo upravljanje vodenim resursima, rast ljudske populacije, itd. (Rebecca et al., 2007.).

Procjene rizika od plavljenja su uglavnom nepredvidive zbog mnogih razloga, što uključuje društvene i klimatske promjene, kao i osnovne teškoće u određivanju klimatoloških rizika ekstremnih događaja koje uzrokuje voda (Nelson, 2006.). Biljne vrste koje pretrpe plavljenje, trpe određene promjene u fitosintetičkom kapacitetu i ponašanju biljaka u narednim stadijima dozrijevanja (Bradford, 1983.).

Plavljenje brzo iscrpljuje kisik iz tla, mijenjajući metabolizam biljnih vrsta, i inhibirajući njihov rast. Usporen rast se ogleda u reduciranoj fotosintezi, translokaciji ugljikohidrata, adsorpciji ugljikohidrata, kao i promjenama u biljnim hormonima. Otpornost biljaka prema plavljenjima je različita, jer zavisi od morfoloških i fizičko – kemijskih prilagođavanja biljaka(Kozlowski, 1984.).

Kada su u pitanju karakteristike tla kao što je pH, plavljenje povećava pH kiselih tla, a smanjuje kod alkalnih vrsta tla. Također je bitno naglasiti da se smanjuje sadržaj organskih materija, jer njihovim razlaganjem nastaju mnogi produkti kao što su ugljen dioksid, metan, huminske materije i drugo, što oštećuje korijenov sistem. Nakon plavljenja na površinama tla kod obradivih parcela nastaje talog koji sprječava aeraciju tla, što takođe dovodi do oštećenja biljaka (Kozlowski,1991.). Ovaj rad je namijenjen da ukaže na probleme i posljedice širih razmjera, a ne samo lokalnog karaktera.

MATERIJAL I METODE

Sjeveroistočna Bosna je dio, koji je najznačajniji po poljoprivrednoj proizvodnji u cijeloj Bosni i Hercegovini. Pored toga, u ovom dijelu BiH, smješteni su mnogi prerađivački kapaciteti teške kemijske industrije, posebno oko Tuzle i Lukavca, odnosno dolinom rijeke Spreče. Na rijeci Spreči, smješteno je i vještačko jezero Modrac, koje pokriva oko nekoliko tisuća hektara obradivog zemljišta.

U dolini rijeke Spreče živi oko pola miliona ljudi, od kojih polovina živi od poljoprivredne proizvodnje, a mnogi, obradivo tlo oko rijeke Spreče upotrebljavaju za proizvodnju voća i povrća za vlastite potrebe. Uslijed toga su urađene određene analize rijeke Spreče i tla na lokalitetu jezero Modrac, do ušća rijeke Spreče, odnosno njenog ulijevanja u rijeku Bosnu. Uzimanje i analizu vode iz rijeke Spreče, radio je Institut za kemijsko inženjerstvo, gdje su korištene standardne metode po važećem pravilniku za kategorizaciju otpadnih voda u BiH. Analize tla su uključivale sljedeće:

1. Vrijednost pH tla je određivana u H_2O (aktivna kiselost) i KCl (supstitucijska kiselost) elektrometrijski na pH – metru sa jon selektivnom elektrodom u suspenziji tla u odnosu 1 : 2,5.

2. Sadržaj humusa u tlu je određivan kolorimetrijskom metodom po Springer-u.

REZULTATI I DISKUSIJA

Tabela 1 Osnovni pokazatelji kvaliteta vode iz rijeke Spreče[9]

Redni broj	Osnovni pokazatelji	Utvrđene vrijednosti na lokalitetima			MDK vrijednosti
		I	II	III	
1.	Otopljeni kisik, mg/l	12,2	12,2	12,3	4,0
2.	Zasićenost kisikom, %	104,2	105	105,4	115 – 125
3.	Petodnevna biokemijska potrošnja kisika (BPK_5) mg O_2/l	5,6	3,0	4,0	7,0
4.	Kemijska potrošnja (HPK) kisika iz $KMnO_4$	7,0	5,7	6,1	20,0
5.	Kemijska potrošnja (HPK) bikromatna metoda mg O_2/l	18,2	54,5	72,7	--
6.	Suspendirane materije mg/l	129,6	75,5	94,3	80
7.	Suhi ostatak filtrirane vode mg/l	721,4	833	813	1.500,00
8.	pH vrijednost	8,4	8,4	8,4	6,0-9,0
9.	Elektroprovodljivost µS/cm	844	983	975	--
10.	Mutnoća NTU	63	48	53	--
11.	Amonijačni N mg/l	0,85	1,45	1,45	10,00
12.	Nitriti (N) mg/l	0,044	0,044	0,055	0,5
13.	Nitrati (N) mg/l	0,38	0,48	0,52	15,00
14.	Kloridi mg/l	189,6	272,9	225,1	--

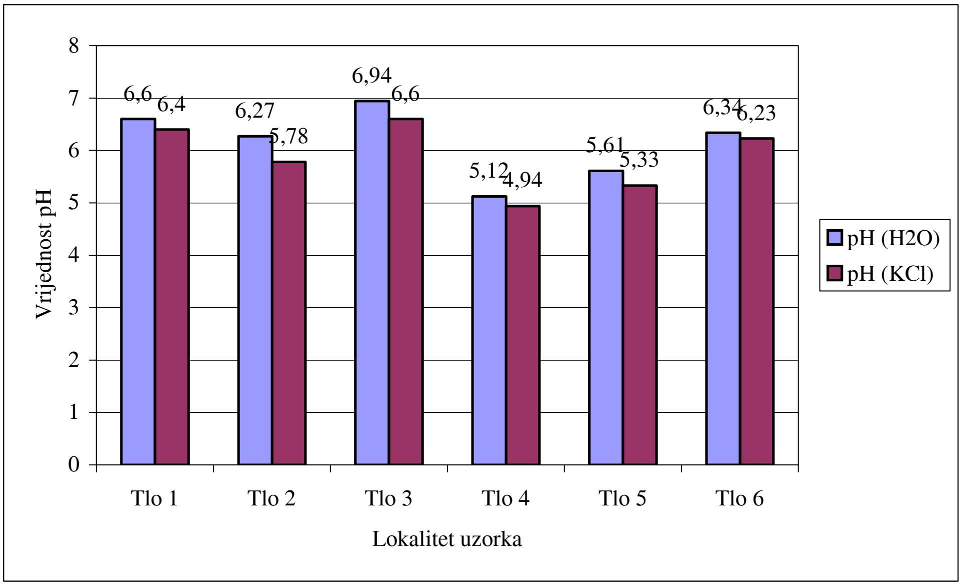
Rezultati kvaliteta vode iz rijeke Spreče, ne pokazuju velike varijacije u smislu promjena pojedinih pokazatelja. Sadržaj otopljenog kisika na sve tri lokacije uzorkovanja i analiza vode iz rijeke Spreče je uglavnom isti, a iznosi 12,2 mg/l. Izmjerena vrijednost je tri puta veća od dozvoljene vrijednosti definirane pravilnikom[9]. Za zasičenost kisika se također ne može konstatirati da je u dozvoljenim granicama, jer je sadržaj manji od donje dozvoljene granice. Petodnevna potrošnja kisika (BPK_5), manja je od dozvoljene i to za sva tri lokaliteta uzorkovanja.

U pogledu kemijske potrošnje kisika, može se reći da je neujednačena, prema objema metodama. Posebno je potrebno istači lokalitet broj 3, gdje je prema bikromatnoj metodi kemijska potrošnja kisika iznosila, 72,7 mg/l. Suspendirane materije izražene kao mg/l su na lokalitetima, 1 i 3 veće od maksimalno dozvoljene, a iznose 129,6 mg/l (lokalitet 1) i 94,3 mg/l (lokalitet 3). Suhi ostatak filtrirane vode, izražen u mg/l je manji od dozvoljene vrijednosti za sve tri lokaliteta.

pH vrijednost na sve tri lokacije je iznosila 8,4, a nalazi se u graničnim vrijednostima. Elektroprovodljivost na drugoj (2) i trećoj (3) lokaciji je veća za oko 100 µS/cm u odnosu na lokalitet 1, što nije slučaj za mutnoću, jer je najveća vrijednost od 63 NTU na lokalitetu 1. Amonijačni N je na lokalitetima 2 i 3 isti i iznosio je 1,45 mg/l, što je viša vrijednost u odnosu na lokalitet 1. Nitriti i nitrati su unutar graničnih vrijednosti, koje su znatno niže u odnosu maksimalno dozvoljene. Sadržaj klorida na lokalitetu 2 je najveći i iznosio je 272,9 mg/l, a najmanji na lokalitetu 1, 189,6 mg/l.

Kao elementi osnovne analize tla uključeni su rezultati određivanja kiselosti, prikazano kao pH u vodi i u 1M KCl-u, sadržaj organske materije i vlage (Keran, 2006.).

Na slici 1. prikazani su rezultati određivanja kiselosti tla Sprečkog polja, izražene kao pH vrijednost.

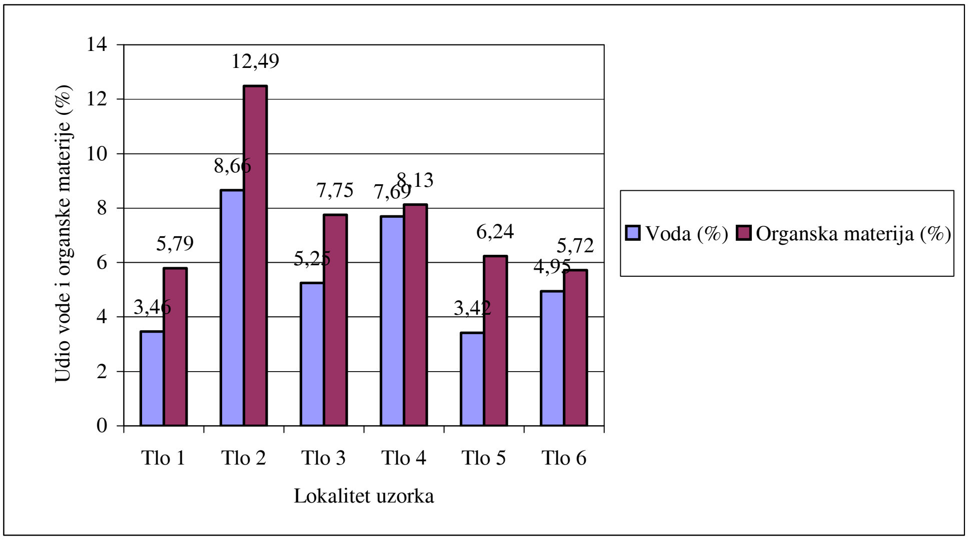


Slika 1 Kiselost uzoraka tla u vodi i u 1M KCl

Na osnovu rezultata prikazanih na slici 1. pokazuju da parcele sa kojih su uzeti uzorci tla za analizu imaju pH ispod 7, što znači da je to tlo kiselo. Uzorak tla, označen kao tlo 3 ima najveću vrijednost pH koja iznosi 6,94 u vodi i 6,60 u KCl. Značajno je naglasiti da tlo sa lokaliteta broj 4. ima najniže vrijednosti pH, u vodi 5,12, a u 1M KCl, 4,94. Uzorci tla, označeni kao tlo 2, 4, 5, su uzeti sa lokaliteta gdje je često plavljenje (Keran, 2006.).

Rezultati određivanja sadržaja vlage i organske materije u tlu sa lokaliteta Sprečkog polja, dati su u procentima, što je dato na slici 2. (Keran, 2006.).

Sadržaj vode i organske materije je predstavljen na istoj slici. Bitno je napomenuti da je udio vode bio najmanji u uzorku tla sa oznakom 5, i iznosio 3,42 %, a najveći u uzorku tla sa oznakom 2, i iznosio 8,66 %. Sadržaj organske materije u tlu je bio različit i varirao je u intervalu od 5,72 %, uzorak tla sa oznakom 6 do 12,49 %, uzorak tla sa oznakom 2.



Slika 2 Sadržaj vode i organske materije u tlu Sprečkog polja

ZAKLJUČCI

Iz navedenog proizlaze slijedeći zaključci:

- pH vrijednost tla sa plavljenih lokacija je znatno niža od pH neplavljenog tla, što znači da je kontaminacija plavljenjem uzrokovala povećanje kiselosti tla;
- prema važećem pravilniku za otpadne vode[(9)], a na osnovu dobijenih parametara, voda u rijeci Spreči pripada trećoj (III) kategoriji;
- Nužna je edukacija stanovništva da ne uzgaja voće i povrće na lokacijama u blizini rijeke Spreče;
- Nužan je stalni nadzor kvaliteta tla i vode u rijeci Spreči, kao i mjere sanacije tla nakon plavljenja.

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9. Pravilnik o otpadnim vodama, Federacija BiH.

ACTUAL SITUATION IN AGRICULTURAL PRODUCTION IN SPRECA RIVER BASIN IN B&H

SUMMARY

Spreca River Basin in the North – East Bosnia and Herzegovina has very good potential for the agricultural production and differenet fruits and vegetables are grown there. In the last fifty years, in this part of B&H, a big industry capacities are placed, including coal mines and different factories such as soda, coke, cement, etc. and all of it presnts a great danger for soil, fruits and vegetables. Beside this, an artificial lake, Modrac, which is also located in this region, is threat to agricultural production downstream Spreca River. In raining pariod, Modrac accumulation cannot receive all amount of water and as consequence, the flooding is very often.

The main purpose of this work is to show the possible threats not only to agricultural production in B&H, but also in the region, and downstream the rivers such as Spreca, Sava and Dunav. Soil samples were taken at six locations, where the flooding is the most often, and analyzed. Results showed that soil from these locations is very acid, pH below 6. Beside this, categorization of water from Spreča river was also performed, and results showed that it belongs to the third category. High pollution of Spreča river affects the soil quality and agricultural production, as well as produces a high acidity of soil.

Key words: *agricultural production, fruits, vegetables, flooding*

35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Expert paper

RESEARCH OF THE BASES FOR DEVELOPMENT OF AGRICULTURAL TRACTORS

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SUMMARY

The results of a three-year research of bases for development of new tractors were presented in this paper. The conceptions and categories were defined according to the minimal drawbar pull and built engines: one-axle tractors 5–15 kW, mini tractors 15.1–30 kW, light tractors 30.1–60 kW, medium tractors 60.1–130 kW, heavy tractors 130.1–260 kW and super heavy tractors > 260 kW.

The needs for tractor models according to categories were defined: light tractors 30–60 kW, five models; medium tractors 60–130 kW, five models and heavy tractors 130–260 kW, five models.

The new and improved existing tractor models were developed like light TP.50 (IMT 2050) and TP.70 (IMT 2070), medium TP.90 (IMT 2090) and TP.140 (IMT 2140) and heavy TP.200 (IMT 2210).

***Key words**: bases, tractor, development, categories, characteristics*

INTRODUCTION

The situation in the field of power machines and tractors is slowly improving, but this is far from an optimal situation in which readiness of the whole mechanization would be in such a state that all farming operations could be carried out to meet the optimal deadline, and that is the beginning of November in the next year. There are still machines which are between 15 and 18 years old, and even it may seem that there are more tractors than necessary, overall efficiency is low, thus mechanization appears to be the key factor for exploitation of the genetic potential of plants. It is estimated that every year, around 18,000 new, two-axle tractors should be introduced into the agriculture, and there should be: 15,000 tractors with engine power of 30-60 kW, 2,000 tractors with engine power of 60-130 kW, and 150 tractors with engine power over 130 kW, [4].

Tractors prices exceed 500 EUR per horse power, and expenses of maintenance and utilization are high, which consequently increases the expenses of production, making our agricultural products loose their competitive edge on the world's market, and our producers incapable of accomplishing complete modern technology for production of plants.

Therefore, the aim of this paper is a research of methods for improvement of production and utilization of tractors, which is the basis for an economical production of high-grade food in plant and cattle-breeding production. New and improved products should be competitive on both domestic and world's market.

For that purpose a research of bases and development of tractors was carried out, and that is for tractors with power:

- 30-60 kW (light tractors);
- 60-130 kW (medium tractors) and
- 130-260 kW (heavy tractors).

METHODS

During the research, an analysis of structure, utilization frequency and the condition of tractors is carried out, as well as the need for realization of complete technology in the production, which served as the basis for the selection of tractor models which need to be developed (light 30-60 kW, medium 60-130 kW, and heavy 130-260 kW).

Afterwards, some initial bases for development and utilization of tractors are done:

- analysis of soil and climatic conditions;
- structure of sowing and applied technology;
- tractive and technological parameters of tractor applications under different conditions;
- analysis of domestic tractor industry possibilities, and
- defining necessary categories of tractors in the range of light, medium and heavy tractors.

For tractor development or improvement of those already existing, there are appropriate methods for the selection of characteristics of:

- engine;
- transmission;
- wheels;
- ergonomic and technical characteristics concerning safety and
- morphological and other tractor systems.

Power and technological characteristics of new and already existing tractors of both IMT and foreign producers' have been studied. This helped define better the characteristics of new tractors or improvement of the already existing in the production program of Machine and tractor industry IMT – Belgrade.

RESULTS AND DISCUSSION

For successful development and economical use of tractors, it is necessary to define soil and climatic conditions, structure and size of properties and parcels, structure of sowing, returns, applied production technology, structure and tractor needs, and achieve a level of development of agricultural machines, [7].

The area of around 4,000,000 hectares of soil suitable for cultivating extends in the plains and hilly mountainous areas where 70% is at an altitude of 500 m. Specific soil resistance found in 93% of area is from 0,4 to 1,0 daN/cm². From the standpoint of mechanization utilization, climatic conditions are rather unfavorable, so the efficiency coefficient of farming periods on soil with medium plowing resistance from 0.7-0.8 daN/cm² , is around 0.65.

Properties are broken up which enables massive utilization of high productive mechanization. 15% of total area is comprised of properties, each having an average size of around 1,500 hectares, and the rest is comprised of properties with size of 3-5 hectares.

The length of a parcel is also small, around 400m on smaller properties, and 1,000 m on larger properties. The size of parcels should be at least 50 hectares with length around 1,000m.

The sowing has such a structure that grains and industrial raising prevail, then fodder and smaller vegetables. Organization of production technology is on a high level, but not in all properties, especially smaller ones in villages where the structure of farmers is very bad, since they are unable to accept modern mechanization.

Structure of tractors is unfavorable, and most of them have average engine power of around 34 kW (around 97.5%) and 66 kW (around 2.5%). The most common are tractors with power of 30-60 kW (light), then 60-130 (medium), and the rarest are heavy tractors with power of 130-260 kW. Development of implements that is achieved in the world is on a considerable level, which inevitably demands development of appropriate tractors.

Numerous construction tests carried out in our country and abroad, [1], [2], [3], [4], [5] and [6], defined the starting parameters for calculation of tractors, such as: tractive efficiency coefficient η_v = 0.60-0.70, coefficient of net traction φ^n = 0.4-0.50, optimal sliding δ = 10-15% and resistance to motion f = 0.06-0.09 for wheeled tractors on stubble.

There is also defined optimal motion speed, working speed 5-15 km/h, and road speed up to 30 km (50 km), and coefficient of time spent during the work with different implements, which is in medium conditions from 0.60 to 0.85.

Categorization of tractors is made according to the minimal drawbar pull (F_n), tab. 1, and according to the engine power at fly-wheel (P_e), tab. 2. These methods of categorization have certain disadvantages, but both of them are applied as the need arises.

According to the categorization of nominal drawbar pull, tractors are classified into n = 15 categories with drawbar pull from F_{min} = 1 kN to F_{max} = 200 kN. An average quotient of geometric progression in the equation (1) in this category is q = 1.460.

Tab. 1 Categorization of tractors,[2]

N^o	Nominal drawbar pull (kN)	
1.	1	F_{min}
2.	2	
3.	5	
4.	7	
5.	10	
6.	15	
7.	20	
8.	30	
9.	40	
10.	50	
11.	60	
12.	80	
13.	100	
14.	150	
15.	200	F_{max}

$$q = \sqrt[n-1]{\frac{F_{max}}{F_{min}}} \tag{1}$$

gde je:

n = 15 number of categories

F_{max} (kN) - nominal draw bar pull for the last category

F_{min} (kN) - nominal draw bar pull for the first category

Categorization according to the rated engine power is comprised of 6 categories of tractors, table 2.

Tab. 2 Categorization of tractors according to rated engine power, [2]

N^o	Categories	Rated engine power (kW)
1.	one-axle	< 15
2.	mini	15 - 30
3.	light	30 - 60
4.	medium	60 - 120
5.	heavy	120 - 240
6.	super heavy	> 240

According to the researches of characteristics of transmision, wheels systems in the usage conditions and defined ergonomic and safety technical characteristics, as well as the testings of characteristics of other producer's tractors, there are defined models and characteristics of light, medium, and heavy tractors.

Light tractors have universal purpose with engine power of 30.1-60 kW, and they are most common in agriculture (around 160,000 tractors),with conception 2WD and 4WD, but there is the need for 15,000 of them per year. Within this category, there are five defined models, tab. 3.

Tab 3 Models and characteristics of tractors power 30-60 kW

N^{o}	***Model***	**Engine power kW/KS**	**Type**		**Category (kN)**
			2WD	4WD	
1.	TP. 40	29.4/40	+	+	7
2.	TP. 50	39.5/54	+	+	10
3.	TP. 60	44.2/60	+	+	10
4.	TP. 70	55/75	+	+	15
5.	TP. 80	58.9/80	+	+	15

Two new basic models of tractors are developed, TP.50 and TP.70, fig. 1, with following characteristics:

- engine IMR, Perkins or John Deere, EURO 2, with engine power of around 36 and 51 kW
- mechanical transmission, completely synchronized with 10 to 15 gears for forward movement and 2-4 for backward movement
- new design, new air-conditioned and safety cabin
- tractors are built according to the international and domestic standards

Besides this, some improvements on the following models were carried out:

- TP.40 (IMT 539); engine D2600T with direct injection, new design, plastic control panel, cabin characteristics improved, more reliable.
- TP. 45 (IMT 550; improved IMT 549): engine JD 5029 with direct injection, or Perkins, or IMR; transmission is mechanically synchronized, more reliable, new pneumatic installation
- Tractors are in assembly line and are exported into the neighboring countries

Medium tractors with engine power of 60.1-130 kW have standard conceptions 2WD or 4WD, intended for more difficult farming operations, and they have universal purpose.

Serbia uses around 25,000 of these tractors, and there is the need for around 2,000 of them per year. In this category there are five defined models, tab. 4.

a) TP. 50 (IMT 2050)

b) TP. 70 (IMT 2070)

Fig. 1 Tractors of category 30.1-60 kW

Tab. 4 Models and characteristics of tractors power 60-130 kW

N°	***Model***	**Engine power kW/KS**	**Type**		**Category (kN)**
			2WD	4WD	
1.	TP. 100	73.6/100	+	+	20
2.	TP. 120	88.3/120	+	+	20
3.	TP. 140	103/140	-	+	30
4.	TP. 160	117.8/160	-	+	40
5.	TP. 180	132.5/180	-	+	40

In IMT in Belgrade, there are two models of tractors built in this category, and those are TP. 90.and TP. 140, fig. 2.

a) TP. 90 (IMT 2090)

b) TP. 140 (IMT 2140)

Fig. 2 Tractors of category 60.1-130 kW

Technical characteristics of TP.90 (IMT 2090) tractor are:

- Engine IMR, Perkins or John Deere, with power of around 73 kW, transmission is mechanical and synchronized with 10-20 gears for forward movement, and 4-6 for backward movement, and with speed of 2 to 30 (40 km/h). Italian hydraulics "MITA", new comfortable, safety cabin, seat GRAMER, steering wheel "KOBO". New modern design.
- One tractor of this model is on testing in India, in a firm "TAFE"

Technical characteristics of TP. 140 (IMT 2140) tractor are:

- Engine IMR, Perkins or John Deere with power of around 100kW. Mechanical transmission, synchronized with inversor, 18 gears with speed of 2-40 km/h. They are provided with hydraulics and power take-off at the back and in front. Air-conditioned safety cabin.
- 25 tractors with Deutz engine are on testing in Algeria.

Heavy tractors with power from 130 to 260 kW are intended for the most difficult farming operations in agriculture. Serbia uses around 1,300 tractors of this type, and there is the need for around 150 tractors of them per year. There are five models in this category, tab. 5.

Tab. 5 Models and characteristics of tractors power 130-260 kW

N^{o}	Model	Engine power kW/KS	Type 4WD	Category (kN)
1.	TP. 200	147.2/200	+	50
2.	TP. 240	176.6/240	+	50
3.	TP. 280	206.1/280	+	60
4.	TP. 320	235.5/320	+	60
5.	TP. 360	265/360	+	80

Main characteristics of TP.200 (IMT 2210) tractor, fig. 3, are: Mercedes engine, Perkins or John Deere with power of around 147 kW. Transmission is synchronized with inversor with 16 gears. "MITA" hydraulics, disc brakes soaked in oil. Steering is hydrostatic with wheels swiveling of 50 degrees. Hydraulics at the back and in front. Air-conditioned safety cabin, built according to the international standards.

Fig. 3 Tractor of category 130.1-260 kW, TP. 200 (IMT 2210)

CONCLUSIONS

On the basis of carried out researches, the following conclusions could be drawn:

- There are bases formed for the development of new tractors, improvement of the already existing tractors, and methods for rational utilization in accordance with the usage conditions
- The tractor models which are required are defined with their basic characteristics of engine power, light (30-60 kW), medium (60.1-130 kW), and super heavy with power over 360 kW.
- New tractors are built, and those already existing are significantly improved
    - light, TP.50 (IMT 2050) and TP.70 (IMT 2070)
    - medium, TP.90 (IMT 2090) and TP.140 (IMT 2140)
    - heavy, TP.200 (IMT 2210)

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 665.334.9:665.75
Prethodno priopćenje
Preliminary communication

FUELING AN AGRICULTURAL DIESEL ENGINE WITH BIODIESEL BLEND - EXPERIMENTAL RESULTS

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SUMMARY

The paper presents some results concerning the use of a Biodiesel type fuel in a direct injection (D.I) Diesel engine. The fuel was produced from waste vegetable oil, collected from the local McDonalds' branch. The tests were developed on a D-110 Diesel engine (S/D= 130/108 mm, ε = 17, four in line cylinders; the engine was mounted on an IRIMD test bed. Biodiesel fuel and 50%Biodiesel+50%Diesel fuel blend (Biodiesel blend) were used as fuels. The use of methylester (Biodiesel type fuel) led t to lower the output power and torque, while BSFC and fuel consumption increased. The autoignition delay decreased by 1…2^o CA. when Biodiesel blend was used in order to fuel the engine.

***Key words**: Biodiesel, Diesel engine, cylinder pressure, autoignition delay*

MATERIAL AND METHOD

The material used for the vegetable oil methylester (VOME) production was waste cooking oil collected from a local branch of the McDonalds' restaurants. The base catalyzed method was used for producing the methylester. Some physical properties of the methylester are shown in Table 1. The engine was fueled with a blend containing 50% Biodiesel and 50% Diesel fuel (B50, Biodiesel blend).

The tests were developed on a D.I. Diesel engine with the following features:

- type: D-110, 4 in line cylinders, water cooled;
- bore/stroke: 108/130 mm;
- compression ratio: 17;
- fixed start of injection (S.O.I.): 18^0 BTDC.

Table 1 Physical characteristics of the fuels

Item	Test method	Fuel		
		Diesel	**Used cooking oil**	**B100***
Density at 15 ^{0}C [g/cm^3]	EN ISO 3675	0.8393	0.891	0.857
Viscosity at 40 ^{0}C [mm^2/s]	EN ISO 3104	4.9	34.0	5.7
Acid value [mg KOH/g]	ASTM D664	0.089	2.67	0.92
Ash content [%}	SR ISO 6245:1995	0.085	0.075	0.038
Flash point [^{0}C]	ASTM D93	69	115	110
Cu corrosion	EN ISO 2160	1b	2e	2a
Surface tension [N/m]	-	0.0281	0.0336	0.0296

*Note: B100 – neat methylester

The engine was mounted on a test bed in order to measure the output power, output torque and fuel consumption and was operated at full load. In order to obtain the cylinder pressure trace, the engine was equipped with a water cooled Kiestler pressure transducer and with a transducer for the crankshaft rotation angle. Using the cylinder pressure trace, the maximum combustion pressure, the heat release and the autoignition delay (defined as the delay between the start of injection and the start of combustion) were calculated.

The brake mean effective pressure (BMEP) was calculated using the relation:

$$p_e = \frac{300 \cdot \tau \cdot P_e}{V_h \cdot n \cdot i},$$

where:

- τ= 4 (number of strokes of the engine cycle);
- P_e – output power [kW];
- V_h – displacement [dm^3];
- n – engine speed [rev/min];
- i - number of cylinders.

In order to calculate the engine efficiency, the following relation was used:

$$\eta = 3600 \cdot \frac{1000}{c_e \cdot Q_i},$$

where c_e is the BSFC [g/kW·h] and Q_i is the heat of combustion [kJ/kg].

RESULTS AND DISCUSSION

The results referring to engine output power and torque are presented in fig. 1 and 2. As reported by other authors [4, 5, 9] and shown in figure 1, the engine power diminished when the B50 fuel was used (because of the lower heat of combustion of the Biodiesel blend); thus, the maximum power has decreased from 38.3 to 36.9 kW. Numbers 1…4 on the chart mark the points where the heat release rate was calculated, using the cylinder pressure trace.

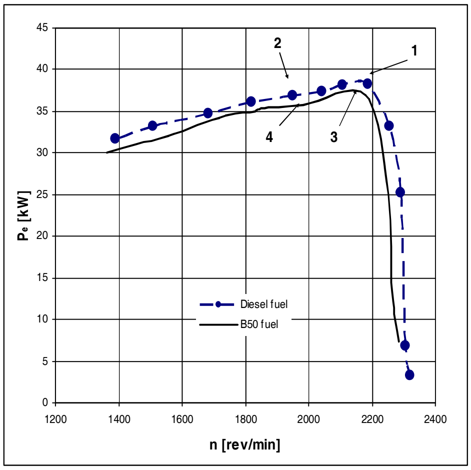

Fig. 1 Output power

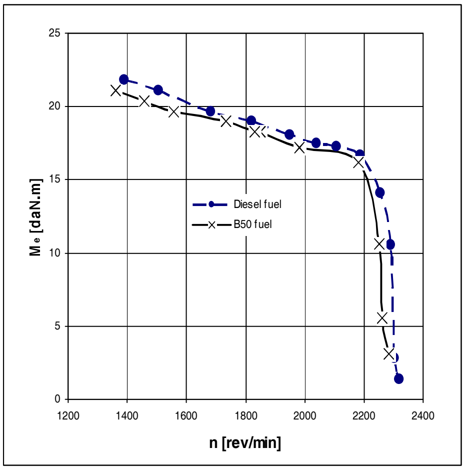

Fig. 2 Engine torque

The use of the B50 fuel also affected the engine torque (fig. 3); the maximum torque dropped from 21.8 daN·m to 20.9 daN·m.

Figures 3 and 4 show the effect of the B50 fuel over the engine's fuel consumption. As expected, when fueling the engine with Biodiesel blend, the fuel consumption increases; thus, the specific fuel consumption increased from 329.3 g/kW·h to 356.9 g/kW·h at 1800 rev/min engine speed. At 2200 rev/min (maximum power regime), the fuel specific consumption increased from 376.2 to 393 g/kW·h.

Brake mean effective pressure (fig. 5) is also affected when the B50 fuel is used to feed the engine, due to the decrease of the output power; BMEP decreased with 0.2…0.3 bar over the entire engine speed range.

Fig. 6 shows an increase of the engine efficiency when the Biodiesel blend is used, probably due to the higher oxygen content of methylester. Depending upon engine speed, the engine efficiency raise was comprised between 0.015 and 0.03 (1.5…3.0%). This effect was also reported by other authors [4, 17].

The experimental results concerning the peak cylinder pressure during combustion are summarized in fig. 7

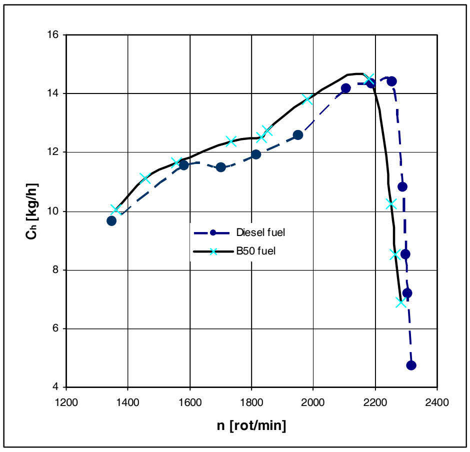

Fig. 3 Fuel consumption

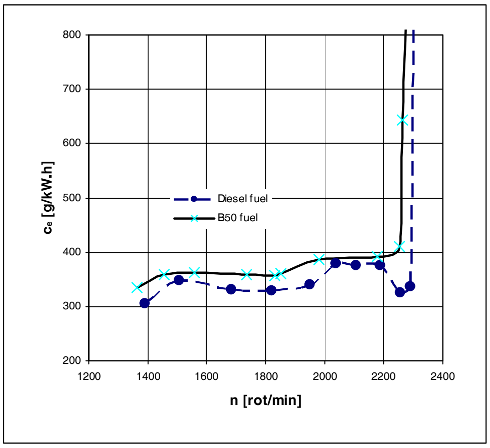

Fig.4 BSFC

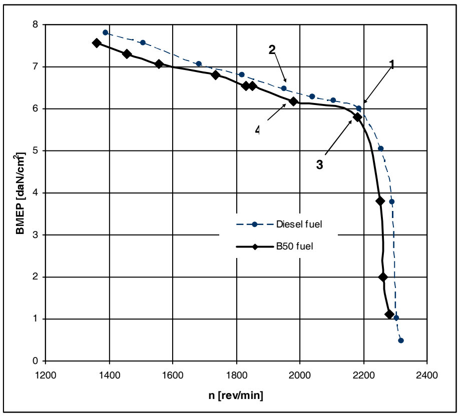

Fig. 5 Mean effective pressure

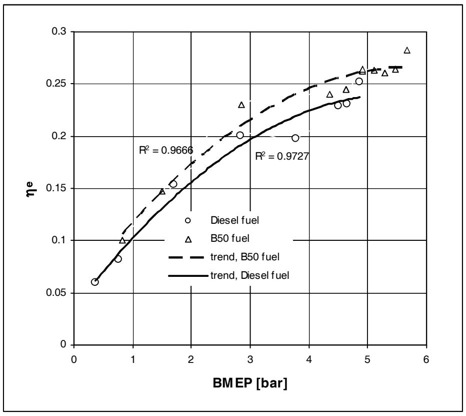

Fig.6 Engine efficiency

For the both fuels, peak combustion pressure increased when engine speed decreased (and respectively BMEP increased); this tendency is more significant for the Biodiesel blend. As a result, for engine speeds up to aprox. 1800 rev/min (high BMEP – fig. 5), the B50 fuel recorded higher peak combustion pressures compared to Diesel fuel; at higher engine speeds, Diesel fuel led to the achievement of higher peak combustion pressures. As shown in another paper [14], the use of the Biodiesel type fuel led to a prolonged injection; the most significant results were recorded for a pump speeds over 900 rev/min (1800 rev/min engine speed). It is known that increased injection duration leads to the decrease of the peak combustion pressure [6] and we think this explains the results shown in fig. 7. These results are in accordance with the ones obtained by other authors [2, 3].

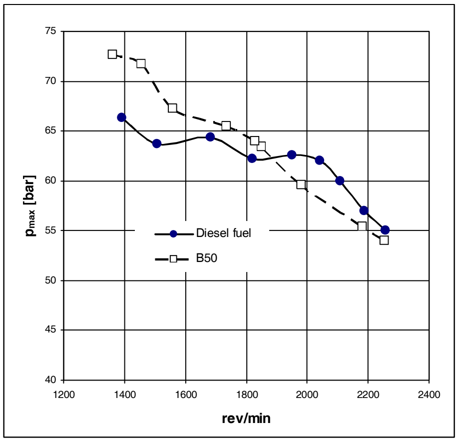

Fig. 7 Peak combustion pressure

Fig. 8 Autoignition delay

The results concerning the autoignition delay, presented in fig. 8 show that increasing the engine speed at constant load results in the decrease of autoignition delay; this is in accordance with the theory [6]: a change in engine speed changes the temperature/time and pressure/time relationships, leads to an increased injection pressure and higher peak compression temperature.

Biodiesel type fuels were reported to have a shorter ignition delay compared to Diesel fuel [10, 18, 19]; our experimental results confirmed that the autoignition delay for the B50 fuel is shorter by 2…4^{0}CA (0.1….0.25 ms).

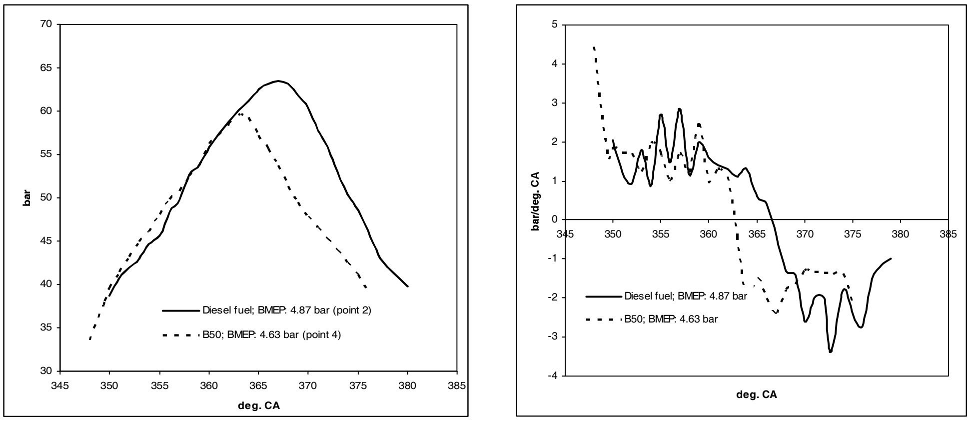

Fig. 9 Combustion pressure and pressure rate - points 2 and 4 (1900 rev/min)

The combustion pressure trace for points 1 to 4 (see fig. 2) are shown in fig. 9 and 10. The charts reveal an earlier start of combustion when the Biodiesel blend is used to fuel the engine, due to the shorter autoignition delay of this fuel. The combustion pressure recorded for the B50 fuel is lower than the one recorded for the petrodiesel: 63.5 bar peak combustion pressure for Diesel fuel and only 59.6 bar for the Biodiesel blend (fig. 9), respectively 56,9 bar and 55.4 (fig. 10).

Figure 11 presents the calculated results for the heat release and heat release rate. For the both fuels, combustion duration decreased when the engine speed increased (for Diesel fuel: from 24^0CA at 1900 rev/min to 20^0CA at 2200 rev/min). When the engine was fueled with Biodiesel blend, the combustion duration decreased (from 24^0CA at 1900 rev/min for Diesel fuel to 19^0CA for B50 and from 20^0CA at 2200 rev/min for petrodiesel to 17^0CA for B50).

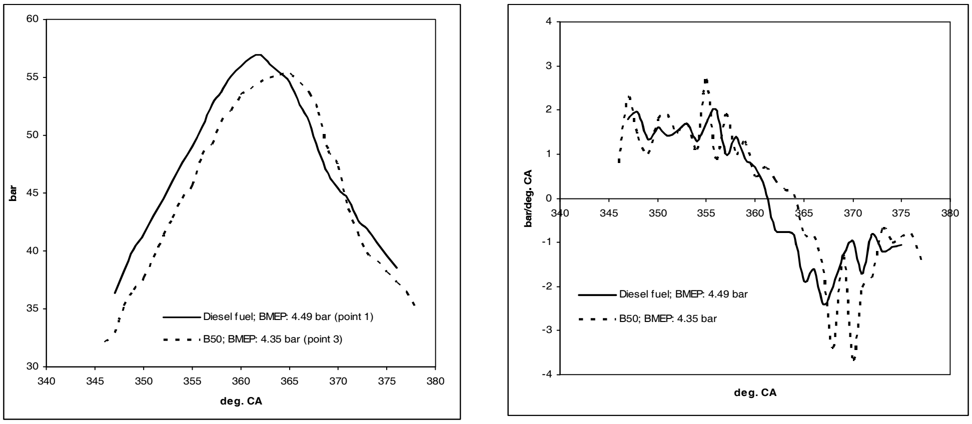

Fig. 10 Combustion pressure and pressure rate - points 1 and 3 (2200 rev/min)

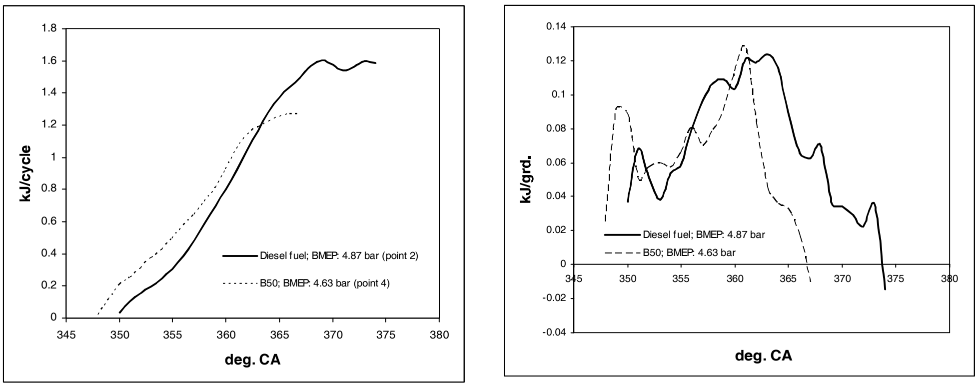

Fig. 11 Heat release and heat release rate - points 2 and 4 (1900 rev/min)

The peak heat release rate decreased as engine speed increased: from 0.123 kJ/0CA at 1900 rev/min to 0.093 kJ/0CA at 2200 rev/min for Diesel fuel and respectively from 0.127 to 0.088 kJ/0CA for the Biodiesel blend.

For the both fuels, at 1900 rev/min, the peak heat release rate was located after TDC (at 361 an respectively 3630CA); due to the lower autoignitoin delay at higher engine speeds, at 2200 rev/min the peak heat release rate was recorded before TDC (at 3570CA for petrodiesel and 3590CA for B50).

There are no major differences between the two fuels regarding the heat release (mass burned fraction).

The overall heat released during combustion is lower for the Biodiesel blend, compared to Diesel fuel (at 1900 rev/min: 1.6 kJ/cycle for petrodiesel and only 1.27 kJ/cycle for B50), due to the lower heat of combustion of the B50 fuel.

CONCLUSIONS

1. A Biodiesel type fuel was produced using waste vegetable oil.
2. A D.I. Diesel engine, mounted on test bed, was fueled with Diesel fuel and Biodiesel blend (50% methylester, 50% Diesel fuel). Engine in-cylinder pressure data were collected and used to evaluate the autoignition delay and the rate of heat release with respect to crank angle.
3. When the B50 fuel was used, power output was reduced by 2…4%, while engine torque was diminished by 4…9%. In the meantime, the fuel consumption and BSF increased.
4. A slight increase in engine efficiency (1.5…3%) was recorded when the Biodiesel blend was used to fuel the engine, probably due to the higher oxygen content of the fuel.
5. Compared to Diesel fuel, a lower autoignition delay (with 2…4^0CA) was registered for the Biodiesel blend.
6. When the engine was fueled with Biodiesel blend, the combustion duration decreased.
7. The overall heat released during combustion is lower for the Biodiesel blend.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 621.436.1:631.372:66.083.2
Stručni rad
Expert paper

MERJENJE KOMPRESIJE IN TLAKA NA ŠOBAH ZA DIAGNOSTICIRANJE TRAKTORSKIH MOTORJEV

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POVZETEK

V prispevku so opisane meritve tlaka kompresije motorja in tlaka odpiranja šob za vbrizgavanje. Pri meritvah smo primerjali razlike delovnega tlaka šob in razlike v tlaku kompresije. Diagnostiko smo izvajali na traktorju Massey Ferguson 3655 in traktorju Steyr 9170, ki imata različno število opravljenih ur. Pri traktorju Massey Ferguson je bilo v 3., 4. in 6. valju preveliko odstopanje od zahtevanega tlaka kompresije, ki ga predpisuje proizvajalec. Pri traktorju Steyr smo ugotovili preveliko odstopanje tlaka kompresije v 6. valju. S temi meritvami smo želeli ugotoviti, ali je po določenih delovnih urah na teh dveh traktorjih manjši tlak kompresije motorja in tlak odpiranja šob za vbrizgavanje goriva.

Ključne besede: *diagnostika, vzdrževanje, tlak kompresije, šobe za vbrizgavanje*

UVOD

S servisiranjem traktorjev po nasvetih proizvajalca lahko traktorju podaljšujemo delovno dobo. Določeni deli v traktorjih so v stalnem pogonu, kar pogojuje hitrejši izrabljenosti. Zato smo v okviru prispevka v traktorju Massey Ferguson 3655 in traktorju Steyr 9170 z diagnostiko (merilec kompresije) preverili tlake v kompresiji motorja. Izmerili smo tlake v valjih motorja in jih primerjali z tlaki, ki jih določa proizvajalec. Kako dolgo vzdržijo ventili, je odvisno od natančne nastavitve. Če se ventil s svojim tesnilnim delom ne usede povsem v sedež ventila, ne omogočimo zadovoljivo odvajanje odvečne toplote, zelo vroči plini uhajajo med tesnilnim delom ventila in sedežem pa ga počasi zažgejo. To pa zahteva dokaj drago popravilo. Prevelike reže (zračnosti) med ventili in nihalnimi vzvodi sicer ne povzročajo škode, vendar pade motorju moč, sliši pa se tudi rožljanje v motorju. Po proizvajalčevih nasvetih za oba traktorja, se morajo preveriti oziroma nastaviti zračne reže na ventilih na vsakih 2000 ur (servis) [1].

Kompresija je odvisna od obrabljenosti motorja in je ni mogoče nastavljati.

Istočasno smo z napravo za preizkušanje šob preverili v šobah tlak in obliko curka vbrizgavanja goriva na traktorju Massey Ferguson 3655 in traktorju Steyr 9170. Pri šobah za vbrizgavanje goriva smo primerjali tlake s tlaki, ki jih določa proizvajalec. Tiste šobe, ki niso imele ustreznega tlaka, smo morali razstaviti in vstavljati nastavne podložke tako dolgo, dokler nismo dobili ustreznega tlaka. Ko je prenizek tlak v šobah, gorivo kaplja v zgorevalni prostor in s tem škoduje batu v valju motorja. To povzroča večje segrevanje motorja, kar lahko privede do poškodb motorja. Ker lastnika nista pravočasno kontrolirala sistema za gorivo (zamenjava filtra za gorivo, očiščevanje usedlin v nizkotlačni črpalki), so nastale po določenih opravljenih urah v šobah napake. To lahko lastnika traktorja drago stane [2].

METODE

Pri poskusu smo ugotavljali, kakšna je razlika v kompresijskem razmerju in preverjali oziroma nastavljali šobe za vbrizgavanje na traktorju Massey Ferguson 3655 (114/155) in traktorju Steyr 9170 (125/170) z naslednjimi merilnimi napravami:

- naprava za merjenje kompresije – Facom avtomotive 911B,
- preizkusna naprava za šobe – Usag 906.

Slika 1 Traktor Massey Ferguson 3655 v remontu

Slika 2 Traktor Steyr 9170 v remontu

Oba traktorja imata neposredno vbrizgavanje dizelskega goriva. Traktor Massey Ferguson 3655 ima vgrajeno visokotlačno rotacijsko tlačilko z Lucas šobami, medtem ko ima traktor Steyr 9170 vgrajeno batno visoko tlačno tlačilko z Bosch šobami [3].

Preizkusna naprava za šobe Usag 906

je naprava za preverjanje tlaka, oblike curka in tesnosti šobe. Proizvajalec je italijansko podjetje Usag. Merilno območje ima od 0 – 400 barov. Sestavljajo jo: manometer, posoda za tekočino, 2 cevi za pritrditev šob, ročni vzvod za potisk tekočine skozi šobe. Vstavi se v primež ali pa jo pritrdimo na večjo leseno ploščo in je tako že pripravljena za delovanje (slika 3).

Slika 3: Merilec tlaka na šobah

Naprava za merjenje kompresije – Facom avtomotive 911B

Proizvajalec je francosko podjetje Facom. Komplet vsebuje: 1 kotni vstavek, 8 preizkusnih vbrizgalnih šob, 4 preizkusne vžigalne svečke, 100 merilnih listkov, priključni kabel dolžine 1,85 m, cev za merjenje kompresije dolžine 360 mm, adapter za vstavke. Merilno območje ima: 5 – 60 bar in 1 – 12 valjev. Na ročaju ima gumb za delovanje merilca (slika 4).

Slika 4 Merilec kompresije z vso pripadajočo opremo

Metode dela

Meritve smo opravljali na dveh traktorjih.

Najprej smo merili kompresijo na traktorju Massey Ferguson 3655 in nato na traktorju Steyr 9170. Po končanem popravilu na obeh traktorjih je bila kompresija takšna, kot jo predpisuje proizvajalec.

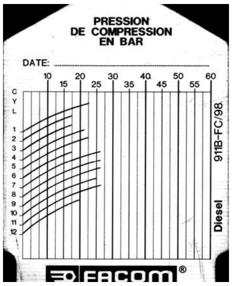
Drugo meritev smo delali z napravo za preizkušanje šob. Traktor Massey Ferguson 3655 ima Lucas šobe s tremi izvrtinami. Traktor Steyr 9170 ima vgrajene Boschove šobe s tremi izvrtinami. Pri traktorju Massey Ferguson se je po 6850 urah moralo ponovno nastaviti šobe na določeni pritisk. Pri traktorju Steyr pa po 5480 urah.

REZULTATI IN DISKUSIJA

Merjenje kompresije

Najprej smo vzeli vse šobe iz motorjev in nato privili cev od merilca kompresije v mesta, kjer so bile šobe. Da dosežemo v vsakem valju izmerjeno vrednost, moramo zaganjalnik traktorja vrteti maksimalno 5 sekund (300 – 400 vrt/min). Na merilcu kompresije opazujemo izmerjene vrednosti [4].

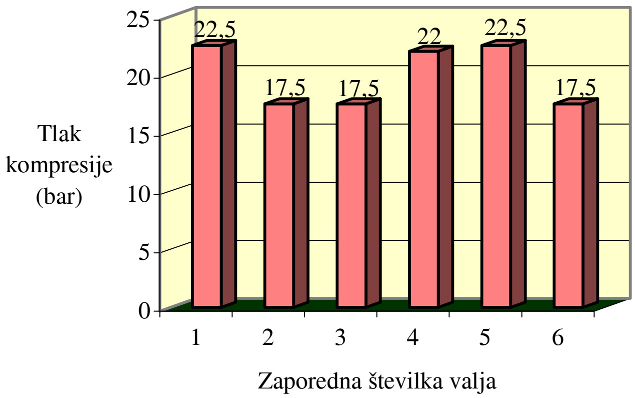
Rezultat merjenja z mehanskim kompresijo metrom je prikazan na sliki 5. Prvih šest črt je za Massey Ferguson in drugih šest črt za Steyr.



Slika 5 Rezultat merjenja z mehanskim kompresijo metrom

MASSEY FERGUSON 3655

Prvo merjenje kompresije je pokazalo napake na 2., 3., in 6. valju motorja. Vzrok za nizek tlak kompresije so bili netesni izpušni ventili (izrabljenost), (slika 6).



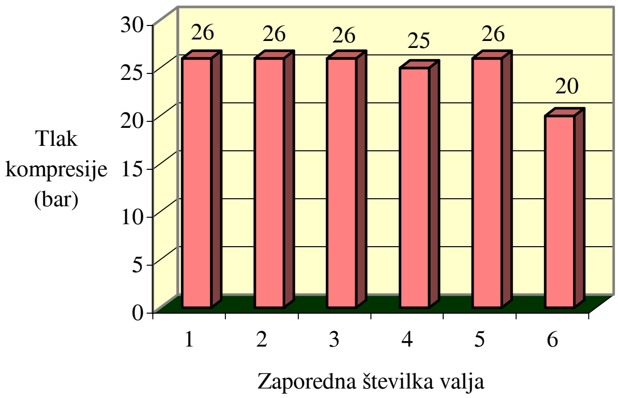
Slika 6 Nepravilni tlak kompresije v traktorju Massey Ferguson 3655

Pri drugem merjenju smo dobili za ta traktor želeni tlak kompresije 22,5 bara.

STEYR 9170

Merjenje kompresije je pokazalo napake na 4. in 6. valju. Vzroki za prenizek tlak so bili izrabljeni izpušni ventili (netesnost), (slika 7).

Po popravilu oziroma zamenjavi ventilov smo dobili želeno kompresijo (26 barov), katero zahteva oziroma predpisuje proizvajalec.

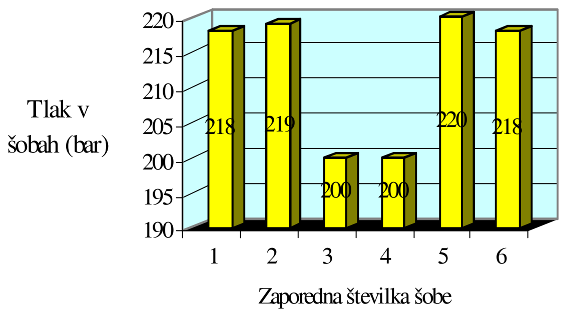


Slika 7 Nepravilni tlak kompresije v traktorju Steyr 9170

Merjenje tlaka v šobah

MASSEY FERGUSON 3655

Najprej smo izvzeli vse šobe in jih očistili z bencinom. Nato smo vsako posebej privili na napravo za merjenje pritiska, jih izpihali in opazovali tlak odpiranja šobe. Napaki sta bili na 3. in 4. šobi (zamašeni), (slika 8). Nista imeli pravilne oblike vbrizgavanja (oblike curka) in prenizek tlak [5].

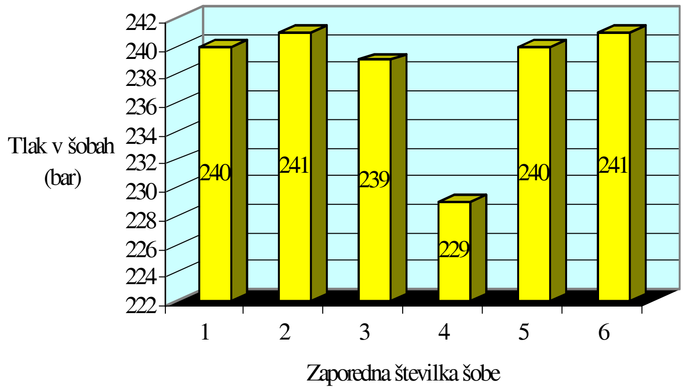


Slika 8 Nepravilni tlak v šobah na traktorju Massey Ferguson 3655

Po merjenju oziroma izpihavanju smo 3. in 4. šobo razstavili in nato, vstavljali nastavne podložke. Podložke so različne debeline (0,1 mm, 0,2 mm, 0,4 mm) in jih vstavljamo, dokler ne dosežemo zaželenega tlaka. Pri teh dveh šobah smo vstavili podložko debeline 0,4 mm. Na koncu smo 3. in 4. šobo še enkrat izpihali in smo dobili pravilen tlak vbrizgavanja.

STEYR 9170

Po demontaži šob smo jih očistili z bencinom in s preizkusno napravo preverili pravilen delovni tlak odpiranja in obliko curka. Pri tem traktorju morajo imeti šobe tlak višji od 236 barov. Preveliko odstopanje od določenega tlaka smo opazili na 4. šobi (slika 9).



Slika 9 Nepravilni tlak v šobah na traktorju Steyr 9170

Četrto šobo smo morali razstaviti in podložiti nastavno podložko debeline 0,2 mm. Po popravilu smo še enkrat preverili, če ima pravilen delovni tlak vbrizgavanja in obliko curka. Na koncu so vse šobe imele predpisani tlak vbrizgavanja. Odstopanja so lahko maksimalno 5 barov [6].

SKLEPI

V valjih so bili prenizki tlaki zaradi izrabljenosti izpušnih ventilov, zato so se vsi ventili morali zamenjati z novimi. Ko ventili ne tesnijo dovolj dobro, se najhitreje opazi na izpuhu, ker takrat motor močneje sivo-modro kadi in potem je tudi slabša moč motorja. To se opazi na večji porabi olja. Iz teh merjenj je razvidno, da lastnika obeh traktorjev nista pravočasno nastavljala zračne reže na ventilih.

Proizvajalca traktorjev predpisujeta odstopanja od zahtevanih tlakov največ 2 bara. Pravilnost tlaka v valjih oziroma pravilno delovanje kompresije je odvisno od tega, če se lastnik traktorja ravna po proizvajalčevih nasvetih za servisiranje in vzdrževanje traktorja. Odvisno je tudi ali ga lastnika vzdržujeta redno in pravočasno.

Pri šobah za vbrizgavanje goriva proizvajalec obeh traktorjev svetuje, da se kontrolira oziroma nastavi tlak po vsakih 2000 urah (servis), na vsakih 500 ur se zamenja filter za gorivo in istočasno se očistijo usedline v nizkotlačni črpalki. Tu imata traktorja različne znamke šob. Ene so Boschove (Steyr), ki so sicer dražje, na drugem pa so Lucasove šobe (Massey Ferguson). Vse šobe pa imajo po tri razpršilne izvrtine. Vse te šobe lahko imajo maksimalno 5 barov odstopanja od določene vrednosti. Delovanje šob je tudi odvisno od čistoče samega goriva oz. od lastnika traktorja, kolikokrat zamenja filtre za gorivo.

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MEASURING OF COMPRESSION AND INJECTION NOZZLE PRESSURE FOR DIAGNOSTIC OF TRACTOR ENGINES

SUMMARY

The paper describes the measurements of pressure in the engine compression space and pressure in the injection nozzles. During measurements the differences in the working pressure in nozzles and the differences in the compression pressure were compared. The diagnostic was performed on the tractor Massey Ferguson 3655 and on the tractor Steyr 9170 having different number of work hours. On the tractor Massey Ferguson there was in the 3rd, 4th and 6th cylinder an excessive deviation from the required pressures specified by the maker. On the tractor Steyr excessive deviation was found in the 6th cylinder. The purpose of the measurements was to establish whether on these tractors the pressure in the engine compression space and in the fuel injection nozzles is smaller after a certain number of work hours.

Key words: *diagnostic, maintenance, compression pressure, injection nozzles*

35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.312
Izvorni znanstveni rad
Original scientific paper

RESEARCHES REGARDING THE UTILIZATION OF ANTE-MOLDBOARD IN THE PLOUGHS BUILDING

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SUMMARY

The plough body with ante-moldboard is a new tillage tool which assures a considerable improvement of the ploughs working process, substituting the outcome achieved by ante-plough-body and the supplementary moldboard. This new tillage tool sections the furrow through the diagonal cross section allowing an entire overturn of the furrow, a better incorporation in soil of the vegetable residues, a better disaggregating of the furrow, a diminution of the plough overall size relative to ploughs with ante-plough-body, and just a diminution of the power consumption especially in the case of the clay soils. In the framework of this paper, an original mathematical model is presented which allow the analytical description of the active surface of any moldboard (cylindrical, cultural, and semi-helical) and the active surface of the ante-moldboard which has a conical shape. This paper show us the experimental results regarding the comparative analysis of qualitative parameters of the ploughing process for a normal plough with variable working width P-2V, and for a plough with ante-moldboard P-2VA, in the same working conditions. The results from this study show that especially for the weighty clay soils, the plough equipped with ante-moldboard accomplish a better working process, with better qualitative parameters, and with a less power consumption.

Key words. *Moldboard, ante-moldboard, plough, qualitative parameter, ploughing*

INTRODUCTION

The plough body with ante-moldboard is a Romanian concept of a new tillage tool for the ploughs, which assures a better incorporation of the vegetables residues in the soil, a better disaggregating of the furrow, and a better leveling of the ploughed surface due to the

180° angle of tilt of the furrow, no matter the depth of the working surface of the plough [1,4]. The ante–moldboard is mounted on the breast of the plough, in front of the so called moldboard replacing the breast of the digger plough and the additional plough as it can be seen in the picture above.

Fig. 1 The plough-body with ante-mouldboard

The working surface of the moldboard is ruled [2,3,4,5,6,7], self-generating itself by shifting a generating line (*g*) on a director curve (δ) embedded in a vertical plan [*V*] crossed on the cutting edge of the moldboard (Fig. 2). The generating line stays parallel with the plane *XOY* and changes the direction towards the *OY* axis with the angle γ, according to a law of the type $\gamma_i=f(Z_i)$, specific to every particular plough.

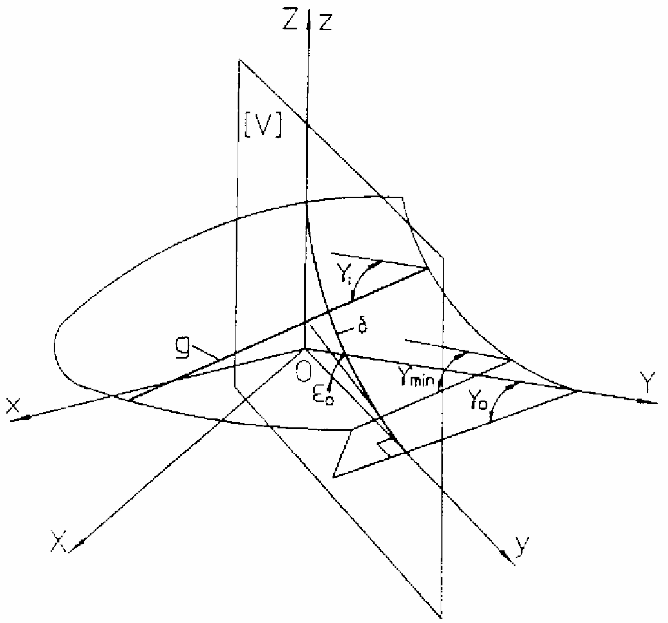


Fig. 2 The active surface of the moldboard

The active surface of the moldboard has a conical shape. The line corresponding to the joint between the share and the moldboard is a generator to the cone of the active surface (Fig. 3).

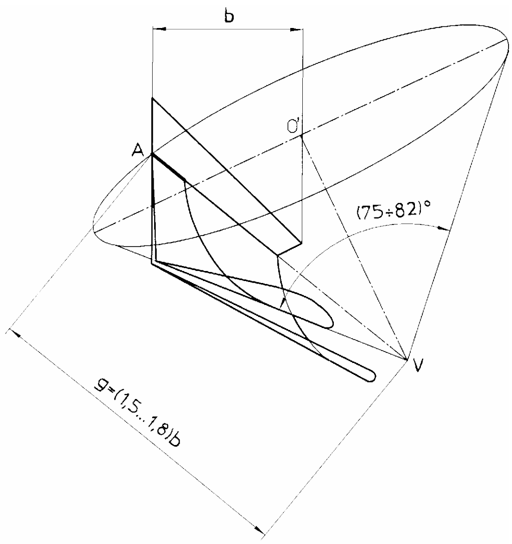


Fig. 3 The active surface of the ante-moldboard

THEORETICAL ELEMENTS

In the figure 4 is presented the three-dimensional view of the ante-moldboard plough and the conical surface on which the ante-moldboard is disposed.

Regarding the variation laws of the angle γ for the various types of moldboards, results the general equation of the active surfaces of the moldboard in the following form:

$$\begin{aligned} & X \cdot (\sin\gamma_0 + \frac{\cos\gamma_0}{tg\gamma_i}) + Y \cdot (\cos\gamma_0 + \sin\gamma_0 \cdot tg\gamma_i) = \\ & = y_i \cdot (\cos\gamma_0 + \sin\gamma_0 \cdot tg\gamma_i) \cdot (\sin\gamma_0 + \frac{\cos\gamma_0}{tg\gamma_i}) \end{aligned} \tag{1}$$

The equation of the active surface of the ante-moldboard, written in the system *OXYZ*, is:

$$\begin{aligned} & (X \cdot \cos\alpha_1 + Y \cdot \cos\alpha_2 + Z \cdot \cos\alpha_3 - X_{O'})^2 + \\ & + (X \cdot \cos\beta_1 + Y \cdot \cos\beta_2 + Z \cdot \cos\beta_3 - Y_{O'})^2 = \\ & = \frac{r^2}{z_V^2} \cdot (X \cdot \cos\gamma_1 + Y \cdot \cos\gamma_2 + Z \cdot \cos\gamma_3 - Z_{O'})^2 \end{aligned} \tag{2}$$

whereat: $z_V = h = g \cdot cos(\alpha/2)$.

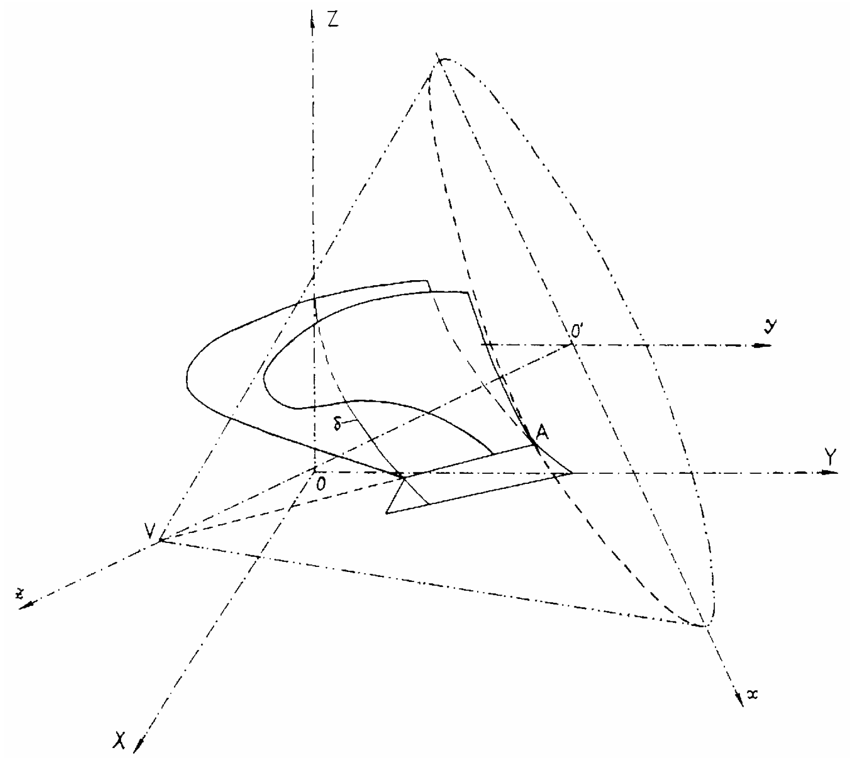


Fig. 4 The three-dimensional image of the ante-moldboard plough

The disaggregating ratio of the furrow can be considerable improved if the plough is fitted with ante plough body for each simple moldboard. The ante plough body is mounted at a 25-30 cm distance in front of the moldboard, on the frame of the plough, breaking in advance a smaller furrow ($a_1 \approx 1/3 \cdot a$ and $b_1 \approx 2/3 \cdot b$) which is disaggregated and tipped over in the ditch of the previous furrow, then is overlaid by the furrow broken and tipped over by the moldboard, accomplishing the complete incorporation of the surface fertilizers and vegetable residues into the soil.

The usage of the plough body with ante plough body has also a series of disadvantages such as: the blockage of the plough with vegetable residues that can catch at the ante plough body and especially the other disadvantage: the growth of the length and the overall size of the plough.

The tillage process can also be done with ploughs appointed with additional moldboard, in which case, under the action of the moldboard, the furrow is displaced on the surface of the moldboard until this one encounters the additional moldboard which is installed on the body of the plough, on its superior side and under its action a part of the superficial ply of the soil is disrupted and shifted into the ditch of the previous furrow, improving in this case also, the disaggregating ratio of the furrow and the incorporation degree of the vegetable residues and fertilizers into the soil.

In the figure 5 is shown the kinematics of the overturn of the furrow in the case of additional moldboard tillage.

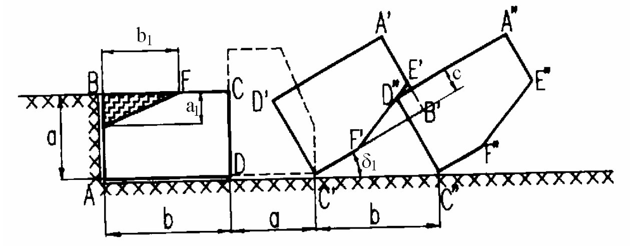


Fig. 5 The kinematics of the overturn of the furrow in the case of additional moldboard

For the furrow into the final position can be written the equation:

$$a = b \cdot \sin \delta_1 + c \tag{6}$$

respective:

$$\sin \delta_1 = \frac{a-c}{b} \tag{7}$$

out of which results the angle of the furrow to the additional moldboard tillage (δ_1), which can be compared with the disposal angle of the furrow disaggregated with the simple moldboard plough (δ):

$$\delta_1 = \arcsin \frac{a-c}{b} \le \delta = \arcsin \frac{a}{b} \tag{8}$$

Unfortunately, the additional moldboard brings its benefic infusion only in the case when the plough works at a maximum depth. Contrariwise, the additional moldboard has no major contribution to the remission of the collocation angle of the furrow in the final position.

The plough body with ante-moldboard sections the furrow through a diagonal cross section, the superior side of the furrow overturns under the action of the ante-moldboard and the inferior side under the action of the simple moldboard of the plough.

Starting from the theoretical study of the kinematics overturning of the furrow with the additional moldboard plough (Fig. 5), the study of the overturning with the ante – moldboard plough can be carried out by the means of individuation at the limits.

Starting from the equation (7), we can write the equation for the angle of disposal of the furrow in final position:

$$\delta_1 = \arcsin \frac{b \cdot [a + (b - b_1) \cdot \frac{a_1}{b_1}] - \sqrt{b \cdot \frac{a_1}{b_1} \cdot \{b \cdot \frac{a_1}{b_1} + b^2 - [a + (b - b_1) \cdot \frac{a_1}{b_1}]^2\}}}{b \cdot \frac{a_1}{b_1} + b^2} \tag{9}$$

Unfortunately, the additional moldboard brings its beneficial infusion of reducing the disposal angle of the furrow and an increase in the balance of the overturn furrow only in the situation when the plough works at the maximum depth. In the figure 6 is shown the influence of the working depth over the efficiency of the additional moldboard.

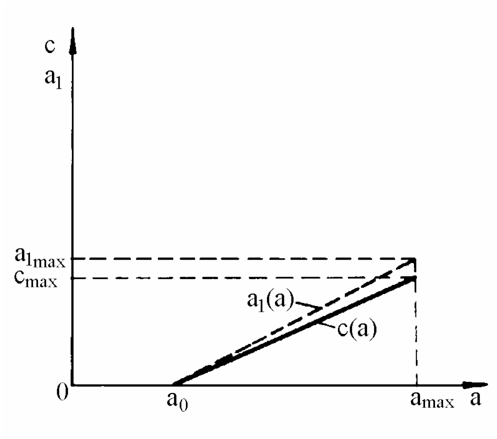


Fig. 6 Influence of the working depth on the additional moldboard plough's efficiency

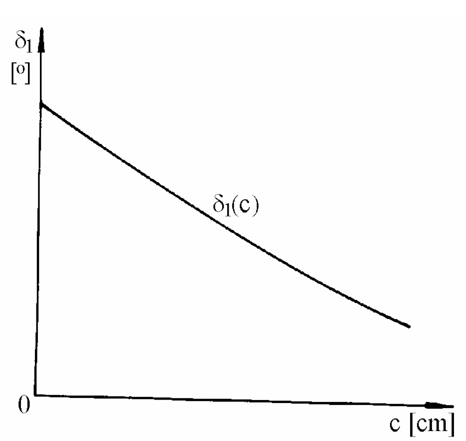


Fig. 7 The influence of the dimension c on the angle δ_1

It can be noticed that the larger is the dimension *c*, the smallest is the disclose angle of the furrow (δ_1) in final position and the more stabile is the overturn furrow. Consequents on figure 6 that if the plough doesn't work at a minimum depth of a_0, the function of the auxiliary moldboard will be inexistent, because the furrow does not get into contact with it. The influence of the *c* dimension upon the disposal angle of the furrow in final position after the overturn, is shown in the figure 7.

Theoretically, joining the following limiting-conditions according to the figure 5, will derive from the equation (7), the disposal angle of the furrow in the case of ante-moldboard tillage:

$$\begin{cases} a_1 \to a \\ b_1 \to b \\ EF \| AC \\ c \cong a \end{cases} \tag{10}$$

respective:

$$\delta_1' = \lim_{a_1 \to a} \arcsin \frac{a-c}{b} \cong \lim_{a_1 \to a} \arcsin \frac{a-a_1}{b} = \arcsin 0 = 0° \tag{11}$$

It ensues that in the case of ante-moldboard tillage the disposal angle of the overturn furrow is 0°, so the furrows are being turned with 180°. The kinematics of the overturning in the case of ante-moldboard tillage is shown in figure 8.

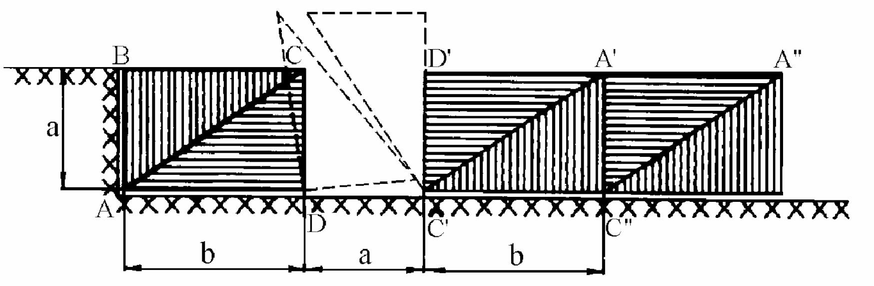


Fig. 8 The kinematics of the overturn of the furrow in the ante-moldboard tillage process

During the working process of the ante-moldboard plough, the furrow is subdued to a series of complex compression stress, to a bending process in a vertical and horizontal plane, and also to a twist in a transversal plane. Consequent upon al these stress the breakage and the crumbling of the furrow occurs during the disaggregating and overturning process. Disregarding the compression, it can be considered that the breakage of the furrow takes place when in the connection sections of the soil particles is being reached the unit stress breakage σ_r and τ_r, whose correspondents are the specific bending and torsion angles. In this case, during the disaggregating process of the furrow, on a linear meter it will be spent a work function of:

$$L_s = M_{rx} \cdot \varphi_{sx} + M_{ry} \cdot \varphi_{sy} + M_{rt} \cdot \varphi_{st} \tag{12}$$

respective:

$$L_s = W_x \cdot \sigma_r \cdot \varphi_{sx} + W_y \cdot \sigma_r \cdot \varphi_{sy} + W_p \cdot \tau_r \cdot \varphi_{st} \tag{13}$$

In which: M_{rx}, M_{ry}, M_{rt} – represents the bending resistant moments, respective, of the overturn of the furrow; φ_{sx}, φ_{sy}, φ_{st} – the specific bending angles, respective of overturn of the furrow; W_x, W_y - modules resistant against bending; W_p - resistance polar module of the crossed section of the furrow; σ_r - the bending breakage effort; τ_r - the torsion breaking effort.

The equation (12) can be also written:

$$L_s = \frac{I_x}{y_{\max}} \cdot \sigma_r \cdot \varphi_{sx} + \frac{I_y}{x_{\max}} \cdot \sigma_r \cdot \varphi_{sy} + \frac{I_x + I_y}{r_{\max}} \cdot \tau_r \cdot \varphi_{st} \tag{14}$$

In which I_x şi I_y represent the inertia moments in the section of the furrow beyond the two axes Ox and Oy whose origin coincides with the centre of gravity of the crossed section of the furrow.

Considering $\varphi_s \cong \varphi_{sx} \cong \varphi_{sy} \cong \varphi_{st}$ şi $\tau_r = k \cdot \sigma_r$ results:

$$L_s = \left(\frac{I_x}{y_{\max}} + \frac{I_y}{x_{\max}} + \frac{I_x + I_y}{r_{\max}} \cdot k\right) \cdot \sigma_r \cdot \varphi_s \tag{15}$$

In the case of a crossed section for a moldboard plough furrow $a{\cdot}b$, the equation (15) becomes:

$$L_{s1} = \left(\frac{b \cdot a^2}{6} + \frac{a \cdot b^2}{6} + \frac{b \cdot a^3 + a \cdot b^3}{6 \cdot \sqrt{a^2 + b^2}} \cdot k\right) \cdot \sigma_r \cdot \varphi_s \tag{16}$$

And in the case of ante-moldboard plough body:

$$L_{s2} = \left(\frac{b \cdot a^2}{12} + \frac{a \cdot b^2}{12} + \frac{b \cdot a^3 + a \cdot b^3}{12 \cdot \sqrt{\frac{1}{9}a^2 + \frac{4}{9}b^2}} \cdot k\right) \cdot \sigma_r \cdot \varphi_s \tag{17}$$

Comparing the two equations (16) and (17) it can be seen that the specific work is smaller in the case of ante-moldboard plough. As exemplification can be taken into consideration a numeric example on which the dimensions of the furrow are: *a=20 cm* and *b=30 cm*. Writing:

$$E_1 = \frac{b \cdot a^2}{6} + \frac{a \cdot b^2}{6} + \frac{b \cdot a^3 + a \cdot b^3}{6 \cdot \sqrt{a^2 + b^2}} \tag{18}$$

respective:

$$E_2 = \frac{b \cdot a^2}{12} + \frac{a \cdot b^2}{12} + \frac{b \cdot a^3 + a \cdot b^3}{12 \cdot \sqrt{\frac{1}{9}a^2 + \frac{4}{9}b^2}} \tag{19}$$

results: E_1=8605,5512 cm^3 , respective E_2=6769,0749 cm^3. Comparing the two results becomes visible an over 20 % reduction of the specific work function necessary for the overturn and the disaggregating process in the case of the ante-moldboard plough, compared to the simple moldboard plough. In the case of ante-moldboard plough must be also taken into consideration the work function necessary for the cutting of the furrow on its diagonal, which does not surpass 10-20 % of the whole work function spent for the desaggregation and the turnover of the furrow. Soehne [6] determined that the resistance of the soil at the pure cutting is relative small, this being important especially in the case of a soil rich in stones and vegetables residues, or in the case of an edgeless blade of the tool. Except those two situations, the cutting component can be precisely ignored.

Considering all these statements, it can be concluded that in the case of ante-moldboard plough, the spent energy during the working process is smaller with 15-20 % comparative with the simple moldboard plough.

METHODS

The comparative experimental tests for the determination of the qualitative index of the tillage for the two ploughs were carried out in the experimental ground of the I.N.M.A. Bucharest, on a plane field, during the september-october of the 1998. The parcel had been previously cultivated with corn, and covered with vegetable residues, specific to a corn cultivated land. The average vegetable residues on a 1 m² was 214,38 g/m², the result coming from the measurements carried out on the micro fields disposed on the diagonal of the experimental parcel.

The average humidity of the experimental soil allotment were at the value of 24,76 %, resulting from the specific analysis of four samples of soil ploughed with the agrochemical bore. The apparent average density of the experimental soil allotment was of 1,317 g/cm^3 , resulting from the analysis of four samples taken from the arable soil with the help of the metallic cylinders at the volume of 200 cm^3.

To determine the working depth have been carried out measurements in 20 points displaced at a distance of 5 meters each, on a 100 m distance of the plough, performing three repetitions for each working depth established (20; 25; 30 cm). Two sets of measurements had also been done in identical conditions, for the assembly made of the tractor U-650 and the normal moldboard plough P-2V, respectively the ante-moldboard plough P-2VA. Both in the P-2V and P-2VA ploughs has been concluded that are kept the three conditions: the standard deviation of the working depth of at least $S_a < \pm\, 0{,}1{\cdot}a_m$, the maximum deviation of the average working surface to be $\Delta_a < \pm\, 0{,}2{\cdot}a_m$ and the variation coefficient of the working depth that must be at least $C_a < \pm\, 0{,}1$.

In order to determine the working breadth, measurements had been taken into 20 different points situated 5 meter each on a 100 meters distance reckoned by the tillage tool, reported to an aiming line displaced at a distance of 3 meters from the allotment, making three repetitions for a single unique established working breadth of 60 m. Two sets of measurements were done in identical conditions for the combiner created by the tractor U-650 and the normal moldboard plough P-2V, respective the ante-moldboard plough P-2VA. It has been also concluded that in the case of the P-2V plough and P-2VA is respected the following condition: the deviation of the standard working breadth of $S_B < \pm\, 0{,}1{\cdot}\mathrm{B}_m$, the maximum deviation from the average working breadth of $\Delta_B < \pm\, 0{,}2{\cdot}\mathrm{B}_m$ and the variation coefficient of the working breadth of $C_B < \pm\, 0{,}1$.

The degree of the soil desegregation has been established with comparative measurements on a number of five sample allotments, of 1 m^2 each, on the whole depth of the tillage done by the assembly compound from the tractor U-650 and the plough P-2V, respective the plough P-2VA, by the means of weighing the processed soil and the grogs resulted. The used formula is the following:

$$M_{ms} = \frac{\sum_{i=1}^{n} \frac{m_{sci}}{m_{sti}}}{n} \cdot 100; \quad [\%] \tag{20}$$

In which: m_{sci} – is the weight of the boulder-rock with a diameter smaller then 5 cm, [kg]; m_{sti} – the total weight of the soil at a single measurement, [kg]; n – the number of the micro parcels, (n=5). The degree of blanketing the soil with vegetables residues has been determined by comparative measurements on a number o five micro-parcels of 1m² each of the vegetable weight remained on the surface of the soil in the case of the tillage with the plough P-2V, respective the plough P-2VA. The used formula is:

$$G_{av} = \frac{\sum_{i=1}^{n} \frac{m_{vti} - m_{vai}}{m_{vti}}}{n} \cdot 100; \quad [\%] \tag{21}$$

In which: m_{vti} – represents the total weight of the vegetable residues initially encountered at the surface of the soil of a micro parcel, [kg], (Table 2); m_{vai} – the weight of the vegetable residues remained on the surface of the soil, [kg]; n – number of the micro parcels, (n=5).

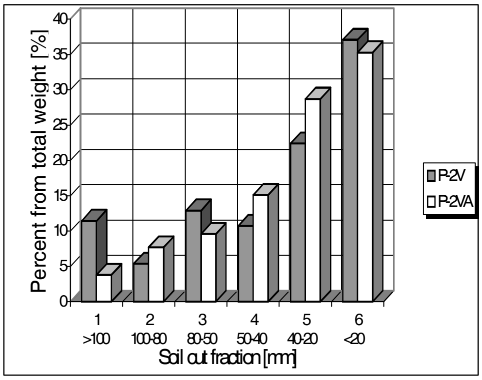
RESULTS AND DISCUSSION

In the table no 1 are shown the comparative data of the experimental measurements obtained as a result of the screening analysis with the determination device of the fractional components of the soil (type I.N.M.A. Bucharest) and the mathematic processing of the data, and in the figure no 9 are shown graphically and comparatively.

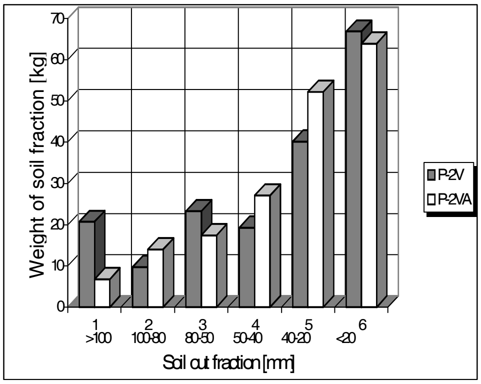
In the table no 2 is shown the comparative data of the experimental measurements obtained and processed mathematically, for the plough P-2V and P-2VA.

Table 1 The determination of the disaggregating degree of the soil

Assembly		Tractor U-650 + plough P-2V						Tractor U-650 + plough P-2VA					
Test		1	2	3	4	5	Av. Value	1	2	3	4	5	Av. Value
Total weight of sample[kg]		175,1	169,9	195,2	168,6	191,4	180,04	189,4	173,6	169,7	187,1	187,2	181,4
Weight of soil cut fraction [kg]	>100 mm	16	21,4	28,2	18,4	19,6	20,72	8	6,8	7,1	6,7	5,5	6,82
	100-80 mm	12,5	6,3	14,6	7,4	7,9	9,74	19,9	15,6	10,2	13,4	10,7	13,96
	80-50 mm	24	11,4	36,1	29,3	15,7	23,3	31,6	12,6	16,5	9,3	17,3	17,46
	50-40 mm	14,8	18,7	10,2	22,4	30,3	19,28	21	23,4	28,5	33,4	29,1	27,08
	40-20 mm	41,3	47,5	25,5	31,8	54,8	40,18	39,5	44,2	48	72,8	56,4	52,18
	< 20 mm	66,5	64,6	80,6	59,4	63,1	66,84	69,4	71	59,4	51,5	68,2	63,9
Percent from total weight [%]	> 100 mm	9,1	12,6	14,4	10,9	10,2	11,44	4,2	3,9	4,2	3,6	2,9	3,76
	100-80 mm	7,1	3,7	7,5	4,4	4,1	5,36	10,5	9	6	7,2	5,7	7,68
	80-50 mm	13,7	6,7	18,5	17,4	8,2	12,9	16,7	7,2	9,7	5	9,2	9,56
	50-40 mm	8,4	11	5,2	13,3	15,8	10,74	11,8	13,5	16,8	17,8	15,5	15,08
	40-20 mm	23,5	27,9	13,1	18,9	28,6	22,4	20,8	25,5	28,3	38,9	30,1	28,72
	< 20 mm	37,9	38	41,3	35,2	32,9	37,06	36,6	40,9	35	27,5	36,4	35,28
Weight of soil particles with ϕ < 50 mm, [kg]		122,6	130,8	116,3	113,6	148,2	126,3	129,9	138,6	135,9	157,7	153,7	143,16
Desegregation degree, [%]		70,01	76,98	59,57	67,37	77,42	70,15	68,58	79,83	80,08	84,28	82,10	78,91



a)



b)

Fig. 9 The comparison of the disaggregating process with the plough P-2V and P-2VA

Table 2 The determination f the covering degree with vegetable residues

Assembly	**Tractor U-650 + plough P-2V**						**Tractor U-650 + plough P-2VA**					
Av. Weight of the vegetable residues, [g/m^2]	214,38						214,38					
Test	1	2	3	4	5	Av. Value	1	2	3	4	5	Av. Value
Weight of the vegetable residues on the surface of ploughing field, [g/m^2]	17,6	15,2	20,3	17,1	21,8	18,4	4,3	5,1	4,7	6,5	5,2	5,16
Vegetable residues covering degree, [%]	91,79	92,90	90,53	92,02	89,83	91,41	97,99	97,62	97,80	96,96	97,57	97,59

CONCLUSIONS

- Our experimental assaying were carried out in almost optimum conditions, registering a slight humidity excess compared to the optimum, and all this was due to the excessively rainy season of the 1998. The optimum humidity of the clay appropriate for the tillage process is 17 %, reported to a clay content of 33% and an apparent density of the soil, on which the tests had been made, of 1,317 g/cm³, being also tolerable the values encompassed between 13-21 %. The developing conditions of the experiments were typical for the 1996-1998 and 2002-2005, when the season for the fall tillage work took place after a very rainy summer and excessively humidity.
- The normal moldboard plough accomplishes a disaggregating degree of the soil of 70,15 % (Table 1) and the ante-moldboard plough accomplishes a better disaggregating degree of 78,91 % (Table1);

- The normal moldboard plough accomplishes a vegetable residues covering degree of 91,41 % (Table 2) and the ante-moldboard plough a better covering degree of 97,59 % (Table 2);
- Comparing at large the qualitative index of the working process of the two ploughs, in identical conditions, can be concluded that the ante-moldboard plough P-2VA carries out a better tillage than the one of the simple moldboard plough, P-2V.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad
Expert paper

ENERGETSKE KARAKTERISTIKE MALČERA INO EURO 250 S DVIJE VRSTE ROTORA

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SAŽETAK

Na malčeru INO EURO 250 ispitivali smo odabrane energetske karakteristike. Na osnovu izmjerenog momenta i broja okretaja na priključnom vratilu traktora, koje je pokretalo neopterećen i opterećen malčer, izračunata je potrebna snaga za pogon malčera. Mjerenja su izvedena kod različitih brzina kretanja i kod različitih biljaka za sitnjenje. Upotrijebili smo dva rotora sa različitim rasporedom radnih elemenata. Ustanovili smo, da je kod upotrebe rotora gdje su radni elementi raspoređeni po spirali sa kutem 30 stupnjeva specifična potrošnja energije od 7,41 do 16,02 kJ/m^2 odnosno od 2,22 do 6,86 kJ/kg svježe mase. Kod upotrebe rotora gdje su radni elementi raspoređeni po spirali sa kutem 45 stupnjeva specifična energija je od 7,88 do 17,75 kJ/m^2, odnosno od 2,63 do 7,28 kJ/kg svježe mase.

***Ključne riječi**: malčer, rotor, moment na priključnom vratilu, potrebna snaga, specifična energija*

UVOD

Malčeri sve više dobivaju na značaju kako u poljoprivredi tako u komunalnim poslovima. Njihova poljoprivredna upotreba nužna je u trajnim nasadima (vinogradarstvo, voćarstvo), kao i ratarstvu (sjeckanje žetvenih ostatka, sjeckanje biljaka, koje rastu na ugaru). Proizvođači malčera proizvode veliki broj različitih modela s različitim radnim elementima (čekići, noževi itd.). U Sloveniji Jejčič (1997), Poje (2003, 2006) testiraju ratarske i komunalne malčere glede potrebne snage i drugih eksploatacijskih karakteristika u realnim uvjetima. Poje (2005) analizira smjer razvoja strojeva za sitnjenje biljnih ostataka, Godeša et all. (2006) vrše mjerenja na malčerima s novom generacijom rotora. U Njemačkoj Brunotte sa suradnicima (1995) detaljno istražuje mehanizaciju za održavanje površina pod ugarom. Istraživanja su fokusirana u kakvoću sitnjenja i potrebnu snagu za pogon kod različitih radnih elemenata različitih strojeva. Sestak (2003) ustanovljava, da kod malčera D 1500/M potrebna snaga na priključnom vratilu raste nelinearno s promjenom brzine kretanja i promjenom količine biljne mase.

U radu je prikazana analiza potrebne snage za pogon malčera INO EURO 250 s novom generacijom rotora, gdje su radni elementi (čekiči) raspoređeni po spirali sa 30 ili 45 stupnjeva.

MATERIJAL I METODE RADA

Eksploatacijske karakteristike proučavali smo na malčeru INO EURO 250. Glavni tehnički podaci predstavljeni su u tablici 1. Nova generacija rotora ima radne elemente razpodjeljene po obodu rotora po spirali sa kutem 30 ili 45 stupnjeva.

Tablica 1 Tehnički podaci proizvođača za malčer

Proizvođač	INO Industrijska oprema Brežice
Model	EURO 250
Radna širina širina (cm)	250
Broj okretaja priključnog vratila (min^{-1})	540/1000
Broj čekiča	28
Masa (kg)	730
Brzina okretanja rotora (min^{-1})	2243

U vidu eksploatacijskih karakteristika istraživali smo potrebnu snagu za pogon malčera preko priključnog vratila traktora kod različitog opterećenja i kod različitog namještenja radnih elemenata – čekiča na rotoru. Sama istraživanja izvedena su i kod različitih biljaka, koje je malčer sitnio i kod različite brzine kretanja traktora. Za pogon malčera upotrijebili smo traktor Fendt Favorit 714 Vario, nazivne snage 110 kW.

Mjerni lanac bio je sastavljena od tri dijela: senzora, digitalnog mjernog pojačala i PC računala za prijem i obradu mjernog signala. Okretni moment i broj okretaja priključnog vratila mjerili smo pomoću dinamometra za mjerenje momenta i prigrađenog senzora vrtnje (T30 FN Hottinger Baldwin Messtechnik). Digitalno pojačalo bio je SPIDER 8 Hottinger Baldwin Messtechnik. Frekvencija uzimanja podataka iznosila je 10 Hz, dok je dužina pojedinog mjerenja ovisila o vremenskom toku rada sa malčerom. Iz izmjerenog momenta i broja okretaja na priključnom vratilu izračunata je potrebna snaga za pogon priključka preko priključnog vratila.

Snaga za pogon:

$$P_p = M\omega \tag{1}$$

$$P_p = M\pi\frac{n}{30} \tag{2}$$

Značenje oznaka:

P_p - potrebna snaga za pogon malčera W

M – moment na priključnom vratilu Nm

ω - kutna brzina rad

n – broj okretaja priključnog vratila min^{-1}

Slika 1 Dinamometar za mjerenje momenta i broja okretaja (T 30 FN Hottinger Baldwin Messtechnik) na priključnom vratilu traktora

Mjerenje potrebne snaga kod rada malčera EURO 250 izveli smo na tri vrste biljaka: na kukuruzu sa korovima, na kukuruzu in na travnjaku. Travnjak je imao 30 % livadne vlasnjače, ostalo je bio engleski ljulj, klupčasta oštrica i mnogocvjetni ljulj. Kod sitnjenja kukuruza imali smo brzinu kretanja 4, 5, 6 i 7 km/h, a na travnjaku još i dodatne brzine 8 i 9 km/h.

Tablica 2 Radni uvjeti kod upotrebe malčera EURO 250

Biljke za sitnjenje	Kukuruz sa korovima	Kukuruz	Travnjak
Brzina kretanja (km/h)	4, 5, 6, 7	4, 5, 6, 7	4, 5, 6, 7, 8, 9
Gustoća biljki (kg/m^2)	5,03	5,21	1,71
Broj okretaja priključnog vratila (min^{-1})	540		
Radna širina (m)	2,30		

REZULTATI RADA I DISKUSIJA

Mjerenjem momenta i broja okretaja na priključnom vratilu traktora izračunali smo potrebnu snagu za pogon malčera preko priključnog vratila kod različite brzine kretanja, kod različitih biljaka i sa dvije vrste rotora. Rezultati mjerenja i izračunata potrebna snaga na priključnom vratilu prikazani su u tablicama 3, 4 i 5. Za pogon neopterećenog malčera s rotorom, gdje su radni elementi raspoređeni po spirali s kutom 30 stupnjeva, potrebna je prosječna snaga 10,18 kW, a s rotorom, gdje su radni elementi razpoređeni po spirali s kutom 45 stupnjeva, potrebno je 3,1 % manje snage.

Mjerenja su pokazala, da je prosječno potrebna snaga za pogon malčera preko priključnog vratila na travnjaku neovisno od vrste rotora između 29 i 45 kW. Postoji trend porasta potrebne snage za pogon sa porastom brzine kretanja traktora. Za sjeckanje kukuruza (bez i sa korovima) potrebno je već kod manjih brzina više pogonske snage, a kod brzina kretanja preko od 6 km/h i na više potrebno je preko 50 kW snage na priključnom vratilu. Kod naših mjerenja i uvjeta rada najviša prosječno potrebna snaga (64 kW) ustanovljena je kod brzine kretanja 7 km/h kod sitnjenja kukuruza sa korovima.

Tablica 3 Prosječno angažirana snaga za pogon malčera EURO 250 kod različitih brzina kretanja, interval vjerojatnosti za snagu, teoretski učinak i specifična potrošnja energije na površino i kilogram svježe biljne mase. Mjerenja izvedena na travnjaku sa površinskom gustočom svježe mase 1,71 kg/m^2

	Brzina (km/h)	Snaga (kW)	Interval vjerojatnosti	Učinak (ha/h)	Specifična potrošnja energije (kJ/m^2)	Specifična potrošnja energije (kJ/kg)
Rotor 30°	3,89	29,13	±0,40	0,89	11,73	6,86
	5,22	33,99	±0,29	1,20	10,20	5,96
	5,54	36,77	±0,55	1,27	10,39	6,07
	6,89	35,64	±0,31	1,58	8,10	4,74
	8,02	37,98	±0,66	1,84	7,41	4,33
	8,90	42,15	±1,14	2,05	7,41	4,33
Rotor 45 °	3,64	28,92	±0,35	0,84	12,45	7,28
	5,03	33,62	±0,42	1,16	10,47	6,12
	5,82	37,10	±0,79	1,34	9,98	5,84
	6,90	40,18	±1,21	1,59	9,11	5,33
	8,02	40,34	±0,80	1,84	7,88	4,61
	8,74	45,38	±1,21	2,01	8,13	4,75

U slikama 2 i 3 prikazana je specifična potrošnja energije kod rada malčera EURO 250 sa različitim rotorima (radni elementi razpodjeljeni po spirali sa kutem 30 ili 45 stupnjeva) kod različitih brzina kretanja traktora i kod različitih biljaka za sitnjenje. Vidljivo je, da se specifična potrošnja energije na jedinicu obrađene površine kod sitnjenja travnjaka i kukuruza bez korova smanjuje sa porastom brzine kretanja, dok kod sitnjenja kukuruza sa korovima ovaj trend nije ustanovljen. Jednaki zaključci mogu se istaknuti i kod specifične potrošnje energije na jedinicu usitnjene mase biljaka.

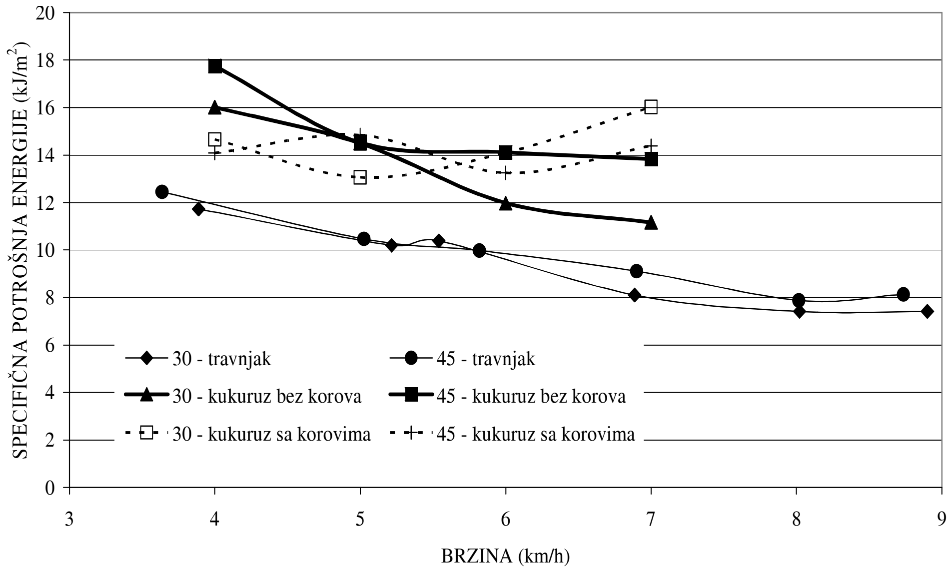
Za utvrđivanje jednakomjernosti odnosno nejednakomernosti potrebnog momenta na priključnom vratilu kod rada sa različitim rotorima izveli smo analizu koeficijenta varijacije. Ustanovljeno je, da je kod rotora sa razpodjelom radnih elemenata po spirali so kutem 30 stupnjeva nejednakomjernost potrebnog momenta manja kod sitnjenja na travnjaku i kukuruzu sa korovima, ali razlike nisu statistički signifikantne. Kod sitnjenja kukuruza bez korova nije razlike.

Tablica 4 Prosječno angažirana snaga za pogon EURO 250 kod različitih brzina kretanja, interval vjerojatnosti za snagu, teoretski učinak i specifična potrošnja energije na površinu i na kilogram svježe biljne mase. Mjerenja izvedena su na kukuruzu sa korovima i sa površinskom gustoćom svježe mase 5,03 kg/m^2

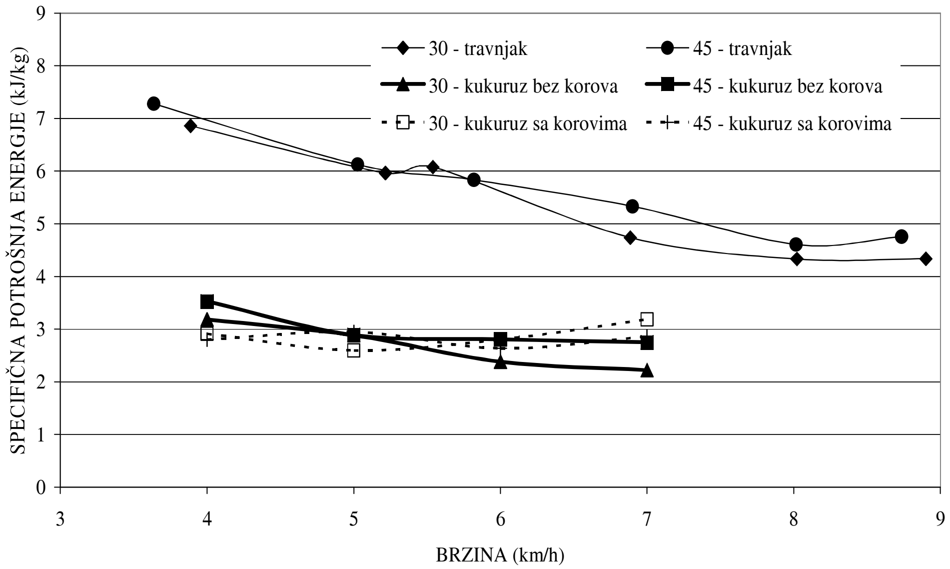
	Brzina (km/h)	Snaga (kW)	Interval vjerojatnosti	Učinak (ha/h)	Specifična potrošnja energije (kJ/m^2)	Specifična potrošnja energije [kJ/kg]
Rotor 30 °	4	37,45	±0,80	0,92	14,65	2,91
	5	41,71	±0,91	1,15	13,06	2,60
	6	54,03	±0,78	1,38	14,10	2,80
	7	71,63	±0,56	1,61	16,02	3,18
Rotor 45 °	4	36,00	±1,40	0,92	14,09	2,80
	5	47,40	±1,19	1,15	14,84	2,95
	6	50,78	±1,00	1,38	13,25	2,63
	7	64,35	±0,87	1,61	14,39	2,86

Tablica 5 Prosječno angažirana snaga za pogon EURO 250 kod različitih brzina kretanja, interval vjerojatnosti za snagu, teoretski učinak i specifična potrošnja energije na površinu i na kilogram svježe biljne mase. Mjerenja izvedena su na kukuruza bez korova i sa površinskom gustoćom svježe mase 5,21 kg/m^2

	Brzina (km/h)	Snaga (kW)	Interval vjerojatnosti	Učinak (ha/h)	Specifična potrošnja energije (kJ/m^2)	Specifična potrošnja energije (kJ/kg)
Rotor 30 °	4	40,91	±1,01	0,92	16,01	3,18
	5	46,30	±1,44	1,15	14,50	2,88
	6	45,91	±1,38	1,38	11,98	2,38
	7	49,94	±1,32	1,61	11,17	2,22
Rotor 45 °	4	45,37	±1,05	0,92	17,75	3,53
	5	46,39	±1,09	1,15	14,52	2,89
	6	54,11	±0,97	1,38	14,11	2,81
	7	61,86	±1,14	1,61	13,83	2,75



Slika 2 Specifična potrošnja energije na jedinicu obrađene površine kod malčera EURO 250



Slika 3 Specifična potrošnja na jedinicu usitnjene mase kod malčera EURO 250

ZAKLJUČAK

Malčer INO EURO 250 ima novu generaciju rotora sa rasporedom radnih elemenata (čekića) po spirali od 30 ili 45 stupnjeva. Ispitivanja potrebne snage za pogon malčera izvedena su na tri vrste biljaka, kod različitih brzina kretanja. Ustanovili smo, da je kod upotrebe rotora, gdje su radni elementi raspoređeni po spirali sa kutom 30 stupnjeva, specifična potrošnja energije od 7,41 do 16,02 kJ/m^2 odnosno od 2,22 do 6,86 kJ/kg svježe mase. Kod upotrebe rotora, gdje su radni elementi raspoređeni po spirali sa kutom 45 stupnjeva, specifična energija je od 7,88 do 17,75 kJ/m^2, odnosno od 2,63 do 7,28 kJ/kg svježe mase.

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ENERGETIC CHARACTERISTICS OF INO EURO 250 MULCHER WITH TWO ROTOR TYPES

ABSTRACT

Selected energetic characteristics were studied on INO EURO 250 mulcher. On the basis of measured torque and number of revolutions of PTO shaft driving unloaded and loaded mulcher the power required for driving of mulcher was calculated. Measurements were performed at different driving velocity and different mulching plants. Two rotors with different position of working elements were used. It was established that when rotor with working elements on spiral of 30 degree is applied the specific energy requirement is from 7.41 to 16.02 kJ/m^2 or from 2.22 to 6.86 kJ/kg green mass. When rotor with working elements on spiral of 45 degree is applied the specific energy requirement is from 7.88 to 17.75 kJ/m^2 or from 2.63 to 7.28 kJ/kg green mass.

Key words*: mulcher, rotor, torque on PTO shaft, power requirement, specific energy*

35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Expert paper

POVRŠINSKA RASPODJELA GRANULA MINERALNIH GNOJIVA RASIPAČEM BOGBALLE

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SAŽETAK

U radu su prikazani rezultati istraživanja kvalitete rada centrifugalnog rasipača tvrtke Bogballe tipske oznake ”L” (L2+). Ispitivanja su provedena početkom studenog 2006. godine na poljoprivrednom gospodarstvu Jelošek. Istraživanja su provedena u poljskim uvjetima rada uz osiguranje svih potrebnih meteoroloških uvjeta s obzirom na temperaturu (>18°C) i relativnu vlagu zraka (< 60%). U istraživanju korišteno je mineralno gnojivo proizvedeno u Kutini tijekom listopada 2006. godine uvrećano po 25 kg i dopremljeno neposredno prije početka istraživanja. Prema granulometrijskom sastavu oba gnojiva imaju povećani postotni udio granula promjera od 2,1 do 5 mm. Tako gnojivo NPK formulacije 7:20:30 ima 87,42%, a KAN 83,67% granula navedenog promjera. Istraživanja su obavljena pri 8 km/h i raspodjeli 400 kg/ha^{-1} NPK formulacije 7:20:30, odnosno 190 kg/ha^{-1} gnojiva KAN-a. Nakon provedenih vaganja granula sakupljenim ispitnim kutijama dobiven je koeficijent površinske raspodjele masa od 6,60% kod gnojiva NPK formulacije 7:20:30 i 6,21% s gnojivom KAN. Na temelju dobivenih rezultata rasipač tvrtke Bogballe tipske oznake ”L” može se svrstati u kategoriju odličnih rasipača kojeg preporučujemo za primjenu na našim površinama.

Ključne riječi: *Površinska raspodjela gnojiva, centrifugalni rasipač Bogballe, mineralna gnojiva*

UVOD

Pri sadašnjoj ratarskoj proizvodnji mineralna gnojiva su značajno sredstvo za postizanje visokih i stabilnih prinosa. Zbog povećanja cijena energenata rastu i cijene mineralnih gnojiva, što značajnije djeluje na smanjenje njihove uporabe. Republika Hrvatska svrstava se u red zemalja s najnižom potrošnjom aktivne tvari po jedinici površine u Europi.

Istovremeno, u razvijenijim zemljama zbog očuvanja prirodnog okoliša, postupno se smanjuje uporaba mineralnih gnojiva. Da bi se izbjegli značajni padovi prinosa ratarskih kultura sve je veći zahtjev za ujednačenijom površinskom raspodjelom mineralnih gnojiva. Ujednačenu površinsku raspodjelu mineralnih gnojiva moguće je obaviti uz primjenu kvalitetnih rasipača i poznavanje djelovanja većeg broja čimbenika koji se pojavljuju za vrijeme njihova rada. Teško je udovoljiti zahtjevu za pravilnom raspodjelom malih masa od 10 do 20 grama mineralnog gnojiva po kvadratnom metru, iako se poljoprivredna tehnika svakodnevno razvija i usavršava. Istraživanja kvalitete raspodjele granula pri radu novih rasipača do sada obavljena su pretežito u ispitnim stanicama pri strogo definiranim radnim uvjetima. Takvi uvjeti se ne mogu zbog vremenskih prilika osigurati pri radu na proizvodnim površinama u polju. Novi centrifugalni rasipači mineralnog gnojiva imaju već ugrađenu preciznost poprečne i uzdužne raspodjele za ostvarivanje varijacijskog koeficijenta od 5 do 15 %. Težnja svakog proizvođača strojeva je pomicanje varijacijskog koeficijenta masenih vrijednosti poprečne raspodjele granula u zonu oko 5%. Međutim i kod novih rasipača također postoje značajnije razlike u kakvoći rada, koje su posljedica različitih brzina rada, neujednačenog granulometrijskog sastava gnojiva, brzine strujanja bočnog vjetra i drugo.

ZADACI I CILJ ISTRAŽIVANJA

Zadatak istraživanja bio je mjerenje granulometrijskog sastava mineralnih gnojiva te utvrđivanje poprečne masene raspodjele granula mineralnog gnojiva. Cilj istraživanja je dolazak do saznanja o kvaliteti rada novog rasipača tvrtke Bogballe u poljskim uvjetima rada s mineralnim gnojivima proizvedenim u Republici Hrvatskoj.

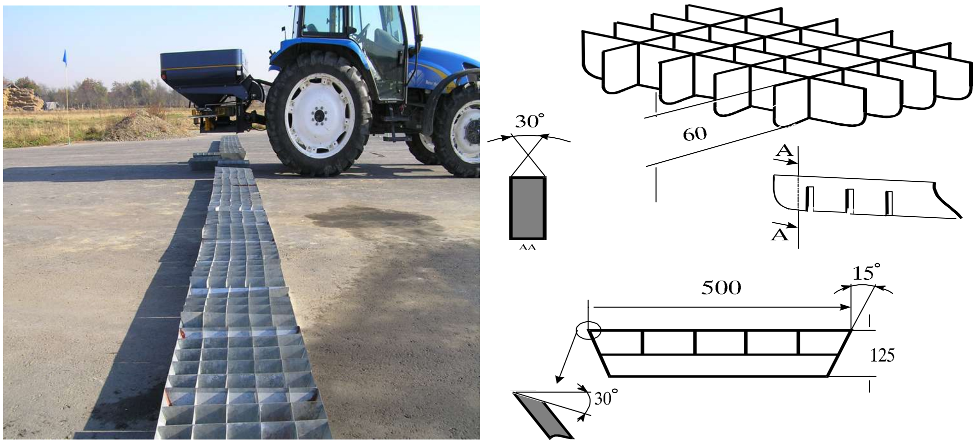
DOSADAŠNJA ISTRAŽIVANJA

Raspodjela granula gnojiva kod većine centrifugalnih rasipača obavlja se lopaticama koje usmjeravaju granule od sredine prema rubovima rasipača. Izuzetak navedenom je tehničko rješenje kod tvrtke Bogballe gdje lopatice usmjeravaju granule s vanjske strane prema sredini rasipača. U konačnici to znači da ćemo imati četverostruko preklapanje pri raspodjeli gnojiva. Ovim načinom rada rasipač, prema ostvarenom koeficijentu varijacije, može se svrstati u odlične rasipače s obzirom na kvalitet rada. Ista saznanja dobivena su testiranjem na danskom Institutu agriculture u ispitnom centru "Bygholm" kao sastavnice Europske udruge ENTAM (European Network for testing Agricultural Machinery). Redakcija časopisa PROFI (Magazin fur Agrartechnik) u broju 12/2003 i 2/2004 iznosi dobivene rezultate njihovih testiranja pri čemu rasipač tvrtke Bogballe zauzima visoku poziciju u ocjenjivanju kvalitete rada centrifugalnih rasipača.

Značajnija saznanja o kvaliteti rada rasipača tvrtke Bogballe na prostorima Republike Hrvatske nemamo.

METODE ISTRAŽIVANJA

Mjerenje preciznosti raspodjele granula mineralnih gnojiva u polju, rasipačem tvrtke Bogballe obavljeno je početkom studenog 2006. godine na obiteljskom gospodarstvu Jelošek u Beketincima. Posude za utvrđivanje površinske raspodjele mineralnog gnojiva izrađene su od pocinčanog lima debljine 0.6 mm prema uzoru na kutije tvrtke Rauch iz ispitnog kompleta "Delta-Praxis", priznatog za ovakav tip istraživanja. Ispitna posuda ima radnu površinu od 0.25 m^2. Tijekom istraživanja mjerenje je obavljeno s 38 kutija postavljenih poprečno na smjer rada rasipača.



Slika 1. Položaj ispitnih kutija u vrijeme provjere rasipača s tehničkim normama izrade u mm

Utvrđivanje granulometrijskog sastava mineralnog gnojiva obavljeno je mehaničkim prosijavanjem svakog uzorka kroz žičana sita određene veličine otvora, te pojedinačnim mjerenjem mase svake izdvojene frakcije. Ostali dio zadataka obavljen je već poznatim standardnim metodama primjenjenim za ovakav oblik istraživanja. Podešavanje rasipača za provjeru obavili su serviseri tvrtke “Findri” iz Sesveta, koji je zastupnik prodaje rasipača tvrtke Bogballe za Hrvatsku.

REZULTATI ISTRAŽIVANJA

Meteorološki uvjeti pri ispitivanju rasipača Bogballe

Ispitivanje rasipača serije ”L” s podešenim radnim zahvatom od 18 m, obavljeno je početkom studenog 2006. godine na obiteljskom gospodarstvu Jelošek u Beketincima. Temperatura i relativna vlažnost zraka predstavljaju utvrđeni su prenosivom meteorološkom postajom u vremenu od 11 - 13 sati. U početnom periodu istraživanja relativna vlažnost zraka iznosila je 58% a pri kraju provjere bila je 52%. Temperatura zraka za vrijeme izvođenja provjere bila je 18 °C u 11 sati i 19 °C u 13 sati. Brzina strujanja zraka paralelnog s tlom u vrijeme ispitivanja rasipača tvrtke Bogballe serije ”L” iznosila je 0,40 do 1,2 m/s. Promjenom položaja ispitnih kutija u odnosu na smjer vjetra značajno je smanjen njegov negativan utjecaj na površinsku raspodjelu granula.

Rezultati vrijednosti granulometrijskog sastava korištenog mineralnog gnojiva

U Hrvatskoj kompleksna gnojiva (NPK) moraju sadržavati najmanje 95% granula promjera od 0.5 do 5 mm, dok kalcijev amonijev nitrat (KAN) s 27% N mora sadržavati svega 92% granula navedenog promjera. Struktura granulometrijskog sastava gnojiva primjenjenog u provedenom ispitivanju rasipača prikazano je u slijedećoj tablici.

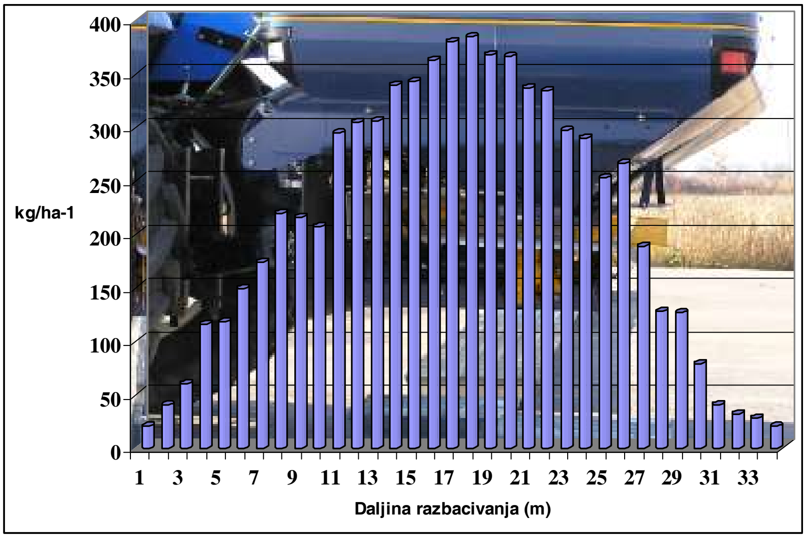
Tablica 1. Prikaz postotnog udjela veličina granula mineralnog gnojiva NPK 7:20:30 i KAN-a 27% N

			Gnojivo NPK 7:20:30			
Statistički pokazatelji	Promjer granula (mm)					
mjerenja	**7.1-10.0**	**5.1-7.0**	**3.1-5.0**	**2.1-3.0**	**1.1-2.0**	**< 1.0**
X (%)	3,07	4,41	79,05	8,37	4,12	0,82
S.d.	0,283	0,252	0,992	0,801	0,342	0,129
KV (%)	9,22	5,70	1,25	9,56	8,31	15,76
			Gnojivo KAN 27% N			
Statistički pokazatelji	Promjer granula (mm)					
mjerenja	**7.1-10.0**	**5.1-7.0**	**3.1-5.0**	**2.1-3.0**	**1.1-2.0**	**< 1.0**
X (%)	0,56	3,69	38,64	45,03	11,20	0,84
S.d.	0,241	0,179	2,477	6,955	6,623	0,118
KV (%)	42,35	4,84	6,41	15,44	59,09	13,96

Jedan u nizu čimbenika koji izravno utječu na kvalitetu rada rasipača svakako je granulometrijski sastav gnojiva. Na povoljan granulometrijski sastav mineralnog gnojiva osim veličine granula čini i njihov međusobno maseni odnos. Iz navedene tablice možemo vidjeti da kompleksno mineralno gnojivo NPK formulacije 7:20:30 sadrži 87,42% granula promjera od 2,1 do do 5 mm, odnosno svega 4,94% granula promjera ispod 2 mm. Dobar međusobni odnos granula gnojiva zabilježen je i kod gnojiva KAN 27% N. Postotni udio granula promjera od 2,1 do 5 mm iznosio je 83,67%. Udio granula u ukupnoj masi, promjera ispod 2 mm iznosio je svega 12,04%. Postotni udio granula (šupljih) promjera 5,1 do 7 mm iznosio je svega 3,69%. Dobrom organizacijom transporta i povoljnim momentom nabavke gnojiva itekako možemo utjecati na poboljšanje površinske raspodjele granula mineralnog gnojiva, kao što je to bio slučaj kod ovoga poljoprivrednog gospodarstva.

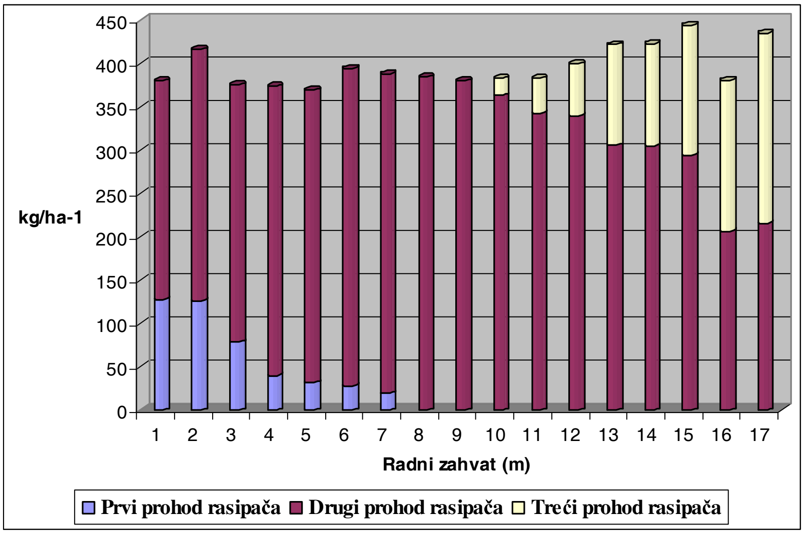
Rezultati istraživanja površinske raspodjele gnojiva

Najbolji koeficijent varijacije površinske raspodjele granula NPK gnojiva formulacije 7:20:30 ostvaren je pri brzini kretanja agregata od 8 km/h i pri raspodjeli gnojiva od 400 kg/ha^{-1} i iznosio je svega 6,60 %. Primjenu gnojiva KAN-a u istim uvjetima karakterizira koeficijent varijacije od 6,21 % pri raspodjeli 190 kg/ha^{-1}.

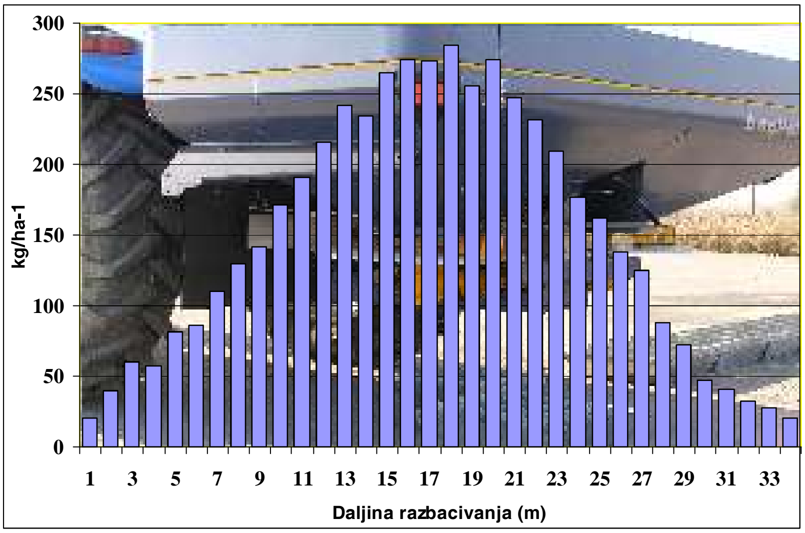


Slika 2. Površinska raspodjela mineralnog gnojiva NPK 7:20:30 (koeficijent varijacije 6,60%)

Iz slike 2. može se uočiti vrlo dobra površinska raspodjela granula mineralnog gnojiva s raspodjelom od 50,78% od ukupne mase na desnoj strani i 49,22% na lijevoj strani pognojene površine. Daljina bacanja granula u provedenim istraživanjima iznosila je 34 m.

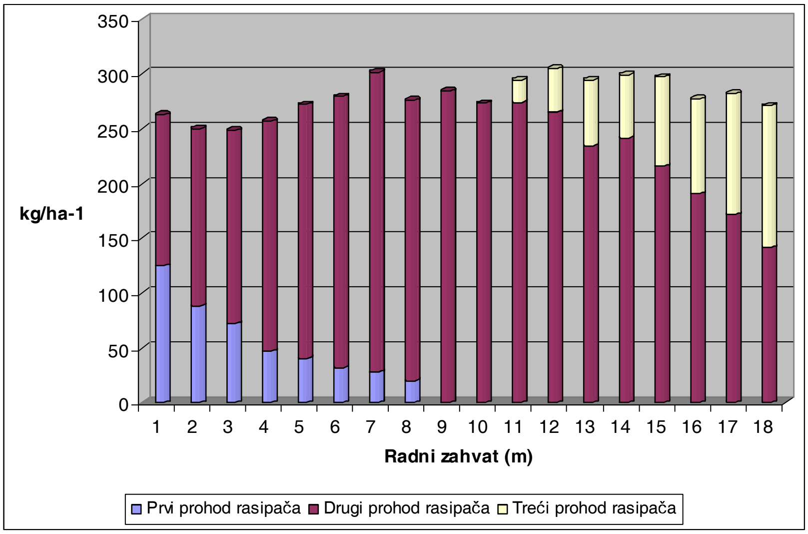


Slika 3. Ukupni površinski udio masa granula gnojiva NPK 7:20:30 ovisno o prohodu rasipača pri radnom zahvatu od 18 m



Slika 4. Površinska raspodjela mineralnog gnojiva KAN uz koeficijent varijacije 6,21%

Iz predhodne slike može se uočiti simetrična podjela granula s obzirom na lijevu i desnu stranu rasipača. Prema dobivenim rezultatima i pravilnim slaganjem prohoda s desne radne strane rasipača ostvaren je i vrlo niski koeficijent varijacije koji ovog rasipača svrstava u najvišu kvalitetnu kategoriju s obzirom na raspodjelu granula.



Slika 5. Ukupni površinski udio masa granula gnojiva KAN ovisno o prohodu rasipača pri radnom zahvatu od 18 m

ZAKLJUČCI

Na temelju dobivenih rezultata provedenog istraživanja kvalitete rada centrifugalnog rasipača tvrtke Bogballe tipske oznake "L" (L2+) mogu se donijeti sljedeći zaključci:

- rasipač tvrtke Bogballe tipske oznake "L" za razliku od uobičajenog načina raspodjele granula lopaticama od sredine prema rubnom kraju rasipača radi tako da od rubova razbacuje granule prema sredini stroja ostvarivši pri tome četverostruko preklapanje;
- istraživanja rasipača obavljena su na izrazito vodoravnoj površini prema napucima servisne službe tvrtke Findri d.o.o. iz Sesveta, tako da su otklonjeni svi čimbenici vezani uz nedovoljno poznavanje stroja;
- u toku istraživanja zadovoljeni su meteorološki čimbenici s obzirom na temperature i vlagu zraka. Temperatura zraka u vrijeme ispitivanja bila je između 18 i 19°C, a relativna vlaga zraka 58 do 52%;
- granulometrijski sastav mineralnog gnojiva KAN 27%N proizvedenog u Kutini (01-02-2-4-4-076/0 od 10/2006) ukazuje na značajan udio frakcija granula promjera 2,1 do 5,0 mm od 83,67% od ukupnog gnojiva;
- granulometrijski sastav mineralnog gnojiva NPK formulacije 7:20:30 proizvedenog u istoj tvornici (01-02-2-4-4-082/0 od 10/2006) ukazuje da se radi o jednom ujednačenom gnojivu s udjelom frakcija granula promjera 2,1 do 5,0 mm od 87,42% od ukupnog gnojiva;
- površinska raspodjela granula gnojiva NPK formulacije 7:20:30 mase 400 kg/ha^{-1} pri 8 km/h ostvarena je uz vrlo nizak koeficijent varijacije od svega 6,60%;
- raspodjela granula mineralnog gnojiva KAN-a ostvarena je uz koeficijent varijacije od 6,21%;
- Na temelju iznešenog rasipač tvrtke Bogballe tipske oznake "L" može se svrstati u kategoriju odličnih rasipača, kojeg i preporučamo za primjenu na našim površinama.

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TRANSVERSE DISTRIBUTION OF FERTILIZER GRANULES BY THE BOGBALLE SPREADER

SUMMARY

The paper presents results of the investigated quality work of the Bogballe firm spreader of the designate type „L"(L2+). The investigations were conducted in the field working conditions characterized by all required weather conditions in terms of the temperature >19^o C and relative air humidity <60%. While investigating, mineral fertilizer produced in Kutina during October 2006, was used per 25 kg sacked and delivered directly prior the beginning of the research. By the granular composition, both fertilizers had increased portion of granules 2.1 – 5 mm in diameter. Thus, 7:20.30 NPK fertilizer had 87.42% whereas KAN 83.67% of the aforementioned diameter granules. The researches were carried out at 8km/h and spreading of 400 kg/ha of 7:20:30 formulated NPK, i.e. 190 kg/ha KAN fertilizer. After the granules have been weighed by the gathered boxes, weight surface distribution coefficient of 6.60% was obtained with NPK fertilizer by 7:20:30 formulation and 6.21% with KAN fertilizer. Based upon the accomplished results, the Bogballe firm spreader of the "L" designation can be included into the category of top quality spreaders recommended to be used on our areas.

Key words*: Fertilizer distribution, centrifugal Bogballe spreader*

35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.363.7:631.374
Prethodno priopćenje
Preliminary communication

UNIFORMITY OF DISTRIBUTION FOR DIFFERENT CONCEPTS OF MIXING-DISTRIBUTION TRAILERS

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ABSTRACT

The aim of this investigation was analysis of main mixing-distribution trailer working parameters. This will serve as a base for evaluation of possibilities for obtaining better meal preparation quality on farms, more uniform meal distribution, higher productivity and energy saving.

Results show that different conceptions of mixing-distribution trailers have different quality of food distribution. Best uniformity of distribution was achieved with trailer with horizontal mixing rotor and with tiller for silage cutting and loading.

Key words*: mixing-distribution trailer, mixing device, uniformity of distribution*

INTRODUCTION

Preparation of quality meal on farms is one of most important parts in breeding process if high quality is to be expected. Mixing-distribution trailers are technical solution that can put together meal preparation, mixing and its distributions farm structures and buildings. Main tasks of mixing-distribution trailer are homogenization of meal concerning its numerous components, and its uniform distribution. Ununiformity of meal distribution should not cross 10 - 15% [4]. In free keeping systems this value can be higher but not more than 20%.

MATERIAL AND METHOD

Four different mixing-distribution trailers were investigated regarding uniformity of distribution. Characteristics of trailers are shown in Table 1.

Tab. 1 Technical characteristics of trailers

Technical parameter	**Trailer**			
	A	B	C	D
Length of trailer [mm]	4830	6990	9520	5650
Width of trailer [mm]	1950	2260	1850	2060
Height of trailer [mm]	2840	2850	2670	2670
Maximal height of trailer [mm]	2840	5670	4850	2670
Trailer mass [kg]	4100	6300	6900	4100
Capacity [m^3]	10	12	15	12
Rotor type	vertical	horizontal	horizontal	vertical
Number of rotors	1	2	2	2
Year of production	2003	2003	2003	2003
Side elevator speed [m/s]	0.38	0.35	0.34	0.38

Trailers were tested in dairy cattle farms «Pionir»-Besni Fok, «Partizanski prelaz»-Vrbovsko and «Mladost»-Jabučki Rit (working units of Agricultural Cooperation Belgrade) from 20.01.2005 up to 10.02.2005. Outdoor temperature was from -4 °C in the morning, up to 5 °C during the day. Relative humidity was 88-94%. Based on feeding technology and regime for dairy cattle maize silage, concentrate in briquettes, alfalfa hay and beer pomace. Meal, formed by mixing all this components, is given two times a day in two combinations:

I - silage : hay : concentrate = 83 : 7 : 10

II - silage : hay : concentrate : beer pomace = 80 : 6 : 9 : 5

Trailers were tested in the open and in the farms. Optimal capacity and uniformity of distribution were investigated. For data analysis statistical method with variation coefficient was applied.

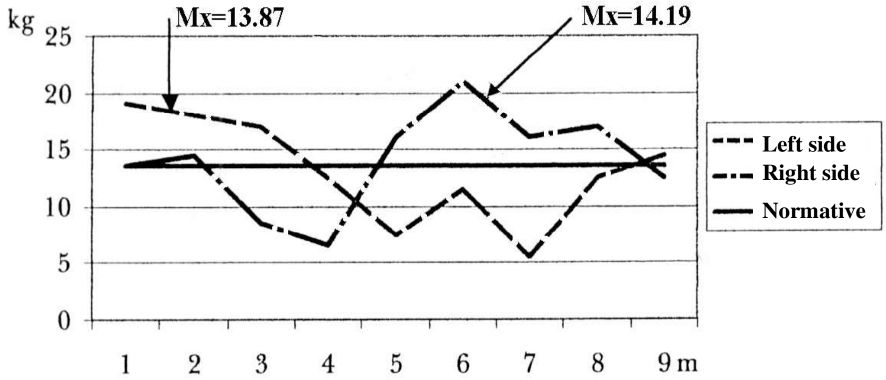
RESULTS AND DISCUSSION

During investigation trailed speed was varied as well as position of on side elevators. These two parameters directly influence on mass discharged (Mx – meal mass needed) and uniformity of disposal (Cv). Table 2 gives uniformity of food distribution for trailer A.

Tab. 2 Uniformity of distribution for trailer A

Test	**Total mass (kg)**	**Speed (km/h)**	**Side elevator speed. (m/s)**	**Average discharge - Mx (kg)**		**Uniformity of distribution - Cv (%)**	
				left side	right side	left side	right side
1	1940	1.14	0.38	13.55	11.8	1.03	7.53
2	1940	1.22	0.38	15.2	14.8	4.03	1.92
3	1940	1.14	0.38	6.5	6.3	23.76	24.86
4	1940	1.41	0.38	20.45	24.9	21.21	33.75
5	1940	1.38	0.38	13.65	13.15	2.32	3.27
Average	1940	1.25	0.38	13.87	14.19	10.47	14.27

For trailer speed of 1.25 km/h uniformity of distribution on the left side was 10.47% and on the right side 14.27% which presents a god working quality concerning proposed meal composition. Problem in exploitation can be different uniformities for left and right side. Average discharge rate Mx = 13.87 kg on the left side and 14.19 kg on right side had fulfilled given task of 13.5 kg/cow (Graph 1).



Graph 1 Stability of trailer A discharge

Table 3 gives uniformity of meal distribution for trailer B.

Tab. 3 Uniformity of distribution for trailer B

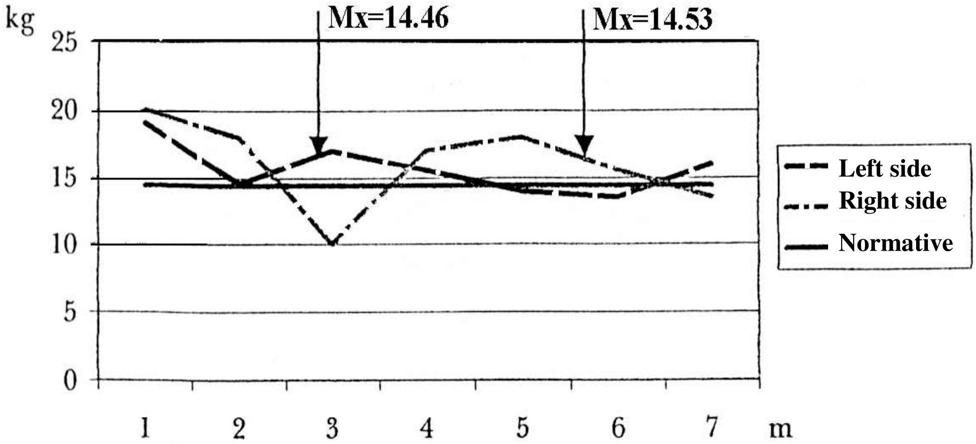
Test	Trailer speed km/h	Average discharge - Mx (kg)		Uniformity if distribution - Cv (%)	
		left side	right side	left side	right side
1	2.97	15.64	16.00	4.10	5.06
2	4.99	10.30	11.20	14.38	11.46
3	4.54	10.80	12.80	12.65	5.95
4	2.85	21.12	18.12	23.02	12.35
Average	3.83	14.46	14.53	13.54	8.71

For trailer speed of 1.25 km/h and side opening in position 10 uniformity of distribution on left side was 13.54 % and on right side 8.71 %, which presents a god working quality concerning proposed meal composition.

It can be seen, from graphic 2, that uniformity of mass distribution from both side of normative line and that Cv spans are not so big. This stability in work shows that correlation parameters Mx and Cv are in optimal correlation.

This investigation shows that there are lot of combinations and different possibilities for programming working regime of trailer. In this case, speed increasing of only 0.2 – 0.3

km/h can perform a good working quality that is proposed by methodology. This means that trailer B has good working parameters.



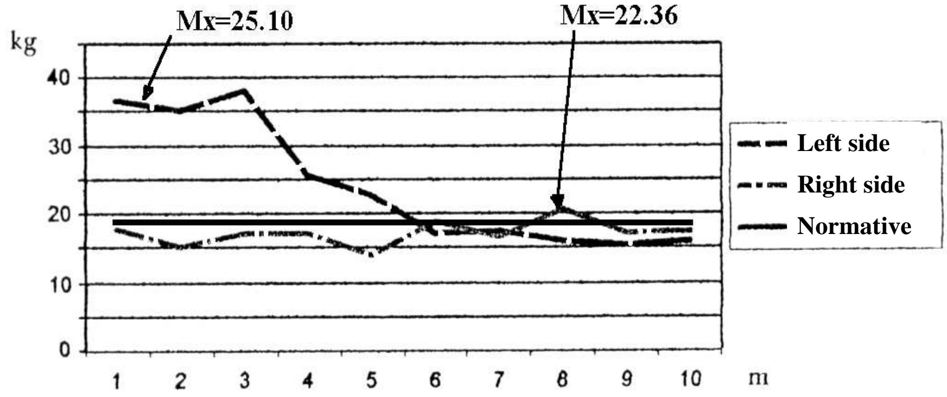
Graph 2 Stability of trailer B discharge

In table 4 uniformity of food distribution for trailer C is shown.

Tab. 4 Uniformity of distribution for trailer C

Test	Total mass (kg)	Trailer speed (km/h)	Side elevator speed. (m/s)	Average discharge - Mx (kg)		Uniformity of distribution - Cv (%)	
				left side	right side	left side	right side
1	5.000	2,21	0,34	13,95	11,65	19,86	21,42
2	5.000	2,45	0,34	48,07	34,25	40,92	23,78
3	5.000	2,33	0,34	21,65	20,20	6,15	4,32
4	5.100	1,50	0,34	24,6	27,6	0,90	10,48
5	4.700	1,58	0,34	17,25	18,08	13,98	8,56
Average	4960	2.01	0.34	25.10	22.36	16.36	13.71

Based on data shown in table 3 it can be concluded that there are huge deviation for given normative. Average discharge on left side was 25.10 kg and on the right side 22.36 kg. These values are too high compared to given normative. It can be concluded that working quality of this trailer is not satisfying. Uniformity of distribution on the left and on the right side is not o desired level (Graph. 3).

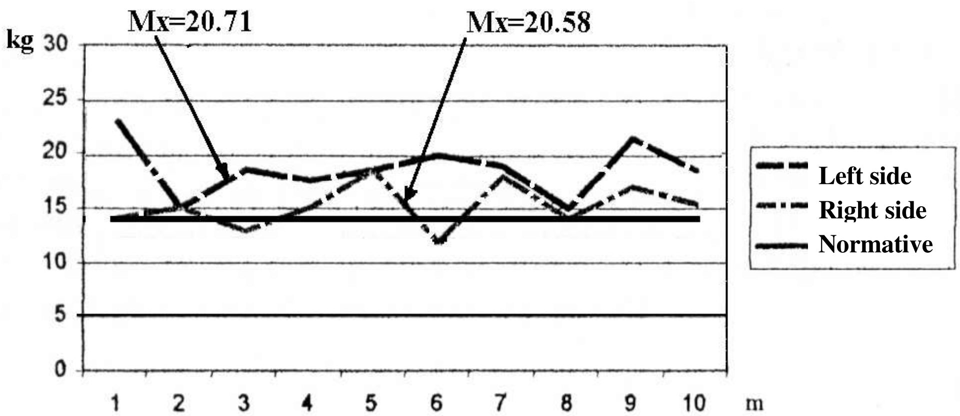


Graph 3 Stability of trailer C discharge

Table 5 gives the results uniformity of distribution for trailer D.

Tab. 5 Uniformity if distribution for trailer D

Test	Total mass (kg)	Trailer speed (km/h)	Side elevator speed (m/s)	Average discharge - Mx (kg)		Uniformity of distribution - Cv (%)	
				left side	right side	left side	right side
1	2320	1.30	0.38	18.02	12.55	6.50	19.50
2	2320	0.93	0.38	24.50	31.80	9.15	27.25
3	2320	1.45	0.38	19.20	24.50	3.64	9.52
4	2320	1.67	0.38	21.14	13.50	1.04	17.20
Average	2320	1.34	0.38	20.71	20.58	5.08	18.36



Graph 4 Stability of trailer D discharge

For trailer speed of 1.34 km/h and side opening of 32.5 cm, uniformity of distribution on the left side was 5.085 and on the right side 18.36% which presents non-satisfying working quality concerning given normative. Average mass discharge on the left side was 20.71 kg and on the left side 20.58 kg. These values are much higher than given normative (14.4 kg/cow) and are in the range of 40% deviation from normative value (graphic 4). Ununiformity of distribution on the left and on the right side is also a problem observed for this trailer.

CONCLUSIONS

From the results of investigation these conclusions can be made:

1. Mixing-distribution trailer A is suitable for working conditions on the farm. Average meal discharge and uniformity of distribution are in correspondence with given normative. Mixing procedure and its quality respond to given working regime.
2. Mixing-distribution trailer B showed the best results in uniformity of distribution as well as in average food discharge. Quality of mixed meal is satisfying.
3. Mixing-distribution trailer C does not fulfill given normative and does not have satisfying working parameters in sense of distribution uniformity as well as in sense of food discharge. Huge differences in left and right side distribution are observed with this trailer.
4. Mixing-distribution trailer D does not satisfy given normative and working quality. With this trailer great deviation in left and right side distribution uniformity.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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THEORETICAL AND EXPERIMENTAL RESEARCHES REGARDING FUNCTIONAL PARAMETERS OF MACHINES FOR FORAGE TRANSPORTATION AND DISTRIBUTION IN CATTLE FARMS

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SUMMARY

The transportation and the distribution of feed for cattle as single ration is generally realised, using special machines which have as components both mixing systems for components and uniform feed distribution systems at mangers. This needs a good correlation of functional and constructive parameters, so to be possible to obtain the mixing of parts as technologies established. Also, the transportation from the loading to the distribution point of fodders to animals must be done with minimum energy consumption at a flow rate which assures the necessary nutriment for animals.

The mathematical modelling of forage distribution process is approached in papier using dimensional analyse by Π *method, through expressing the physical link between major parameters which interfere in process based on realised experimental researches.*

Based on dimensional analyse of seven main parameters which characterise the working process of this type of machines was established the implicit homogeneous function which describe the functional link between this parameters: $f(Q, h, P, \rho_v, R_f, G_t, q_m) = 0$*, where Q (kg/s) – the distribution flow rate of machine; h (m) – the height of the exhaust-distribution window for forage; P (W) – the required power for forage distribution at mangers;* ρ_v *(kg/m3) – the bulk density of the distributed unified;* R_f *– the masic ratio between roughage / concentrate forage;* G_t*(%) – the average crumbling degree of roughage;* q_m *(kg/m) – the forage mass distributed per meter of mangers.*

After accomplishment of experimental researches in exploitation using romanian manufactured machines RTA-4.5 and RTA-9 and of machines STORTI and SEKO (Italy), based on the experimental obtained results, presented in paper, and on the analyse method mentioned above, was established the calculus expression, for the consumed power in the proccess

$$P^{0,821} = 5{,}871\frac{G_t^{1,902}}{\rho_v h^2}\frac{Q^{2,464}}{q_m^{0,643}}\frac{1}{R_f^{1,895}},$$

according to the others parameters taken in account, inclusive the coefficients of criterial equation.

The expression allows a quick estimation at feed distribution to animals knowing the others process parameters, being useful both to the machine constructors and to the exploitation specialists.

Key words*: unified distribution in cattle farms, mathematical modelling, Π method of dimensional analyze, consumed power*

INTRODUCTION

In cattle farms, feed transportation and distribution at mangers is realized mechanized with specialised technological trailers. This have as components both feed distribution systems at mangers and mixing systems for components, realized such a unified which contains in greatest part all components for animals feed.

Homogenous mixing of this components and result unified distribution in optimum quantity, according to animal feed requirements, needs a good correlation of functional and constructive parameters of unified mixing trailers, which must realized this operations at low energy consumption.

On the other hand, mathematical modelling of feed distribution process at mangers is difficult to perform due to the great number of parameters which influence the process.

These parameters regard both physical-mechanical properties of the mixed feeds and their participation in recipe, and of constructive and functional working parts characteristics of feed distribution machines.

A useful method for mathematical approached of forage distribution process at mangers, in correlation with required energy consumption is dimensional analyse method.

In this paper as study method is used Π dimensional analyse method which allowed physical connexion expression of main process parameters based on minimal experimental research.

THEORETICAL ELEMENTS

Regarding dimensional analyse theory, selection and constructive operation finalization, stages and process characteristics parameters setting remains at observer will, as function of accessible measurement possibilities. Dimensional analyse starts from process quantification, set experimental stages and allowed researcher to find the explicit expression which may determine technical system improvement in process.

For unified distribution process in cattle farms characterization by using dimensional analyse Π method, were taking in research the following parameters, considered to be important in process achievement: Q (kg/s) – the distribution flow rate of machine; h (m) – the height of the exhaust-distribution window for forage; P (W) – the required power for forage distribution at mangers; ρ_v (kg/m3) – the bulk density of the distributed unified; R_f – the mass ratio between roughage / concentrate forage; G_t(%) – the average crumbling degree of roughage; q_m (kg/m) – the forage mass distributed per meter of mangers.

There are considered as main parameters Q, h, P and ρ_v, R_f, G_t, q_m secondary parameters.

The functional link between system parameters and process parameters, taking separately, may be dimensional described by homogeny implicit function:

$$f(\rho_v, R_f, G_t, h, q_m, Q, P) = 0 \tag{1}$$

Eq.(1) transformed in an π_i undimensional complex arguments function, has the form:

$$F(\pi_1, \pi_2, \pi_3, \pi_4) = 0 \tag{2}$$

Using solving procedure proposed by Π method [6], where determined π_i undimensional complex arguments expression, which are presented as:

$$\pi_1 = \frac{h^2 P^{1/2} \rho_v}{Q^{3/2}} = const. \tag{3}$$

$$\pi_2 = R_f = const. \tag{4}$$

$$\pi_3 = G_t = const. \tag{5}$$

$$\pi_4 = \frac{P^{1/2} q_m}{Q^{3/2}} = const. \tag{6}$$

This undimensional complex arguments show the physical link between the choose main parameters (Q, h, P) and secondary parameters (ρ_v, R_f, G_t, q_m).

If are chosen as main parameters anyone of other parameters, with impose restrictions respected, π_i undimensional complex argument expressions, resulted in this new situations, are combinations of expressions (3)–(6) determined above.

Taking into account expressions (3)–(6), criterial equation (2) of feed distribution process at mangers takes the aspect:

$$F\left(\frac{h^2 P^{1/2}\rho_v}{Q^{3/2}}, R_f, G_t, \frac{P^{1/2} q_m}{Q^{3/2}}\right) = 0 \tag{7}$$

Relations $\pi_i = const.$ show that in every exploitation working conditions, π_i undimensional complex argument value is preserve from one concrete case to other [5,6]. So:

$$\frac{h^2 P^{1/2}\rho_v}{Q^{3/2}} = \alpha_1 \tag{8}$$

$$R_f = \alpha_2 \tag{9}$$

$$G_t = \alpha_3 \tag{10}$$

$$\frac{P^{1/2} q_m}{Q^{3/2}} = \alpha_4 \tag{11}$$

Analysing π_i argument expressions, it is established that the mass ratio between roughage/concentrate forage R_f and the average crumbling degree of roughage G_t, represent constants of unified distribution process at cattle.

In process description may take in study and other parameters, undimensional complex argument numbers adequate growing, [4,5,6,7].

According with dimensional analyse theory, every π_i undimensional complex is a function of other undimensional complexes, so that every parameter is a function of other process parameters. So:

$$\pi_1 = f_1(\pi_2, \pi_3, \pi_4) \tag{12}$$

$$\pi_2 = f_2(\pi_1, \pi_3, \pi_4) \tag{13}$$

$$\pi_3 = f_3(\pi_1, \pi_2, \pi_4) \tag{14}$$

$$\pi_4 = f_4(\pi_1, \pi_3, \pi_4) \tag{15}$$

Taking into account above presents, may be considered that consumed power in unified distribution process can be calculated with one of relations:

$$P^{1/2} = \frac{\alpha_1 Q^{3/2}}{h^2 \rho_v} \tag{16}$$

$$P^{1/2} = \frac{\alpha_4 Q^{3/2}}{q_m} \tag{17}$$

An explicit forma of criterial equation (7) is:

$$\pi_1 = C \cdot \pi_2^a \cdot \pi_3^b \cdot \pi_4^c \tag{18}$$

where: *C, a, b, c* represents a constant, respectively exponents, which are experimentally determined.

By replacing π_i argument expressions in relation (8) and expliciting the necessary power for unified distribution at mangers, it is obtain the relation:

$$P^{(1-c)/2} = C \frac{R_f^a}{h^2} \frac{G_t^b}{\rho_v} \frac{q_m^c}{Q^{3(c-1)/2}} \tag{19}$$

MATERIALS AND METHODS

For c constant determination and exponents a, b, c from relation (19), it were be done experimental research with four unified distribution trailers in cattle farms: RT-4.5 and RTA-9 (made in Romania) and STORTI-9.5 and SEKO L-1005 (made in Italy), pointing out functional parameters analysed in theoretical study.

Because constructive and functional parameters of feed distribution machine parts depend in great part of feed physical characteristics (crumbling degree, bulk density, natural gradient angle, the average crumbling degree, friction coefficient, reliability, compactivity, humidity, abrasivity, and adherence), which were determined for unified recipes obtained after homogenisation.

Concentrated feed (corn, barley, pea) for mixed unified were obtained in hammer mills equipped with sieves of 3–4 mm, in orifice diameters. The obtained particle dimensions, had modulus between 1.8 – 2.6 mm, classified as gross, recommended to be administrated in ruminant feed. Fibrous feed (hay, wheat straw) and corn cob were processed in fibrous chopping machine (DI-55), equipped with a sieve of 16 mm in orifice diameters.

Table 1 Some physical characteristics of unified distributed at animals

No.	Feed type	Bulk density (kg/m^3)	Natural gradient angle (degree)	Humidity %	Crumbling degree Crumbling length repartition, (%)				
					0–10 mm	11–20 mm	21–30 mm	31–50 mm	51–100 mm
1	Grass silo	750	55	61	11.4	29	18.3	26.6	14.7
2	Corn silo	740	50	72	12.5	32.6	24.5	18.3	12.1
3	Recipe R_1	672	38	55	8.2	11.6	24.2	42.2	13.8
4	Recipe R_2	376	36	25	22.4	45.8	26.5	5.3	-
5	Recipe R_3	610	29	65	9.5	13.6	27.9	30.5	18.5
6	Recipe R_4	672	37	68	13.5	32.8	21.6	30.3	1.8

For each machine were effectuated a lot of 17 experiments for π_i undimensional complex value determination and for their calculus equation of intermediary constants, according to Π dimensional analyse method.

The calculus was made both for every kind of experimented machine, following mathematical procedure according to Π method theory and for most used medium values of main parameters at other four machines (table 2).

Table 2 Functional parameter experimental medium values of some unified distributing trailer at cattle

Parameter / Machine	Q (kg/s)	h (m)	P (W)	ρ_v (kg/m^3)	R_{fc}	G_t (%)	q_m (kg/m)
RT-4.5	44,83	0,47	16928	672	2,44	21,14	39,5
RTA-9	41,25	0,40	22816	376	1,50	10,45	35,7
STORTI-9.5	28,27	0,50	23552	610	1,02	22,22	55,1
SEKO L-1005	36,60	0,57	38272	672	0,67	15,29	53,6

In the paper is presented only the used procedure for most usual medium values of parameters at all for machines, obtained values for experimental constants C, a, b and c being very close of one obtained at the procedure followed for each machine (see table 4).

At tests it starts with known values of input parameters ((R_f, G_t, ρ_v, h) determining output parameter values P, Q, q_m.

Process parameter medium values, determined in experiments and used in dimensional analyze from this paper, are synthetic presented in table 2.

Based on table 1 data, it was graphic represented, with soft TableCurve 3D v.4.0, the dependence of one process parameter as function of other two, other parameters taking result values or used values in the working process. This graphics are presented in figure 1.

Constant values α_1, α_2, α_3, α_4 were calculated using relations (8)–(11) for all four mentioned machines. These are presented in table 3.

Table 3 α_i constant values for machines used at experiments

Machine	RT-4.5	RTA-9	STORTI-9.5	SEKO L-1005
α_1	63.57	34.29	155.55	189.23
α_2	2.44	1.5	1.02	0.67
α_3	21.14	10.45	22.22	15.29
α_4	17.12	20.35	56.25	47.36

Taking into account the dependence π_1 first undimensional complex argument for the other three complex arguments π_2, π_3, π_4, according to explicit function (18), by replacing with upper values, results the following equation:

$$\alpha_1 = C \cdot \alpha_2^a \cdot \alpha_3^b \cdot \alpha_4^c \tag{20}$$

and after logarithm application, equation (16) take the form:

$$\ln \alpha_1 = \ln C + a \cdot \ln \alpha_2 + b \cdot \ln \alpha_3 + c \cdot \ln \alpha_4 \tag{21}$$

After constant values α_i^j replacing in relation (21) presented and calculated above, it was obtained a four equation system with four unknown (C, a, b, c) which have been solved on a Pentium IV PC, using Maple soft.

For experimental data shown in table 2, after computing, it was obtained for constant C and exponents a, b, c the following values: a = -1,89496; b = 1,90218; c = -0,64294; C = 5,87085, [4,7].

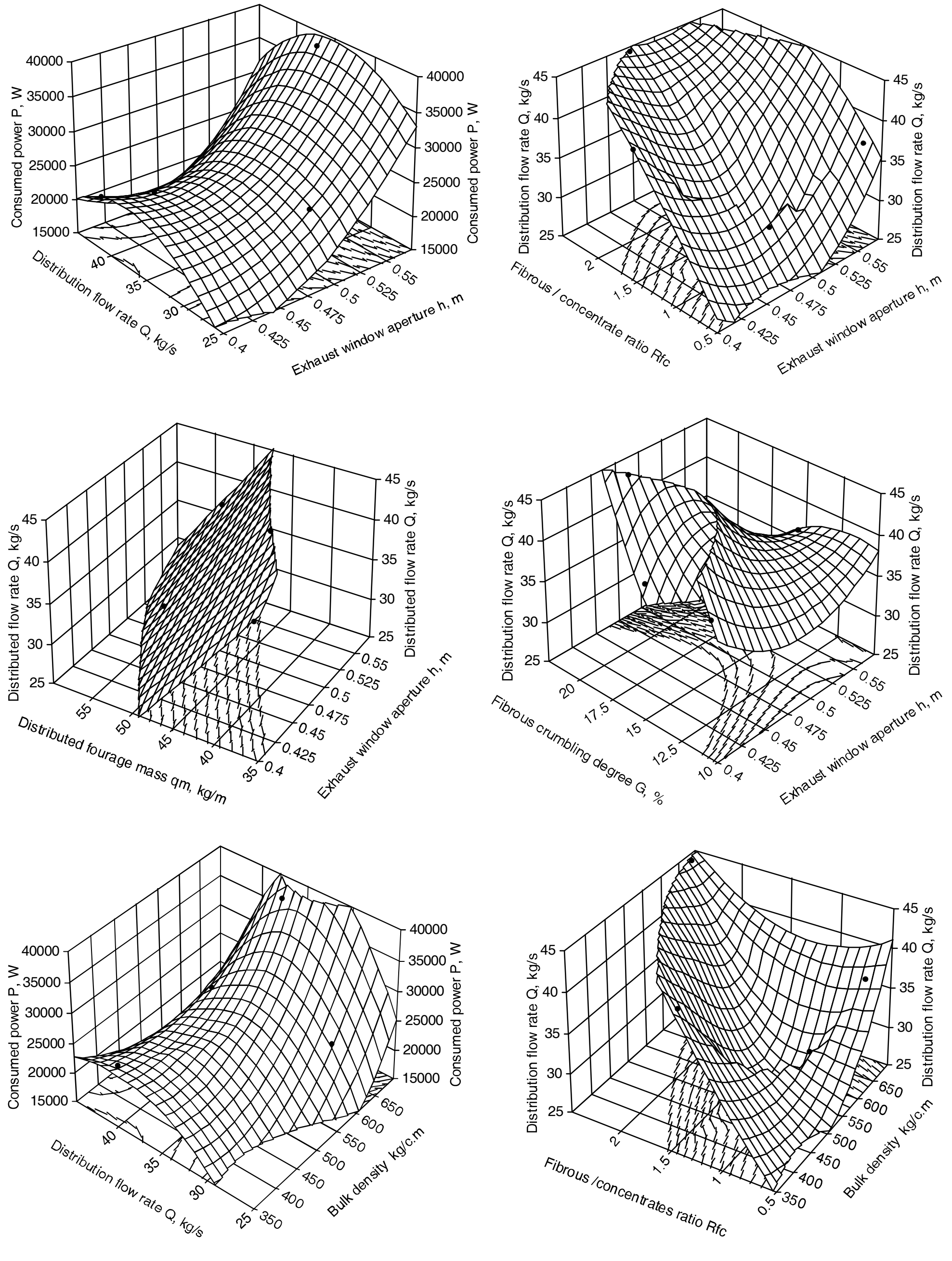

Figure 1 The dependence graphics of process parameters as function of one another, at unified distributing with mixing trailers in cattle farms

Using this values, relation (19), which shows the dependence of consumed power in process by other process parameters taking in study, change in:

$$P^{0,821} = 5,871 \frac{G_t^{1,902}}{\rho_v h^2} \frac{Q^{2,464}}{q_m^{0,643}} \frac{1}{R_f^{1,895}} \qquad (22)$$

with which can be mathematical modellating feed distribution process at mangers.

Taking into account relation (22), obtained bay dimensional analyse with process parameters medium values at all four trailers it was graphical represented required power variation for feed distribution at mangers in cattle farms as function of other process parameters, using MathCad Profesional soft. The result graphics are presented in fig.2.

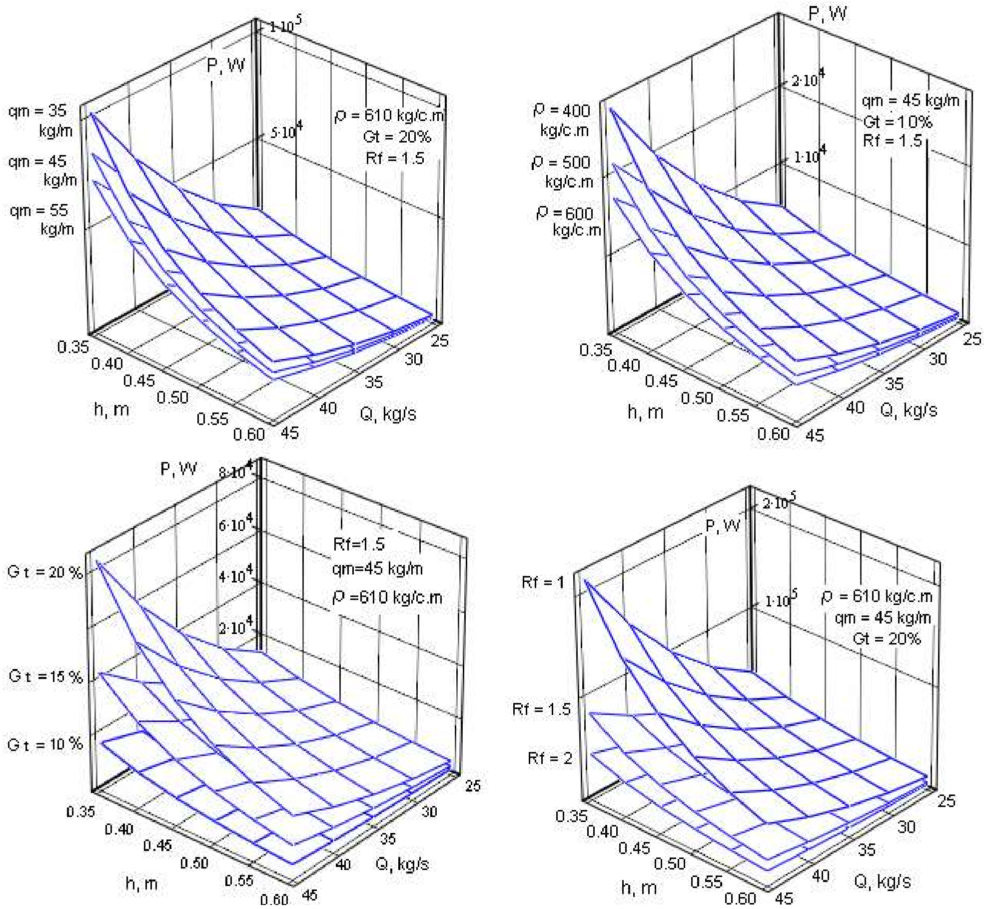

Figure 2 Consumed power variation as function of Q and h parameters, at different values for ρ, q_m, G_t, R_f parameters, graphically presented based on relation (22)

On the other part, using calculus procedure for C, a, b, c experimental constants, for each trailer, presented in papers [5] and [6], it were determined their values showed in table 4.

Their medium values are very similar with the other one based on parameter medium values used in dimensional analyse.

Substituting these values in general relation (19) may be estimated the consumed power for every kind of analysed machine as function of other parameter known values for the working process.

Table 4 Constant C and exponents a, b, c values, obtained by dimensional analyse, at four mixing trailers

Machine	a	b	c	C
RT–4.5	-1,8723	1,827	-0.683	5,8251
RTA–9	-1,9181	2,1653	-0,6481	5,862
STORTI–9.5	-1,9054	1,9405	-0,6050	5,866
SEKO L-1005	-1,9272	1,9292	-0,6164	5,871
Medium value	-1,9004	1,9910	-0,6050	5,8463

CONCLUSIONS

By complex dimensional analyse may be mathematically study and modelled every working process of a machine or an agricultural installations.

As a result of Π dimensional analyse method application at unified distribution process in animal farms, by taking into study of main process parameters, it was determined the relation (22), which mathematically express physical dependence between consumed power at distribution and the other working process parameters for the following trailers: RT-4.5, RTA-9, STORTI-9.5 and SEKO L-1005.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631.563:633.15
Prethodno priopćenje
Preliminary communication

TEHNIKA U UZGOJU I USKLADIŠTENJU SILAŽNOG KUKURUZA U AG-BAG CRIJEVA

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SAŽETAK

Istraživanje uporabe tehnike u uzgoju i uskladištenju (spremanju/konzerviranju) hibrida kukuruza Pioneer PR35P12, PR34F02, PR34B23, PR34A92 i PR34N43 obavljeno je 2006. god. na obiteljskom gospodarstvu «Simental Commerce» Osijek, lokacija Tenja. Najveći urod od 65.238 kg ha^{-1} uz 35,41 % suhe tvari izmjeren je kod hibrida PR34A92, a najmanji od 57.857 kg ha^{-1} uz 39,45 % suhe tvari kod hibrida PR35P12. Prešanje silažnog kukuruza u crijeva od folije obavljeno je sa siloprešom AG-BAG G-6000. U crijevo ispunjeno silažom kukuruza u duljini 55-56 m (bruto duljina iznosi 60 m) stane oko 150 tona silaže, što je oko 2,6-2,7 tone po metru duljine. Na gospodarstvu «Simental Commerce» u jesen 2006. godine u 14 crijeva uskladišteno (spremljeno/konzervirano) je oko 210 vagona silažnog kukuruza.

Ključne riječi: *tehnika, silažni kukuruz, urod, uskladištenje, silopreša*

UVOD

Nekada je kukuruz bio glavna hrana siromašnijeg dijela pučanstva i koristio se uglavnom kao kukuruzni kruh ili kuhana brašnasta masa (palenta, pura ili žganci). Kukuruz industrijski prerađen nalazimo kao kukuruzno brašno, gris, kruh, pahuljice, ulje, razni slatkiši, žvakaće gume, alkohol i bezalkoholna pića, ali i nama malo poznati razni farmaceutski, kozmetički, kemijski, tekstilni i drugi proizvodi (Pioneer A DuPont company, 2003.). U Hrvatskoj je danas najvažnija primjena kukuruza u ishrani stoke u obliku suhog zrna, klipa i cijele biljke (silaže).

Osnovna obrada tla za sjetvu kukuruza ovisi o pretkulturi. Osnovnu obradu tla u dubinu 25-30 cm treba obaviti u jesenskom razdoblju, a zajedno s oranjem treba obaviti i osnovnu gnojidbu. U rano proljeće treba obaviti dopunsku obradu tla, tj. zatvoriti brazdu kako bi se spriječio gubitak akumulirane vlage i pripremilo tlo za sjetvu. Mrvičasti površinski sloj tla i posteljicu za zrno najpraktičnije je obaviti sjetvospremačem (Zimmer et al. 2004.). Za silažu od cijele biljke treba izabrati hibride srednje i kasne vegetacije (FAO 400, 500 i 600), te sklop povećati za 10-15%. U istočnim područjima Hrvatske osim navedenih hibrida mogu se sijati i hibridi skupine FAO 600 i 700 (Majdak et al. 2001.).

Košnju cijele biljke najpogodnije je obaviti u fazi voštane zriobe kada u zrnu ima 30-35% vlage. Prinosi silažnog kukuruza su najčešće 40-60 t ha^{-1}. Konzerviranje sječkane mase cijele biljke kukuruza u istočnoj Hrvatskoj obavlja se, uglavnom, u horizontalnim silosima različitih volumena. Međutim, od prije tri godine u istočnoj Slavoniji na dobro opremljenim obiteljskim gospodarstvima silažni kukuruz vrlo se uspješno uporabom preše AG-BAG sprema-konzervira u crijeva od folije (Csermely et al.,2003.), (Čuljat , 2003.), (Čuljat, 2005.).

U ovom se radu iznose rezultati uzgoja pet hibrida kukuruza Pioneer sjeme grupa FAO 500 i 600 i uporaba tehnike u postupku uskladištenja silažne mase u AG-BAG crijeva na oglednom obiteljskom gospodarstvu «Simental Commerce» Osijek na lokaciji Tenja u 2006. godini.

MATERIJAL I METODE

Uzgoj pet hibrida kukuruza Pioneer sjeme i uskladištenje (spremanje-konzerviranje) silažne mase obavljeno je u 2006. godini na mješovitom obiteljskom gospodarstvu «Simental Commerce» Osijek. Nakon žetve ječma obavljena je plitka obrada tla tanjuračom. Na površinu pokusa raspodjeljen je stajnjak u dozi 60 t (6 vagona) ha $^{-1}$ i zaoran četverobrazdnim okretnim plugom. U osnovnoj gnojidbi na tlo je raspodjeljeno 600 kg ha^{-1} N:P:K formulacije 0:20:30 i Urea u količini 500 kg ha^{-1}. Zatvaranje zimske brazde obavljeno je sjetvospremačem, a sjetva hibrida kukuruza PR35P12, PR34F02, PR34B23, PR34A92 i PR34N43 26. travnja šestrednom sijačicom Maxem RAU. Podešeni razmak zrna u redu za sve hibride bio je 18,35 cm, a dubina sijanja 5-6 cm. Sklop je utvrđivan na dužini 14,3 m. Kultivacija i prihrana usjeva nisu obavljene. Zaštita usjeva obavljena je s Primextra Gold u dozi 3,5 l ha^{-1}, Motivel u količini 1 l ha^{-1} i Cambio u dozi 2 l ha^{-1}. Košnja hibrida kombajnom John Deere 6810 (6 redi) s adapterom Kemper Champion 4500 obavljena je 7. rujna. Podešena duljina sječenja bila je 4-5 cm. Vaganje uroda obavljeno je stacioniranom vagom na farmi Simental Commerce u Tenji, a suha tvar u Zavodu za tlo Osijek. Prešanje silažnog kukuruza obavljeno je siloprešom AG-BAG G-6000 (www.ag-bag.de), a radi povećanja aerobne stabilnosti kukuruzne silaže (10) u masu je tijekom prešanja uređajem «Spotlyte» dodan inokulant Pioneer 11C33 u dozi 1 g po toni silaže.

REZULTATI I DISKUSIJA

U vegetaciji silažnog kukuruza na pokusu uz selo Tenja u Osječko-baranjskoj županiji izmjerena je količina i raspored oborina kako prikazuju tablice 1 i 2.

Tablica 1 Količina (mm) i raspored oborina
Table 1 Precipitation (mm) in growing season

Mjesec/Month	IV	V	VI	VII	VIII	IX	Ukupno/Total
2006.	95,5	79,3	92,5	15,3	122,6	8,7	413,9
1993-06.	59,0	65,6	65,6	67,9	75,2	78,2	411,5

U razdoblju od travnja do rujna 2006. god. na eksperimentalno polje palo je 413,9 mm ili 0,6 % više oborina u odnosu na višegodišnji prosjek. Izrazito manje oborina izmjereno je u srpnju (15,3 mm) i rujnu (8,7 mm), a više u svim ostalim mjesecima, posebno u kolovozu (122,6 mm) u odnosu na višegodišnji prosjek.

Tablica 2 Srednje mjesečne temperature zraka (ºC)
Table 2 Average air temperature (ºC)

Mjesec/Month	IV	V	VI	VII	VIII	IX	Srednja/Average IV-IX
2006.	12,9	16,4	20,5	24,0	19,6	17,9	18,6
1993-06.	11,8	17,6	20,7	22,1	21,5	16,5	18,4

Srednja mjesečna temperatura zraka za razdoblje od travnja do rujna 2006. god. za 0,2ºC je manja od višegodišnjeg prosjeka. Topliji mjeseci bili su travanj, srpanj i rujan, a nešto hladniji svibanj, lipanj i kolovoz.

Tablica 3 Utvrđeni sklop biljaka , (10^3)
Table 3 Plant population, (10^3)

Uzorak/ Hibrid Sample/Hybrid	PR35P12	PR34F02	PR34B23	PR34A92	PR34N43
1.	69	70	69	69	72
2.	72	66	76	71	69
3.	68	72	70	70	69
4.	71	66	73	75	71
Prosjek/Average	70	68,5	72	71,25	70,25

Tablica 4 Sadržaj suhe tvari i urod
Table 4 Dry matter content and yield

Hibrid/Hybrid	PR35P12	PR34F02	PR34B23	PR34A92	PR34N43
Suha tvar/Dry matter (%)	39,45	34,88	38,31	35,41	37,47
Urod/Yield kg ha^{-1}	57.857	58.095	63.571	65.238	60.476

Najbolji sklop od 72.000 biljaka/ha utvrđen je kod PR34B23, a najmanji od 68.500 biljaka/ha kod PR34F02 (Tablica 3). Najveći urod od 65.238 kg ha^{-1} uz 35,41 % suhe tvari izmjeren je kod hibrida PR34A92, a najmanji od 57.857 kg ha^{-1} uz 39,45 % suhe tvari kod hibrida PR35P12 (Tablica 4).

Pokošen i usitnjen silažni kukuruz uskladišten (spremljen/konzerviran) je u crijeva od folije. Ključno oruđe bila je silopreša tip G-6000 tvrtke AG-BAG, na koju je dograđen uređaj za aplikaciju inokulanta Pioneer 11C33 pod nazivom «Spotlyte». Novo proizvedeni inokulant je vodotopivi prah, koji se pakuje u bočicama od 50 g i dostatan je za 50 t silirane mase. Korištena su crijeva duljine brutto 60 m, promjera 2,4 m i debljine 0,28 mm, a za pogon preše traktor snage motora 55 kW (75 KS). U crijevo ispunjeno silažom kukuruza u duljini 55-56 m (bruto duljina iznosi 60 m) stane oko 150 tona silaže, što je oko 2,6-2,7 tone po metru duljine. Na gospodarstvu «Simental Commerce» u jesen 2006. godine u 14 crijeva uskladišteno (spremljeno/konzervirano) je oko 210 vagona silažnog kukuruza. Analiza silaže nije učinjena.

ZAKLJUČAK

Nakon provedenog ispitivanja mogući su sljedeći zaključci:

- Obiteljsko gospodarstvo «Simental Commerce» u uzgoju silažnog kukuruza u polju i uskladištenju (spremanju/konzerviranju) silaže u crijeva od folije na farmi koristilo je učinkovitu tehniku i primjenilo najnovija tehnologiju dobivanja kvalitetne stočne hrane.
- Najveći urod od 65.238 kg ha^{-1} uz 35,41 % suhe tvari izvagan je kod hibrida PR34A92, a najmanji od 57.857 kg ha^{-1} uz 39,45 % suhe tvari kod hibrida PR35P12.
- Uporabom silopreše AG-BAG tip G-6000 na gospodarstvu je u jesen 2006. god. u 14 crijeva uskladišteno (spremljeno/konzervirano) oko 210 vagona silažnog kukuruza. Učinak inokulanta Pioneer 11C33 na silažnu masu kukuruza nije ispitan.

Prihvatljivost tehnike i tehnologije uskladištenja (spremanja/konzerviranja) silažnog kukuruza u crijeva od folije u interesu naše poljoprivredne proizvodnje treba svakako detaljnije istražiti.

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BREEDING AND STORAGE TECHNOLOGY OF SILAGE CORN IN AG-BAG BOWELS

SUMMARY

Research of usage technique of breeding and storaging (store/preservation) zea mays hybrids Pioneer PR35P12, PR34F02, PR34B23, PR34A92 and PR34N43 was carry out in 2006. on family farm «Simental Commerce» Osijek, location Tenja. Preculture was barley, after which was with harrow done soil tillage. Manure was distributed in dose of 60 t/ha, and ploughed with four furrow revolving plough. In base fertilization on field was distributed 230 kg ha^{-1} pure N, 120 kg ha^{-1} P and 180 kg ha^{-1} K. Sowing of hybrids, with grain distance in row at 18,35 cm was performed with pneumatic sowing machine Maxem RAU (6 row). Cultivation and additional fertilization wasn't performed. Sprayer RAU 18 m was used in application pesticides Primextra Gold, Motivel and Cambio. Mowing was done with silage combine John Deere 6810 (6 row) with adapter Kemper Champion 4500. Highest yield at 65.238 kg ha^{-1} with 35,41 % dry matter was measured at hybrid PR34A92, and lowest at 57.857 kg ha^{-1} with 39,45 % dry matter at hybrid PR35P12. Pressing silage corn in bowels from foil was done with silage haste AG-BAG G-6000. Capacity of bowel filled out with silage corn in length of 55 – 56 m (brutto length is 60 m) is cca 150 tones of silage, which is at 2,6-2,7 tones per meter of length. On family farm «Simental Commerce» in autumn 2006. year in 14 bowels was stored (store/preservation) about 210 wagons of silage corn. Effect of inokulant Pioneer 11C33 on zea mays silage was not tested.

Key words: *technology, zea mays silage, yield, storage, silage haste*

35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Re paper

USPOREDBA UZORKA RASPODJELE PESTICIDA U KROŠNJI STABALA JABUKA PRILIKOM APLIKACIJE AKSIJALNIM I RADIJALNIM RASPRSKIVAČEM

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SAŽETAK

U dva voćnjaka jabuka proučavana je depozicija in prekrivenost sa fluorescentnim markerom prilikom prskanja standardnim aksijalnim razprskiva-čem (Agromehanika AGP 400 ENU) i radijalnim razprskivačem sa cijevnim usmjerivačem (Unigreen Turboteuton P 4+4). Prvi voćnjak uzgajan je u obliku vrlo vitkog vratila (VVV) sa razmakom sadnje 0,7x2,8 m, prosječnom visinom stabla 3–3,4 m, LAI 2,45–2,8 i TRV 9800 m^3 te drugi voćnjak u obliku modificiranog vitkog vratila (MVV) sa razmakom sadnje 1,5 x 4 m, visinom stabla 3,2–3,7 m, LAI 2,5–2,9 i TRV 13500 m^3. Depozit markera (Helios – UV marker) proučavan je u četiri točke krošnje stabla pomoću fluorometrične analize fluorescentnog markera. Pokrivenost proučavana je u šest točaka analizom WSP (water sensitive paper) pomoću aparata Optomax image analyser. Otopina markera aplicirala se mlaznicama Lechler TR i Lechler ITR kod 350 l i 700 l vode / ha. Kod voćnjaka VVV izmjerene su značajne razlike u pokrivenosti izmeta aksijalnog i radijalnog razprskivača. Kod uzgojnog oblika MVV radijalni razprskivač postigao je značajno veću pokrivenost u svih šest točaka krošnje. Rezultati mjerenja depozita na lišću nisu identični rezultatima mjerenja pokrivenosti. Kod uzgojnog oblika VVV oba razprskivača formirala su jednako-mjeran depozit na lišću u donjem djelu krošnje, dok je u vrhu krošnje radijalni rasprskivač formirao veći depozit usprkos manji pokrivenosti. Kod uzgojnog oblika MVV u svim točkama krošnje stabla kod radijalnog rasprskivača izmjeren je značajno veći depozit markera na lišću u usporedbi sa aksijalnim rasprskivač-em.

Ključne reči: *jabuka (Malus domestica Borkh.), prskanje, rasprskivač, depozit pesticida, prekrivenost pesticidom*

UVOD

Aksialni pršilniki so prevladujoča konstrukcijska oblika pršilnikov, ki se uporabljajo v trajnih nasadih v večini sadjarsko pomembnih evropskih držav. Delež ostalih konstrukcijskih oblik (radialni in tangencialni) je v uporabi pod 10 %. Najverjetnejši vzrok je v tem, da so aksialni pršilniki najbolj univerzalno uporabni in zanesljivi. Uporaba radialnih pršilnikov z usmerniki (tako imenovani »octopus« pršilniki) je v mnogih državah EU v porastu. Ti pršilniki so postali dovršeni in so po uporabnih lastnostih že skoraj popolnoma primerljivi z aksialnimi pršilniki.

Na splošno raziskovalci ocenjujejo, da je distribucija škropilne brozge znotraj krošnje jablanovih dreves standardnih gojitvenih oblik pri radialnih pršilnikih z usmerniki zraka nekaj boljša, kot pri klasičnih aksialnih pršilnikih (Holownicki et al., 2000; Matthews, 2000; Panneton et al., 2005). Z usmerniki zraka lahko curke zraka usmerimo po potrebi glede na strukturo krošnje, tako dobimo bistveno bolj izenačen depozit, kot pri aksilanih pršilnikih, kjer zračnega curka ne moremo poljubno usmerjati (De Moor et al., 2000). Gojitvena oblika dreves ima velik vpliv na notranjo distribucijo škropilne brozge (Travis et al., 1987; Cross et al., 2001). Posamezen tip pršilnika lahko da boljše rezultate pri enih gojitvenih oblikah, drug tip pršilnika pri drugih gojitvenih oblikah (Cross et al., 2003).

V kmetijstvu v bodoče pričakujemo občutno redukcijo porabe pripravkov za varstvo rastlin. Delno je zmanjšanje porabe le-teh moč doseči tudi z uporabo modernejših strojev za aplikacijo pripravkov. Ob nakupu novega stroja, ki ga pridelovalec povprečno uporablja približno 10-15 let, se je potrebno pravilno odločiti in izbrati sodobno tehnologijo. V raziskavi smo želeli primerjati kakovost nanašanja škropilne brozge med aksialnim in radialnim pršilnikom pri jablanah gojitvene oblike vitko vreteno. Izbrali smo dva pršilnika nižjega cenovnega razreda. Pri standardnih aksialnih pršilnikih nižjega cenovnega razreda opažamo, da pri sodobnih gojitvenih oblikah jablan, kot je zelo vitko vreteno, ne morejo zagotoviti dovolj kakovostnega nanosa škropilne brozge, ker je razmerje med višino dreves in medvrstno razdaljo sajenja neprimerno za njihove konstrukcijske značilnosti. Zanimalo nas je, ali radialni pršilnik z usmerniki nudi boljše rezultate pri škropljenju, kot aksialni pršilnik.

METODE DELA

Izbrali smo dva nasada jablan in dva pršilnika. Z obema pršilnikoma smo nanašali škropilno brozgo pri enakih delovnih parametrih (poraba vode, vozna hitrost, enake šobe) in naredili analizo porazdelitve škropilne brozge po krošnji dreves. Delovni parametri obeh pršilnikov so prikazani v tabeli 1. Za analizo porazdelitve škropilne brozge smo uporabili metodo ugotavljanja depozita fluorescentnega sledilca (Helios SC 500 – uvitex fluroscentni sledilec, Novartis (Syngenta) Agro Švica) in metodo analize ugotavljanja pokritosti s škropilno brozgo z analizo WSP (water sensitive paper) lističev z napravo Optomax image analyser. Pri škropljenju s 350 litri vode na ha smo uporabili 3 ml Helios SC 500 na 100 l vode, pri škropljenju s 700 l/ha pa 1,5 ml Helios 500 na 100 l vode. Analizo depozita sledilca na listju smo opravili v štirih točkah v krošnji, analizo pokrovnosti na WSP lističih (% coverage) pa v šestih točkah v krošnji. Za vsako varianto škropljenja smo depozit in pokrovnost analizirali na štirih drevesih, ki so si v vrsti sledila na razdalji 5 metrov. Opazovane točke v krošnji so označene na sliki 1.

Značilnosti obeh nasadov jablan so bile naslednje:

a) zelo vitko vreteno (ZZV – angl. super spindle); sajenje 0,7 x 2,8 m, višina krošnje 3-3,4 m, LAI 2,45-2,8 in TRV 9800 m^3;

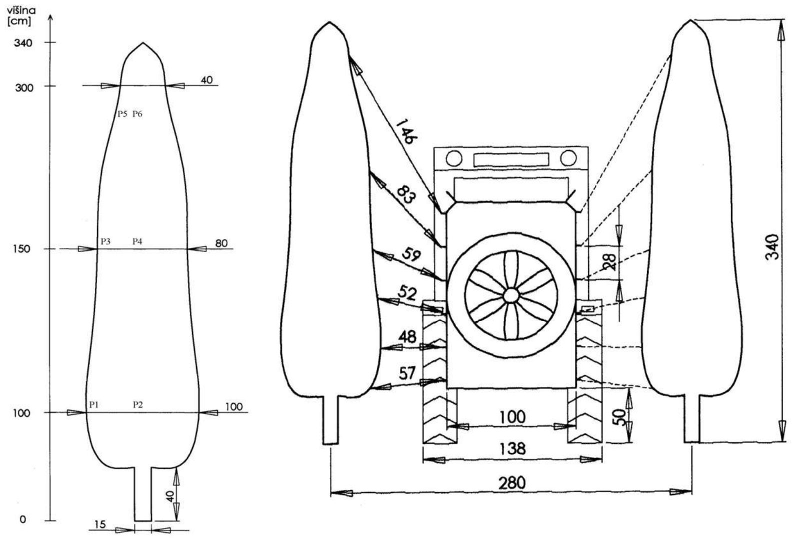
b) modificirano vitko vreteno (MVV – angl. modifide slender spindle); sajenje 1,5 x 4 m, višina krošnje 3,2-3,7 m, LAI 2,5-2,9 in TRV 13500 m^3.

Kot aksialni pršilnik smo uporabili nošeni pršilnik Agromehanika AGP 400 ENU z volumnom soda 400 l. Kapaciteta aksialnega ventilatorja je max. 48. 000 m^3/h. Vgrajena je bila črpalka BM 65/30 (max. 30 barov delovnega pritiska, 65 l/min). Največja izstopna hitrost zraka skozi vertikalni izstopni kanal je bila približno 30 m/s.

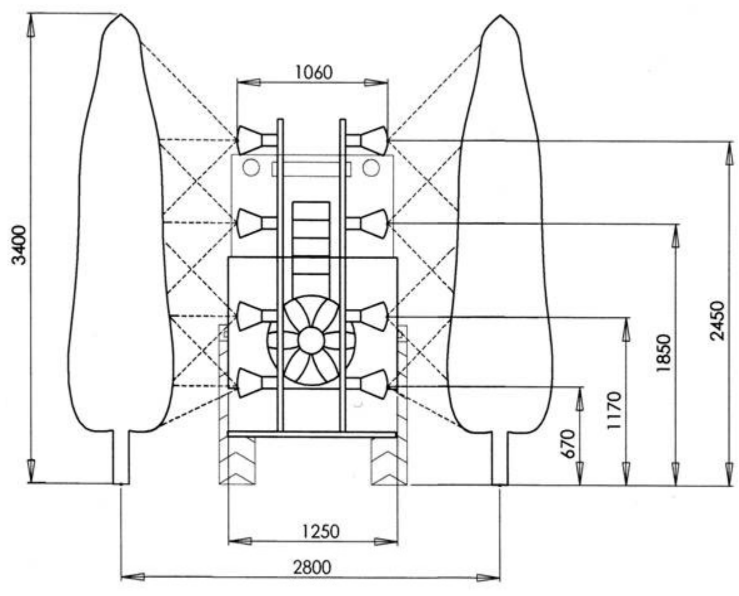
Kot radialni pršilnik smo uporabili nošeni pršilnik Unigreen TurboTeuton P 4+4 z volumnom soda 450 l. Imel je 8 gibljivih usmernikov zraka in radialni ventilator (A – 500) za dovajanje zraka. Kapaciteta ventilatorja je bila 15. 000 m^3/h. Črpalka APS 96 (max. 40 barov delovnega pritiska, 90 l/min). Največja izstopna hitrost zraka iz ustja usmernika je bila 70 m/s. Pri škropljenju v nasadu ZZV sta imela oba pršilnika vgrajenih 12 šob (6+6), pri gojitveni obliki MVV pa 14 šob (7+7).

Tabela 1 Uporabljene šobe in delovni parametri pršilnikov
Table 1 Tested nozzles and working parameters of sprayers

TIP ŠOBE:	DELOVNI PRITISK:	PRETOK ŠOBE:	VOZNA HITROST:	HEKTARSKI IZMET:	VELIKOST KAPLJIC: VMD (μm)
Gojitvena oblika zelo vitko vreteno:					
Lechler TR 80-015 Standardna šoba (ST)	5 barov	0,76 l/min	5,5 km/h	350 l/ha	160 ± 20
Lechler ITR 80-015 Antidriftna šoba (AD)	5 barov	0,76 l/min	5,5 km/h	350 l/ha	390 ± 20
Lechler TR 80-03 Standardna šoba (ST)	5 barov	1,53 l/min	5,5 km/h	700 l/ha	250 ± 20
Lechler ITR 80-03 Antidriftna šoba (AD)	5 barov	1,53 l/min	5,5 km/h	700 l/ha	500 ± 20
Gojitvena oblika povišano vitko vreteno:					
Lechler TR 80-015 Standardna šoba ST)	5 barov	0,76 l/min	4,6 km/h	350 l/ha	160 ± 20
Lechler ITR 80-015 Antidriftna šoba (AD)	5 barov	0,76 l/min	4,6 km/h	350 l/ha	390 ± 20
Lechler TR 80-03 Standardna šoba (ST)	5 barov	1,53 l/min	4,6 km/h	700 l/ha	250 ± 20
Lechler ITR 80-03 Antidriftna šoba (AD)	5 barov	1,53 l/min	4,6 km/h	700 l/ha	500 ± 20



Slika 1 Prostorska umestitev aksialnega pršilnika v nasadu gojitvene oblike zelo vitko vreteno
Picture 1 Spatial arrangement by axial sprayer in the super-spindle shaped orchard



Slika 2 Prostorska umestitev radialnega pršilnika v nasadu gojitvene oblike zelo vitko vreteno
Picture 2 Spatial arrangement by radial sprayer in the super-spindle shaped orchard

REZULTATI IN DISKUSIJA

Rezultati analize pokrovnosti škropilne brozge na WSP papirju

Primerjava rezultatov pokrovnosti (coverage na WSP papirju) pri zelo vitkem vretenu (glej tabela 2) kaže, da sta si oba preskušena pršilnika dokaj enakovredna. V povprečju je bila dosežena pokrovnost pri pršilniku Unigreen večja pri obeh tipih šob, tako pri antidriftni šobi (ITR), kot pri standardni šobi (TR).

Tabela 2 Coverage (%) vrednosti ugotovljene z analizo WSP lističev v odvisnosti od tipa pršilnika, tipa šobe, porabljene vode in položaja na drevesu
Table 2 Coverage (%) found with analysis of WSP slips in dependence from sprayer model, nozzles, spray volume and positions of slips in tree

	Zelo vitko vreteno		Povišano vitko vreteno	
	Aksialni pršilnik AGP 400 ENU	UNIGREEN pršilnik TT 4+4 z usmerniki	Aksialni pršilnik AGP 400 ENU	UNIGREEN pršilnik TT 4+4 z usmerniki
Posamične primerjave med šobami – povprečje obeh porab vode in šestih položajev skupaj:				
AD - Lechler ITR	14,13 a ***B***	24,32 b ***A***	10,27 a ***B***	30,68 a ***A***
ST - Lechler TR	16,20 a ***B***	29,55 a ***A***	11,22 a ***B***	29,13 a ***A***
Posamične primerjave med obema porabama vode – povprečje šestih točk skupaj:				
350 L / ha	11,41 b ***C***	22,32 b ***B***	6,09 b ***D***	21,08 b ***B***
700 L / ha	18,92 a ***B***	31,55 a ***A***	15,39 a ***C***	38,70 a ***A***
Posamične primerjave med posameznimi položaji na drevesu – povprečje obeh porab vode				
P1	22,59 a ***CD***	44,39 a ***A***	14,79 a ***CD***	36,09 a ***A***
P2	10,77 b ***E***	29,92 c ***C***	10,61 b ***D***	25,08 c ***B***
P3	22,38 a ***CD***	36,9 b ***B***	8,81 b ***D***	32,7 b ***A***
P4	21,01 a ***D***	42,60 a ***A***	14,91 a ***CD***	33,02 c ***A***
P5	9,66 b ***E***	5,92 d ***F***	7,45 c ***E***	13,94 d ***CD***
P6	4,58 c ***F***	2,38 d ***F***	7,89 c ***E***	18,70 d ***C***

*Male črke (a, b, c, …) služijo za primerjanje povprečij znotraj posameznega pršilnika, velike črke za primerjavo povprečij med pršilnikoma. Povprečja označena z enako črko, se med seboj ne razlikujejo značilno po Tukey-evem testu pri ($\alpha \leq 0{,}05$).

*Small letters (a, b, c..) serve for comparing means between the specific sprayer, while capital letters serve for comparing averages between both sprayers.

Obseg povečanja pokrovnosti zaradi povečane porabe vode, je bil pri obeh pršilnikih približno enak. Če naredimo primerjavo po posameznih točkah krošnje (P1; P2; P3; ….) vidimo, da je pršilnik Unigreen dosegel boljšo pokrovnost v točkah od 1 do 4, medtem ko je bil primerjalni aksialni pršilnik nekoliko boljši v zgornjem delu krošnje (točki 5 in 6). To je verjetno posledica neustrezne usmeritve usmernikov zračnega toka, ki nista bila dovolj usmerjena navzgor. Točke višje od 3 metrov so verjetno za takšno konfiguracijo pršilnika težje dosegljive in je potrebno dodati dodaten par usmernikov zraka. Za kvalitetno delovanje sistemičnih pripravkov potrebujemo vsaj 10 % pokrovnost. Vrhovi dreves pri zelo vitkem vretenu nudijo zračnemu toku zelo majhen upor, zato v tistem območju dreves prihaja do zelo majhnih turbulenc. Turbulence znotraj krošnje povečajo depozicijo škropilne brozge na listje. Zanimiva je primerjava med točkama 3 in 4. V notranjosti krošnje, ob deblu, bi pričakovali manjšo pokrovnost, vendar ni bilo tako. Velike razlike ni bilo. Se pa rezultati med pokrovnostjo in depozitom v teh dveh točkah pogosto ne ujemajo, na kar zelo vpliva hitrost vetra. Ob preveliki hitrosti vetra škropivo iz vejic na zunanjem robu krošnje, ki so zelo blizu pršilnika, zračni tok odnese. Kljub veliki pokrovnosti na WSP lističu, je lahko dejanski depozit škropiva v tistih točkah majhen.

Pri povišanem vitkem vretenu so bili rezultati podobni, kot pri zelo vitkem vretenu. Povprečno, pri obeh tipih šob in pri obeh porabah vode, smo z uporabo pršilnika Unigreen dosegli nekaj večjo pokrovnost. Pri drugem gojitvenem tipu je bil pršilnik Unigreen boljši tudi v zgornjem delu krošnje, kar je presenetljivo, saj so tudi ta drevesa bila precej višja od 3 m. Očitno je povečana gostota krošnje nekoliko povečala turbulenco v notranjosti krošnje, kar je povečalo pokrovnost na vrhu. V spodnjem delu krošnje povišanega vretena je bila pokrovnost nekaj manjša, kot v spodnjem delu dreves gojitvene oblike zelo vitko vreteno, kar je bilo pričakovano (posebej v notranjem delu).

Rezultati analize depozita na listju

Depozit na listju predstavlja najbolj realno merilo kakovosti nanosa škropilne brozge. Lahko se precej razlikuje od rezultatov v zvezi s pokrovnostjo. Ni zanesljivo, da vse kapljice, ki na WSP papirju pustijo barvno sled, na površini WSP papirja tudi ostanejo. Zračni tok jih lahko odpihne, lahko pa zdrsijo s površine listov zaradi delovanja raznih fizikalnih sil. Pri oblikovanju depozita na listju pridejo do izraza tudi učinki šob. Tako je bil na primer pri zelo vitkem vretenu in uporabi standardnega pršilnika, depozit pri antidriftni šobi (51,45 %) boljši kot pri standardni šobi (48,05 %), pri uporabi radialnega pršilnika Unigreen pa je bilo ravno obratno, standardne šobe (57,53 %) so dale boljši rezultat kot antidriftne šobe (48,6 %). Takšni rezultati so verjetno posledica interakcij med lastnostmi vetra in velikostjo kapljic. Distribucija bolj drobnih kapljic je pri pršilniku Unigreen nekaj boljša, kot pri standardnem aksialnem pršilniku in obratno, pri standardnem pršilniku je nekaj boljša distribucija večjih kapljic. Pri zelo vitkem vretenu se normalizirani depoziti na listju v nobeni od štirih preučevanih točk niso izrazito razlikovali med seboj, kar kaže, da sta si bila pršilnika pri tej gojitveni obliki po kakovosti nanosa dokaj enakovredna.

Pri gojitveni obliki povišano vreteno smo s pršilnikom Unigreen na listju ustvarili nekoliko večje depozite, kar se ujema z rezultati pokrovnosti na WSP lističih. Normaliziran depozit 35 % na vrhu krošnje je dober rezultat, glede na to, da konfiguracija pršilnika ni bila optimalna za višino gojitvene oblike, kot smo jo uporabili v poskusu.

V literaturi nismo našli člankov, ki bi obravnavali primerjavo podobnih tipov strojev pri gojitveni obliki zelo vitko vreteno, zato naših rezultatov ne moremo neposredno primerjati z rezultati drugih raziskovalcev.

Nekaj študij vpliva pretoka in hitrosti zraka (Doruchowski, 1997, Holownicki et al, 2002) je pokazalo, da pri velikih hitrostih zraka škropivo odnese z listja in zato so depoziti škropiva nižji, kot običajno pričakujemo. Če v našem poskusu primerjamo pri drevesih gojitvene oblike zelo vitko vreteno depozit v točkah 3 in 4 opazimo, da je imel aksialni pršilnik nekaj boljši depozit, kot radialni. Morda je to bila posledica manjše hitrosti zraka pri aksialnem pršilniku. Pri radialnem pršilniku je z listov na zunanjem robu krošnje odneslo več škropiva, kot pri aksialnem pršilniku. V tem oziru se naši rezultati ujemajo z rezultati zgoraj navedenih avtorjev. Edini poskus, ki je primerljiv z našim in, ki smo ga našli v literaturi je poskus, ki so ga je izvedel Holownicki in sodelavci (2000) na jablanah dveh primerljivih gojitvenih oblik. Oblika njihovega pršilnika ni bila popolnoma primerljiva našemu. V njihovem poskusu so bile razlike med aksialnim in modificiranim aksialnim (radialnim) pršilnikom s cevnimi usmerniki značilne. Pršilnik s cevnimi usmerniki je oblikoval večji in bolj enakomeren depozit škropiva. Tudi v njihovem poskusu so bile razlike med preučevanima pršilnikoma manjše pri drevesih gojitvene oblike zelo vitko vreteno, kot pri drevesih z širšo krošnjo (angl. semi-dwarfed trees).

Tabela 3 Vrednosti normaliziranega depozita (*) škropilne brozge ugotovljene z analizo depozita fluorescentnega sledilca v odvisnosti od tipa pršilnika, tipa šobe, porabljene vode in položaja na drevesu
Table 3 Values of normalized deposit (*) of spray found with analysis of deposit fluorescent tracer in dependence from sprayer model, nozzles, water quantities and the slip positions in the tree

	Zelo vitko vreteno		Povišano vitko vreteno	
	Aksialni pršilnik AGP 400 ENU	UNIGREEN pršilnik TT 4+4 z usmerniki	Aksialni pršilnik AGP 400 ENU	UNIGREEN pršilnik TT 4+4 z usmerniki
Posamične primerjave med šobami - povprečje obeh porab vode in štirih položajev skupaj				
AD - Lechler ITR	51,45 a ***A***	48,86 b ***B***	39,28 a ***C***	65,01 a ***A***
ST - Lechler TR	48,05 a ***B***	57,53 a ***A***	31,67 b ***D***	51,35 b ***B***
Posamične primerjave med obema porabama vode - povprečje štirih točk skupaj				
350 L / ha	47,99 a ***C***	59,51 a ***A***	20,18 b ***D***	32,42 b ***C***
700 L / ha	51,51 a ***B***	46,88 b ***C***	50,77 a ***B***	83,94 a ***A***
Posamične primerjave med posameznimi položaji na drevesu - povprečje obeh porab vode				
P1	61,77 a ***A***	57,07 b ***AB***	38,47 b ***B***	84,04 a ***A***
P3	49,31 b ***B***	45,06 c ***B***	51,78 a ***C***	65,45 b ***B***
P4	64,10 a ***A***	75,61 a ***A***	31,32 b ***D***	47,67 c ***C***
P5	23,82 c ***D***	35,03 d ***C***	20,33 c ***E***	35,57 d ***D***

* Enota = (µg sledilca / cm^2) / (g sledilca / ha listja) = % vrednosti ugotovljenega depozita glede na teoretični depozit. Primer; vrednost 38% pomeni, da je na kolektorju (LISTJE) bilo v neki točki krošnje ugotovljeno 38 % od teoretično pričakovanega depozita. Če smo teoretično pričakovali 100 µg sledilca / cm^2 smo dejansko izmerili 38 µg sledilca / cm^2

* Unit = (µg tracer / cm2) / (g tracer / ha leaves) = % rate between measured deposit and theoretical deposit. Example; value 38% means that the real deposit measured on the leaves amounted to 38% of theoretical deposit. If expected theoretical deposit amounted to 100 µg of tracer / cm2, the real deposit amounted to 38 µg tracer / cm2

ZAKLJUČKI

Glede na sodobne zahteve do pršilnikov za uporabo v profesionalni proizvodnji jabolk, nobeden od obeh preizkušenih pršilnikov ni dosegel dovolj velike stopnje izenačenosti pokrovnosti in depozita po vsem volumnu krošnje dreves. Pri obeh so se pokazale pomanjkljivosti v vrhovih dreves. Vrednosti za pokrovnost pod 10 % in normalizirani depoziti pod 30 % ne zagotavljajo zanesljivega delovanja kemikalij tudi, če so te sistemično delujoče. Pri zelo vitkem vretenu sta si bila pršilnika enakovredna, v nasadu z gojitveno obliko povišano vitko vreteno, je dal radialni pršilnik boljše rezultate. Poskus kaže, da lahko z uporabo radialnega pršilnika z gibljivimi cevnimi usmerniki zraka zagotovimo enako, ali celo nekaj bolj kakovostno distribucijo škropilne brozge, kot s standardnim aksialnim pršilnikom.

Pri analizi kriterija kakovost nanosa škropilne brozge, ob nakupu novega pršilnika, lahko pridelovalcem svetujemo, da bodo z uporabo radialnih pršilnikov dosegali enake ali boljše rezultate pri zatiranju bolezni in škodljivcev jablan, kot z uporabo aksialnih pršilnikov. Ob nakupu je potrebno pretehtati tudi druge kriterije (kakovost materialov, ergonomija dela, poraba goriva, …), ki niso bili predmet naše raziskave in, ki lahko povzročijo, da vseeno damo prednost tradicionalnemu aksialnemu pršilniku.

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THE COMPARISON OF DEPOSIT PARTITIONING PATTERNS WITHIN THE APPLE TREE CROWN RESULTING FROM SPRAYING WITH AXIAL OR RADIAL ORCHARD SPRAYER

ABSTRACT

Spray deposit partitioning and spray coverage were studied in two apple plantations of different training systems after application of sprays either with an axial fan orchard sprayer (Agromehanika AGP 400 ENU) or with an radial orchard sprayer with flexible air ducts (Unigreen TurboTeuton P 4+4). The orchard trained according to the super-spindle system (SS) had the following characteristics: planting distances were 0.7 x 2.8 m, tree crown height 3-3.4 m, LAI 2.45-2.8 in TRV 9800 m^3). The orchard trained according to the modified slender-spindle system (MSS) had the following characteristics: planting distances were 1.5 x 4 m, tree crown height 3.2-3.7 m, LAI 2.5-2.9 in TRV 13500 m^3). The spray deposit on leaves was analysed in four crown positions applying fluorometric methods (Helios day - UV tracer). The spray coverage (%) at six crown positions was determined by use of water sensitive papers (WSP) analysed with Optomax image analyser. Sprays were applied with two different types of nozzles (Lechler TR and Lechler ITR) at two spray volumes (350 and 700 l/ha). Significant differences among spray coverage values were determined in most of studied crown positions of trees trained according to the SS system. In lower crown positions higher coverage values were determined after spray application with radial sprayer, but higher coverage values in positions at the top of the tree crowns were noticed after application with axial sprayer. In orchard with MSS trees the radial sprayer provided significantly higher coverage values for all six studied crown positions. The results of measurements of tracer deposit on leaves were not identical to the results on spray coverage. In SS orchard, both sprayers formed comparable tracer deposits at lower and middle crown positions. At the tree tops, the radial sprayer provided higher deposit as axial sprayer. In orchard trained according to the MSS system, the radial sprayer provided significantly higher deposits in all the studied crown positions.

Key words: *apple, spray application, orchard sprayer, spray deposit, spray coverage*

35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Preliminary communication

COMBINES STABILITY

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SUMMARY

The paper presents analytical stability analysis of universal combine employed on inclined terrain at constant velocity and linear trajectory. Applied simulation algorithm is based on 3D analytical geometry and total-search optimization method. Enchaesing the combines stability by introducing ballast on the rear bridge is also disscussed.

Key words: *Stability, combine, weight center, analytical geometry.*

INTRODUCTION

The stability conditions of a universal combine specified to work in nominally horizontal terrains are analyzed in this paper. It is evident that combines of this kind sometimes fall outside the nominal inclination range. Most frequently, these situations are caused by inadequate combine handling, as well as by inclination, roughness, himudity and inhomogenity of the terrain, incorrect servicing procedure, etc.

Stability possess a crucial role in the combines dynamics, functionality, reliability and security. Proper function can be achieved only if the combine slope is deeply enough within the stability domain defined by adequate transversal and lateral inclination angles. Most commonly, header "corrects" the combine instabillity causing or not some machine damage. Fortunatly, hard accidents with human injuries are fairly rare in comparison to tractors and hill combines. However, the human health and security has a crucial role in contemporary agriculture. Therefore, development and application of different methods specified for improving the combines stability has an important place in the process of their design and exploitation.

Theoretically, the full analogy between the kinematics of four-wheels tractor and universal combine exists (fig. 1). The approximate method [1] for estimating the four-wheels tractors 3D spatial stability is available nowadays. It has been developed by advancing the classic mechanical approach (see [5]). Up to date, this method has been successfully used to compare the stability domains of different tractor-machine agregates employed in tillage and seeding processes [2], [3], [4]. Therefore, the same approach is applied in this work to estimate the stability domain of an older combine type (ZMAJ 143), which is still widely used in Serbia.

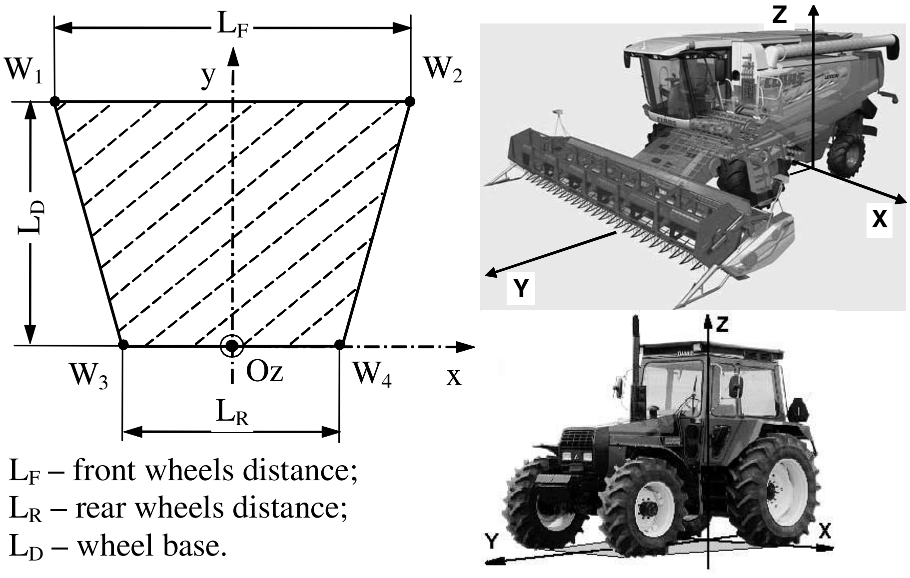


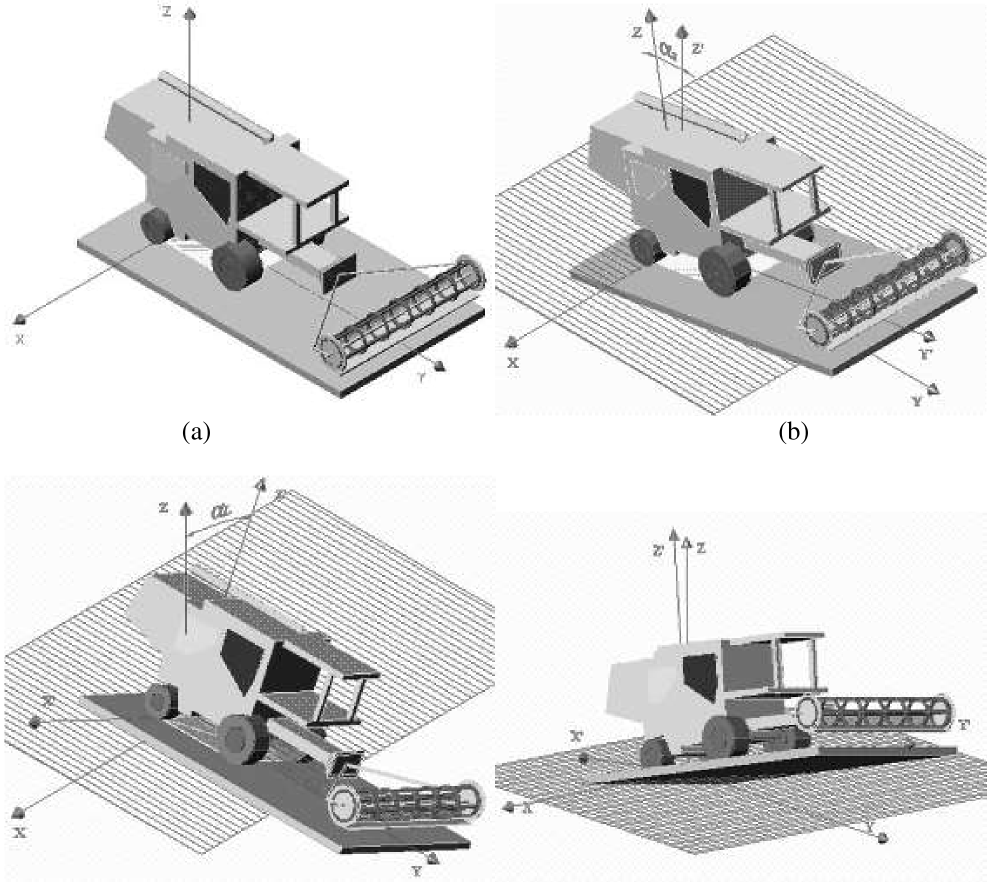
Fig. 1 Defining the reference coordinate system and supporting surface mapping – the analogy between a combine and a wheel tractor

MATHEMATICAL METHODS

The model assumes flat solid terrain and combine in peace or at linear uniform motion. Theoretical supporting surface is a trapezoid defined by wheel positions, fig. 1. Combine is considered as a solid-body system consisting of one or more inflexibly connected components (the basic machine, header, grain in bunker and ballast). Thus, at zero slope angle, the system weight-center *C* coordinates x_C, y_C, z_C are:

$$x_C = \frac{\sum_{i=1}^{n} x_i \cdot G_i}{\sum_{i=1}^{n} G_i}, \quad y_C = \frac{\sum_{i=1}^{n} y_i \cdot G_i}{\sum_{i=1}^{n} G_i}, \quad z_C = \frac{\sum_{i=1}^{n} z_i \cdot G_i}{\sum_{i=1}^{n} G_i}, \tag{1}$$

where x_i, y_i and z_i are the coordinates of the components weight-centers and G_i are their weights. The orientation of the machine system, which is dependent on the basic plane inclination, is defined in the reference coordinate system sketched in figs. 1 and 2.



(a) (b) (c) (d)

Fig. 2 A definition sketch of a combine orientation and slope angles: (a) horizontal terrain; (b) longitudinal slope, angle α_P; (c) lateral slope, angle α_B; (d) general case.

Simulation of the transversal longitudinal and lateral slope is performed by two successive rotations, L_T and L_L, of the supporting points and combine system gravity center C around the "*Ox*" and "*Oy*" axis, respectively. If the position of the supporting point "*Wj*" is defined in the reference coordinate system by the vector r_j, its position on the surface inclined at transversal slope angle α_T is:

$$r_{Tj} = [\ L_T\ ] \cdot [\ r_j\ ]\ ,\ (j=1,2,3,4.) \tag{2}$$

By analogy, lateral inclination (angle α_L) is simulated by matrices multiplication:

$$r_{TLj} = [L_L\ ] \cdot [r_{Tj}\ ] = [L_L\ ] \cdot [L_T\ ] \cdot [r_j\ ]\ . \tag{3}$$

Rotation matrices are:

$$L_T = \begin{bmatrix} cos\,\alpha_T & 0 & -sin\,\alpha_T \\ 0 & 1 & 0 \\ sin\,\alpha_T & 0 & cos\,\alpha_T \end{bmatrix}, \quad L_L = \begin{bmatrix} 1 & 0 & 0 \\ cos\,\alpha_L & 0 & -sin\,\alpha_L \\ sin\,\alpha_L & 0 & cos\,\alpha_L \end{bmatrix}. \tag{4}$$

After these two rotations, all four supporting points W_1, W_2, W_3 and W_4 are lying on sloped plain surface:

$$(r - r_{LT1})\cdot[(r - r_{LT2})\times(r - r_{LT3})] = 0\,. \tag{5}$$

The analogue procedure is applied to vector r_C defining the system weight-center $C(x_C, y_C, z_C)$ position for a horizontal combine:

$$r_{TL_C} = [L_T\,]\cdot[r_C\,] = [\,L_L\,]\cdot[\,r_{T_C}\,] = [L_L\,]\cdot[L_T\,]\cdot[r_C\,]\,, \tag{6}$$

giving new position $C_{TL}(x_{C_{TL}}, y_{C_{TL}}, z_{C_{TL}})$ for a combine on a sloped surface.

After two rotations, directional line of the combine gravity force passes through the weight center $C_{TL}(x_{C_{TL}}, y_{C_{TL}}, z_{C_{TL}})$ and is directed by unity vector $\vec{p}$ (0,0,-1), what give the following equations

$$x = x_{C_{TL}}\,, \quad y = y_{C_{TL}}\,. \tag{7}$$

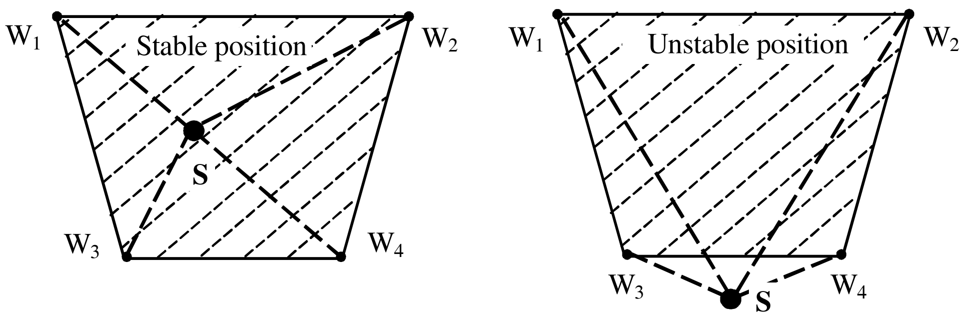


Fig. 3 Defining the stability range, by checking the position of intersection point S.

The combine system is in a stable position only if directional line of its resulting gravity force crosses the inner area of the supporting trapezoid sketched in fig.1, which is defined by wheels supporting points. Depending on this condition, combine system can be treated as stable or not. A simple way to check whether the condition is satisfied or not is to calculate the coordinates (x_S, y_S, z_S) of the cross-point $\boldsymbol{S}$, which represents the intersection point of the supporting plane (5) and directional line of the system's gravity force (7). As it can be seen in fig. 2, the summa of four triangles areas is identical to the surface of trapezoid in the combine stable position:

$$S(\Delta W_1 W_2 U)+S(\Delta W_1 W_3 U)+S(\Delta W_3 W_4 U)+S(\Delta W_4 W_2 U)=S(W_1 W_2 W_3 W_4) \tag{8}$$

For unstable system. This is not the case:

$$S(\Delta W_1 W_2 U)+S(\Delta W_1 W_3 U)+S(\Delta W_3 W_4 U)+S(\Delta W_4 W_2 U)>S(W_1 W_2 W_3 W_4). \tag{9}$$

RESULTS AND DISCUSSION

Computer evaluation of the stability domain of the universal combine ZMAJ 143 is performed in two steps. The first phase comprehended four basic cases. In the first case, the stability of basic machine with empty bunker and without header is tested. The rest three cases were focused to combine with header in transport position, and three levels of bunker crop filling: empty, half-filled (1150 kg) and full-filled (2300 kg of grain). The results are presented in fig. 4.

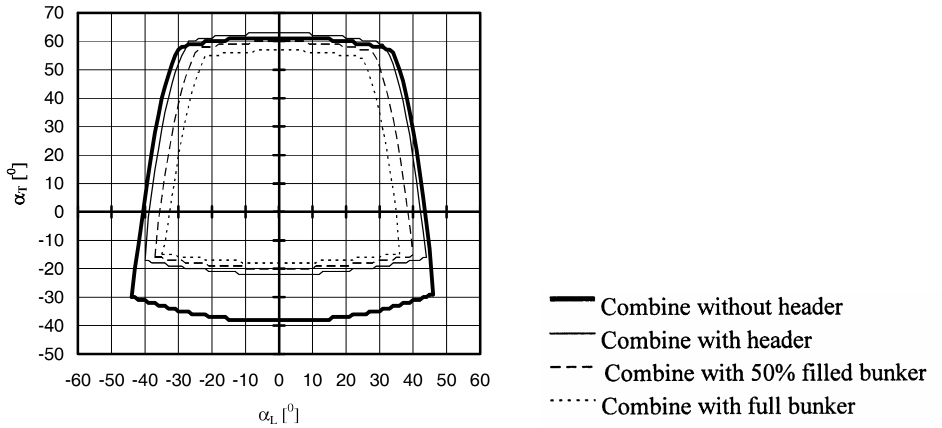


Fig. 4 The border angles of the combine stability domain.

In this figure, the abscissa is related to lateral α_L, while the ordinate represents the transversal α_T slope angle. The stability border lines of tested combine configurations are represented by different lines described in legend.

For the basic machine without header and with empty bunker, the pure negative transversal slope (lateral inclination angle α_L is zero and combines front side is lower than the rear side) is critical. The border stability angle in this case is -38^0. If the terrain slope is positive (the front combines side is higher than the rear side), the border angle is very high:

α_T=60^0. Stability domain is nearly symmetrical according to ordinate axis in this case, as well as in all other tested cases. Header mounting, signifficantly reduces the combines stability domain only in the critical area, i.e. at nominally pure negative transversal slope angles and zero lateral slope angles. Thus, the allowed terrain slope angle reduces to only -22^0 (for the empty bunker).

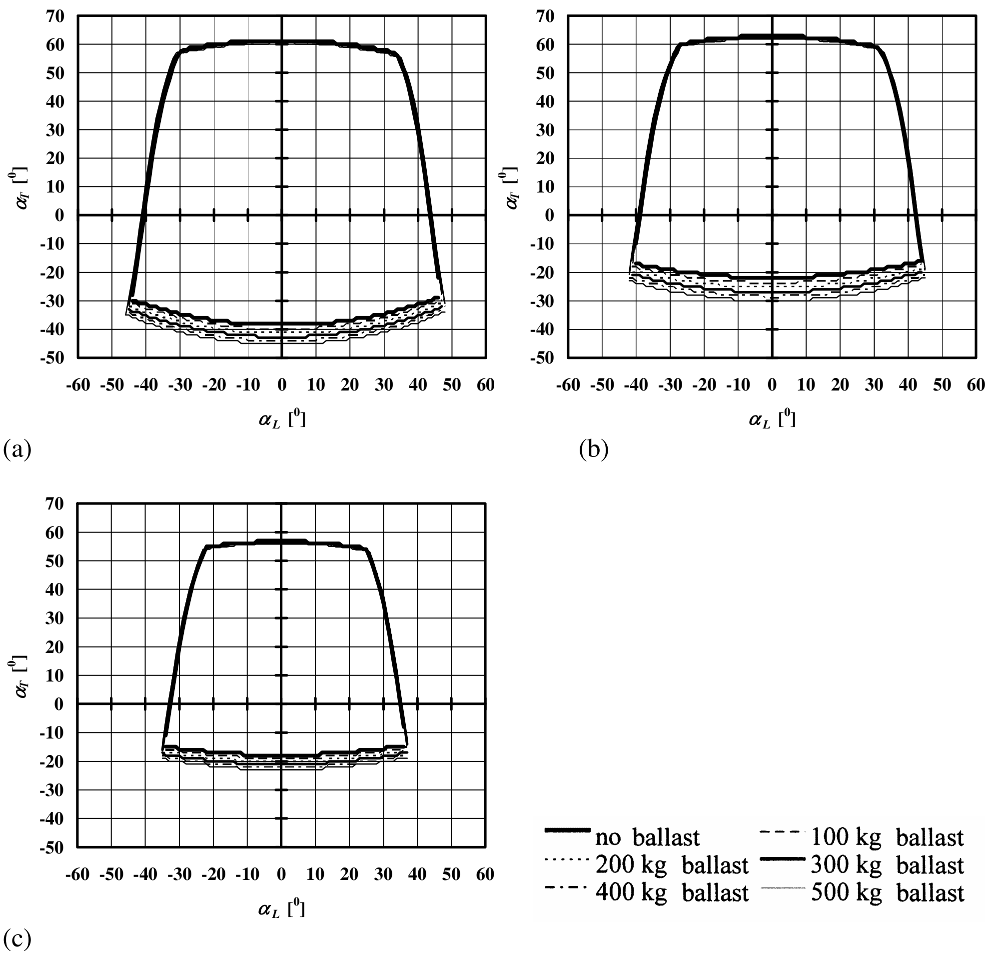


Fig. 5 The border angles of stability domain of universal combine with and without the additional weights on the rear bridge: (a) empty combine without header; (b) empty combine with header and (c) combine with header and full bunker (2300 kg of grain)

During the harvesting process, the bunker is continously filled-up by grain. Consequently, the combine system weight-center becomes higher, decreasing the stability domain. Half-filled bunker changes the value of the critical transversal slope angle to -20^0. With 100% full bunker and header in transport position, the analogue value is -18^0, showing the fairly weak influence of the crop weight on the stability domain. Therefore, presented results verify (under speciffic design parameters of the combine) dominant header role in decreasing the stability domain. Simultaneously, the lateral combine stability is less critical in all tested cases: lateral border angles are between $\pm 30^0$ i $\pm 45^0$, depending on the transversal slope of the supporting surface.

To enlarge the stability domain, speciffic analysis of the same machine is performed in the second research stage: gradual adding the ballast mass of 100, 200, 300, 400 and 500 kg on the rear combine bridge is simulated. Simultaneously, the consequent stability domains are calculated, showing the ballast influence on the combine stability range. Three basic configurations are comprehended: basic machine, complete combine (with header and empty bunker) and combine with header and bunker full of grain (2300 kg). Results of these simulations are drawn in fig. 5.

As it can be seen in this figure, additional weights are not necessary for a basic machine, although each 100 kg of additional mass increases the critical slope angle for about 1.5^0. With header mounted, the contribution of additional mass is approximately identical. That way, the critical slope angle can be increased from 22^0 to 30^0 by adding the 500 kg ballast on the rear bridge. It is significant mass, not specified by the manufacturers design. Therefore, a variety of new serious “questions” related to combine motion system, control, tyres, ballast mounting etc. may arise.

The most critical slope angle of only -18^0 arises when the bunker is full, fig. 6c. The ballast enlarges the stability domain in the critical region of negative transversal angles for only about 1^0 by each 100 kg of ballast. That way, the 500 kg of ballast changes the critical combine slope angle from -18^0 (without ballast) to -23^0. Simultaneously, the ballast negligibly changes the transversal stability at positive transversal slope angles.

On the other side, the ballast has no significant influence on lateral combine stability, which is satisfactory in all tested variants even without additional weights.

CONCLUSION

According to theoretical mechanics, the gravity force center of the tested combine with header in transport position is fairly high and too close to the front bridge. Its position cause the high-level transversal asymmetry of the stability domain and, consequently, decreases the critical slope angle of the terrain which still guarantee the combines stability. Additional ballast on the rear bridge slightly increases the stability range of the most critical combine configuration (combine with header and full bunker of grain): about 1^0 for each 100 kg ballast mass. Furthermore, presented results assume ideal conditions. By analogy to similar classic approaches, like [5], in the real dynamic conditions the theoretical slope values should be divided by security factors not smaller than 1.5.

Future research studies should comprehend the experimental combine testing by employing the hydraulic platform, as well as in the real dynamic conditions. Consequently, the adequate values of a correction factor would be provided for theoretical results presented in this paper. Further advancing the procedure toward real dynamic conditions is also needed.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Prethodno priopćenje
Preliminary communication

PREDICTIONS REGARDING THE INFLUENCE OF THE MATERIAL MOVEMENT ALONG THE SIEVE ON SEEDS SEPARATION IN CLEANING SYSTEMS FROM THE CEREAL COMBINE

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SUMMARY

The seed separation process on the cleaning systems from the cereal combines takes place, especially, due to the relative movement of the material printed by the oscillation of the sieve frame.

Based on the kinematical analysis of the driving mechanism, the kinematic and dynamic parameters of the sieves separation surface can be determined.

The movement of the material layer on sieves, due to sieves operating by the driving mechanism of the cleaning system, must transmit to the particles a movement both on a normal direction and along the sieve, which allow the relative movement of the particles one against the other and against the separation surface.

The present paper presents both the computer analysis results on superior sieve kinematics of the cleaning system from the cereal combines with a usual cleaning system as well as the motion conditions of the material on the sieve, expressed by mathematical relations, depending on the main parameters of the system.

For the analysed system, having an $L = 1.2$ m long Petersen sieve with adjustable vents and the inclination angle $\alpha = 9°$, at an oscillation frequency of 280 osc./min, there were determinate the specific inertial forces operating on the material which are included between 17.4 f.u./m.u. (force units/mass units) at the feeding end of the sieve and 16.9 f.u./m.u. at the rear end of the sieve. Based on the quantity and direction of these forces, there can be made some appreciations on the relative movement of the material along the sieve and on their influence on *the separation efficiency, for three vibration frequencies: 240, 280 and 335 osc./min.*

The researches results are useful to both the designers and users of the cereal combines, contributing to the enlargement of the database related to the optimum constructive and functional parameters of the cleaning system from the cereal combines.

***Key words**: harvesting combine, cleaning system, seeds separation, relative movement, grain losses*

INTRODUCTION

Over the years, numerous theoretical and experimental researches were done on cereal harvesting combines, generally, and on seed cleaning systems from the combine, especially, [1–4,7,9–11,13,14,16,17]..

These researches develop in time due to the complexity of the seed cleaning and separation phenomenon, to the physical proprieties modification of the harvested biological material and to the construction and working modification of the harvesting combines, [5,8,15].

Seeds separation on the cleaning system sieves of the combine results from the relative movement of the material along the sieving surface, which it is due to the sieve frame movement.

The relative movement of the material on the surface of a vibratory plane sieve, in the presence of an air jet, depends on several factors: the kinematical regime of the sieve, characterised by $k=A\cdot\omega^2/g$ (A - vibration amplitude of the sieve, ω - angular speed of the crank gear); the inclination angle of the sieve with the horizontal surface α; the angle between the vibration direction and the horizontal surface ε; the sliding angle between particles and sieve φ; the velocity and direction of the air jet blowing from below the sieve v_a, respectively angle β; as well on the physical, mechanical and aerodynamic proprieties of the particles (dimensions, specific mass, individual mass, coefficient of the aerodynamic resistance et al.), [1,3,12,14,16].

Relative to these factors, the particle can be in relative repose on the sieve or it can have a relative movement in both ways, with or without detachment, [12,14].

The theoretical and experimental data regarding the relative movement of the pile along the sieve shows that an efficient seed separation through the sieve orifices takes place when the material has a relative movement in both ways along the sieving surface with a tendency to take off and to move way to the feeding end, [1,3,12,14].

Taking account of these factors, we specify in the paper the conditions in which this type of relative movement takes place and the concordance with the separation efficiency along the sieve, experimentally determinate.

THEORETICAL ELEMENTS

The relative movement of the pile components depends both on the separation surfaces movement and on the construction and working parameters of these surfaces, [14].

At the same time, the pile stratification on the sieves surface and the seed separation from the pile cannot take place without the action of internal forces able to loosen the action of the internal bound forces between the seeds and the other pile components allowing the seeds to move in the material layer and to pass through the orifices of the separation surface, [1,3,4].

In the analysis of the relative movement of the material on the sieve, we have considered the following simplifying hypotheses: the material is composed from individual particles, having the same mass and dimensions, not interacting between them (this way we can study the movement of a single particle - seed); the sliding angle between particles and sieve is constant; the influence of the material layer thickness on the particle movement along the sieve is neglected; the air jet, over and below the sieve, is homogeneous in any point of the sieve breadth.

The main forces acting on material particles are: its own weight mg, the reaction of the sieve plane N on the particle; the friction force $F_f = N \cdot \tan\varphi$ opposing to the relative movement (φ - friction angle of the particle with the sieve); the inertial force $F_i = m \cdot a$ which has reverse sense as the sieve acceleration a; the Coriolis force $F_c = 2 \cdot m \cdot \omega_s \cdot v_r$ (ω_s - the angular velocity from the sieve plane-parallel motion, v_r - particle relative velocity reported to sieve) perpendicular to the sieve, with variable sense (contrary to the Coriolis acceleration); the action force of the air jet from the vent F_a passing through the sieve orifices (the aerodynamic force). From our analyses, the Coriolis force has an insignificant influence on the material movement because its value is negligible in comparison to the other forces (ω_s and v_r have small values), [12–16].

The main force acting on pile particles lying on the sieve surface is the inertial force F_i (the angle of the acceleration vector with the sieve plane δ), imparted by the sieve through its oscillatory movement, which represents the dynamic effect of the sieve movement on the material lying on it. That force has a tangent component along the sieve F_{it} and a normal component to the sieve (perpendicular to the sieve plane) F_{in}.

The tangent component of the force F_{it} is the force that imparted the particles the motion along the sieve, up or down, (towards an end or the other) as it is oriented, while the normal component of the inertial force F_{in} is the force responsible of the stratification and can determine both the detachment of the material from the sieve surface, if the force value exceeds certain determined values, and the seeds passing through the sieve orifices, depending on sieve orientation, above or below the sieve.

Relevant analysis and comparative efficiency anticipations of the separation done by different cleaning systems from the existing combines, can be done by comparative examination of the two components of the inertial forces imparted by the sieves of the cleaning systems to the material, taking in considerations the their experimental performances, presumed known, [12–15].

Considering that the superior sieve of any cleaning system of the cereal combines is the most important part of it, because here take place the elimination of a large quantity of foreign elements, respectively straw particles, the analysis done in this paper refers to that sieve.

The driving mechanism of the cleaning system from the classic combines has a general cinematic design like in fig. 1, [14].

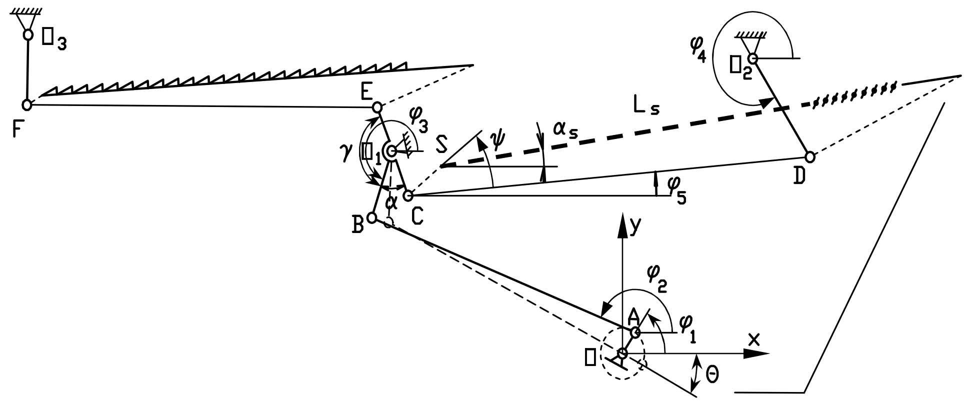


Figure 1 The driving mechanism scheme of the cleaning system from the classic combines

The movement of the pile components depends on the movement of the cleaning system sieves from the combines by the velocities and accelerations imparted to the pile components.

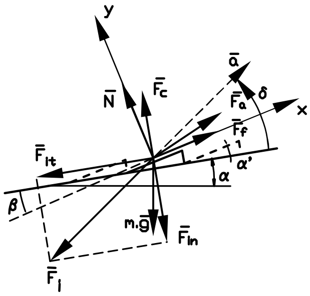
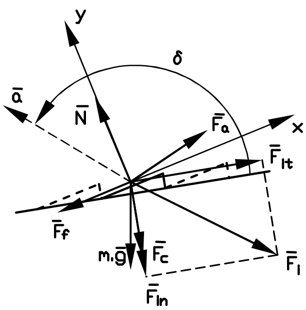
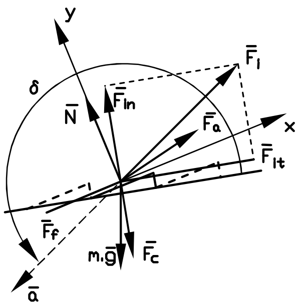
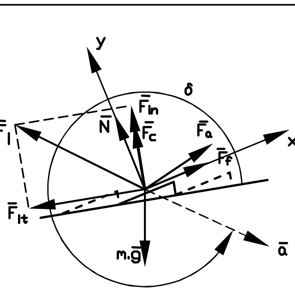
The kinematics of the separation surfaces can be analysed by the cinematic study of the driving mechanisms of the cleaning systems that often are crank mechanism with winch and balancer for the main acting part completed with crank mechanisms for hanging part of the sieve block (blocks) and of the pile-oscillating conveyor (see fig. 1).

Different configurations of the forces acting on a single particle, for the positions corresponding to a complete rotation of the driving mechanism winch of the sieve frame, are synthesized in the figures from table 1, were the sieve acceleration sense is represented with a dotted line (the direction of the Coriolis force F_c corresponds with the positive sense of the angular speed from the plane-parallel movement of the sieve – eccentric rotation to left).

To study the driving mechanism influence on the inertial forces imparted to the material on the cleaning systems sieves from combine, a Turbo Pascal calculus programme was run on a Pentium IV computer.

The velocities and accelerations were determinate, based on the calculus programme, for the superior sieve from several cleaning systems of the combines, as well for an experimental stand that have the characteristics of the classic cleaning systems, in different equidistant points along the sieve length [14].

Table 1 Forces acting on the material and the movement conditions on the sieve

Angle δ	The scheme of the acting forces	The movement possibility and the condition required for this movement to take place	Observ.
$\delta \in [0, \pi/2]$		Downward movement on the sieve blades $F_i^{s}(j) > g\frac{\sin(\varphi-\alpha-\alpha')}{\cos(\delta-\alpha'+\varphi)} + \frac{F_a}{m}\frac{\cos(\beta-\alpha'+\varphi)}{\cos(\delta-\alpha'+\varphi)}$	
$\delta \in [\pi/2, \pi]$		Upward movement on the sieve blades $F_i^{s}(s) > \frac{F_a}{m}\frac{\cos(\beta-\alpha'-\varphi)}{\cos(\delta-\alpha'-\varphi)} - g\frac{\sin(\varphi+\alpha+\alpha')}{\cos(\delta-\alpha'-\varphi)}$	The Coriolis force F_c was neglected α' – the angle of the disks with the sieve plane;
$\delta \in [\pi, 3\pi/2]$		Upward movement on the sieve blades $F_i^{s}(s) > \frac{F_a}{m}\frac{\cos(\beta-\alpha'-\varphi)}{\cos(\delta-\alpha'-\varphi)} - g\frac{\sin(\varphi+\alpha+\alpha')}{\cos(\delta-\alpha'-\varphi)}$ Detachment $F_i^{s}(s,d) < \frac{F_a}{m}\frac{\sin(\beta-\alpha')}{\sin(\delta-\alpha')} - g\frac{\cos(\alpha+\alpha')}{\sin(\delta-\alpha')}$	φ – sliding angle; β – the angle of the air jet direction with the sieve plane.
$\delta \in [3\pi/2, 2\pi]$		Downward movement on the sieve blades $F_i^{s}(j) > g\frac{\sin(\varphi-\alpha-\alpha')}{\cos(\delta-\alpha'+\varphi)} + \frac{F_a}{m}\frac{\cos(\beta-\alpha'+\varphi)}{\cos(\delta-\alpha'+\varphi)}$ Detachment $F_i^{s}(j,d) < \frac{F_a}{m}\frac{\sin(\beta-\alpha')}{\sin(\delta-\alpha')} - g\frac{\cos(\alpha+\alpha')}{\sin(\delta-\alpha')}$	

MATERIALS AND METHODS. INTERPRETATION

The program was complete to obtain the values of the specific inertial force (in N/kg) that the superior sieve of these systems imparted to the material from their surface, respectively to obtain the angle of this force vector, [14].

The experimental stand (see fig. 1), for which the calculus was done, presents the following geometrical characteristics: OA=35 mm; AB=728 mm; O_1B=150 mm; O_1C=90 mm; xO_1=–681 mm; yO_1=262 mm; CD=1158 mm; O_2D=110 mm; $\psi=28.5^o$; CS= 180 mm; $\alpha_s=7^o$; $\theta=-9.35^o$; L_s=1200 mm; $\alpha/\gamma=35/145^o$, the number of rotations of the eccentric (radius OA) is 240, 280 and 335 rot/min.

For these data, the components values of the specific inertial force acting on the material lying on the sieve, related to the rotation angle of the driving mechanism eccentric, for an oscillating frequency of 280 osc/min, are presented in table 2, [14].

The hodographs of the inertial forces, for the three oscillation frequencies, are presented in fig. 2. On the charts are presented both the possible types of the material movement, corresponding to the angle of the eccentric from the driving mechanism φ_1 (upward movement on the sieve, downward movement on the sieve or repose), as well the friction cone of the material with the sieve ($\varphi \approx 20$ - 30^o).

Table 2. The inertial forces values related to the angle of the eccentric from the driving mechanism, for an oscillating frequency of 280 osc/min

Angle	Sieve initial point			Sieve midpoint			Sieve endpoint		
φ_1	F_{it}	F_{in}	F_i	F_{it}	F_{in}	F_i	F_{it}	F_{in}	F_i
0	15.84	7.14	17.38	15.84	6.51	17.13	15.84	5.88	16.90
30	14.32	4.95	15.15	14.32	4.57	15.03	14.32	4.2	14.92
60	9.96	0.2	9.96	9.96	0.3	9.96	9.96	0.41	9.97
90	2.27	-3.78	4.41	2.27	-3.37	4.06	2.27	-2.96	3.73
120	-7.91	-4.11	8.91	-7.91	-3.78	8.77	-7.91	-3.45	8.63
150	-16.82	-1.15	16.86	-16.82	-1.19	16.86	-16.82	-1.22	16.86
180	-19.89	0.72	19.90	-19.89	0.47	19.89	-19.89	0.23	19.89
210	-16.03	-1.19	16.07	-16.03	-1.21	16.07	-16.03	-1.24	16.08
240	-7.72	-3.99	8.69	-7.72	-3.67	8.55	-7.72	-3.35	8.42
270	1.77	-3.81	4.20	1.77	-3.41	3.84	1.77	-3	3.48
300	9.71	0.07	9.71	9.71	0.19	9.71	9.71	0.31	9.71
330	14.48	4.99	15.32	14.48	4.61	15.20	14.48	4.23	15.09
360	15.84	7.14	17.38	15.84	6.51	17.13	15.84	5.88	16.90

It was experimentally established that the most efficient frequency is 280 osc/min, which assures both a good separation along the sieve, as well a good transport of the unseparated material on the sieve, [14].

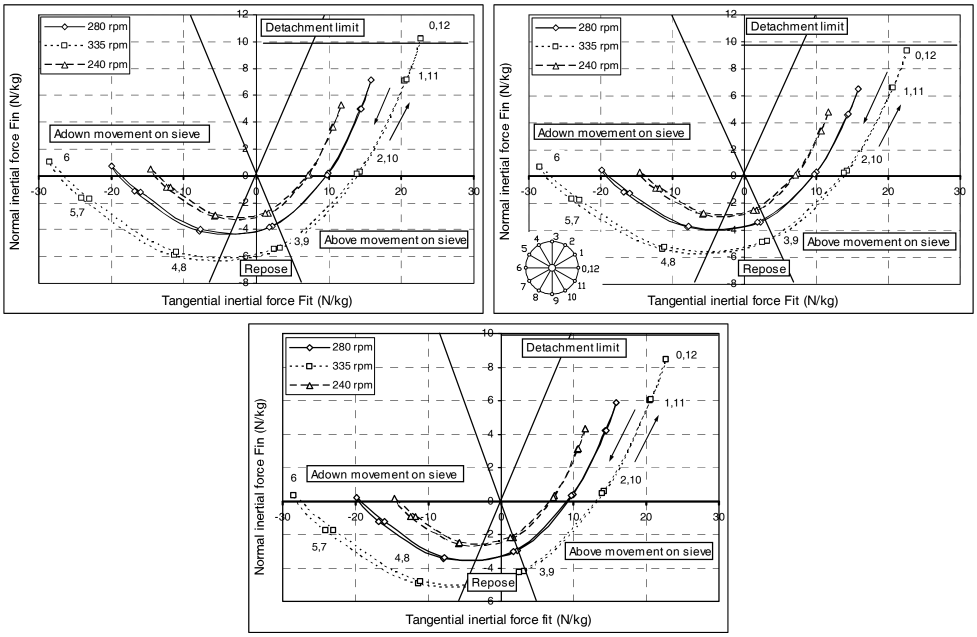


Figure 2 The hodograph of the inertial forces acting on the material along the sieve surface, at each end and in the middle of the sieve (the friction cone for a 20° angle)

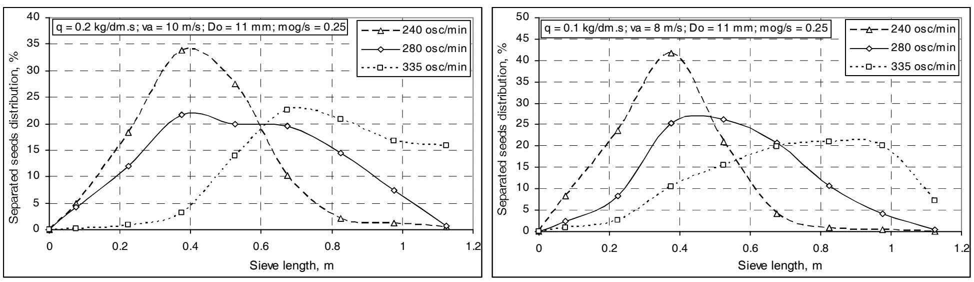


Figure 3 The distribution curves of the separated seeds along the sieve length, for three values of the oscillation frequency

For the oscillating frequency of 280 osc/min, although the seed separation is good, the material agglomerates on the first half of the sieve and the transport of the material to the sieve endpoint is compromised.

For a 335 osc/min frequency, the material is transported to the endpoint of the sieve and the seeds no longer have the time to pass through orifices causing bigger losses even for small feeding flows.

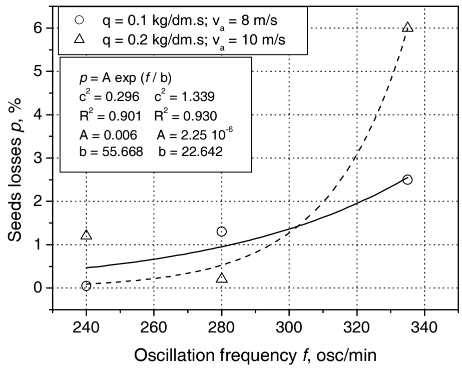


Figure 4 The variation of the seeds losses at the endpoint of the sieve vs. the oscillation frequency

From the hodographs analysis of the inertial forces (fig. 2) acting on the material lying on the superior sieve of the analysed cleaning system, it comes out that the material moves along the sieve in both ways, mainly upward, that is to the endpoint of the sieve; the rotation angle for the upward movement of the crank is about 180^o in comparison with the angle for the downward movement of 150^o. The upward movement (to the endpoint of the sieve) is increasing if we consider, as well, the aerodynamic force sense of the air jet blowing from below the sieve. At the same time, it comes out that the tangential inertial forces have values slightly equal both for the upward and downward movement, improving the transport of the material along the sieve and the seed passing through the orifices from the vertical wall of the sieve disks.

It also results that the normal inertial forces do not exceed the values that can assure the material detachment of the sieve only for high oscillation frequencies and at the beginning of the sieve.

As well, the tangential inertial force is the same in all the sieve points because of the constant angular speed of the driving mechanism eccentric, for the same values of the rotation angle and the normal inertial forces are modifying due to the different length of the balancers for the suspending sieves block.

By the calculus programme was determined the amplitude of the sieve oscillations in the downward movement on the sieve $\varphi_1 \in (\pi/2, 3\pi/2)$ and in the upward movement $\varphi_1 \in (-\pi/2, +\pi/2)$. The values obtained were 20.44 mm, respectively 21.73 mm at the sieve initial point and 20.22 mm, respectively 21.77 mm at the sieve endpoint when the disks width was 20 mm.

Related to the amplitude values of the sieve oscillations, it is recommended that its values to be at least equal with the disks width, which was took in account in the experimental installation, for the considered constructive parameters [1,3,14].

For the experimental verification of the theoretical prediction (see table 1 and fig. 2), winter wheat pile was used and, the methodology of experimentation and the obtained data were presented in authors papers [14,15].

In fig. 3, there are presented the distribution curves of the separated seeds along the sieve for the oscillating frequency at which the theoretical study was done, for the feeding flow q_1=0.1 kg/dm·s and q_2=0.2 kg/dm·s, respectively for the air jet speeds at the exit of the vent

v_a = 8 m/s and v_a = 10 m/s, for an ratio of material other than grain/seeds mog/s = 0.25 and an orifices opening of D_o = 1.1 mm, measured by the disk height from the sieve plane.

The curves from fig. 3 were graphically represented based on the results obtain in experimentations and presented in table 3.

Analysing the curves of the seeds separation along the sieve length (fig. 3) for the same oscillation frequency as in theoretical analysis, it comes out a concordance with the conclusions of the theoretical study. Most seeds separated on the first part of the sieve at an oscillation frequency of 240 osc/min, with the material being transported toward sieve endpoint and with rather low seeds losses. While at an oscillation frequency of 335 osc/min, a larger quantity of the material was transported faster toward sieve endpoint. In this case, the separation of the seed is more pronounced in the second half of the sieve, toward the sieve endpoint and seeds losses increase considerable (L_s = 1.2 m). The phenomenon is taking place both for low feeding flows (q_1=0.1 kg/dm.s), as well for higher feeding flows (q_2=0.2 kg/dm.s).

Table 3 Distribution of the separated seeds along sieve length

Probe no.	The middle of the sieve interval from where the seeds are collected x, (m)								Over the sieve
	0.075	0.225	0.375	0.525	0.675	0.825	0.975	1.125	
1	f = 240 osc/min; q = 0.1 kg/dms; v_a = 8 m/s; D_j = 11 mm; mog/s = 0.25								
	8.3	23.5	41.8	20.9	4.2	0.8	0.3	0.1	0.1
2	f = 280 osc/min; q = 0.1 kg/dms; v_a = 8 m/s; D_j = 11 mm; mog/s = 0.25								
	2.5	8.3	25.3	26.3	20.8	10.8	4.2	0.4	1.4
3	f = 335 osc/min; q = 0.1 kg/dms; v_a = 8 m/s; D_j = 11 mm; mog/s = 0.25								
	0.9	2.7	10.5	15.6	19.8	20.9	20	7.1	2.5
4	f = 240 osc/min; q = 0.2 kg/dms; v_a = 10 m/s; D_j = 11 mm; mog/s = 0.25								
	5	18.4	33.8	27.5	10.2	2.1	1.2	0.6	1.2
5	f = 280 osc/min; q = 0.2 kg/dms; v_a = 10 m/s; D_j = 11 mm; mog/s = 0.25								
	4.2	12	21.6	19.9	19.5	14.5	7.4	0.7	0.2
6	f = 335 osc/min; q = 0.2 kg/dms; v_a = 10 m/s; D_j = 11 mm; mog/s = 0.25								
	0.2	0.8	3.1	13.9	22.6	20.8	16.8	15.8	6.0

In fig. 4, the variation of the seed losses is presented for the analysed experimental cases and it is noticed an increase of seed losses at the same time with the increase of the oscillation frequency. Realising a regression analysis of the obtained data, with the MicroCal Origin software, based on a function like $p = A \cdot \exp(f/b)$ (p – seed losses, in %; f – oscillation frequency, in osc/min, A, b – coefficients), it is noticed a good correlation of the experimental data, probed by value of the correlation coefficient for the two situations R^2 = 0.90, respectively R^2 = 0.93.

CONCLUSIONS

Mainly, the inertial forces acting on material particles, with their normal and tangential components, influence the dynamic of the material movement on sieves surface from the combines cleaning system. The constructive and functional characteristics of the sieve driving mechanism and the angle of the driving mechanism eccentric in rotation movement give the values of these forces. The cinematic and dynamic analysis of the driving mechanism form these cleaning systems, for different oscillation frequencies, determine the value of the inertial forces acting on the material from the sieve, in relation with the winch angle. Thus, the material movement on the sieve can be predicted and there can be make appreciations on system efficiency, related to the degree of the seeds separation along the sieve and to the seeds losses at the sieve endpoint.

From our analyses, the increase of the sieve oscillation frequency had lead to higher values of the inertial forces, the material moved faster on the superior sieve surface of the cleaning system and the seed losses have increase considerably.

A lower oscillation frequency can assure a lower level of the seed losses, but the material left on the sieve is no longer transported properly, it agglomerates in the first half of the sieve. Thus, the purity of the material collected under the sieve can decrease.

For a cleaning system with the similar characteristics with the analysed one, the optimum oscillation frequency is between 270 – 280 osc/min. This frequency assures both a lower level of the seed losses and a optimum transport of the material on the sieve toward the sieve endpoint, for sieves with lengths of at least 1200 mm.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.363.7
Stručni rad
Expert paper

EVALUATION OF THE OPTIMAL MIXING TIME AT HORIZONTAL AND VERTICAL FEED MIXERS

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ABSTRACT

Mixing is one of the most important operations in the process of feed manufacturing, which objective is to produce feed where nutrients and medication are uniformly distributed. A satisfactory mixing process produces a uniform feed in a minimum time with a minimum cost of labor and power. Feed that is not uniform results on low animal performance. The study evaluated the optimal mixing time at 1,0 ton vertical mixer and horizontal 0,3 ton mixer. Protein, Calcium and ash are used as "markers" to test mixer performance. Ten samples were collected every two minutes starting from minute 2 to minute 14. The coefficient of variation (CV) is used to determine mixer performance. The standard for uniform mixing is CV of 10 % or less. The CV over 10 % indicates non uniform feed. Also was evaluated the technical characteristics of feed manufacturing plant with vertical mixer and plant with horizontal mixer. The production capacity per hour and per day and energy consumption is also measured at each manufacturing plant. Particle size uniformity is determined and expressed by sieving of finished feed with a dry sieving test, passing a sample through a series of sieves to separate coarse, medium and finer particles.

When ash used as marker the CV was less then 10 % after 8 minutes of mixing at both, horizontal and vertical mixer. The optimal mixing time was reached after 10 minutes of mixing. When Calcium used as marker at horizontal mixer the CV was satisfied after 6 minutes, but optimal mixing time was achieved after 8 minutes of mixing. At vertical mixer the CV was less then 10 % after 10 minutes. When protein used as marker at horizontal mixer the CV was satisfied after 8 minutes. The optimal mixing time at vertical mixer was reached after 10 minutes of mixing.

Key words: *vertical and horizontal mixers, production capacity, energy consumption, the optimal mixing time*

INTRODUCTION

One of the most important and critical steps in the production of finished poultry feed is feed mixing, whose goal is to attain a perfect dispersion of ingredients in a feed. The lack of adequate feed uniformity can cause decreases in animal performance and reduced profitability. Periodic evaluation of the mixing equipments and process must be done to assure that the program in use is a program that produces the uniformity that is desired. Feed mixing uniformity dependents on technical characteristics of feed manufacturing plant, mixing time, the mixer filling coefficient, particle size and shape and feed ingredients chemical characteristics. The more these characteristics vary from one ingredient to another, the more difficult is to mix them together. As feed mixing uniformity is determined through the coefficient of variation (CV), it was calculated after we determined the mean and standard deviation for each set of samples within each mixer. The chemical assay for nutrient such content of ash, protein and calcium was used to determine the CV. Different studies indicated that the mix is uniform if CV is less than 10 %. Based on this rate, the optimal mixing time of poultry feed is determined in two basic types of mixers, horizontal and vertical mixer.

Feed uniformity is determined at laying hens ration and broiler chick ration at horizontal and vertical mixer. From each mixer ten samples are taken every two minutes of mixing, starting immediately after the second minute until the twelfth minute in the horizontal mixer, and after the fourth minute until the fourteenth minute in the vertical mixer.

The study evaluated the technical characteristics of feed manufacturing plant with vertical mixer and plant with horizontal mixer that is fully mechanized. The production capacity per hour and per day and energy consumption is also measured at each manufacturing plant. Particle size uniformity is determined and expressed by sieving of finished feed with a dry sieving test, passing a sample through a series of sieves to separate finer particles from coarser ones. The coefficient of variation of ash, calcium and protein for all six mixing times is analyzed and calculated by a statistical program.

MATERIALS AND METHODS

Feed uniformity is determined at laying hens ration and broiler chick ration at horizontal and vertical mixers. The horizontal dual ribbon mixer (Photo 1) utilizes a double spiral ribbon turning on a horizontal shaft (Photo 2) that moves feed from one end of the mixer to the other, while the inside ribbon moves feed in the opposite direction. In the vertical screw mixer (Photo 3) one large auger turn on vertical shaft, circulate feed ingredients from top to bottom. These mixers generally have a longer batching time as compared to the horizontal ribbon type mixer.

The study evaluated the quality of milling at the hammer mill (Photo 4) comprised of a series of disks mounted on the horizontal shaft, free swinging hammers running parallel to the shaft and through the rotor disks. Ingredients are held in the grinding chamber until it is reduced to the size of the openings in the screen.

Photo 1 Horizontal dual ribbon mixer

Photo 2 Double spiral ribbon

Photo 3 Vertical screw mixer

Photo 4 Hammer mill with 4mm screen

The evaluated feed mills had the following characteristics: (Table 1).

Table 1 Feed mill technical characteristics

	Vertical mixer	**Horizontal mixer**
Manufacturer	1 Maj, Bogatič	Silomoks, Dublje
Hammer mill power (kW)	11,0	11,0
Mixer diameter (mm)	1,200	1,100
Mixer power (kW)	4,0	2,2
Mixer filling capacity (kg)	1,000	300
Rotation number of mixer element (rot/min)	200	59
Screen hole diameter (mm)	4	4
Number of electro motors	8	11
Overall power of electro motors (kW)	20,5	23,3

From each mixer ten samples are taken every two minutes of mixing, starting immediately after the second minute until the twelfth minute in the horizontal mixer, and after the fourth minute until the fourteenth minute in the vertical mixer.

RESULTS AND DISCUSSION

Before determination of food uniformity, the finished feed particle sizes were analyzed with a dry sieving test system (Cerlstevens and Silver, 1962). Finer particles were present at 67,5 %, mediums ones were present at 18,7 % and coarser particles at 13,7 %. The finer particles from 400-1.000 microns were present at 45,6 % in the tested feed. The coefficient of variation of feed particle sizes was less than 10 % during all mixing times, except in the first two minutes of the mixing time. This presents a quality grind that has a positive impact on feed uniformity.

Results of production and energy consumption are given in Table 2.

Table 2 Poultry feed production and energy consumption

Feed mill type	**Production Kg/h**	**Consumption kw/h**	**Production kg/kwh**	**Price €/ton**
Vertical	1.390	7,5	185	0,31
Horizontal	2.470	11,2	220	0,26

In the table 3 are presented the results of ash, calcium and protein content at horizontal and vertical mixers for broiler and layer feed.

Table 3 Feed uniformity for broilers and layers at different mixing time presented through the coefficient of variation

Mixing time (min)	Ash (CV %)				Ca (CV %)				Protein (CV %)			
	H/B	V/B	H/L	V/L	H/B	V/B	H/L	V/L	H/B	V/B	H/L	V/L
2	13.00		13.42		10.05		29.37		17.13		10.46	
4	8.27	6.15	13.12	23.04	3.27	4.53	24.36	20.02	8.19	10.30	11.69	6.68
6	13.34	2.94	16.28	9.02	5.62	5.28	25.74	8.30	8.96	9.94	9.48	7.33
8	3.82	15.97	9.90	3.01	3.34	14.37	21.67	3.49	6.94	10.98	6.28	6.84
10	8.27	12.64	4.93	5.61	6.66	15.70	10.82	6.31	4.18	4.31	2.91	5.47
12	8.01	12.57	2.78	5.58	3.85	13.01	3.60	4.55	1.27	4.05	2.48	2.41
14		8.07		1.42		4.42		4.04		3.13		1.69

H/B = Horizontal mixer / Broiler feed
V/B = Vertical mixer / Layer feed

CONCLUSIONS

Feed manufactory production capacity - The average production rate of partly mechanized vertical mixer was 11,2 mt/day. The fully mechanized horizontal mixer had an average production rate of 19,8 mt/day.

Energy consumption - the energy consumption at vertical mixer was 0,31 €/mt with a production of 185 kg of produced feed for each kilowatt spent. Within the horizontal fully mechanized mixer the energy consumption was 0,26 € per mt of produced feed with a production of 220 kg for each kilowatt spent.

Determination of food uniformity through the coefficient of variation (CV) - When ash was used as an indicator for feed uniformity, the calculated coefficient of variation (CV) indicated that both mixers were able to manufacture uniform poultry feed after 8 minutes, but CV was optimal after 10 minutes. When calcium was used as an indicator for feed uniformity at the horizontal mixer, the CV indicated that the uniform mix was achieved after the sixth minute, but it was optimal after the eighth minute. In the horizontal mixer with calcium as an indicator, the feed uniformity was reached after the tenth minute. When protein was used as an indicator for feed uniformity in the vertical mixer the optimal CV was reached after the tenth minute compared to the horizontal mixer where the optimal CV was reached after the eighth minute.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Pregledni rad
Review paper

STANJE RAZVOJA BIOSENZORA ZA PRIMJENU U POLJOPRIVREDI

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SAŽETAK

Biosenzori kao biološki uređaji za prepoznavanje predstavljaju interdisciplinarno sučelje između okoliša i sustava obrade podataka, a povezivanje biomolekularne i poluvodičke tehnologije često vodi do novog rješenja senzora. Biosenzori na poluvodičkoj osnovi daju se oblikovati modularno, pa je postalo moguće i njihovo povezivanje u senzorski sustav smješten na jednom čipu. Iako je razvoj biosenzora prvotno bio vezan uz medicinu, u posljednjem je desetljeću značajano poraslo i zanimanje za primjenu u poljoprivredi.

Ovaj rad prikazuje stanje razvoja različitih vrsta poluvodičkih struktura s efektom polja razvijenih upravo za zadatke detektiranja u poljoprivredi, kao što je to primjerice razvoj biosenzora za otkrivanje malih koncentracija organskih mirisnih supstancija, nastalih povezivanjem antene insekta s tranzistorom koji radi s efektom polja, ili razvoj biosenzora za detektiranje insekticida i herbicida. Biološka osnova ovih senzora čini ih idealnim instrumentom za utvrđivanje prisutnosti toksičnih tvari u vrlo malim tragovima.

Ključne riječi*: biosenzori, poljoprivreda, tranzistori s efektom polja*

UVOD

Biosenzori su kemijski senzori i služe za utvrđivanje prisutnosti bioaktivne supstancije (enzima, mikroorganizama, antitijela, stanica) u biološkim proizvodnim procesima. Djelovanje zasnivaju na sloju enzima ili mikroba, koji u doticaju s analiziranom supstancijom izazivaju biokemijske reakcije i promjene [2, 3].

Naziv senzor dolazi od latinskog sensus za osjetilo i njime se označava prvi član mjernog lanca u kojem se mjerna veličina pretvara u električni signal. Živi je organizam pun bioloških senzora, pa tako čovjek doživljava okoliš preko svojih osjetilnih organa, tzv. receptora, sićušnih osjetila smještenih na rubovima živčanog sustava. Vanjske podražaje receptori pretvaraju u električne signale koji zatim preko živaca dospijevaju u mozak, centar živčanog sustava, i tu tek nastaje osjet. Pretpostavlja se da čovjek posjeduje oko 10^9 do 10^{11} receptora. I odatle potječe pomisao stvaranja umjetnih biosenzora, uređaja koji na ulaznu pobudu, izazvanu nekom biokemijskom veličinom, generiraju mjerljivi električni izlazni signal kao odziv.

Biosenzorska tehnologija je interdisciplinarna i spaja područja kemije i molekularne biologije s elektronikom i obradom podataka. Sve dublje spoznaje o molekularnim procesima u biologiji i sve minijaturnije izvedbe elektroničkih elemenata otvorile su i mogućnosti njihovog povezivanja. Utvrđeno je tako da je moguć dvosmjerni prijenos signala između jedne biološke stanice i jednog unipolarnog tranzistora, tranzistora s efektom polja kratice FET (Field Effect Transistor) [4].

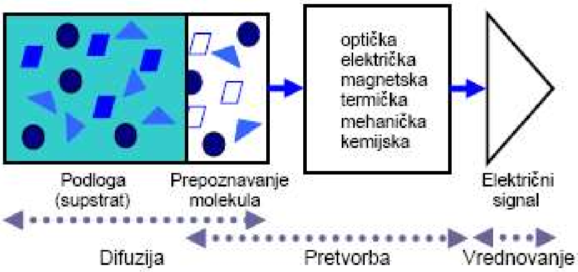
VRSTE BIOSENZORA

Biosenzor se može zamisliti kao uređaj koji se sastoji od biološkog sustava za prepoznavanje, nazvanog bioreceptor, i od pretvornika. Interakcija biološke osnove (analita ili supstrata) s bioreceptorom oblikovana je tako da u pretvorniku proizvede efekt, kojim nastala informacija konvertira u mjerljivi električni signal proporcionalan koncentraciji specifične supstancije ili niza supstancija, slika 1. U usporedbi s ostalim kemijskim biosenzori imaju prednosti ali i nedostatke, tablica 1.

Po načinu djelovanja (difuzija u slici 1) mogu se razlikovati: enzimski senzori, senzori s cijelim stanicama, imunološki senzori / DNA-testovi i senzori iz tkiva i organa, a prema vrsti pretvorbe najzastupljeniji su: poluvodički, optički i piezoelektrični [1, 3].

Poluvodički biosenzori najprisutniji su u prvenstveno u medicinskoj dijagnostici. Tu spadaju primjerice CMOS mikročipovi (Complementary Metal-Oxide Semiconductor) s visokim stupnjem integracije elektroničkih elemenata. Jedan DNA mikromatrični čip omogućuje paralelno utvrđivanje specifičnih količina DNA sekvenci u nekom uzorku. Primjenu u poljoprivredi našli su prije svega tranzistori koji rade s efektom polja.

Optički biosenzori koriste se za različite vrste spektroskopije (apsorpciju, fluorescenciju, fosforescenciju, refrakciju, disperzivnu spektrometriju) u cilju utvrđivanja spektrokemijskih svojstava uzoraka, kao što su: amplituda, energija, polarizacija i vremensko kašnjenje. Najčešće mjereni parametar je amplituda elektromagnetskog spektra, koji korelira s koncentracijom pojedinih sastojaka istraživanog uzorka.



Slika 1 Načelo djelovanja biosenzora

Tablica 1 Usporedba svojstava kemijskih senzora i biosenzora

Kemijski senzori	Biosenzori
loša granica dokazivanja	vrlo duboka granica dokazivanja
loša razlučivost	vrlo dobra razlučivost
široko područje linearnosti	vrlo široko područje linearnosti
mogu raditi i bez reagensa	rade s reagensima
duga životna dob (mjesecima do godinama)	kratka životna dob (danima do mjesecima)
jeftini u proizvodnji i primjeni	skupi u proizvodnji i primjeni
daju se po volji minijaturizirati	minijaturiziranje smanjuje granicu prepoznavanja
vrijeme reakcije kratko	vrijeme reakcije različito

Piezoelektrični biosenzori svoj rad zasnivaju na promjeni mase piezoelektričnih kristala nastaloj kao posljedica biokemijskih reakcija. Prvo se utvrdi rezonantna frekvencija piezokristala, a promjenom mase nastaloj vezivanjem pojedinih kemijskih elemenata, titranje se javlja pri nekoj drugoj frekvenciji. Mjerljiva razlika obaju frekvencije korelira s povećanjem mase i mjera je za prisutnost i koncentraciju određene supstancije.

POLUVODIČKI BIOSENZORI

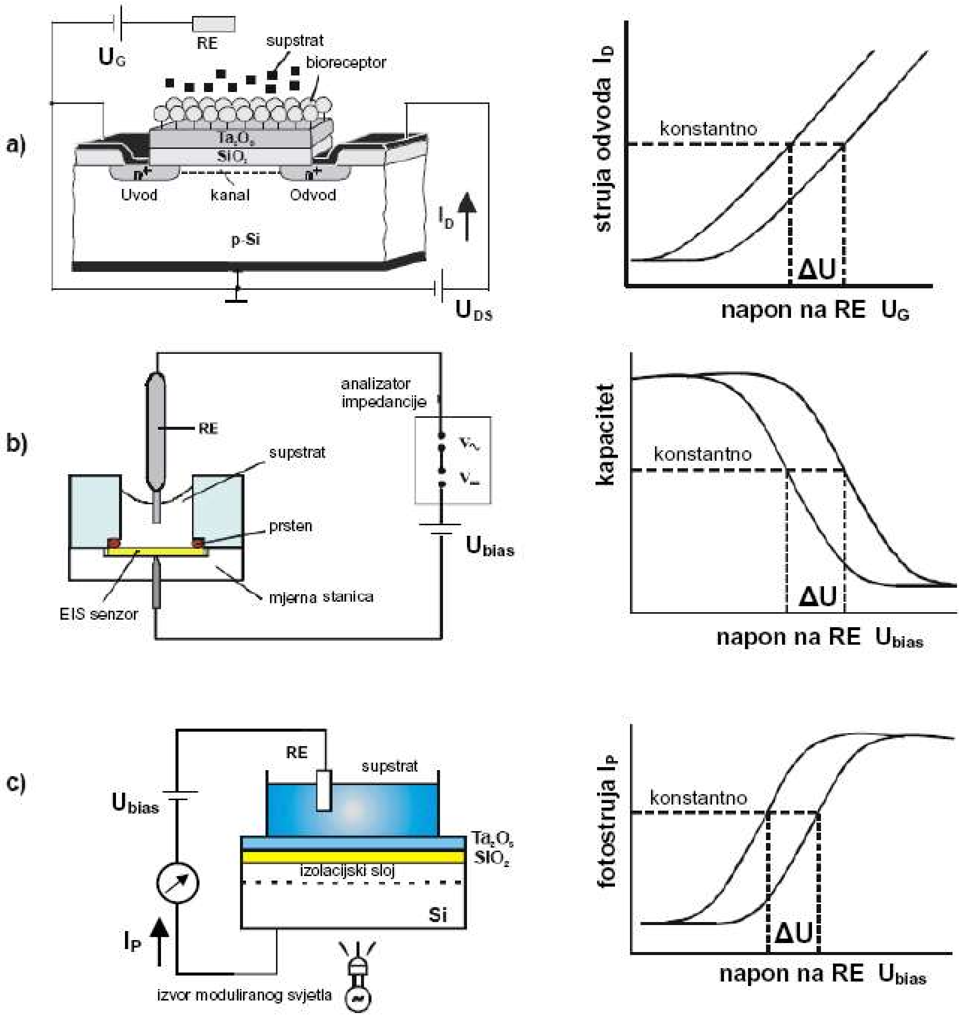
Dominira razvoj i primjena poluvodičkih senzora, pa je pored već spomenutih CMOS mikročipova naglasak na razvoju i primjeni: ISFET-a (Ion-Sensitive Field-Effect Transistors), EIS-a (Electrolyte-Insulator-Semiconductors) i LAPS-a (Light-Addressable Potentiometric Sensors). Ove tri vrste uređaja predstavljaju temeljnu strukturu za nove generacije kemijskih i bioloških mikrosenzora [7]. Načela detektiranja i izgled izlaznog senzorskog signala prikazan je u slici 2, a pregled razvijenih senzora dan je u tablici 2. Iz izmjerene razlike napona ΔU da se zaključiti na koncentraciju sastojaka koji se detektiraju.

Tablica 2 Pregled razvijenih ISFET-a, EIS-a i LAPS-a

Vrsta senzora	Ion/supstrat	Osjetljiva membrana /bioreceptor	Vrsta pretvarača
ph senzor	H^+, OH^-	Si_3N_4, Al_2O_3, Ta_2O_5	porozni EIS/ LAPS/ISFET
ionski senzor	K^+, Li^+, Cs^+, Ca^{2+}, Mg^{2+}, NO_3^-, SO_4^{2-}	polimerska membrana, ionofora	EIS/LAPS/ISFET
enzimski senzor	glukoza, urea, penicilin, alliin, pesticidi, cijanidi	glukozna oksidaza, ureaza, penicilinaza, alliinaza, organofosfor, hidrolaza, cijanidaza	ISFET/porozni EIS/LAPS
insektni čip	cis-3-hekso-1-ulje	insektna antena	ISFET

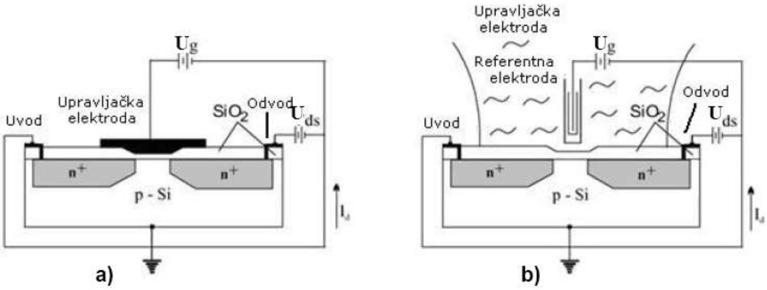
ISFET i njegove izvedenice (ph-FET, EnFET, BioFET)

Ionski osjetljiv tranzistor s efektom polja ISFET u mogućnosti je vrlo pouzdano izmjeriti napon ili naboj nakupljen na površini supstrata (otopine, elektrolita) pomoću upravljačke odnosno referentne elektrode RE i pretvoriti ga u električni signal. Elektroda RE u kontaktu je s elektrolitom i mjeri koncentraciju iona u njemu.



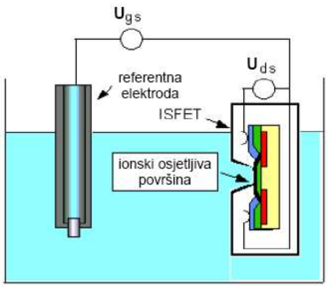
Slika 2 Načela detektiranja: a) ISFET-a, b) EIS-a, c) LAPS-a

ISFET je nastao od MOS-FET-a (Metal-Oxide Semiconductor FET), slika 3a, u kojem je upravljačka elektroda odvojena od čipa i kao referentna uronjena u ispitivanu otopinu, slika 3b [1]. Izvorišno je to silicijski MOS-FET p-tipa, u kojem su dva difundirana n-područja (uvod i odvod) međusobno odvojena kanalom p-tipa i premoštena metaliziranom upravljačkom elektrodom. Kod ISFET-a se površinski potencijal mijenja nakupljanjem naboja na površini upravljačke elektrode, a kod novijih izvedbi metalizirana elektroda izvedena je kao neorganska osjetilna membrana od nitrida.



Slika 3 Shematski prikaz: a) MOS-FET-a, b) ISFETA-a

Jednu varijantu ISFET-a predstavlja pH osjetilni ISFET nazvan pH-FET. Kod njega se vodljivost p-kanala mijenja s pH vrijednošću otopine odnosno s koncentracijom H^+ iona, pa je električni signal ovisan o promjeni pH vrijednosti u blizini referentne elektrode, slika 4.



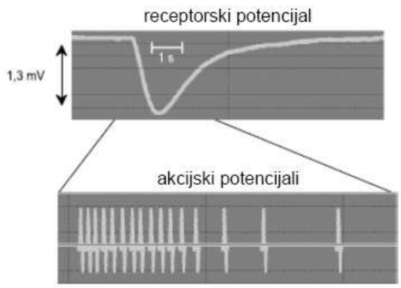
Slika 4 Shematski prikaz ph-FET-a

ISFET, kod kojeg je upravljačka elektroda zamijenjena biokatalitičkim slojem (enzimom) naziva se EnFET (Enzyme sensitive FET). Karakterizira ga fizikalna nestabilnost, osjetljivost na svjetlo i smanjenje odziva s povećanjem kapaciteta međuspremnika za ione.

Dok su pH-FET i EnFET općenito kemijski senzori, ISFET optimaliziran i prilagođen organskom okružju, biološki je, i naziva se BioFET (Biologically sensitive FET). U njemu je upravljačka elektroda zamijenjena nekom organskom tvari.

Kao biološki receptori kod biosenzora pretežito se koriste enzimi, tu i tamo pojedine stanice, a rjeđe složenije strukture. No, najviše je istraživanja vršeno s minijaturnim antenama insekata koji imaju visoko razvijeno osjetilo njuha za specifične kemijske signale. Utvrđeno je da se u toj anteni stvaraju dipolni potencijali proporcionalni koncentraciji određenih mirisa. U nastavku je stoga ovaj senzor označen jednostavno bioFET-om [8, 9].

Dipolni potencijali nastali u anteni djelovanjem mirisne tvari prenose se preko elektrolita na bioFET, tamo pretvaraju u odgovarajuću struju i mjere. Biofizika i kemorecepcija kod insekata tijekom ovog procesa detaljnije je objašnjena u [8]. Rezultat je, da u unutarnjem segmentu receptorskih stanica, dendrita, nastaje receptorski potencijal, čija visina korelira s koncentracijom mirisa, i koji može doseći i nekoliko mV, slika 5. On se zatim u vanjskom segmentu prekodira u slijed akcijskih potencijala kojima se dobivena informacija prenosi duž živčanih vlakana.



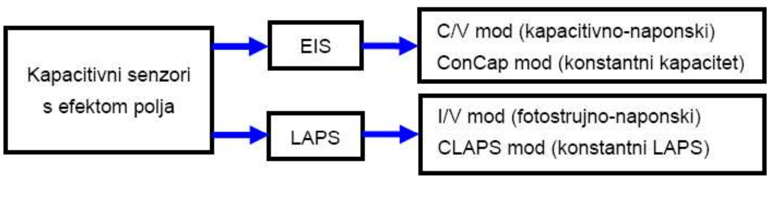
Slika 5 Prekodiranje receptorskog potencijala u slijed akcijskih potencijala

Kako ukupna množina receptorskih proteina povezana s molekulama mirisa ne bi dalje rasla, po nastanku mjernog signala mora doći do deaktiviranja mirisne tvari.

Biološku osnovu bioFET-a čine električni procesi na staničnim membranama. Stanična membrana odvaja unutrašnjost stanice, staničnu plazmu, od njenog okoliša, a zadatak joj je u prvom redu ograničiti električnu vodljivost u vodi topivih iona i molekula. Nositelji funkcija membrane su brojni proteini uležišteni u lipidnu strukturu membrane.

EIS i LAPS

Oba ova senzora kapacitivni su, a koriste mjerne postupke prikazane u slici 6[7]. Kod EIS-a su to kapacitivno-naponski postupak (C/V) i postupak s konstantnim kapacitetom (ConCap), a kod LAPS-a fotostrujno-naponski (I/V) i postupak s konstantnom fotostrujom (CLAPS).



Slika 6 Mjerni postupci kod EIS-a i LAPS-a

EIS radi na osnovi površinskog potencijala vodene otopine. Potencijal koji djeluje na referentnoj elektrodi sastoji se od nalegnutog napona U_{bias} i razlike potencijala nastalog na površini. U analizatoru impedancije ta se razlika pretvara u kapacitivnu vrijednost senzora.

I LAPS radi s površinskim potencijalom vodene otopine. Između referentne elektrode RE uronjene u elektrolit i donje strane poluvodiča narine se prednapon U_{bias}, ali se zbog izolacijskog sloja ne javlja struja [6]. Tek osvjetljavanjem poluvodiča moduliranim svjetlom dolazi do toka fotostruje I_P, čija amplituda ovisi o površinskom potencijalu na osvjetljenom mjestu.

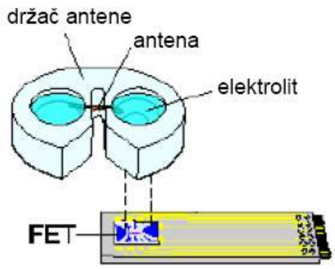
PRIMJERI PRIMJENE U POLJOPRIVREDI

U području agrara postoje brojne mogućnosti za primjenu biosenzora, a one koje se posebno ističu i o kojima postoje objavljene informacije sistematizirane su u nastavku.

Ono što je u nastavku djelomično dotaknuto, ali gdje se mogu očekivati nove aktivnosti u primjeni biosenzora je obradivo tlo koje ima posebnu ulogu kao pročišćavač i zaštitni sloj za podzemnu vodu te kao najznačajniji sudionik u agrarnoj proizvodnji. Nadzor i kontrolu pojedinih svojstava tla i rezervi pitke vode uskoro će najvjerojatnije preuzeti biosenzori.

Korištenje insekata kao biosenzora

Da bi se dobio osjetljivi bioFET nužno je modificirati ISFET tako da se u njega integriraju svojstva visoke osjetljivosti insektne antene, a imobilizirana antena se mora povezati s ionski osjetljivom upravljačkom elektrodom preko elektrolitskog kontakta [8]. Jedno od rješenja je da se djelić antene uloži u kupku s elektrolitskom otopinom i poveže s upravljačkom elektrodom FET-a, a kupka i štampana pločica FET-a fiksiraju u teflonskoj podlozi prema slici 7. Mirisna tvar se privodi kroz utor smješten u držaču antene.



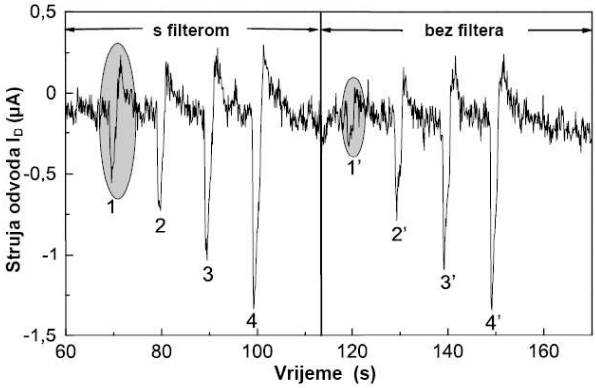
Slika 7 Senzorska glava s FET-om u zajedničkoj teflonskoj podlozi

Do danas su poznata istraživanja s antenama krumpirove zlatice i smrekovog prelca. BioFET s antenom krumpirove zlatice primjenjen je u utvrđivanju štete na biljkama, a s antenom smrekovog prelca u ranom otkrivanju požara [8].

Utvrđivanje štete na biljkama

Krumpirova zlatica ima prvorazredni osjećaj za miris koji sadrži prvenstveno primarne alkohole i aldehide. U pokusima je primjenjena tzv. adaptivna metoda [8], što znači da se koristi mirisna tvar određene koncentracije prilagođena određenoj vrsti insekata i ciljno provociranom referentnom iznosu antenskog potencijala.

Korištene su slijedeće vrste koncentracija mirisne tvari koja sadrži heksanol i na koju reagira krumpirova zlatica te izmjereni pripadajući senzorski signali: 500 ppt (signali 1/1' u slici 8), 5 ppb (2/2'), 50 ppb (3/3') i 500 ppb (4/4'). Struja zraka je prvo propuštena kroz filter od aktivnog ugljena, kako bi bila oslobođena mirisne tvar i kako bi se bioFET adaptirao na tu vrstu mirisa (signali 1, 2, 3, 4).



Slika 8 Dokazivanje štete na biljkama adaptivnim postupkom

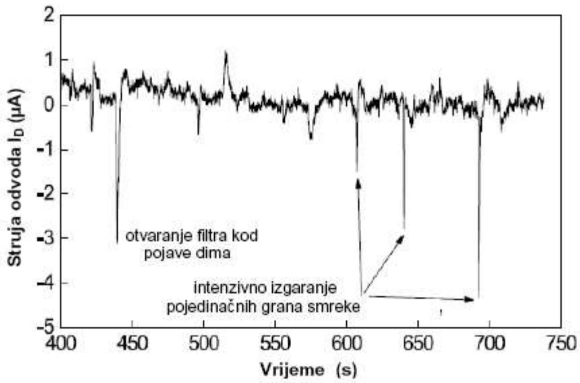
U drugom dijelu istraživanja, u jedan plastenički zasad krumpira s oko 1000 biljaka unese-na je jedna biljka napadnuta krumpirovom zlaticom i par metara udaljena od bioFET-a. Dobiveni su signali 1', 2', 3', 4' desno u slici 8. Zbog adaptiranja došlo je do pada vrha signala 1' prema signalu 1, a ostali vrhovi ostali su nepromijenjeni. Znak je to da je senzor registrirao prisutnost oboljele biljke, pa se zahvaljujući dobivenom signalu biljke mogu pravovremeno zaštititi.

Rano otkrivanje požara

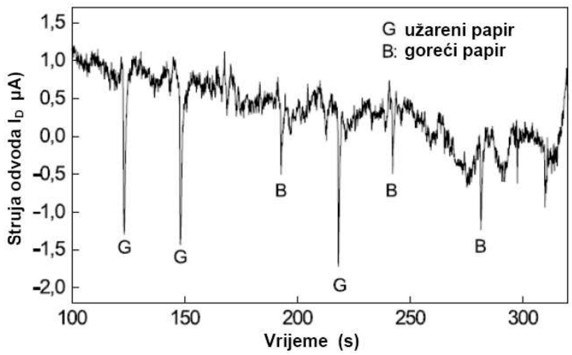
Dokazano je da su guajakol i okten tipični plinovi koji se razvijaju pri izgaranju materijala biljnog podrijetla, a oni se mogu detektirati pomoću bioFET-a koji kao receptor koristi imobiliziranu antenu smrekovog prelca. Rezultate istraživanja s plinovima pri izgaranju grana smreke i papira prikazuju slike 9 i 10 [8].

U slici 9 prikazano je detektiranje plinova nastalih izgaranjem grana smreke, koji su nastrujavani na biosenzor tako da mu se približe na udaljenost između 50 cm i 10 cm. U lijevom dijelu slike najprije se uočava jedan jasni signalni vrh izazvan otvaranjem filtra s aktivnim ugljenom, jer dolazi do iznenadnog naletavanja plinova izgaranja na senzor, a zatim slijede različiti vrhovi nastali zbog različitih udaljenosti od izvora požara.

U slici 10 prikazana je reakcija senzora na užareni papir bez plamena (G) i izgaranje s vidljivim plamenom (B). Kod slučaja G senzorski signali znatno su viši nego u slučaju B. Ukupno uzevši biosenzor s insektnom antenom pogodan je za konstrukciju senzora za rano otkrivanje požara kod organskih tvari.



Slika 9 Utvrđivanje mirisa izgaranja grana smreke



Slika 10 Utvrđivanje mirisa pri izgaranju papira

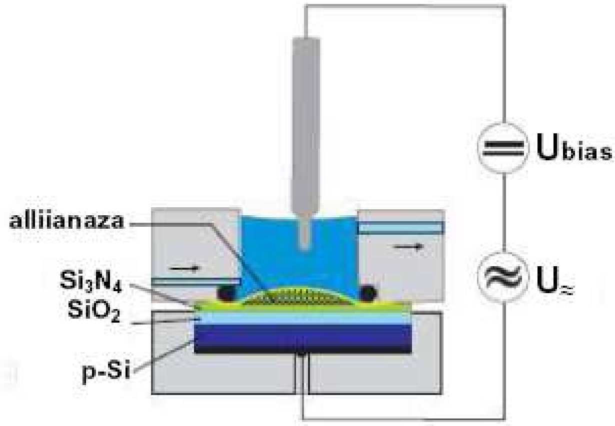
Otkrivanje prisutnosti toksikoloških tvari u tlu

U razvojnoj su fazi i biosenzori za detekciju insekticida, herbicida i pesticida [5], [10]. Trenutno se eksperimentira s nekoliko izvedaba EnFET-a s imobiliziranim slojem raznih enzima. Dosadašnje iskustvo pokazuje da su oni u stanju brže i kvalitetnije utvrditi postojanje različitih toksikoloških sastojaka insekticida, herbicida i pesticida od postojećih metoda utvrđivanja.

Biosensor za češnjak

Ovim senzorom mogu se detektirati vrijedni sastojci češnjaka ili neke druge biljke. Za miris i medicinsko djelovanje češnjaka znanstvenici drže odgovornom supstanciju alliin, jedan spoj sumpornog oksida. Primjena ovog senzora očekuje se u području ljekovitog bilja te u kontroli proizvodnje u farmaceutskoj industriji i u industriji živežnih namirnica.

Biosenzor je jedan EIS senzor koji koristi enzim alliinazu i katalizira sadržaj alliina u uzorku u alicin, piruvat i amonijak, slika 11. Enzim alliianaza nalazi se ispod jedne membrane, iznad koje dolazi otopina istraživanog češnjaka. Količina enzimatski tvorenih ph aktivnih supstancija piruvata i amonijaka direktno je proporcionalna sadržaju alliina, a promjena ph vrijednosti mjera je za kvalitetu istraživanog češnjaka.



Slika 11 Shematski prikaz biosenzora za češnjak

Biosensor za detekciju arsena u vodi

Ovaj senzor koristi nepatogenu genski modificiranu bakteriju Escherichia Coli imobiliziranu zajedno s jednim hranjivim supstratom na papirnoj traci koja se uranja u ispitivanu vodu. Ako uzorak sadrži anorganski arsen, bakterije proizvode odgovarajuću količinu enzima beta-galaktozidaze koji u kontaktu s indikatorskom supstancijom X-gal papirnu traku oboji plavom bojom. Intenzitet boje korelira s koncentracijom arsena u uzorku. U trenutnoj fazi razvoja ovaj senzor još ne tvori uporabiv električni signal.

ZAKLJUČAK I PERSPEKTIVA

Najimpresivniji od navedenih biosenzora zasigurno je bioFET s insektnom antenom. On bi se u budućnosti mogao kombinirati s plinskim senzorom i tako bi nastao hibridni sa širim područjem primjene, primjerice u dokazivanju pojave raznih vrsta otrovnih i opasnih plinova kod izgaranja organskih tvari. On se može i dalje minijaturizirati pa ga pojedini kukci mogu nositi na sebi, a podaci slati jednoj centralnoj stanici. Na taj bi se način mogla otkriti rasprostranjenost nekih štetnih tvari.

Obradivo tlo ima i značajnu biološku funkciju. Organski ugljikovi spojevi nastaju djelovanjem brojnih mikroorganizama. Sitna bića kao što su bakterije i gljivice proizvode i koriste različite ugljične tvari stvarajući od tla korisnu osnovu za proizvodnju hrane. Spoznaje o tome kako se vežu strane tvari u tlu, kakve fizikalno-kemijske interakcije nastupaju između minerala i organskih tvari s jedne i stranih tvari s druge strane i kakva je mobilnost stranih tijela u tlu zasigurno će moći dati budući biosenzori. Prostor za daljnja istraživanja s biosenzorima nepregledan je.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Pregledni rad
Review paper

AGRICULTURAL PIPE NETWORKS MAINTENANCE USING ROBOTIC SYSTEMS

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SUMMARY

In this paper, the usage of in-pipe robots in agricultural field is emphasized, then an analysis of the in-pipe robots is presented and the authors' contribution in this field is largely discussed. Several in-pipe minirobots developed by the authors are described. Our efforts are focused on the in-pipe mobility and corresponding actuation systems. Several functional characteristics (e.g. the maximum/minimum inner pipe diameter, the speed) are given. The possibilities to use these robotic systems for inspection, exploration and maintenance of the pipes for liquids transportation in agricultural field (irrigation water, drinking water, effluent water) are highlighted.

Key words: *in-pipe robots, mechanism, linkages, pipe networks maintenance*

INTRODUCTION

Robotics is one of today's fastest growing engineering fields. Robots are designed to remove the human factor from intensive labour or dangerous work and also to act in inaccessible environment but they are no longer exclusively used by the heavy production industries. A high number of devices have been introduced in the agricultural field in order to support or even take place of the work of man, especially when it comes to hard work to be done in open field, [1] – [4].

The idea of applying robotics technology in agriculture is relatively new, more and more robots being used especially at the harvesting stage, [13]. The agricultural industry is behind other industries in using robots because of the sort of jobs involved, in which many repetitive tasks are not exactly the same every time. Fruit picking robot and sheep shearing robots are already designed to replace human efforts. In most cases, a lot of factors have to be considered (e.g. size and colour of the fruit to be picked) before the commencement of a task. Erriu et al. describe a new method and a robotic system designed to harvest saffron flowers based on this method, [2]. A two fingers device for flowers detaching was experimentally tested. Anderson et al. [1] have developed a family of intelligent autonomous robotic vehicles that are capable of individual or cooperative operations in a precision agriculture environment. The system consists of a group of autonomous vehicles, equipped with location detectors (DGPS) and environment sensors (sonar and laser), connected together via a radio link. Other experimental applications of robots in agriculture include a machine for the automatic break-up of pork carcasses, transplanting of seedlings, pruning grapevines, and picking apples (Kondo et al, [4], [12]).

The pipelines are the major tools for the transportation of drinkable water, effluent water, fuel oils and gas. A lot of problems caused by aging piping networks, corrosion, cracks, and mechanical damages are possible. So, continuous activities of inspection, maintenance and repairing are strongly demanded. Because these operations are expansive, the application of the robots appears to be one of the most attractive solutions. The key problem in the design and implementation of these robotic systems consists in combining the capacity of self-moving with the one of self-sustaining and the property of low weight and dimension. Despite the mechanical and robotic systems introduced in agricultural field, the pipe inspection is not so much automated.

IN - PIPE ROBOTS CLASSIFICATION

The in-pipe robots can be classified into several elementary categories, according to the locomotion mechanisms as shown in figure 1, [6], [8], [9]. Most of them have been designed based on specific tasks. In figure 1a, the *pig* type robot is presented. This is passively driven by fluid pressure inside pipelines and employed for the inspection of pipelines with large diameters. The robots belonging to this category have the following disadvantage: they can be rotated around their longitudinal axis, the position and speed of motion are difficult to control. The *wheel* type robot is illustrated in figure 1b, being similar to the plain mobile robots. The robots of this type have the advantage of an easy control of direction and speed, but it is possible for them to capsize, thus block themselves inside the pipe. Figure 1c shows the *crawler* type robot with caterpillars instead of wheels. The mobile robots with caterpillars are very stable and can move over the obstacles.

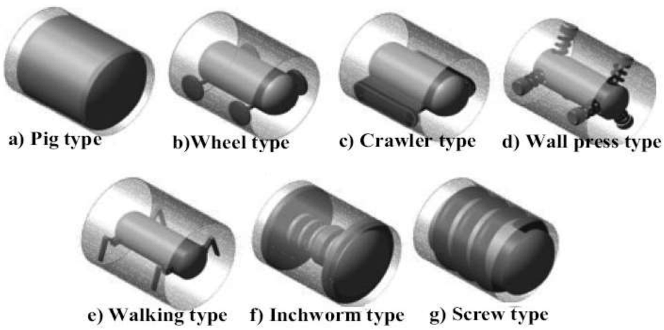


Figure 1 Classification of in-pipe robots according to the locomotion mechanisms

The *wall press* type robot is shown in figure 1d. This one has flexible mechanisms for pressing the wall, i.e. it has the advantage of climbing vertical pipelines. This in-pipe robot type comprises some expanding mechanisms which push the inner pipe surface, in order to fix the system. *Walking* type robot is presented in figure 1e; it possesses articulated legs and it can produce various motions, to achieve the movement of the system inside the pipes. The *inchworm* robot type, given in figure 1f, is usually developed for pipelines with very small diameter. The *inchworm* type robots have three modules: two of them are able to work in radial contraction-extension, to support on the walls, one is working in axial contraction-extension to create a step. Finally, figure 1g shows a *screw* type robot; these in-pipe robots are very robust and they can climb vertical pipes. Screw type robots take the motion of a screw when inserted in the pipelines.

The above-mentioned robots generally travel along horizontal pipelines smoothly, but some of them move along vertical pipelines or elbows (bend pipes, L-shaped pipes). Only few of them can achieve the selective navigation in common type of branches (T-shaped pipes) or in vertical pipes. These mobile robots are defined by different locomotion methods, different actuation schemes, certain sensorial subsystems, particular communications modules and specific constructive solutions. Some important constraints were taken into account in their development: the variation of the in-pipe diameter, the existence of wastes or liquid or under-pressure gas in pipe, the in-pipe surface state, the distance that the robot should cover, the pipe material a.s.o.

According to their autonomy, the mobile in-pipe robots for inspection-exploration tasks can be classified as follows, [11]:

- permanently remote controlled robots by human operators which command and control all tasks, including elementary ones;
- periodically remote controlled robots by human operators which control only global decisional level;
- autonomous robots that are able to perform the predefined tasks based on their own decision ability, working in a partially known environment.

According to their mechanical structure, the in-pipe robots are, [11]:

- robots with a rigid structure – used to inspect pipes with a certain diameter;
- robots with an adaptable structure – contain mechanisms that allow adapting to different pipe diameters.

THE DEVELOPED IN-PIPE MINIROBOTS

The field of mobile robots is an important research domain of our group. In previously papers we proposed few educational wheeled mobile robots, [8], a series of inchworm mobile robots, actuated by miniature electromagnetic actuators [7], pneumatic linear actuators, [9], or by new high performance actuators, e.g. shape memory alloy actuators, magnetostrictive actuators, [11]. Several in-pipe mobile minirobots are already developed, [10] but they have small overall dimensions being designed for as small as possible pipe diameters.

The aim of our current work is to study a mobile minirobot that is composed of two four-bar linkage mechanisms, each one with the opposite elements equal and parallel. The minirobot moves through three wheels: the driver wheel r_H and the driven/guide wheels r_S, r_A (figures 2, 3, 4 and 5). The driver wheel is mounted on a platform which is interconnected through the joints E, I, E', I' with the mechanisms.

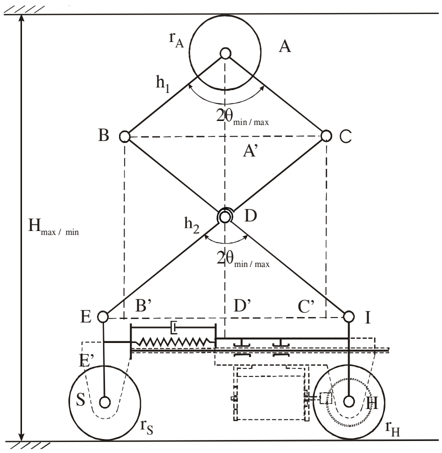


Figure 2 The structural scheme of the minirobot

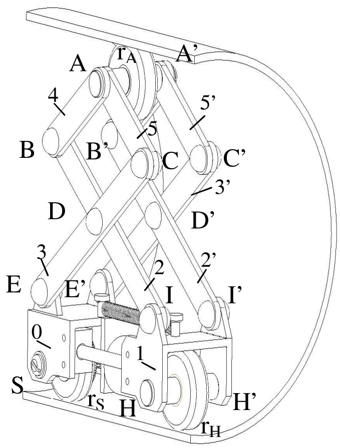


Figure 3 The 3D model of the minirobot

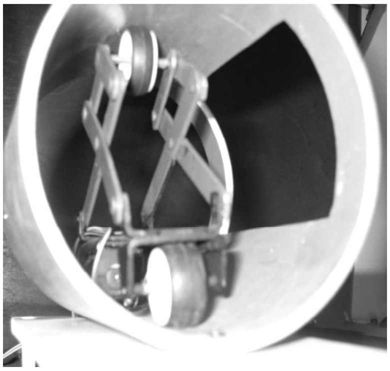


Figure 4 The simulation of the in-pipe locomotion

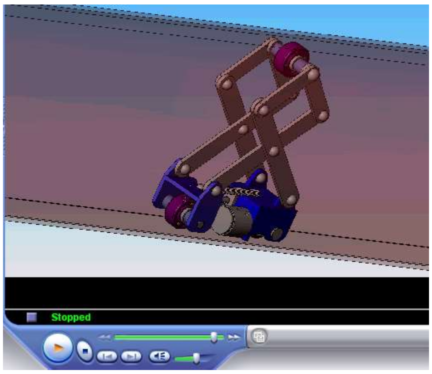


Figure 5 The developed first prototype

This structure allows obtaining the variable height depending on angle (2θ), between the elements 4 and 5 (or 4' and 5'), $\theta \in \{40° \div 80°\}$, to inspect pipes with variable diameters within 80 and 150 mm. The structure of the minirobot is very light, the platform and the current feeding lines weights about 250 g. The force which the minirobot mechanism exercises on the pipe walls is generated with the help of an extensible resort. The minirobot keeps its stable balancing, due to the exercised force of the three wheels on the direction of the pipe diameter. The driver wheel and the driven/guide wheel is made by rubber for obtaining greater adherence in pipe. The lengths of the elements in the minirobot's structure are h_1= 33 mm, h_2=89 mm, and the width of the robot is 41 mm (AA`=SS`=HH`=41 mm). The radius of the wheels are: 15 mm, the upper wheel (r_A) has the width of 11,6 mm and the wheels on the main platform (r_S, r_H) have the width of 5,4 mm. The driver wheel is actuated by a D.C. motor through a planar gear wheel.

The relations between the lengths of the robot elements are (fig. 2): $AC\| = BD = h_1$; $AB\| = CD$, $AB = AC$, $BI = CE = h_2$.

The height of the robot can be determined with the relation:

$$H = 2r + d + h_1 \cos(\theta) + h_2 \cos(\theta)\,, \qquad (1)$$

where r is the radius of the wheels and d is the distance EE' (EE'= d = 28 mm).

The maximum and minimum height of the robot can be determined based on the angle θ and on the lengths of the elements h_1, h_2 with the relation:

$$H_{\min/\max} = 2r + d + (h_1 + h_2)\cos(\theta_{\max/\min}) \; (2)$$

and the maximum and minimum width of the minirobot can be determined with the relation:

$$L_{\min/\max} = 2(h_2 - h_1)\sin(\theta_{\max/\min}) \qquad (3)$$

where $\theta_{\min}$ and $\theta_{\max}$ are maximum and minimum limits of the angle θ.

In figure 6, it is given the second constructive variant of an in-pipe inspection minirobot, which was designed, modelled and developed. The minirobot contains the three above-presented mechanisms, symmetrically disposed along the longitudinal axis of the robot. The force that the minirobot mechanism exercises on the pipe walls is generated with the help of an extensible spring. The helical spring disposed on the central axis assures the repositioning of the structure, in the case of the pipe diameters' variation. The components of the minirobot are, (fig. 6c): 1 – helical spring, 2 – translational element, 3 – actuator support, 4 – worm wheel, 5 – worm gear, 6 – actuator, 7 – central axis, 8 – link, 9 – wheel.

The wheels at the back are driven by three DC motors, through reduction transmissions. The weight of the minirobot (the weight of current feeding wires is also considered) is 350 g, and the wheels have the radius r = 50 mm and the length 16 mm; the component elements have the lengths: $h_1 = 30\,mm$, $h_2 = 70\,mm$, $h_3 = 105\,mm$. The actuation of the driver wheels is made through two worm gears with z_1 = 1, z_2 = 30.

In the robot’s structure, there is a mechanism (fig. 8a), composed of a translational input element, and two structural (Assur) groups RRR, (EmT(1) + RRR(2,3) + RRR(4,5)).

The robot’s height can be determined with the relation:

$$H = 2r + 2d + 2h_2 \cos(\theta) , \qquad (4)$$

where r is the radius of the wheels and d is the distance EE’ (EE’= d = 28 mm).

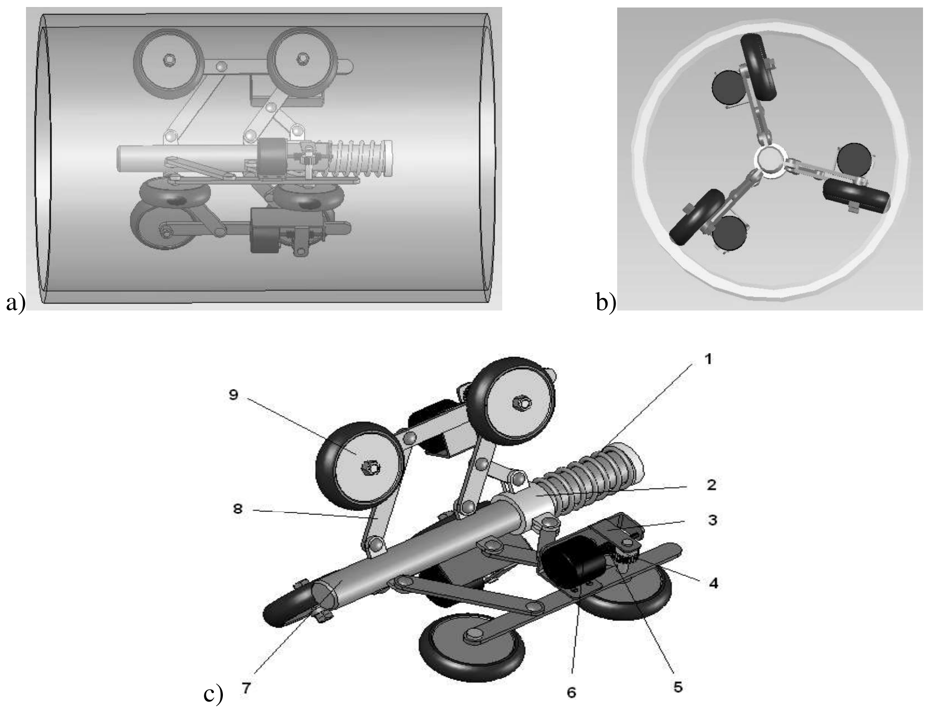


Figure 6 3D model of the minirobot

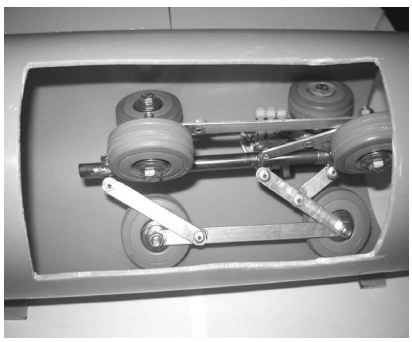
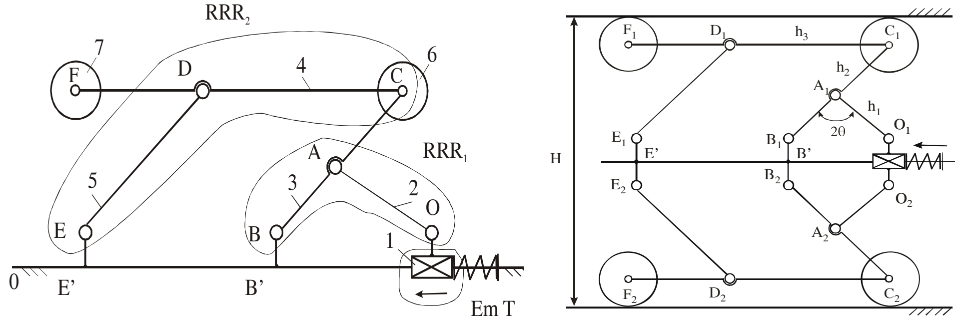


Figure 7 Picture of the developed in-pipe minirobot



a) b)

Figure 8 The elementary mechanism (a) and the structural scheme of the minirobot (b)

The maximum and minimum height of the robot can be determined based on the angle θ and on the lengths of the elements h_1, h_2, with the relation:

$$H_{\min/\max} = 2r + 2d + h_2 \cos(\theta_{\max/\min}) \qquad (5)$$

where $\theta_{\min}$ and $\theta_{\max}$ are the maximum and minimum limits of the angle θ.

These minirobots have movement capacities for inspection in (140 – 175) mm diameter pipes in horizontal or vertical configuration. In figure 9 the 3D model of the minirobot in a curved pipe is illustrated. For pipes with elbows (tubular network in T or L shape) we propose the usage of a minirobot, which is made of two modules connected with a spherical joint. The modelling of this structure, which will be developed in the near future, is presented in figure 10.

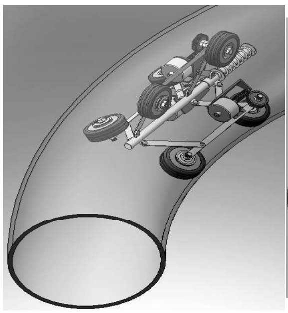
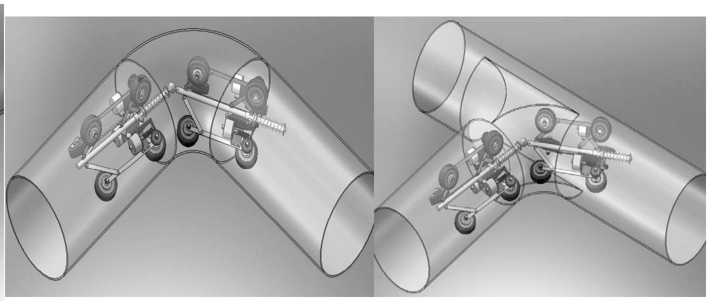


Figure 9 3D model of the minirobot in a curved pipe



a) b)

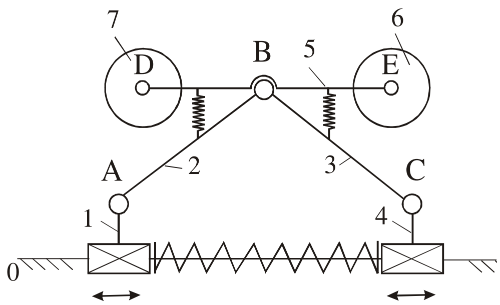
Figure 10 3D model of the minirobot in a tubular network pipe in T or L shape

The minirobot is powered through wires and it is controlled with the aid of a microcontroller *ATMEL Atmega8535*. An interface realized in *Delphi* software was developed. The drive DC motors can be powered with the voltage between 3-12 V. The two presented structures allow the usage of a CCD camera for pipe inspection or other devices needed in detecting of a malfunction in the pipes (remote-controlled laser measuring systems, sensors).

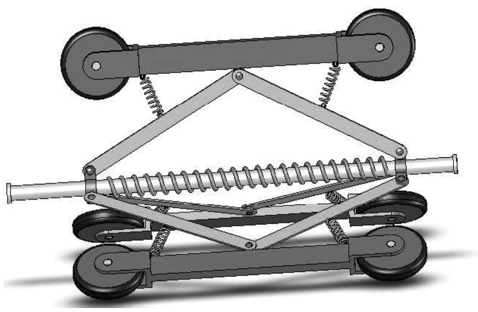
NEW IN-PIPE MINIROBOTS

In this paragraph, new in-pipe minirobots are introduced. For these designs, the experimental prototypes are under development.

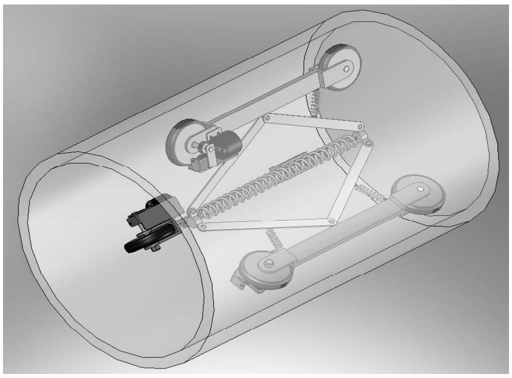
In figure 11b, the 3D model of the third studied robotic system is given. The robot has an adaptable structure based on three five-bar mechanisms, symmetrically disposed at 120˚. It is a wheeled type robot having six wheels placed at the end of the support elements. Because the mechanism is positioned symmetrically, the structure is in equilibrium, both in horizontal and vertical movements within the pipes. The actuating of the robot can be done by using three DC or stepper motors.



a)



b)



c)

Figure 11 3D model of a 3rd mobile in-pipe robot (b, c), and its mechanism (a)

The fourth adaptable structure that can be used for developing an in-pipe inspection robot is given in figure 12. The basic mechanisms of this structure are also five-bar mechanisms (figure 12a). In the structure of the robot, there are three mechanisms of this sort, at 120° around the longitudinal axis. In order to block the rotation of the translation elements 1 and 4 along this axis, the central axis of the robot has been designed with a hexagon-shaped section. Between the translation elements and the axis' ends, there are two helical springs, which sustain the structure of the robot and develop the pushing force of the wheels towards the inner wall of the pipe. The actuating of this structure can be realized also with DC or stepper motors.

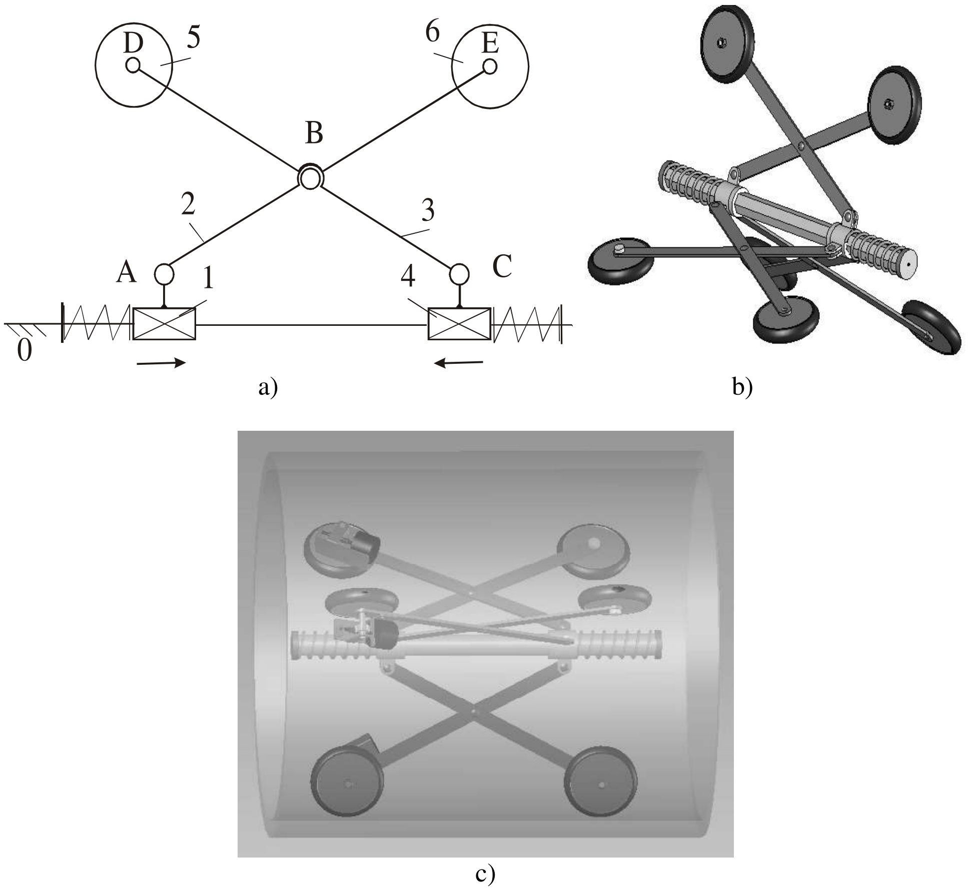
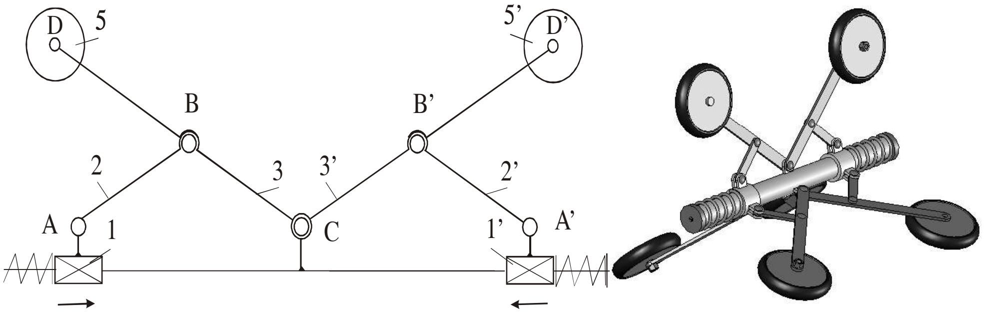
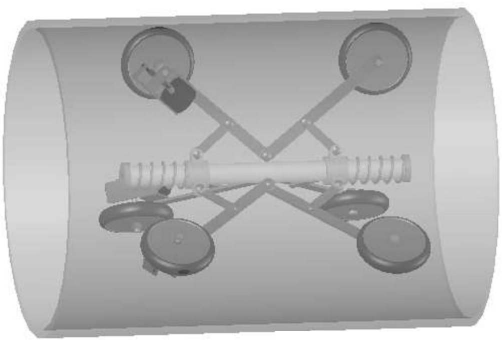


Figure 12 3D model of the 4th in-pipe robot based on five-bar mechanisms (b, c), and its elementary mechanism (a)

In figure 13, it is given a last structure (the fifth) of a in-pipe robot, composed of 6 slider-crank mechanisms. These are disposed each two in three plans at 120° along the central axis. Like the previous model, the structure contains two translation elements and two helical springs. The same actuating solution can be applied.



a) b)



c)

Figure 13 3D model of the 5th in-pipe robot based on a slider-crank mechanism (b, c), and its elementary mechanism (a)

CONCLUSION

A very important design goal of the mobile in-pipe robotic systems is the adaptability to the inner diameters of the pipes In this paper, we proposed several wheel type in-pipe minirobots, defined by an adaptable structures, based on different mechanisms.

First, two developed and experimentally tested prototypes of in-pipe inspection minirobots are described. The first prototype was designed in order to inspect pipes with variable diameters within 80 and 150 mm, and second one has movement capacities for inspection in 140 - 175 mm pipe diameters. In the second part, another three structures based on five-bar, respectively, slider-crank mechanisms are proposed. For these, the experimental prototypes are under development.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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DETECTION OF LOCUSTS USING NEAR-INFRARED SPECTROSCOPY AND CLUSTER ANALYSIS

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SUMMARY

The main objective of this study was to investigate the feasibility of the Near Infrared spectroscopy (NIR) techniques for rapid detection of locusts from their environment such as vegetation, using a Fourier Transform Near-Infrared spectrometer (FT-NIR). Stones, grass, soils and locusts composed of all the 79 samples. The spectra of all samples were analyzed within a range of 3996-12489.5cm^{-1}. Complex-linkage models were developed. The classification accuracy was calculated to assess the classification capability of calibration models. Different samples were correctly classified in rates of >91.67%%.The study demonstrated that using the established calibration models, locusts could be predicted with classification accuracy over 91.67%.

Key words: *NIR Spectroscopy, locusts, cluster analysis*

INTRODUCTION

Locust swarms can attack large ranges of the land surface. If a swarm destroys the harvest, this can mean the financial ruin for whole regions. Most damage is caused by young larvae in nurseries. The key to effective management of locust outbreaks is early detection of the marching juveniles (bands), because control of flying swarms is expensive and ineffective.

Numerous studies have focused on the development of methods for detecting locusts.(Crooks and Archer, 2002; Dai et al.,2004; Ma et al., 2002; When et al., 2004) However no published research has validated whether models developed using Near-Infrared spectroscopy (NIR) technology can be used to detect locusts. Spectroscopic methods have the potentials to recognize patterns or to classify products (Birth et al., 1985; Carline et al., 2000; Hourant et al., 2000; Lankmayr et al., 2004; Maghirang et al., 2003).

Near-infrared spectroscopy instruments are also recognized as effective tools due to their fast and more flexible sample handling.

This research aims to extend the knowledge of using NIR for locust detection. The idea is that, if NIR reflectance is able to classify samples, this will give an indication that NIR has a potential to detect the locusts from their background.

MATERIALS AND METHODS

Sample preparation

Samples of locusts as well as grass, soil and stones were obtained from a local supplier (Cangzhou, Hebei Province). Locusts were reared in groups of 100 individuals at 50-60% relative humidity and 30° C in glass tanks measuring 38 x 38 x 52 cm. Locusts are at the flightless first-, second-, third- and fourth-instar stage. Out of a total number of 79 spectra, 55 were randomly selected to form a training set and were used to develop cluster calibration models. The remaining 24 spectra formed a validation set to verify the prediction capability of the calibration models (table 1 and 2).

Spectral Collection

All samples were scanned in the range of 3996-12489.5 cm^{-1} using a Fourier Transform Near-Infrared spectrometer(FT-NIR) (Matrix-I, Bruker Optik GmbH, Germany) which measure reflectance spectra in a spectral resolution of 16cm^{-1}, yielding 1102 values per spectrum. Sample cups are on samples rotators for maximizing the measured surface and improving the stability of the calibration. 120 coadded scans were taken for each sample to improve the signal-to-noise ratio. The OPUS software (Bruker Optik GmbH, Germany) was used for instrument control and computation. All spectra were recorded and stored in a PC. Figure 1 is the spectra of samples after the baseline correlation.

Table 1 Samples in training set

The serial number of samples in training set	Classes
1-13	Locusts (1st-instar nymphs)
14-28	Locusts (2nd-instar nymphs)
29-37	Locusts (3rd-instar nymphs)
38-43	Locusts (4th-instar nymphs)
44-47	Non-locusts(soil)
48-53	Non-locusts (grass)
54-55	Non-locusts (stones)

Table 2 Samples in validation set

The serial number of samples in training set	**Classes**
56	Locusts (1st-instar nymphs)
57-65	Locusts (2nd-instar nymphs)
66-69	Locusts (3rd-instar nymphs)
70-74	Locusts (4th-instar nymphs)
75	Non-locusts(soil)
76-78	Non-locusts (grass)
79	Non-locusts (stones)

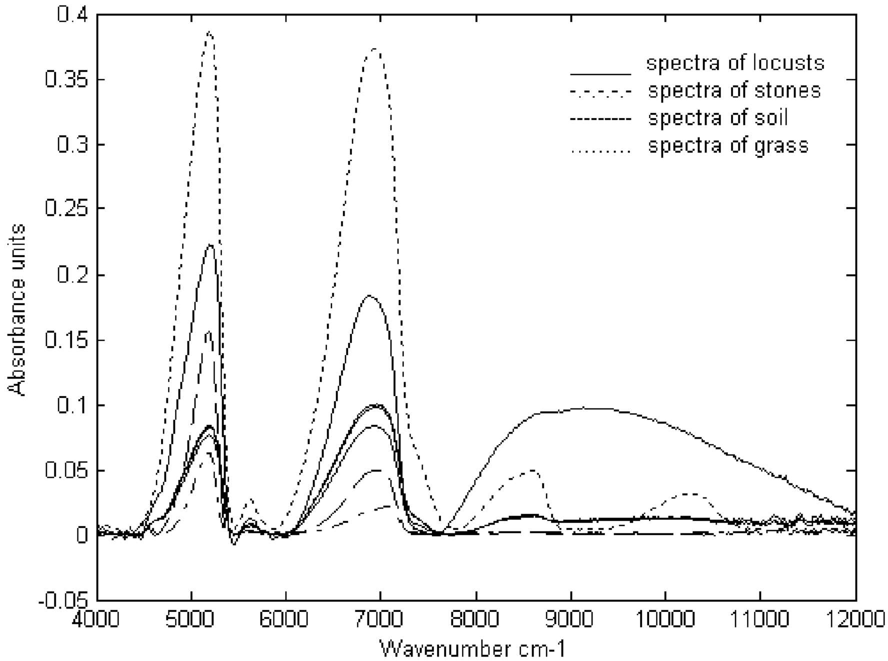

Fig.1 NIR spectra of samples

Calibration and Data Analysis

Spectral analysis was conducted using OPUS v5. To process the obtained spectral data we established a classification system using cluster analysis. Samples should be classified either as locusts or as non-locusts.

Cluster analysis methods such as complete-linkage, single-linkage, average-linkage, weighted-average linkage, median algorithm, Ward's algorithm and centroid algorithm were compared on all samples. These spectra were preprocessed using automatic baseline correction to remove the baseline effects from the spectra occurred during spectral collection. Eliminating the useless wavelength regions which had no or very less contribution to parameter prediction would simplify the calibration models and reduce the time for required computation. The classification accuracies for both training and validation set were calculated to evaluate classification performance of the calibration model. The best calibration model was chosen with the highest values for the classification.

RESULTS AND DISCUSSION

The comparison of all algorithms with vector normalization and without any preprocessing were done (table 3). Figure 2 is the result of complex-linkage cluster analysis on training samples within the spectral range of 3996-11502cm^{-1}.The best wavelength regions for predicting the locusts' outbreak were selected and the prediction accuracy of the developed models was tested. With vector normalization, complete-linkage gave better results than single-linkage and other methods with the classification accuracy of 100% on training set and 91.67% on validation set. The dead locusts in validation set are the reason of low accuracy. If these heterogeneities are rejected, the classification accuracy on validation set is 100%. The complete-linkage was selected to build the model. Figure 3 shows the sample of no.68 in validation set was correctly classified by this model.

Table 3 Results of samples in training set

Cluster method	Preprocessing	Samples in class 1	Samples in class 2
complete-linkage	vect. norm.a	1-43	44 –55
	no prep.b	1-28□37□44-48□52-55	29 –36□38-43, 49-51
single-linkage	vect. norm.	1-43□47-53	44-46,54,55
average-linkage	vect. norm.	1-28□44-55	29-43
median algorithm	vect. norm.	1-10□14-23□44-55	11-13□ 24-43
Ward's algorithm	vect. norm.	1-28□44-55	29-43
centroid algorithm	vect. norm.	1-43□49-53	44-48□ 54-55

[a] vector normalization
[b] no preprocessing

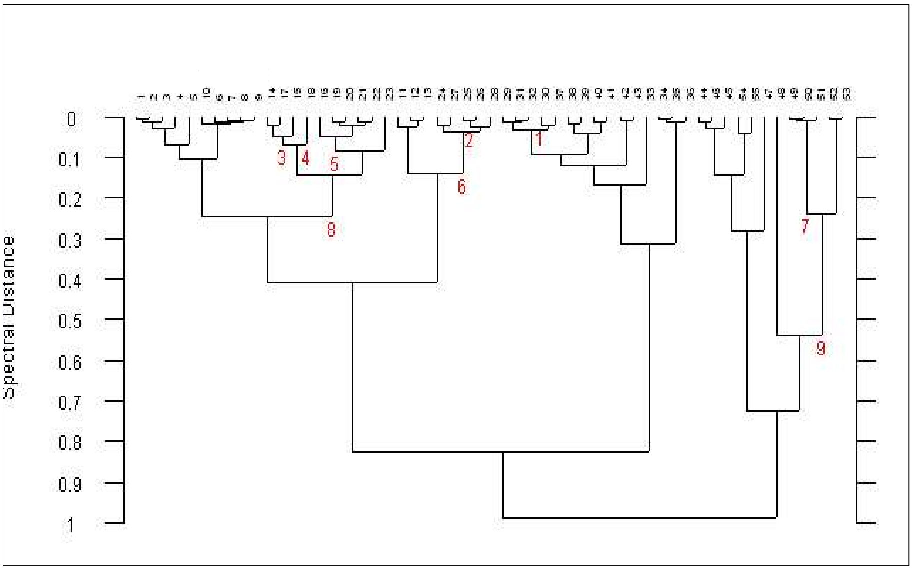

Fig2 Result of complex-linkage cluster analysis on training samples within the spectral range of 3996-11502cm-1

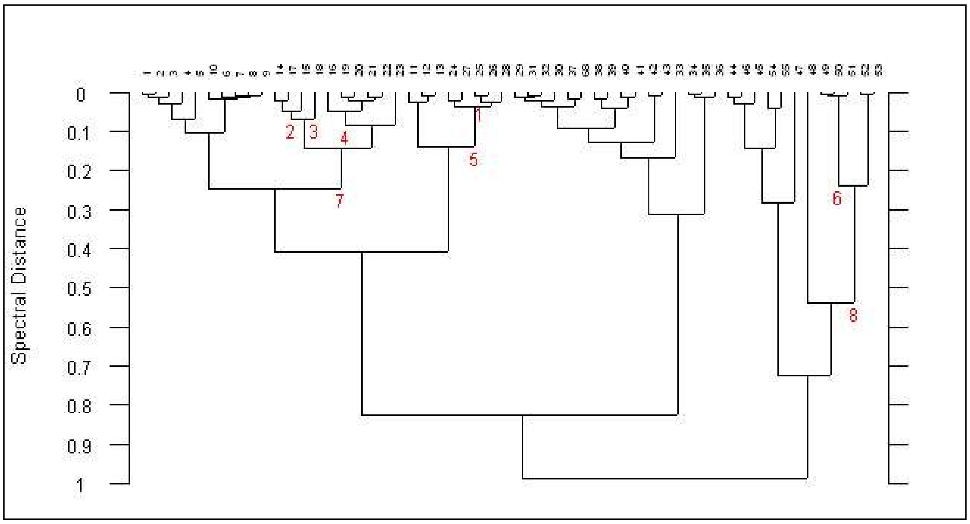

Fig 3 Result of cluster analysis on validation sample no. 68

CONCLUSIONS

As an introductory evaluation, we present results demonstrating that the NIR and cluster analysis based model is capable of monitoring young larvae in nurseries by identifying them from their environment. Complex-linkage calibration models using a wavelength range of 3996-11502cm^{-1} could track the samples with high accuracy.

Laboratory tests show the potential of the model as a reliable tool to be employed in the monitoring of young larvae in nurseries. This model can permit scaling from laboratory experiments to large populations in the field and hence give information for controlling locust outbreaks.

ACKNOWLEDGMENTS

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 543.4:621.3.08
Izvorni znanstveni rad
Original scientific paper

DEVELOPMENT OF A SPECTROSCOPY-BASED CROP NITROGEN SENSOR

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SUMMARY

A crop nitrogen sensor was developed based on spectroscopy. The sensor is composed of an optical unit and an electronic unit. The optical unit is designed to have four channels, two upward and two downward, to measure the spectral reflectance of the plant canopy and sunlight respectively. The wavebands measured are 610 nm and 1220 nm. The upward channels measure the sunlight in order to avoid the influence caused by the angle of solar incidence. The downward channels measure the reflected light from the plant canopy. Each channel has a similar structure and consists of an optical window, a washer, a filter, and a transducer. The electronic unit consists of an amplifier, an A/D, a microprocessor, a LCD, and a Flash Disk. The calibration test shows that the sensor is reliable. The result of field test shows that it has a close linear correlation with the reflectance measured by Crop Scan at 610 nm, but the correlation between them needs to be improved at 1220 nm. The NDVI measured by the developed sensor has a high correlation with the plant nitrogen content and chlorophyll content.

Key words: *crop nitrogen content, spectroscopy, precision agriculture, NDVI*

INTRODUCTION

Nitrogen content of the crop is an important index used to evaluate the growth status and predict the yield and the quality of the crop. Thus it is necessary to detect and analyze the nitrogen status of the crop in real time. As we know, nitrogen has a great effect on the spectral reflectance of the crop. If there is nitrogen deficiency, the chlorophyll content will decrease, resulting in reduction of the spectral reflectance at NIR band and increase of the spectral reflectance at visible band. Hence the crop nitrogen content can be estimated by analyzing these spectral features of crop canopy.

In recent years, some researches have been conducted to develop ground-based remote sensing systems to detect nitrogen content of the plant. Stone et al. (1996) developed optical sensors to detect nitrogen availability for winter wheat. The result shows that there is a close correlation between the vegetative nitrogen content and the spectral index. Heege and Thiessen (2002) reported an on-the-go control system of site-specific nitrogen top dressing by sensing crop reflectance. R. Sui, et al. (2005) developed a detector of nitrogen status in cotton. It was reported that the device was not interfered by solar radiation.

Now there is no practical device to detect crop nitrogen content for Chinese farmers. Thus it is necessary to develop such device that can be conveniently operated by farmers in the field. Our objective is to design a crop nitrogen sensor to measure the spectral reflectance of the crop canopy to determine N status in the plants.

DEVELOPMENT OF A CROP NITROGEN SENSOR

Structure

Figure1 shows the structure of the crop nitrogen sensor based on optical principle. It is composed of an optical unit and an electronic unit. The optical unit was designed to have four channels with different wavebands. The channels 3 and 4 measure the sunlight, while channels 1 and 2 measure the reflected light from the plant canopy. Since the angle of solar incidence can change the output of the transducer, the milky diffuse glass is used as the optical window of channel 3 or 4 in order to prevent this influence. The optical mirror is chosen as the window of channels 1 and 2. When using this sensor to measure crop canopy, the optical unit is lift on the top of the canopy and the output of the optical unit transmitted to the electronic unit.

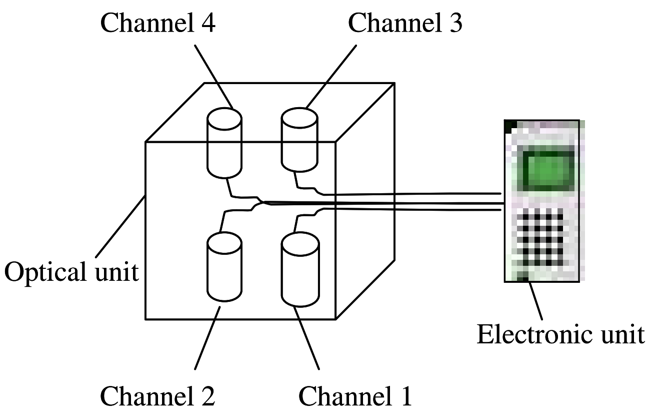

Figure 1 The structure of the crop nitrogen sensor

Each channel had the same structure as shown in Figure 2. It consists of an optical window, a washer, a filter, and a transducer. Channels 1 and 3 have the same filters and transducers. The wavelength of the filter is 610 nm. The transducer is made with Si. The wavelength of the filter in channels 2 and 4 is 1220 nm, and the transducer used is made with InGaAs. The wavebands are determined based on the research report (Xue Lihong, 2004).

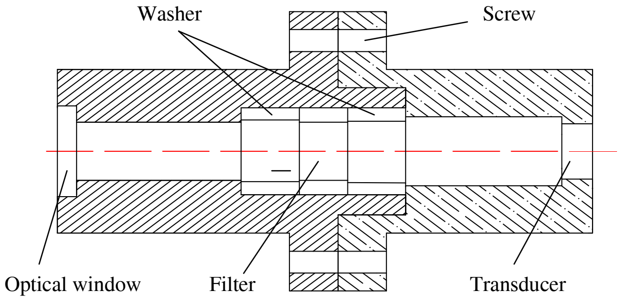

Figure 2 The structure of the channel

In Figure 3, d_1 is the diameter of the optical window, d_2 is the diameter of the sensed area, h is the distance between the optical window and the plant canopy. The angle of view is 30º. S_{leaf} is the sensed area of the sensor. In this system, d_1 is 20 mm and h is more than 1m. Hence we got the following two equations.

$$d_2 \approx 2h \times \tan 30^{\circ} \tag{1}$$

$$S_{leaf} = \frac{\pi}{4} \times d_2^2 \tag{2}$$

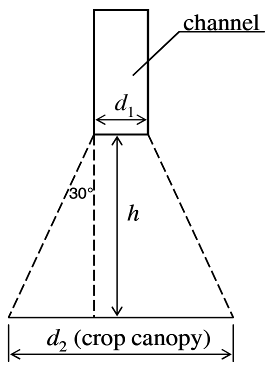

Figure 3 Sensed area of the sensor

Hardware

Figure 4 shows the structure of the electronic unit. The transducers convert the optical signal into the electronic signal. The electronic signal goes through an amplifier and an A/D to be digitalized. The digital signal is calculated into nitrogen content or chlorophyll content in the plants by the microprocessor, and the result is displayed on the LCD and stored in the Flash Disk via the USB port. The keyboard is used to input the indications to the microprocessor.

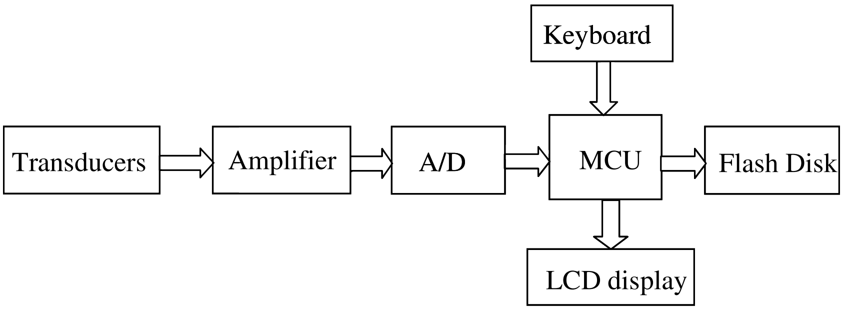

Figure 4 The structure of the electronic unit

Software

The program consists of four subprograms: sampling, calculating, displaying, and storing. Figure 5 shows the Flow chart of the main program.

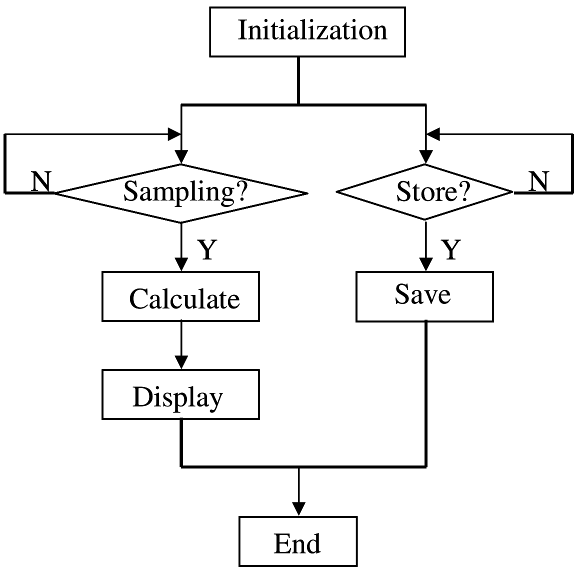

Figure 5 Flow chart of the main program.

PERFORMANCE TESTS AND RESULTS

Calibration Test

Firstly, calibration tests of the sensor were carried out in China Agricultural University in a sunshiny day. A white board was put on the ground out of the shadow for calibration and an ASD FieldSpec spectroradiometer was used as a reference. The spectral region of the spectroradiometer is 325-1075 nm with resolution of 1 nm. The tests were conducted once every 20 minutes from 10:00 AM to 16:00 PM. We measured the solar illumination with the luminometer at the same time. Each measurement was repeated five times and the average was taken as the final result.

In the Figure 6, we found that there was a good correlation between the solar illumination and the output of the four channels measured by the sensor. Comparing the measured result of the ASD with the four output voltages of the sensor, a good correlation was also obtained.

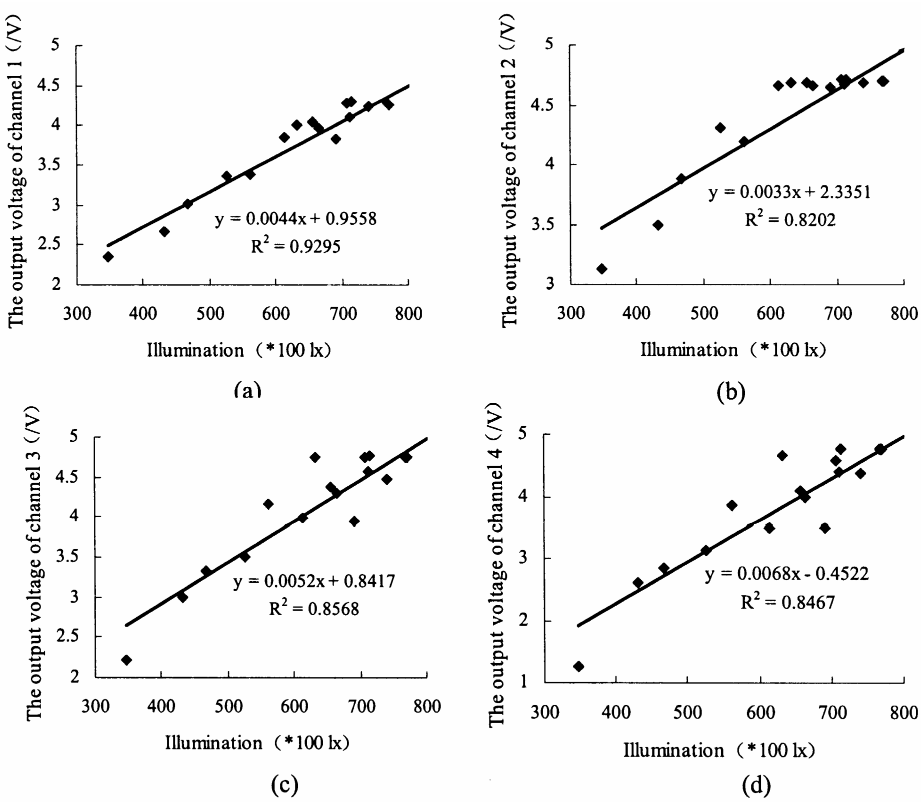

Figure 6 Comparison of the illumination and the output voltages of four channels

Field Test

To evaluate the performance of the sensor, we conducted a field test in a wheat farm on March 24, 2006. There were 24 grids in the experiment field and the nitrogen contents in different grids seemed to have a great variation. The area of each grid was 5×5.5 m^2. The wheat was only ~10 cm in height and hence didn't cover the entire ground surface. We used the developed sensor and Crop Scan to measure the reflectance of the wheat canopy. The height from the canopy to the sensor was about 10 cm, while the Crop Scan was put at a height of 2 m above the ground. Each grid was measured five times along the two diagonals of each grid and the average was taken as the final result. At every sampling point, the plant samples were collected to measure the nitrogen content in the laboratory. Crop Scan is a portable multi-spectral radiometer with 16 wavebands with spectral range of 425-1650 nm. The angle of view is 31.1º.

Figure 7 shows the leaf reflectance measured by the developed sensor. It has a close linear correlation with the data measured by Crop Scan (R^2 = 0.7604) at 610 nm. However, the correlation between those at 1220 nm is not as good as expected (Figure 8).

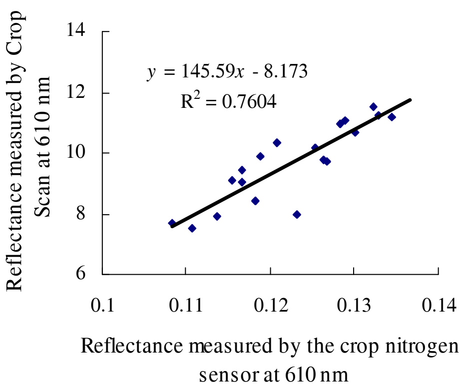

Figure 7 Relationship between the crop nitrogen sensor and Crop Scan at 610 nm

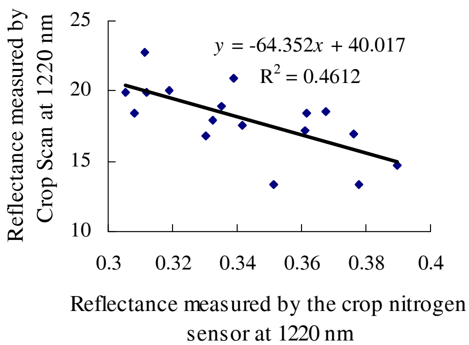

Figure 8 Relationship between the crop nitrogen sensor and Crop Scan at 1220 nm

As discussed previously, the spectral reflectance of the wheat canopy rises in the NIR band and falls in the red band as nitrogen content of wheat plant increases (Stone et al. 1996). Thus there should be a negative correlation between spectral reflectance data at NIR band and the data at red band. The result measured by the crop nitrogen sensor is consistent with this conclusion (Figure 9). It can be concluded that the reflected light from the plant is clearly measured by the sensor. Figure 10 shows the result obtained by Crop Scan. It appears that most of the reflected light measured by Crop Scan was from the soil since the reflectance of soil falls both in the red band and the NIR band when nitrogen content of the soil increased (Zheng Lihua, 2005). The possible reason is the height of wheat. Crop Scan was put much higher, so the sensed area is larger and both the crop canopy and soil background were measured. Therefore, it is needed to put the two equipments at the same height and measure at the same point in the next test.

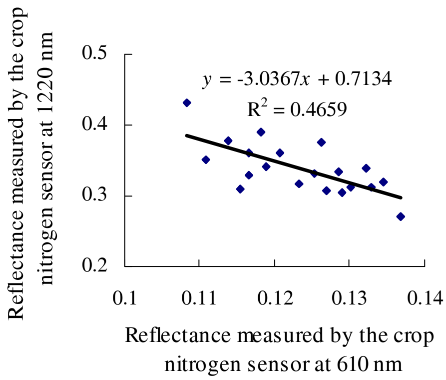

Figure 9 Comparison of the reflectance data of the crop nitrogen sensor between 610 nm and 1220 nm

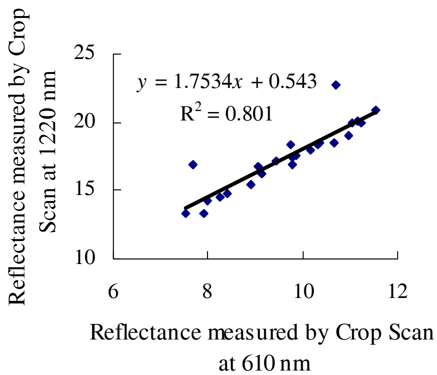

Figure 10 Comparison of the reflectance data of Crop Scan between 610 nm and 1220 nm

Then we conducted anther field test in the greenhouse on November 11, 2006. The leaves of the tomato were measured by the crop nitrogen sensor and sampled to measure the chlorophyll content and the nitrogen content in the lab. There were 24 samples in total. All the leaves were cut from different individual plant. The nitrogen content of the leaf was measured by the N-Tester. And the chlorophyll content of the leaf was measured by an UV-VIS Spectrophotometer. Firstly, each leaf was cut into small pieces and then weighed 0.4g. Secondly, the test tubes were filled with 25 ml mixture of acetone and ethanol with the proportion of 2:1. Then the weighed leaves were put into different test tubes. After 24 hours, the chlorophyll content of the leaves could be measured. During the 24 hours, the test tubes were shaken three times to dissolve the chlorophyll in the mixture completely. Figure 11 shows the relationship between the chlorophyll content and the nitrogen content. It demonstrates that chlorophyll and leaf nitrogen content are correlated.

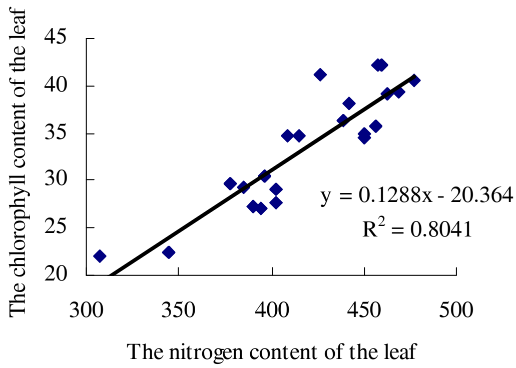

Figure 11 The relationship between the chlorophyll content and the nitrogen content of the tomato leaf

The Normalized Difference Vegetation Index (NDVI) has been widely used to monitor the growing status of crop. It is calculated as a ratio between measured reflectance in the red band and that in the near infrared band. These two spectral bands are chosen because they are most affected by the absorption of chlorophyll in leafy green vegetation. An NDVI value of zero means no green vegetation and close to +1 (0.8 - 0.9) indicates the highest possible density of green leaves (Labus M P, 2002, Calera, 2001, Galvao L S, 2000). The equation calculating NDVI is as follow (Rouse J W, 1973):

$$NDVI = \frac{R_{IR} - R_R}{R_{IR} + R_R} \tag{3}$$

where R_{IR} represents the reflectance in the near infrared band and R_R represents the reflectance in the red band. In our test, the R_{IR} was the reflectance at 1220 nm and the R_R was the reflectance at 610 nm. The result shows that the NDVI measured by the crop nitrogen sensor had a positive linear correlation with the leaf chlorophyll content (Figure 12). Comparing the NDVI measured by the crop nitrogen sensor with the nitrogen content in the leaf, a good correlation was obtained (Figure 13).

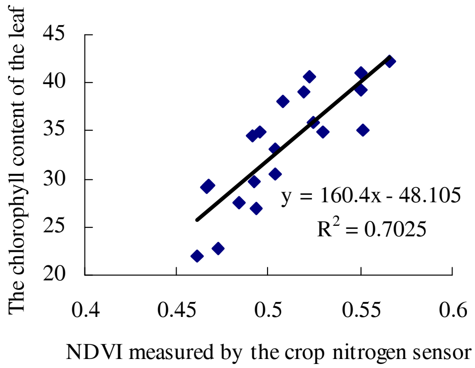

Figure 12 The relationship between the chlorophyll content and NDVI measured by the crop nitrogen sensor

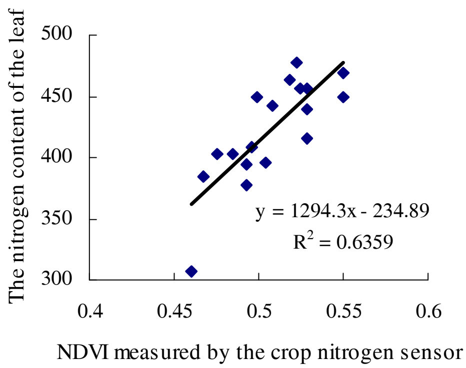

Figure 13 The relationship between the nitrogen content and NDVI measured by the crop nitrogen sensor

CONCLUSIONS

A spectroscopy-based crop nitrogen sensor was developed and tested in the field. The spectral reflectance measured by the crop nitrogen sensor showed a close correlation with that measured by Crop Scan at 610 nm wavelength ($R^2 = 0.7604$), but not with that at 1220 nm wavelength ($R^2 = 0.4612$) due to interference from the soil background. The result of the greenhouse test proved that the NDVI measured by the crop nitrogen sensor had a close correlation with the plant nitrogen content and chlorophyll content. In the future, more field tests are needed to improve this sensor.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 634.11:635.076
Izvorni znanstveni rad
Original scientific paper

THE EFFICIENCY OF APPLE YIELD FORECASTING BASED ON THE IMAGE ANALYSIS UNDER THE MID-EUROPEAN GROWING CONDITIONS

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ABSTRACT

In 2005 the possibility of early apple yield forecasting based on the image analysis was researched in five mid-European countries (Slovenia, Austria, Italy, Switzerland and Germany) within ten orchard growing regions. In the average the yield was overestimated for 5%, whereas it was varying between -9% and +8% in the specific growing areas. The greatest differences were established in South Tyrol-Italy (-18%) because of the unlevelled sampling procedure and in Canton Wallis-Switzerland (+16%) as the orchards were trained in a combination of trellis and spindle growing form. The best accuracy of the forecast was established in the 'Golden Delicious' (+3%) and 'Gala' (+9%) varieties. Contrary, the yield of the 'Elstar' was overestimated most (+21%) since the variety is known on his great altering in yield. Thus, the common image capturing procedure needs to be revised for the future forecast of this particular variety.

Kay words: *apple, yield, image analysis, Austria, Germany, Italy, Slovenia, Switzerland*

INTRODUCTION

Apple with the average annual production of 10 million tons represents the most important deciduous fruit in the EU-25 countries (Anonymus, 2006). However, the varying annual yield requires a constant planning of harvesting and a storage capacity as well as it is often reflecting in the market prices instability (Lambrechts, 2001, Ramos and Lieberz, 2003). For those reasons researching of the efficient forecasting model for predicting the future yield was always important task not only from scientific but also growers' point of view.

From early 1980es the modelling of apple yield grown in his popularity, due to the increased computer capacity as a substitute for a large-scale orchard experiments (Hester and Cacho, 2003). However, despite all holistic methods developed by horticulturists, the Bavendorf mechatronic model introduce by Winter (1986) is still the most important method for forecasting the yield in the middle Europe.

The time-consuming field measurements required by the Bavebdorf model encouraged Stajnko et al. (2001, 2002) to improve the data collection in the orchard completely. By introducing the visualization of the apple tree canopy and developing the image analysis algorithm as a new effective tool for a variety adopted data acquisition in the spindle trained orchard.

In 2003 the method was successfully tested not only under local conditions but also in other middle-European experimental orchard stations, whereby the majority of apple orchards were relatively young. One year later a group of researching stations and apple producers' organisations decided to test the accuracy of the image based method on the large-scale production level.

The main objective of this paper is to demonstrate and evaluate the applicability of the method for predicting the diameter, number and future yield in particular high density parcels growing under different European production, terrain and varieties conditions.

METHODS

Experiment features

The experiments were performed at local producers in five countries; Austria, Germany, Italy, Slovenia, and Switzerland including ten regions: Bodensee, Elbe, Rheinland, Sachsen, Eastern Slovenia, Steiermark, South Tyrol, Thurgau, Waadt, Wallis, and four research stations: Bavendorf, Haidegg, Kleinaltendorf, Gačnik. It was decided to take in all regions similar, most important verities from the Mid-European assortment, therefore Breaburn, Gala, Golden Delicious and Jonagold were chosen for the research.

Experimental orchards

The age of the orchard and the density of the trees were the base criteria for the number of apple trees and images being captured from a particular orchard. According to proposed procedure of the method all orchards were then divided into three groups;

a) plantations with small, young trees till the fourth vegetation (15 trees captures from one side of the tree)
b) plantations with bigger, young trees till the fourth vegetation (15 trees captures from both sides of the tree), and
c) plantations with full-productive trees after the sixth vegetation (30 trees captures from both sides of the tree).

Images were captured subsequently from 28th June 2006 on the most south regions (South Tyrol and Slovenia), till 19th July 2006 on the most north region (Elbe, Sachsen) after manual or chemical fruit tinning. Several co-operators from different regions captured images by digital cameras in a resolution equal or better than 1280x 960 pixels. Later images were transferred to University of Maribor by mail or using a FTP protocol.

Different algorithms for analysing of particular apple variety were described in details by Stajnko et al. (2004, 2005), however for performing the program accurately a few locally adopted threshold settings had to be processed for each region prior processing.

The efficiency of apple yield forecasting based on the image analysis was calculated by dividing forecasted with harvested yield, and was expressed as index.

RESULTS AND DISCUSSION

As seen from Figure 1, the average index between estimated and harvested yield reached 1.05, whereby in eight regions the difference was less than 0.09 and in five areas up to 0.25, respectively. The reason for most outstanding forecast in Wallis and Sachsen lies in the specific trained form (Palmette, Solaxe), while the South Tyrol was represented with only one sample parcel per variety. Contrary, on the Bavendorf and Elbe stations the samples did not fit to the algorithm requirements completely, since there were actually only single rows of experimental trees and not parcels. .

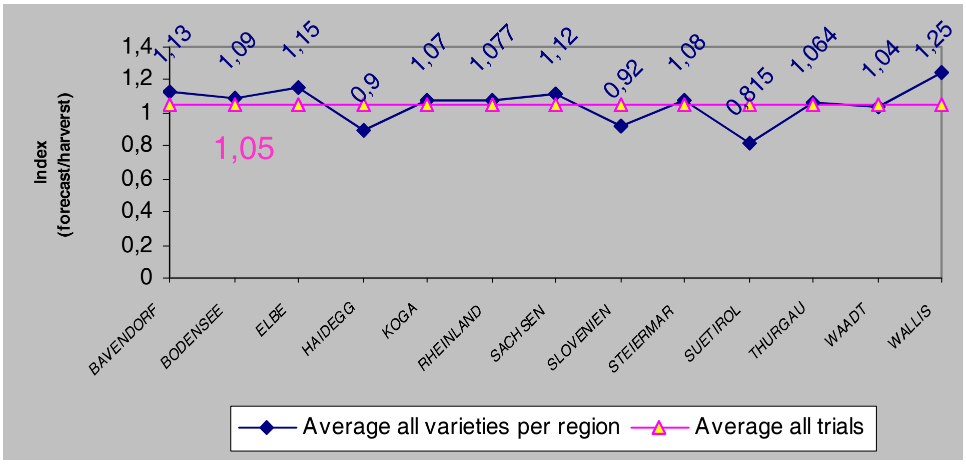

Figure 1: Index of all varieties from particular region

As a late autumn variety the ‘Braeburn’ is known on its long growing period, therefore the fruit weight at harvest depends very much on the local climate conditions, which influence the length of fruit ripening significantly. Thus, the difference between the estimated and harvested yield varied greatly. The best forecast was established for the

Bavendorf Station (+ 1.941.00 kg/ha, index 1.06) and the most outstanding one for the Heidegg (+1497 kg/ha, index 1.54). As seen from the Figure 2, on the northern regions (Elbe, Rheinland) the forecast was overestimated most, while on the contrary the forecast for south region Wallis and Bodensee showed the biggest underestimation, which proved the upper hypothesis.

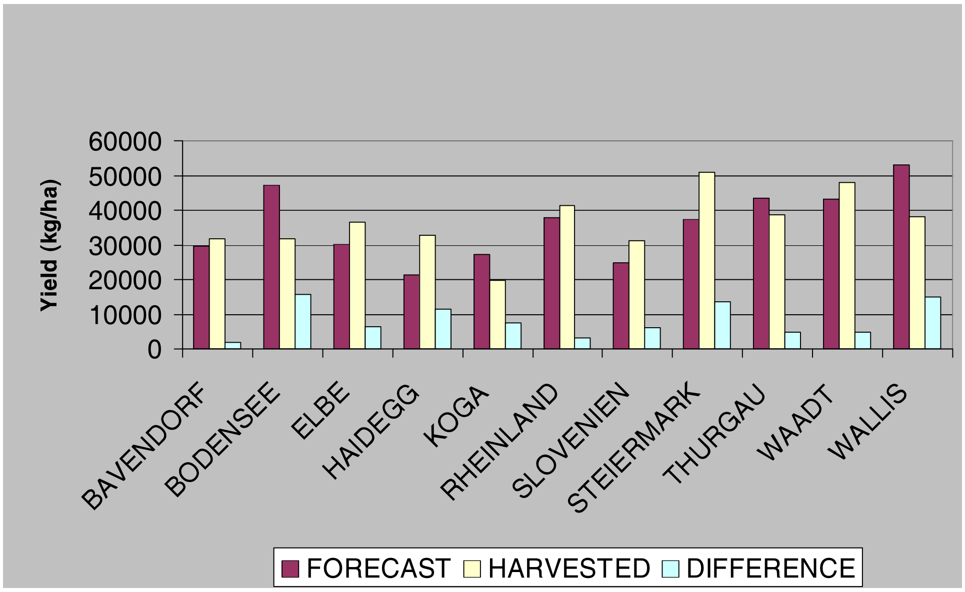

Figure 2: The difference between forecasted and harvested yield of ‘Braeburn’

Contrary to the ‘Braeburn’, the ‘Gala’ was the earliest variety in our trails. Since its genetic potential can be developed almost equally in all regions, the average estimation with index 1.08 is very good (Figure 3). Besides, in seven of all regions the forecast was better than 1.07, so the forecast for Gala is assumed to be superior to the common methods. However, due to some unexpected local training characteristic, the yield was underestimated over 20 % in Elbe, South Tyrol, Sachsen and Wallis. To increase the accuracy of the yield forecasting in this particular regions, additional parameters have to be added into algorithm for the next season.

The ‘Golden Delicious' variety is one of the oldest and most popular ones in Europe. Since for almost all regions the growing curves with the fruit mass are available, the yield forecast was relative easier to proceed. As seen from Figure 4, the estimated yield of the ‘Golden Delicious' lies in four regions under 5 % difference and under 10% in the next two. We strongly believe that also for other regions much better forecast is possible to estimate, whenever a local specific training characteristic is introduced into algorithm.

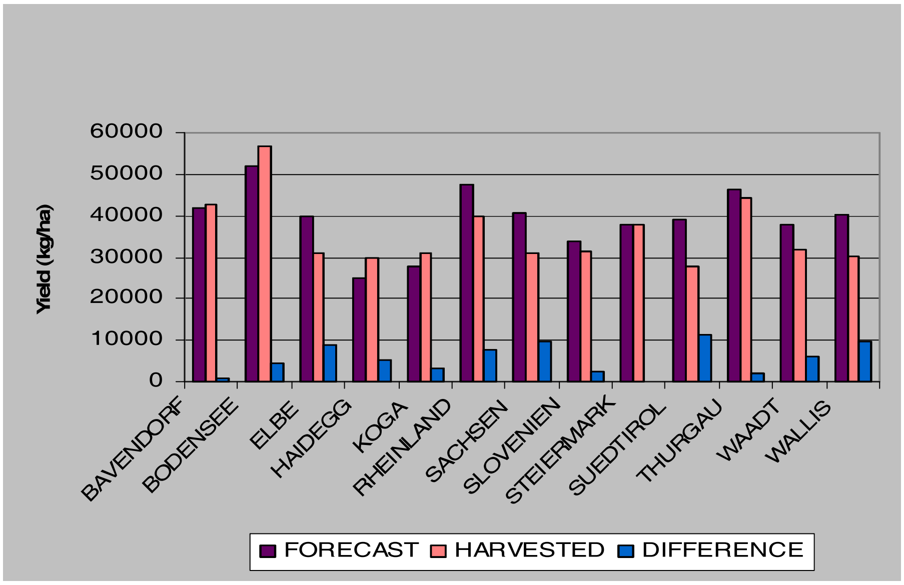

Figure 3: The difference between forecasted and harvested yield of 'Gala'

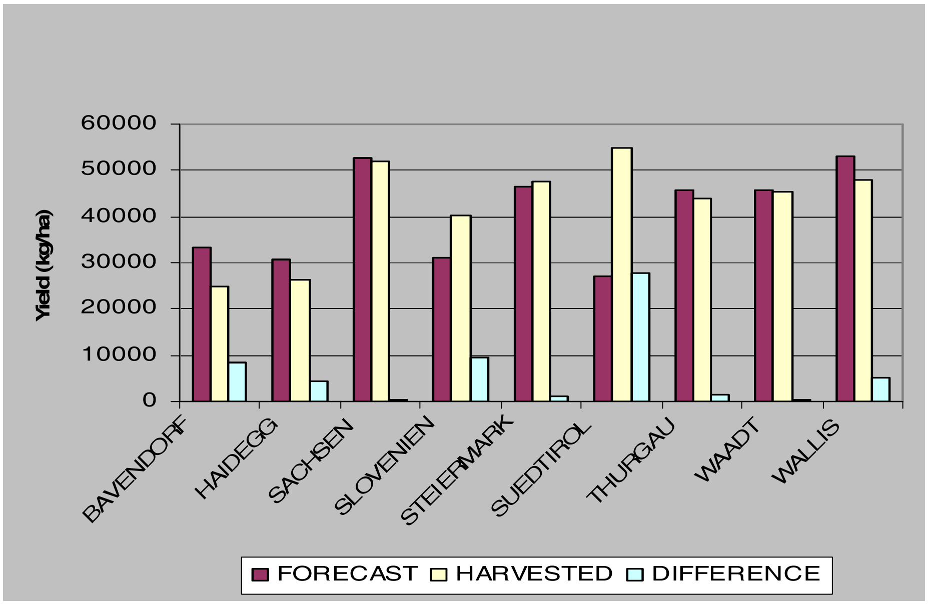

Figure 4 The difference between forecasted and harvested yield for 'Golden Delicious'

The yellow-red fruit colour of 'Jonagold' is relatively difficult to develop in all growing regions, therefore the producers are waiting for it pretty long. Thus, also the fruit weight at harvest depends very much on the local climate conditions. Subsequently, a difference between the estimated and harvested yield varied greatly. As seen from Figure 5 the excellent accuracy was estimated in Waadt (index 1.01) and still acceptable 1.11 for Bodensee, Steiermark and Wallis, respectively. Again on the most northern regions (Elbe, Sachsen) the yield was overestimated most due to the smaller fruits than planned in the algorithm. In most regions the fruit weight was shown to be the most important reason for the relative bigger deviations in forecasts, therefore also for the 'Jonagold' additional characteristics of the growing curves are suggested to be introducing into the algorithms for the following seasons.

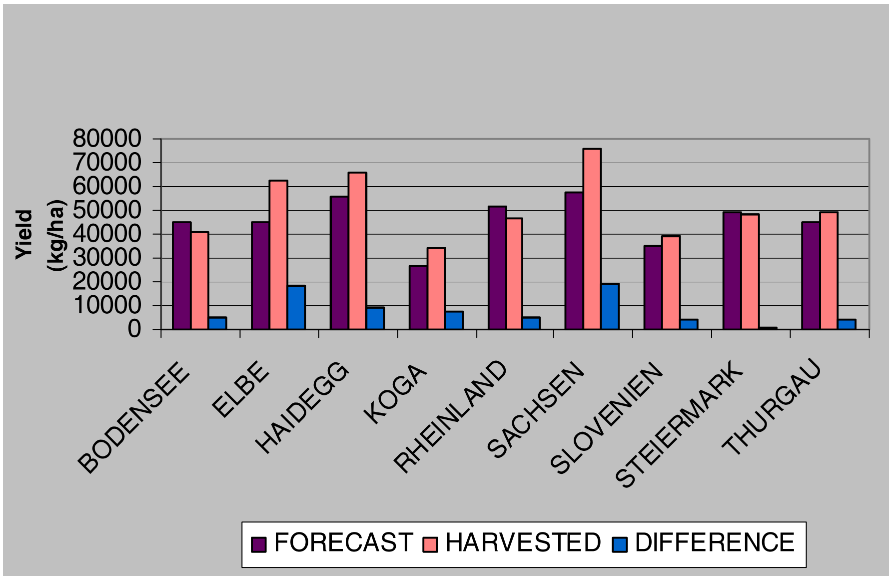

Figure 5: The difference between forecasted and harvested yield of 'Jonagold'

CONCLUSION

The first large scale experimental introduction of the image-based forecasting of the future yield showed that the image capturing followed by image analysis algorithm was technically performed excellent on all experimental orchards. The index between the forecasted and harvested yield reached in the average a very promising 1.05. Whenever having in mind that the South Tyrol was represented only with a few very high varying experimental orchards and the Wallis plantations are trained as a mixture of Spindle and Palmette or in a Solaxe form even better forecast is expected to be establishing in the next years. However, for increasing the yield forecast even more accurately, additional local adopted growing curves for specific apple varieties (Breaburn, Jonagold) need to be implemented into algorithms, which should be founded on the local long-term measurements. The increase of accuracy in the Palmette and Solaxe trained orchards can be achieved by developing specific canopy simulation algorithms and by rising of the total number of images being captured from sample trees, whereby a special intention must be paid on the upper part of the tree canopy.

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UČINKOVITOST PROGNOZIRANJA URODA JABUKA ANALIZOM SLIKA U SREDNJEEUROPSKIM UVJETIMA

SAŽETAK

U 2005 godini proučavana je mogućnost primjene ranog prognoziranja uroda jabuka pomoću analize slike u pet srednjeeuropskih zemalja (Slovenija, Austrija, Italija, Švicarska, Njemačka) u deset voćarskih regija. U prosjeku sav ubrani urod bio je manji od očekivanog za 5 %, dok je u pojedinim rajonima varirao između -9% i +8%. Iznimke predstavljaju Južni Tirol (Italija) s -18% zbog nehomogenog uzorka i Wallis (Švicarska) s +16% radi specifičnog kombiniranog uzgojnog oblika palmete i uskog vretena.

Najbolje rezultate postigli smo kod sorti 'Golden Delicious' +3% i 'Gala' +9%, a najslabije kod sorte 'Elstar' +21% koja je jako sklona alternanciji, pa se u budućnosti predviđa dopuna standardnog postupka snimanja u voćnjaku.

Ključne riječi*: jabuka, urod, analiza slike, Slovenija, Austrija, Italija, Švicarska, Njemačka*

35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631.347:634.11:778.3
Prethodno priopćenje
Preliminary communication

MOŽNOST UPORABE DIGITALNE FOTOGRAFIJE ZA UGOTAVLJANJE KAKOVOSTI NANOSA ŠKROPILNE BROZGE

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SAŽETAK

Cilj našega poskusa je bil ugotoviti primernost digitalnega fotoaparata za ugotavljanje kakovosti nanosa škropilne brozge v sadovnjaku, s pomočjo UV sledilca (tracerja) Helios SC500. Na drevesa smo na šestih mestih v štirih ponovitvah pritrdili jablanove liste, in WSP lističe, ki so služili za primerjavo rezultatov. Fotografiranje je bilo izvedeno neposredno v nasadu z digitalnim fotoaparatom Olympus C-3000, vgrajenim na zaprto škatlo, v kateri je UV žarnica osvetljevala liste poškropljene z UV sledilcem. Dobljene fotografije so bile obdelane z računalniškim programom LabVIEW IMAQ Vision. Rezultati so pokazali, da zaradi visokih temperatur pri fotografiranju neposredno v nasadu, pride do zelo slabe kakovosti fotografij zaradi segrevanja CCD senzorja (šum tipala). Posledica je bila slaba korelacija med rezultati analize pokrovnosti na WSP lističih in vrednostmi za pokrovnost ugotovljenimi s fotografiranjem.

Ključne reči: *škropilna oprema, pršilnik, jablana (Malus domestica Borkh.), sledilno barvilo, pokrovnost z oblogo škropiva, Image processing, Image analysis*

UVOD

Uspešna pridelava v kmetijstvu je zaradi vse večjega potenciala bolezni, škodljivcev in plevelov, v veliki meri odvisna od kakovosti nanosa škropilne brozge, torej od naprav za nanašanje fitofarmacevtskih sredstev (škropilnik, pršilnik). Za ugotavljanje kakovosti nanosa škropilne brozge na ciljno površino se uporablja več metod, ki temeljijo na kemijskih analizah ali na vizualnih analizah.

Kakovost nanosa lahko merimo na tri načine:

- Merjenje pokrovnosti škropilne obloge (coverage values). Z različnimi vizualnimi metodami določimo delež (%) ciljne površine, ki je prekrita z oblogo škropilne brozge. Meritve se najpogosteje izvajajo z uporabo na vlago ali na olje občutljivih lističev (Water sensitive paper – WSP, Oil sensitive paper).

- Število zadetkov kapljic (number of droplet impacts / cm^2) je lahko merilo kakovosti nanosa, vendar je interpretacija podatkov zelo težka, ker imajo različne kemikalije, različne zahteve za izenačenost depozita škropilne obloge. Število zadetkov kapljic je zelo odvisno od velikostnega spektra kapljic in količine porabljene vode. Izvrednotenje parametrov impaktov poteka z računalniškimi algoritmi analize slike.
- Ugotavljanje dejanskega depozita s pomočjo kemijskih metod analize kolektorjev (naravni listi, očesih, plodovi, papirčki, …) daje najbolj realno sliko kakovosi nanosa (Koch, H., Knewitz H., 2006).

S kemijskimi analizami se najbolj natančno ugotavlja depozit škropilne brozge. Temeljijo na fluorometriji, kolorometriji, fotometriji ali na kvantitativni analizi. Pri teh metodah se uporabljajo sledilci (tracerji), ki jih pri kemijskih analizah detektiramo na različne načine (HPLC, AAS, Fluorometrija, …). Pogosto se uporabljajo flourescentni barvni sledilci in fluorometrične metode, ki so relativno preprosti in poceni (Pergher G., 2001).

MATERIALI I METODE

Zastavljeni poskus je bil izveden vzporedno v poskusu, kjer so se ugotavljale relacije in medsebojni vplivi med tipom šob, količino porabljene vode in tipom pršilnika na enakomernost porazdelitve škropilne brozge v dveh različnih gojitvenih oblikah jablanovih dreves.

Poskusni nasad

Poskus je potekal na posestvu Univerzitetnega kmetijskega centra Fakultete za kmetijstvo v Hočah pri Mariboru.

Naziv nasada	Gojitvena oblika	LAI	Starost nasada
Pod bloki	Zelo vitko vreteno 0,7 x 2,8 m višina do 3,40 m	2,45 - 2,8	6 let
Pod gradom	Povišano vitko vreteno 1,5 x 4 m višina do 3,7 m	2,5 – 2,9	12 let

Poskus je bil zastavljen v štirih ponovitvah, ki so si sledile v isti vrsti. Na drevo smo na šestih lokacijah vzporedno postavili kolektorje (Slika 1), ki so bili vpeti v ščipalke. Kot kolektorje smo uporabili: WSP listič, filtrski papir, list jablane in list pobarvan s črno barvo brez sijaja. V prispevku so prikazani le rezultati analize WSP lističev in zelenih listov.

Uporabljeni pršilniki in delovni parametri

Za škropljenje smo uporabili sadjarsko vinogradniški traktor New Holland TN75V. Preskušana sta bila:

- pršilnik izdelovalca Agromehanika AGP 400 ENU, z aksialnim ventilatorjem in usmernikom zraka,
- pršilnik Unigreen turbo teuton P 4+4, z radialnim ventilatorjem in cevnim razvodom zraka.

Tabela1 Uporabljene šobe in njihovi delovni parametri
Table 1 Tested nozzles and spraying parameters

Tip šobe	**Delovni tlak**	**Vozna hitrost**	**Hektarski izmet**	**Velikost kapljic VDM (μm)**
Lechler TR 80-015	5 barov	5,5 km/h	350 l/ha	160 ± 20
Lechler ITR 80-015	5 barov	5,5 km/h	350 l/ha	390 ± 20
Lechler TR 80-03	5 barov	5,5 km/h	700 l/ha	250 ± 20
Lechler ITR 80-03	5 barov	5,5 km/h	700 l/ha	500 ± 20

Uporabljeni testni lističi, sledilec in merilna oprema

Za testne lističe (nosilce) so bili uporabljeni: water sensitive paper (WSP) proizvajalca Sygenta - Novartis agro, filtrski papir, in naravni listi jablane. WSP lističe smo analizirali na napravi Optomax image analyser.

Kot sledilec je bilo uporabljeno UV flourescentno barvilo HELIOS SC500, proizvajalca Syngenta – Novartis Agro. Hektarska doza je bila pri vseh uporabljenih šobah 5,25 g čistega sledilca na ha.

Za namen fotografiranja listov v nasadu je bila izdelana mobilna za svetlobo nepropustna škatla velikosti 400 x 400 x 300 mm, ki je v notranjosti pobarvana s črno barvo brez sijaja (slika 2). Na gibljivem pokrovu škatle je bil preko adapterja pritrjen digitalni fotoaparat Olympus C3000 z ločljivostjo tri milijone pixlov. Na objektiv digitalnega fotoaparata je bil privit najprej rumeni filter (Cokin C001/46 Yellow filter) in nato predleča za makro fotografijo (Cokin C104/46 Close-up 4D). V škatli so bile vgrajene štiri UV svetilke (Blacklight Blue F6WT5/BLB), ki jih je napajal 6 voltni svinčev akumulator.

Za analizo fotografij posnetih z digitalnim fotoaparatom smo uporabili algoritem (Coverage) pripravljen v okolju programa LabVIEW IMAQ Vision.

V obeh nasadih smo z različnimi kombinacijami šob poškropili drevesa na katerih so bili v šestih točkah pripeti kolektorji. Po vsakem škropljenju smo počakali, da se lističi posušili, nakar smo jih shranili za naknadno analizo. Poškropljene naravne liste smo fotografirali neposredno v nasadu tako, da smo vsak list posebej vstavili v zaprto škatlo. Zaporedje fotografiranja je bilo v vseh ponovitvah enako.

Zaradi nizkega korelacijskega koeficienta (R^2=0,22) med rezultati iz WSP in naravnih listov in ker so statistične metode pokazale nelogične rezultate, smo opravili naknadni poskus, kjer smo vzpostavili podobne pogoje, kot so bili v nasadu v času fotografiranja v nasadu. Testni list smo fotografirali pri neprestano vklopljenem LCD monitorju fotoaparata na zunanji temperaturi 35°C. Opravili smo pet ponovitev, s 30 minutnimi presledki. V vsaki ponovitvi smo napravili 40 fotografij, v razmiku 1 minute eno za drugo.

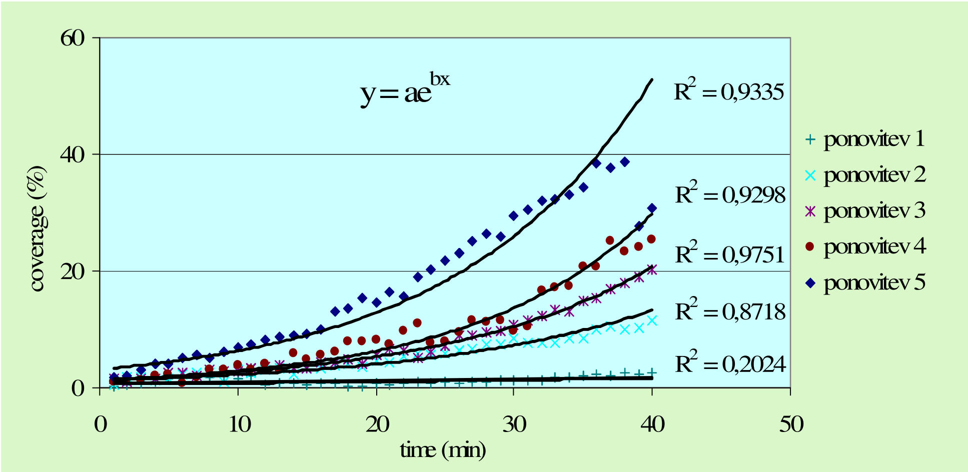
Slika 1 Namestitev kolektorjev v ščipalke
Picture 1 Placing of collectors in the clothespeg

Slika 2 Zaprta škatla za fotografiranje
Picture 2 Box for image capture

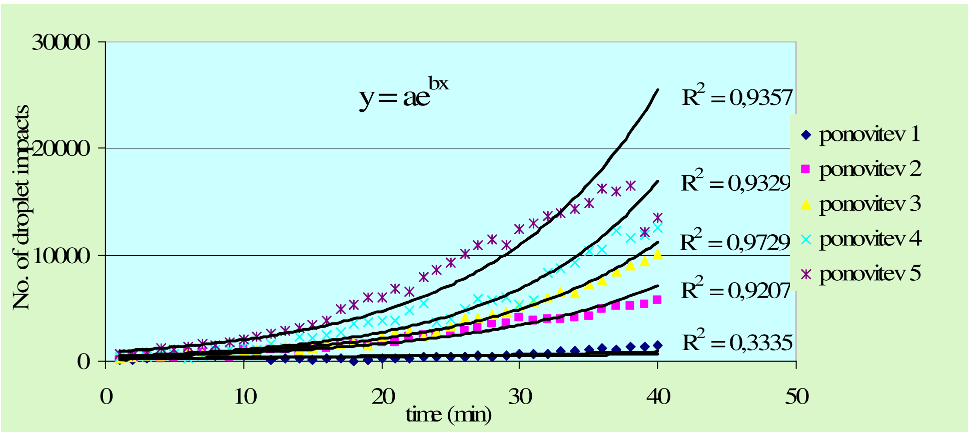
REZULTATI I DISKUSIJA

Cilj poskusa je bil doseči čim večjo korelacijo med rezultati analiz WSP lističev in meritvami s pomočjo digitalne fotografije, vendar je zaradi zunanjih vplivov korelacija s časom fotografiranja, močno padala. Statistične metode so pokazale nelogične rezultate.

S poskusom, kjer smo fotografirali vedno isti objekt, je bilo ugotovljeno, da se z naraščanjem časa, ko je aparat vklopljen, pokrovnost in število izmerjenih impaktov značilno povečuje. Pri prvem vklopu fotoaparata je naraščanje vrednosti počasnejše, pri vsakem od naslednjih, pa se vrednosti hitreje povečujejo. Povečuje se variabilnost med podatki, kar kaže vedno večja strmina krivulje, če v grafu 1 in 2 primerjamo nize od 1 do 5.



Graf 1 Prikaz odvisnosti pokrovnosti določene s pomočjo programa Labview IMAQ Vision po analizi fotografije od časovnega zamika med prvim posnetkom in naslednjimi posnetki, pri večkratnem zaporednem fotografiranju istega objekta, pri istih nastavitvah fotoaparata (časovni niz 40 minut, z enominutnimi presledki)
Graph 1 Correlation between coverage values on leaves determined with Labview IMAQ Vision programme for analysis of photograph and time delay between first taken photograph and next photographs. Sequential photographing of the same object was performed, with the same settings of camera in one minute intervals between single shots and 30-minute interval between two series of 40 shots



Graf 2 Prikaz odvisnosti števila zadetkov kapljic (n/cm^2) od časovnega zamika med posnetki
Graph 2 Dependence of number of hits of drops (n/cm2) from time delay between shots

Tabela 2 Prikaz nekaterih parametrov variabilnosti rezultatov glede izmerjene pokrovnosti v različnih časovnih nizih od prvega opravljenega posnetka pri nepretrganem fotografiranju v časovnem nizu 40 minut z enominutnimi vmesnimi presledki
Table 2 Some statistical parameters of variability of coverage values measured in different delayed time sets from first shot at sequentional photographing in one-minute intervals and 30 minute intervals between series of shots

	Niz 1 (1 – 10 minuta)	**Niz 2 (11-20 minuta)**	**Niz 3 (21-30 minuta)**	**Niz 4 (31-40 minuta)**
Povprečna vrednost	2,3435	4,9533	9,4692	16,0632
St. odklon	1,47015	3,75940	7,47274	11,15411
Povprečje ± standardna napaka povprečja	2,3435± 0,20791	4,9533± 0,53166	9,4692± 1,05681	16,0632± 1,57743
Najmanjša vrednost	0,33	0,14	0,62	1,31
Največja vrednost	6,85	15,41	29,38	38,63

*povprečja petih meritev na vsako minuto časovnega niza
*means of five measurements of every minute of time set

Iz tabele 2 je vidno, kako različen rezultat glede povprečne pokrovnosti dobimo med obdelavami posnetkov, ki so bili napravljeni v zaporedju eden za drugim. Povprečna vrednost ugotovljena na prvih desetih posnetki se je povečala za sedemkrat pri zadnjih desetih posnetkih, kljub temu, da smo vedno fotografirali isti objekt.

ZAKLJUČAK

Kakovost posnetkov kompaktnega digitalnega fotoaparata se v primeru, kadar se ta uporablja pri višjih zunanjih temperaturah (nad 30 ^{o}C) in kadar je vklopljen dalj časa (več kot 20 minut), zelo poslabša. Zaradi segrevanja CCD tipala, ki lahko nastopi tako zaradi zunanje temperature, kot tudi zaradi samega delovanja fotoaparata, se na posnetkih pojavi šum kot motnja, ki popači fotografijo. Šum manjšega obsega se na fotografijah lahko z različnimi orodji delno odstrani, vendar pri računalniški vizualni obdelavi (npr. štetje števila impaktov ali ocena stopnje pokrovnosti) povzroči nerealne rezultate.

Da se izognemo digitalnemu šumu, je potrebno poskrbeti, da je zunanja temperatura čim nižja in da fotografiranje izvajamo v zelo izenačenih pogojih.

Pri kompaktnih fotoaparatih lahko delovanje LCD monitorja močno segreva CCD senzor, saj sta vgrajena zelo skupaj, lahko celo na isti ploščici tiskanega vezja z ene in druge strani. Za boljše rezultate mora biti čas fotografiranja krajši (do 10 minut) z čim daljšimi presledki.

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POSSIBLE APPLICATION OF DIGITAL IMAGES FOR ESTIMATING THE QUALITY OF PESTICIDE COVERAGE

ABSTRACT

The goal of our research was to evaluate possible application of a digital camera for estimating the quality of pesticide coverage in the orchard with the implementation of UV tracer Helios SC 50. A natural apple leaf and WSP paper as a standard were hung up on six measuring places on each of four experimental trees. Images was captured by an Olympus 3000 camera with filter. After spraying, each leaf was put into the black box with UV bulb (Blacklight Blue F6WT5/BLB light) as a luminance source. Images were post–processed with own code (Coverage) developed with the LabVIEW and IMAQ Vision software package. The correlation coefficient (R^2=0,22) between WSP and the leaves was estimated. The main reason for low correlation could be the high temperature in the orchard during the experiment, which overheated CCD device and produced unexpected noise on the images.

***Key words**: spraying adjustment, sprayer, droplets, tracer, coverage targets, image processing, image analysis*

35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.331.5:635.64
Stručni rad
Expert paper

EXISTING STATE ON NONDESTRUCTIVE MEASUREMENT OF PLANT GROWTH BASED ON MACHINE VISION AND RESEARCH ON APPLICATION OF TOMATO SEEDLINGS

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SUMMARY

As one of the most important technologies for plant growth modeling, the research of nondestructive measurement based on machine vision is of great significance in hastening development of digital agriculture. In this paper, we have given the example applied to nondestructive measurement of tomato seedlings in greenhouse. The leaf areas of tomato seedlings are obtained nondestructively by the nondestructive detection image capturing and image processing algorithms proposed. By analyzing the results between machine vision based measurements and manual measurements, the best correlation coefficient of leaf areas is 0.9822, which shows that the algorithm can be used in nondestructive measurement of the tomato seedlings.

Key words: *machine vision, image processing, nondestructive measurement, tomato seedling*

INTRODUCTION

The growth status of crops is synthetically influenced by the heredity character and the environment, so it can be denoted by the morphologic character parameters and the physiological enginery index. So getting the morphologic character parameters and the physiological enginery index in time has an important significance to the diagnosis of the growth status of the plants and the productive instructions. The traditional ways to get the morphologic character parameters and the physiological enginery index have limitation. Sometimes they can not get the parameters and the index synchronously; sometimes they use the destructive measurement; or they can not test and measure continuously; or they use the touch sensors to measure, but the sensors are much expensive currently and the touch with the plant will influence the growth inevitably. Recently, the research of the continuous and fast non-destructive measurement by using the machine vision system has become more and more remarkable.

People have done a lot of researches on monitoring plants in the greenhouse using machine vision technology. At present, the representative research achievement focused on 3 aspects: . Identification of crop morphology; . Nutrition deficiency estimate of crops; . Non-destructive measurement. In China, the application of machine vision in agricultural engineering mainly focused on the detection and classification of farm products, such as fruit surface defect, rice appearance and ripe degrees of the farm products and weed in the crop. In the field of nondestructive detection, the research in China started late but develops quickly. And many researchers did some instructive attempt.

On the basis of the present researches and the latest scientific achievements, it is possible to study and realize the non-destructive measurement of crops and the method of diagnosis and evaluation.

RESEARCHES OF TEST AND MEASUREMENT OF LEAF AREAS OF TOMATO SEEDLINGS BASED ON MACHINE VISION

Method of leaf area measurement

In order to describe the growth of plants quantitatively, their exterior morphologic character parameters, such as the areas of the leaf and the height of the plant, should be measured. As an example of the non-destructive test and measurement during growth of plants based on machine vision, this paper discusses the non-destructive measurement of the leaf areas, which is collected from the tomato seedlings cultivated in the greenhouse. Primarily the tomato seedlings should be collected by a prepared machine vision system. As the digital image is made up of pixels, the areas of the leaves from the tomato seedlings need to be obtained by using the calibration of the machine vision system, which means that the area of a single pixel should be known. So a calibration experiment (Sun et al, 2006) in which a one-yuan coin is chosen to be the calibration reference, need to be done before the measurement.

This paper chose the tomato seedlings as the object, and did continuous non-destructive measurement in the early period of their growth. The experiments were operated in the greenhouse. The average air temperature was 24.6 degrees centigrade; the average soil temperature was 20.1 degrees centigrade; the average air humidity was 41.6%. The tomato variety was Zhongshu No.6, which were respectively cultivated in a 72-holed-plug and a nutrition pot whose diameter was 8 cm. and the culture medium was consisted of grass carbon and Vermiculite.

The measuring values of the area of the leaves can be calculated by using the following formula:

$$\frac{A_C}{N_C} = \frac{A_L}{N_L} \tag{1}$$

In this formula, A_C represents the actual area of the coin for the calibration (mm); N_C represents the number of pixels of the coin in the image, which is binarized; A_L represents the projection area of the leaves (mm); N_L represents the number of the pixels of the leaves in the image, which is also binarized.

In order to get the relationship between measuring values and actual values, we also need to obtain the actual area of the leaves. At first, the leaves were supposed to be measured by the measuring device, since it is the most common way to get the area of the leaves. The device has a clip and a screen. Leaves should be clipped and moved out, so they could be scanned by the sensor attached to the clip, and then the screen would show the area of the leaves. But the tomato seedlings were very small, and the leaves of the seedlings were even smaller than the clip. Errors of the measuring results were rather big, and could not used at all. So the conditional measuring ways by hands was chosen. We drew points along the edge of the leaf on graph paper, and then tried to draw up the edges and counted the numbers of the squares, which were inside the edges. The numbers were considered to represent the actual area. It also assures the continuity of the test and the measurement.

Process of measurement

In the process, the color images collected by the machine vision system were gray-scaled, filtered by median value filter and binarized. And then the conjunction between every two leaves was cut off by erosion process. So the area of the two leaves was calculated respectively. The procedure is shown in Figure 1.

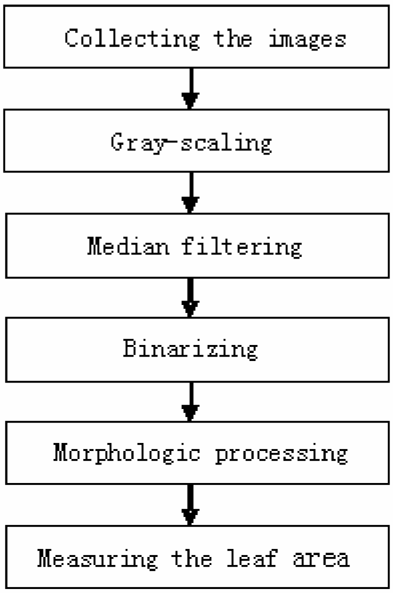

Figure 1 Procedure of the measurement based on the machine vision system

Because of the phototropism of tomato plants, the seedlings do not grow upright. So it is needed to photograph the seedling for three times, which is turned 120 degrees after each photographing. The three images are obtained for every leaf. The measuring values are corrected by the instructions below:

- Eliminate the too small measuring values caused by the incline of the object.
- Eliminate the too large measuring values cause by the environment such as the shadows.
- Average the measuring values which are relatively exact.

The images in Figure 2 (a), (c), (e) (b), (d), (f) are the gray-scaling images and their result images after the pretreatment. Table 1 represents the measuring values of the leaves in Figure 2 respectively. Correction of the measuring values follows the former instructions, and we could get that:

Leaf 1: After eliminating the smaller measuring values caused by the incline of the leaves in the image in Figure (e), we choose the average 79.9 mm^2 of the image in Figure (a) and the image in Figure (c) as the result.

Leaf 2: We choose the measuring value 54.52 mm^2 of the image in Figure (e) photographed vertically as the result.

Leaf 3: After eliminating the measuring value of the enlarged regions in Figure (a) caused by the image segmentation and the measuring value of the smaller leaf areas in Figure (b), we choose the measuring value 88.32mm^2 of Figure(e) as the result.

Leaf 4: After eliminating the measuring value of the enlarged region in Figure (a) caused by the image segmentation and the measuring value of the smaller leaf areas in Figure (e), we choose the measuring value 19.37mm^2 of Figure (c) as the result.

Both the measuring value and the actual value measured by handwork are showed in Figure 3, and the correlation coefficient is 0.9978.

Table 1 Result of the measurement

	Leaf 1(mm^2)	**Leaf 2(mm^2)**	**Leaf 3(mm^2)**	**Leaf 4(mm^2)**
(a) (b)	79.43	51.82	90.43	22.36
(c) (d)	80.37	51.06	86.14	19.37
(e) (f)	77.95	54.52	88.32	20.70
Corrected measuring value	79.9	54.52	88.32	19.37
Actual value	64	47	72	18

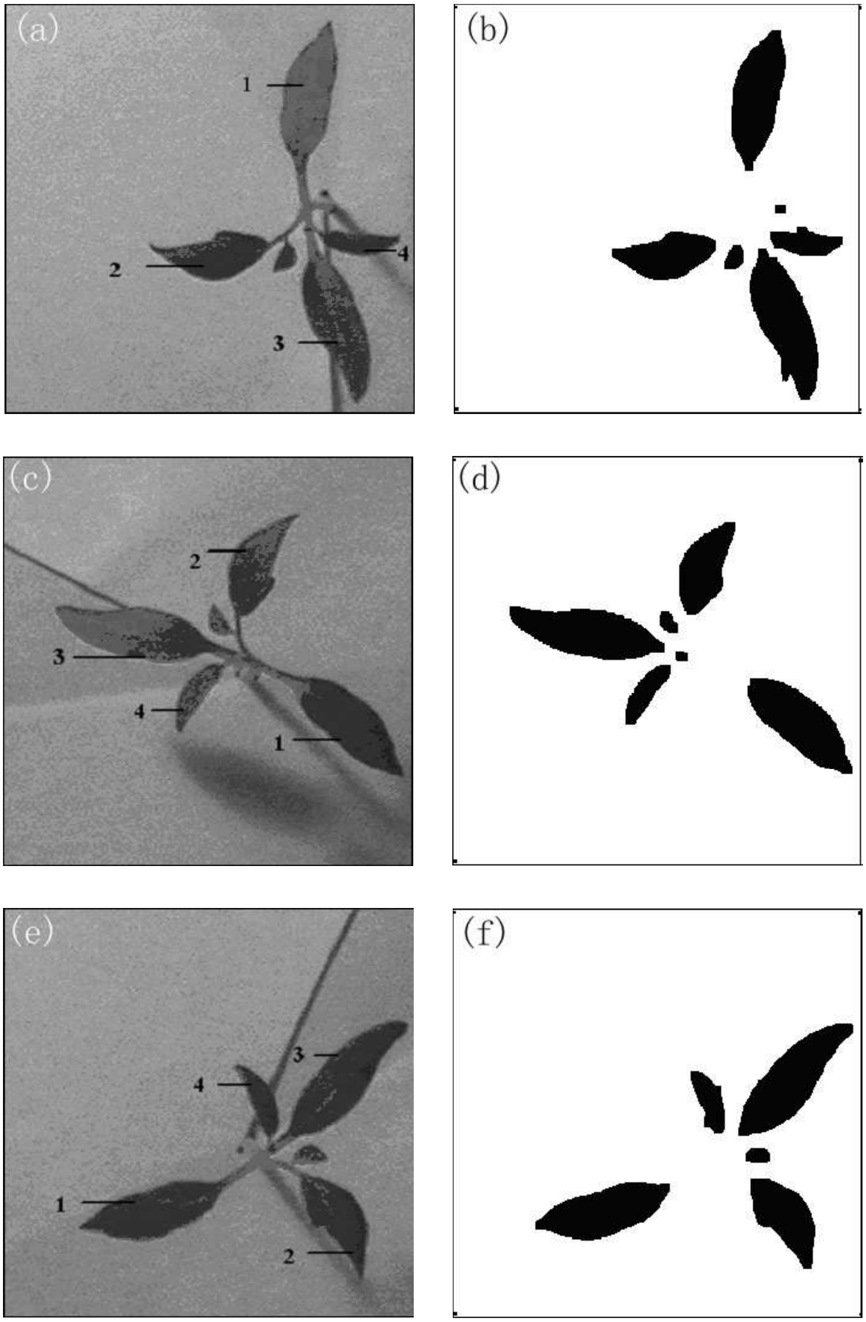

Figure 2 Color images and mages after the pretreatment of the same seedling

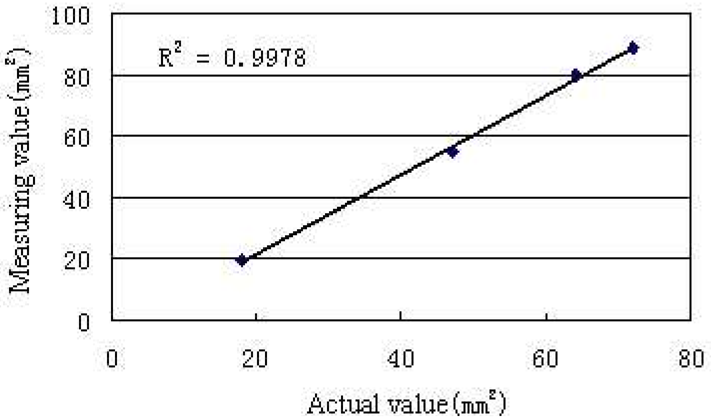

Figure 3 The relationship between the measuring values and the actual values

Analysis of the measurement result

When the leaves are measured by machine vision system, because of the influencing factors (the shooting angle, the shadow caused by the lamp-house and the image processing algorithm), some declinations still existed. So the data from 18 leaves from 9 seedlings in different periods are referred to discuss the influencing factors.

By analyzing the correlation, we find that the correlation coefficient of the measurement of the seedlings in early days is rather small, which were 0.6-0.8. With the growth of the seedlings, the correlation coefficients of the measurement of the tomato leaves are largely enhanced when they extend and still do not overlap each other, which were over 0.9. The biggest correlation coefficient reaches R^2=0.9822, and the average correlation coefficient after continuous measurement is R^2=0.8505. By analyzing the above-mentioned results, we find the following influencing factors.

The leaves of the tomato seedlings in the early days of growth are rather small. The numbers of the pixels are largely influenced after the image processing, which refer to the used erosion process to cut off the conjunction between two leaves and the used conditional expansion to resume the leaf area regions. At the same time, the phototropism of the seedlings made the obliquity of the leaves on some parts of the seedlings a little big. So the images photographed from the upright direction could not reflect actual size of the seedlings. As a result, the correlation coefficient of the actual value and the measuring value is rather small. But as the angle of leaves and the photographing angle are vertical, a relatively preferable correlation can be obtained.

By analyzing and summarizing the influencing factors in the process of the non-destructive measurement, we can find that: The influence of the shadows can be reduced by improving the illumination conditions. The incline of the seedlings caused by the phototropism also can be reduced by illuminating the seedlings from different angles. The influence of the image morphologic process can be reduced by controlling the numbers of the image erosion and the image expansion properly. So, when doing non-destructive measurement on the leaves of the tomato seedlings, we can obtain better correlation coefficient by using appropriate algorithms and controlling the measuring environment of the greenhouse properly.

CONCLUSIONS

As an example of the non-destructive test and measurement of growth of plants based on machine vision, this paper discusses the non-destructive measurement of the leaf areas of tomato seedling in the greenhouse. By using the non-destructive algorithm mentioned in this paper, we got the measuring data of the leaf areas, and did analysis in the correlation between the measuring value and the actual value. And we also discuss the factors, which influence the correlation. The smaller the leaves are, the bigger the errors become, which results in small correlation. With the growth of the seedlings, the leaves extend and still do not overlap each other, so the correlation coefficient becomes bigger. The biggest correlation coefficient reaches R^2=0.9822, and the average correlation coefficient reaches R2=0.8505. It indicates that the algorithm proposed in this paper can be used in the non-destructive measurement of the tomato seedlings.

Considering the results and the analysis, we should improve the surrounding environment in the greenhouse, especially the illumination, to reduce its influence.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Pregledni rad
Review paper

RECENT DEVELOPMENTS OF EARTH OBSERVATION TECHNIQUES FOR LAND AND WATER ENGINEERING

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SUMMARY

During recent years there has been much progress in understanding land surface-atmosphere processes and their parameterisation in the management of land and water resources. Earth Observations techniques in different regions of the electromagnetic spectrum have been used for about three decades to monitor land surface. Nowadays, these techniques are ready for being transferred to operative applications in the field of land and water engineering. In the same time, technological developments of new generation of remote sensors –with improved spatial and/or temporal resolution- provide the opportunity for new observational and modelling perspectives.

In this work, a brief overview of current techniques and recent developments for the management of land and water resources experienced by the University of Naples "Federico II" will be given, with particular emphasis to the following issues:

- *estimation of land surface parameters, i.e. vegetation cover and Leaf Area Index;*
- *estimation of water balance terms, i.e. evapotranspiration and crop water requirements.*

New techniques in the acquisition and processing of Earth Observation data may improve the accuracy of estimation of these parameters and terms, with great benefits for a better understanding and analysis of land and water resources.

***Key words**: Earth Observation satellites, water resources, evapotranspiration, Leaf Area Index.*

INTRODUCTION

The potentiality of Earth Observation techniques in supporting the management of land and water resources has been nowadays widely recognised. Twenty-five years of observations with the multispectral Thematic Mapper on board the Landsat satellites series have shown that is possible to detect land-use variations with great detail in many areas. Multi-temporal and multi-spectral classification techniques integrated with ground reference data may be applied to retrieve detailed land use mapping and agricultural inventories. In more recent applications, vegetation and soil cover maps are considered as basilar input for physically based models of land surface processes, i.e. used for water management at basin scale, for evaluating the impact of irrigation in large areas on the acquifer regimen or the analyse land-use in relation to run-off phenomena (Schultz et al., 2000).

As today, we have assisted two main developments: a) the availability of new generations of sensors, with enhanced spectral and spatial resolution and angular viewing possibilities; b) a detailed knowledge of the land surface processes through their mathematical description based on measurable parameters. These advancements have made possible a quantitative approach in the interpretation of data from remote sensing, diversely from more traditional applications focused on qualitative and descriptive information, such classification studies for land-use and land-cover mapping. Thanks to the improved observation techniques and the capability to analyse the reflectance behaviour of complex vegetated surfaces, it is nowadays possible to better characterize land surface processes by means of a better estimation of relevant parameters.

In the spatial analysis of hydrological processes, which are of particular interest for the management of land and water resources, there are two main fields of interest in using Earth Observation data:

1. estimation of *land surface parameters*, in particular the Leaf Area Index;
2. estimation of *water balance terms*, i.e. evapotranspiration and crop water requirements.

In this paper, we briefly report on recent experiences on these issues carried out at the University of Naples "Federico II" and their impact on operative applications of Earth Observation data.

METHODS (1): MAPPING LAND SURFACE PARAMETERS FROM E.O. DATA

Remote sensing from space - or Earth Observation (E.O.) - has shown its potentiality in the detection of land surface parameters characterising the status of vegetation, i.e. the Leaf Area Index *LAI* which has particular relevance in many land surface processes. Several studies have evidenced that the value of *LAI*, the leaf optical properties, their spatial distribution and orientation respect to the illumination and viewing angles affects the way the vegetated surface interacts with solar radiation i.e. the surface reflectance (Baret et al., 1991). For more than two decades, starting from the first E.O. satellite, the Landsat-1, up the latest very-high resolution sensors (2.8 m in the case of IKONOS), a feasible approach to estimate vegetation parameters, and in particular *LAI*, has been based on empirical relationships with nadir-viewing measurements of canopy reflectance in the red and infrared bands. This approach implicitly assumes that all other factors, except *LAI*, influencing the spectral response of canopy are fixed. Different types of Vegetation Indices, *VI*, have been defined to reduce the effects of soil reflectance variability. Despite the large effort in improving the performance of such empirical formula, this approach still present limitations, since it is site and sensor specific, it requires reliable ground reference data for calibration and it quickly saturate becoming insensitive to variations of *LAI* at high values (Gobron et al., 1997). Moreover, *VI* can not take into account that the canopy reflectance depends on the canopy structure (*LAD*, the leaf spatial distribution, row orientation, and spacing), leaf and soil optical properties, sun-target-sensor geometry (Bacour et al., 2002). More recently, physical approaches based on the application of canopy reflectance models (CR) allow to take into account all the vegetation characteristics influencing the spectral response. The development of new remote sensing platforms and sensor capabilities with simultaneous multi-directional observations (e.g., MISR, POLDER, CHRIS/PROBA), together with advances in canopy reflectance modelling (Chopping 2000; Verstraete et al., 1990) can better characterize the anisotropic reflectance behaviours over vegetation canopies and improuve the estimation of land surface parameters such as *LAI* and surface albedo (hemispherically and spectrally integrated surface reflectance).

The satellite PROBA carrying on-board the spectral imager CHRIS offers the unique potential to acquire at high spatial resolution, spectral and directional data sets and, from these, to study the biophysical and biochemical properties of vegetation canopies. The University of Napoli Federico II has taken part to the SPARC campaign, organised by the European Space Agency in the agricultural site of Barrax (N30°3', W2°6'), in the La Mancha region of Spain, during July 2003 and July 2004. The land cover was dominated by large, uniform stands of alfalfa, corn, sugar beet, onions, garlic and potatoes. Around 35% of the area was irrigated while the remaining 65% was dry land. Hyperspectral, multiangular images were acquired by CHRIS/PROBA on 12 and 14 July 2003 (minimum satellite zenith angle 19,4° and 27,6°) and on 16 July 2004 (minimum satellite zenith angle 8,4°). Five images with different view angles (along-track zenith angles – fig.1) and 62 spectral bands (from 410 nm to 1050 nm) per angle were acquired for each pass. The covered image area is 14 km x 14 km (748 X 748 pixels) with a spatial resolution of 34 m (fig.1).

During each campaign, intensive field non-destructive measurements of *LAI* were made in different types of crop by means of the digital analyzer Licor LAI-2000; this instrument, which represents a standard measurement in remote sensing field campaigns, was operated near dusk and dawn (to reduce the effect of multiple scattering).

Two different approaches have been selected in the retrieval of the *LAI*. In first instance, a semi-empirical approach based on the relationship between the Weighted Differences Vegetation Index *WDVI* and *LAI* was tested (Clevers, 1989). CHRIS/Proba images acquired from a view angle closer to nadir were chosen. The following equation, defined by was calibrated by using the field measurements:

$$LAI = -\frac{1}{\alpha}\ln\left(1-\frac{WDVI}{WDVI_{\infty}}\right) \qquad (1)$$

The $WDVI_\infty$ values, that is the asymptotical value of *WDVI* for $LAI \rightarrow \infty$, ranges from 64 to 68, while the average value of α resulted 0.47. The empirical relationship has been validated by using 40 independent field measurements. The RMSE ranges from 0.46 m^2m^{-2} (12/07) and to 0.59 m^2m^{-2}(14/07) calculated for all the crops in the study area.

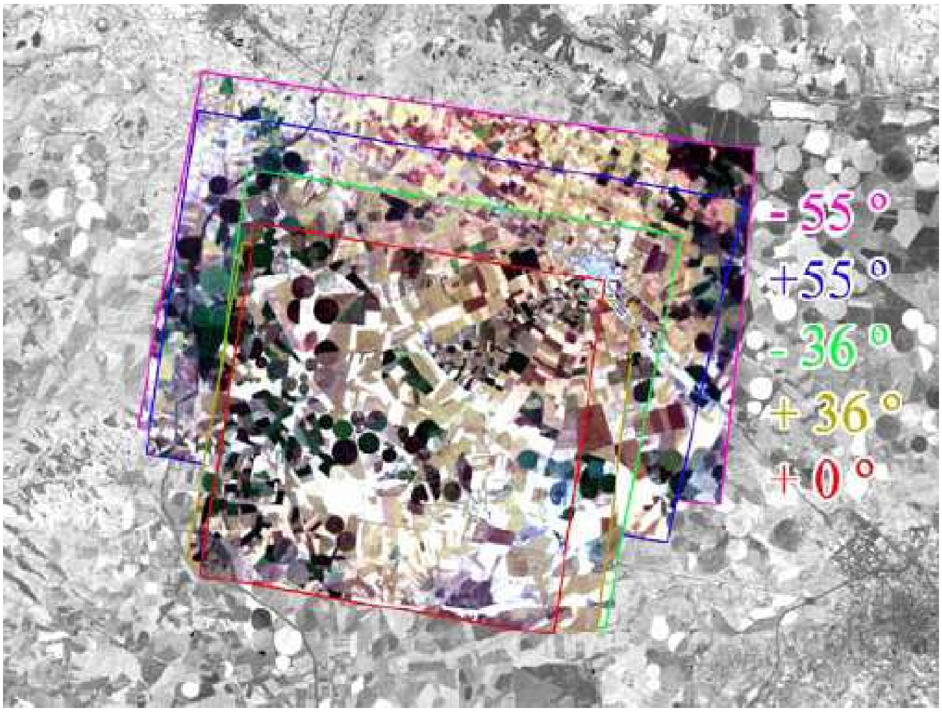

Figure 1 Multiangular CHRIS/PROBA imagery (14th July 2003)

The equation (1) has been applied by the author in several experimental sites and it has been proved to provide satisfactory results for most operational applications (D'Urso et al., 1999; Consoli et al., 2006).

Successively, the canopy reflectance model SAILH (Verhoef, 1984) has been numerically inverted by using CHRIS/PROBA observations as input data. An optimal set of spectral bands has been selected in the visible region (516- 685 nm), in the red edge (702- 769 nm) and in the infrared (776- 932 nm). The inversion procedure was applied to a wider range of crops (alfalfa, corn, potato, sugarbeet, onion and garlic) with different geometrical structure and biophysical proprieties. The RMSE, evaluated on 40 in-situ measurements of *LAI*, was in the range between 0.5 and 1.1 m^2m^{-2}. The results for different alfalfa fields are shown in Fig.2. The estimation error is similar to what obtained with the empirical equation (1), but with the difference that in this case no calibration data are required, at the cost of increased computing time and complexity.

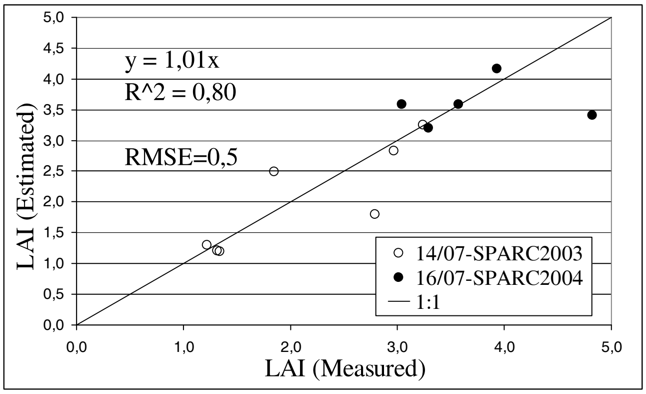

Figure 2 Measured vs estimated LAI for different alfalfa canopies (12 samples) from SPARC2003 and SPARC2004 CHRIS data

These results provide good evidence that multi-angular and hyper-spectral data may have real potential for estimating the Leaf Area Index of agricultural crops, without requiring intensive field data collection for calibration. In addition, the advantage of physically based models of canopy reflectance, such as the model SAILH used here may provide additional information on crop structure, leaf chlorophyll and leaf water content. Furthermore, from the knowledge of the bi-directional reflectance function of the canopy it is possible to estimate with greater accuracy the surface albedo ρ, required in several eco-physiological models and land-surface processes.

METHODS (2): ESTIMATE OF WATER BALANCE COMPONENTS.

The potential rates of transpiration and soil evaporation and the amount of intercepted precipitation are determined by vegetation cover on the soil surface and by the climatic parameters (solar incoming radiation R_s, air temperature T, relative humidity RH and wind speed U). The potential evapotranspiration ET_p (cm d^{-1}) from a canopy uniformly covering the soil surface may be estimated by using the well-known schematisation of Monteith, adopted in FAO-56 procedure (Allen et al., 1998). This approach requires the knowledge of the surface albedo, ρ, the leaf area index LAI and the crop height, h_c, which can be derived from the elaboration methods shown in the previous section. In this case, the calculation of canopy resistance is performed assuming a minimum value, i.e. 70 sm^{-1}, corresponding to potential conditions. As such, ET_p can be expressed as a function of climatic data and of a vegetation-dependent parameters:

$$ET_p = f\left(LAI, \rho, h_c; Rs, T, RH, U\right) \tag{2}$$

For canopies not covering completely the soil surface, the potential soil evaporation can be estimated from ET_p in function of LAI:

$$E_s = ET_p e^{-cLAI} \tag{3}$$

where c is an extinction coefficient. The potential transpiration rate is then derived as:

$$T_p = ET_p - E_s = ET_p\left(1 - e^{-cLAI}\right) \tag{4}$$

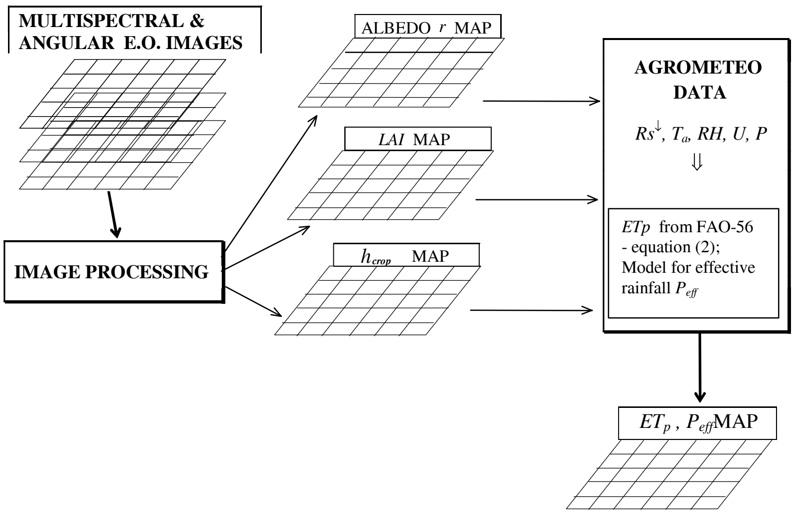

Figure 3 Conceptual framework for mapping ETp and Peff

Also the amount of intercepted precipitation is related to *LAI*, and different empirical approaches can be found in the literature (Liu, 1996). Thus, the maps of potential evapotranspiration and intercepted rainfall can be obtained from E.O. data by means of the procedure sketched in Fig.3.

This approach has been validated in an irrigated alfalfa field in southern Italy by comparing flux measurements carried out by means of a Bowen-Ratio instrumentation and ET_p data derived from the elaboration of Landsat images (D'Urso et al., 2006).

From the knowledge of ET_p and P_{eff} it is possible to derive maps of crop water requirements at the same spatial resolution of E.O. data. This approach has been used by the author in a study-area in southern Italy also to define the upper boundary condition in the application of a one-dimensional soil water balance (D'Urso et al., 1999).

In a recent EU project – DEMETER (Osann Jochum et al., 2006)- a similar methodology has been implemented to support the management of water resources at two different levels: 1) district management; 2) farm management. In the first case, by combining GIS tools with the methodology outlined above, it is possible to estimate the total water demand W_{irr} for an irrigation district represented by a set of parcel of area A_i, each one characterised by an irrigation efficiency η_i:

$$W_{irr} = \sum_{i=1}^{n} \frac{\left(ET_{p,i} - P_{eff,i}\right) A_i}{\eta_i} \tag{5}$$

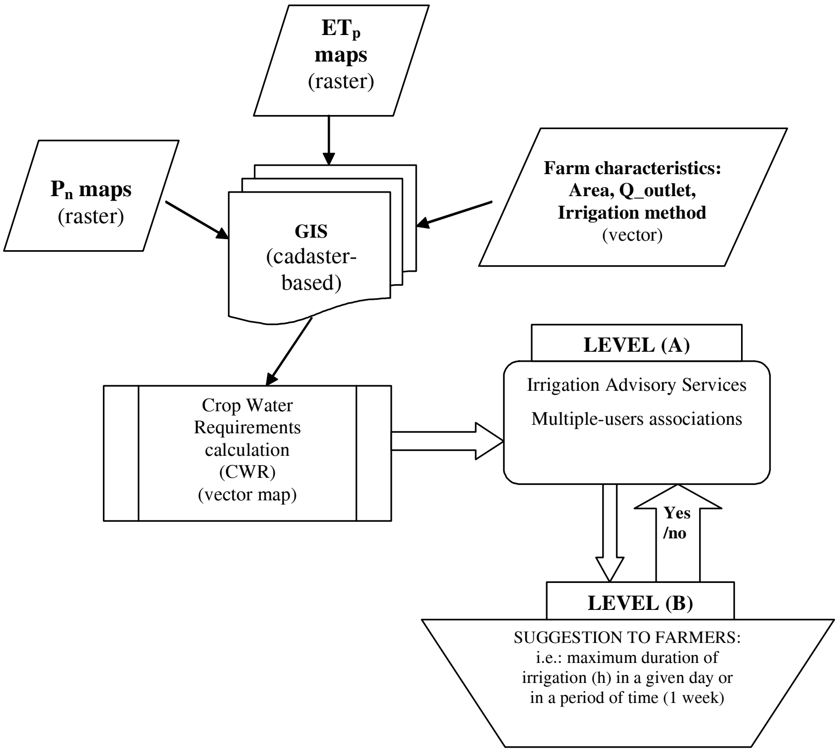

Figure 4 Schematization of the procedure adopted to derive crop water requirements from multiple source data.

A sketch of the procedure is shown in fig.4. This methodology will be applied in different irrigated areas in southern Italy for the project AQUATER (Rinaldi et al., 2006).

OPERATIONAL ASPECTS FOR THE UTILISATION OF E.O. DATA IN WATER MANAGEMENT.

An important aspect in the operational utilisation of E.O. data is the distribution of timely information products to the final users. Within the EU-funded DEMETER project a prototype procedure has been developed in an operative context in three irrigation districts in Italy, Spain and Portugal.

Basic and advanced products, such as evapotranspiration and crop water requirements maps, based on satellite images and personalized for each farm and each parcel have been delivered by using new Information Technology media. Weekly reports were generated and sent to the farms by SMS, MMS and E-mail. Generally, the reports were available to the farmers in less than 24 hours after satellite acquisition, depending on satellite images providers, in the following two formats: (1) simple text report and (2) standard report. The first was used to generate simple text SMS, including the parcel code and the water required. The second sent by MMS and email as a jpeg image showed the parcel variability in a color combination image and an evapotranspiration map (Fig.5).

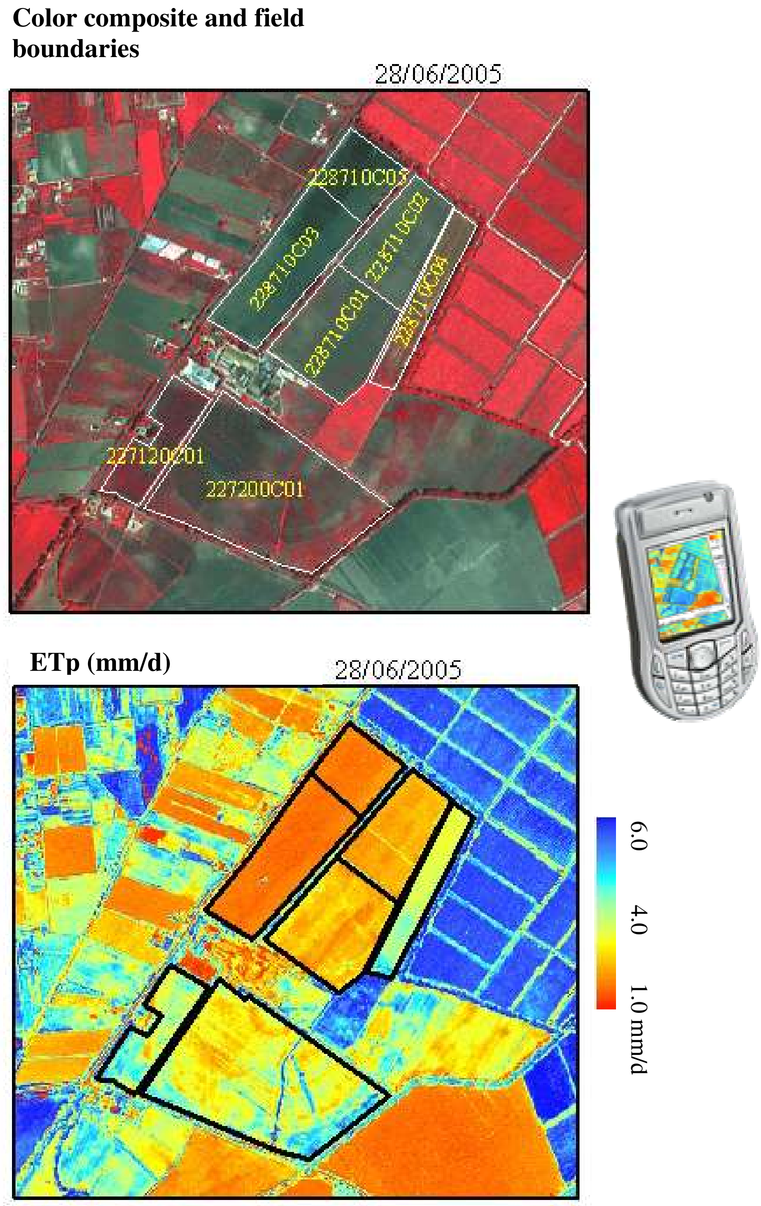

Figure 5 Example of information distributed to farmers via MMS (mobile phones) and E-mail: colour composite derived from IKONOS images (2.8x2.8 m) and maximum evapotranspiration map for a period of 4-7 days around the acquisition date

The data were managed by the users autonomously for the irrigation scheduling and, if necessary, they were approached individually to provide a more personal assistance with direct face-to-face contact.

In order to provide weekly information, multi-sensor data were acquired from different satellites i.e. Landsat-5-TM, SPOT constellation and IKONOS. The acquisitions were planned in such a way that it was possible to achieve a revisit time between 7-10 days. Capability of re-scheduling the satellite acquisition plan and the possibility to find alternative sources of E.O. data was also explored before the campaign and taken into account in order to overtake possible technical problems due to image acquisition failure or for not suitable weather conditions during satellite overpass.

CONCLUSIONS

From the experiences briefly presented here, it is possible to conclude that the improvements in the spatial and radiometric accuracy of new sensors and the possibility of multiple-angle simultaneous observations allow for a more accurate estimation of variables involved in the study of land surface processes. Apart from these new perspectives in front-end research, experiences such as those presented in this paper are already transferable to applications in the management of water resources, as shown by the prototype developed in Demeter for supporting water management in irrigated areas, and ready to be implemented in different environments.

New space-born platforms will become operational more and more frequently and constellations of small satellites operated by private companies will be booming during the next few years. Super-spectral and high resolution data are already becoming available at lower costs. Thanks to the development of the Web, the time lag between satellite acquisition and availability of data to the final user has sharply decreased.

It is not difficult to positively assess the “cost-benefit” effectiveness of using E.O. data in operational contexts, with tangible benefits for a better management of land and water resources.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631. 165:635.07
Stručni rad
Expert paper

POČETAK PRECIZNE POLJOPRIVREDE U HRVATSKOJ NA BAZI KARTE PRINOSA

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SAŽETAK

U radu su prikazani rezultati i naravno iskustva prvog elektroničkog kartiranja u Republici Hrvatskoj obavljenog tijekom žetve uljane repice 2006. godine na površinama firme Kutjevo d.d., Ratarstvo i Stočarstvo-Ovčare.

Ključne riječi: *Elektroničko kartiranje uroda, precizna poljoprivreda, žetva, uljana repica*

UVOD

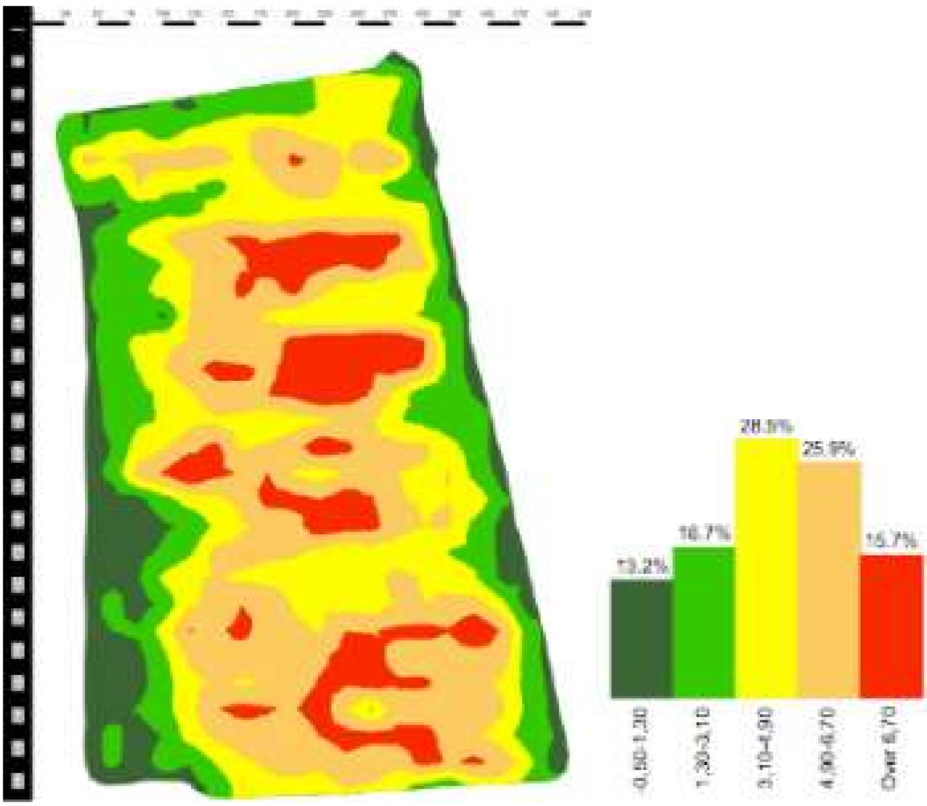
Prvim korakom, tzv. stvaranjem elektroničkih karata uroda-prinosa smo ovladali.

Koraci precizne poljoprivrede su:

1. skupljanje podataka i izrada karata:
   - površine table, radi se jednom, ukoliko se ne mijenja
   - opskrbljenosti hranjivima uzimanjem uzoraka tla, od jedne do 5 godina,
   - kontrola Nmin ili Hydro N senzorom, ovisno o načinu obrade tla, svake godine
   - utvrđivanje pH vrijednosti, prije svakog dodavanja vapna (svakih 3-5 godina), te
   - karta prinosa, svake godine
2. obrada podataka unošenjem podataka u kartu s rasterom, tj. poljem podijeljenim na kvadratiće i različitim doziranjem gnojiva i zaštitnih sredstava prema plodnosti svakog kvadratića površine,
3. korištenje podataka za program gnojiva i/ili zaštite, te
4. dokumentiranje i pohrana podataka.

Postupci uvođenja Precizne poljoprivrede usmjereni su na snimanje karte prinosa, kao indirektnog pokazatelja efektivne plodnosti po dijelovima tabli snimljenih istovremeno s žetvom. Prva slika pokazuje da se pojedini dijelovi table jako razlikuju po plodnosti i izgleda kao tigrova koža. To je uočljivo opažanjem iz zraka, tj. iz aviona pri niskom letu kod prihranjivanja i prskanja. Najviše je na ujednačavanju plodnosti tabli učinio dr.sc. Mijo Sabolić, tvrtka Poljodar-TIM u Daruvaru, iako ima jedna od najtežih tala za obradu u Hrvatskoj, oteta od rijeke Ilove. Zahvaljujući upravo ujednačavanju plodnosti tabli postiže rekordne prinose, ravne najboljim svjetskim rezultatima, što ne ide bez preciznih postupaka u obradi i gnojidbi. Kako je Mijo Sabolić pilot ima mogućnost i nadzora svojih njiva iz zraka. Stoga on detaljno poznaje svaku stopu svoga gospodarstva, jer njive gleda iz zraka, obilazi ih u svim fazama porasta bilja, a uz to i redovito kontrolira sadržaj hranjiva u tlu.

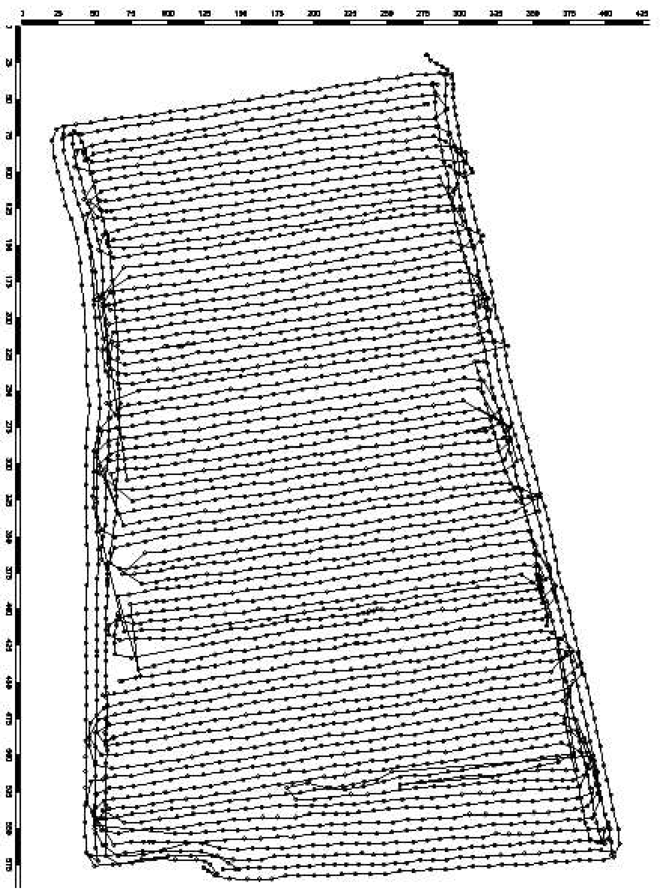
Precizna poljoprivreda je relativno novo područje, no zahvaljujući intenzivnom razvoju elektronike danas je dosegla punu primjenljivost i nismo zakasnili s primjenom ako krenemo odmah. Prvim koracima je već ovladala tvrtka Kutjevo d.d., pod vodstvom dipl.ing. Kazimira Đakovića. To su mu omogućila dva kombajna Claas Lexion 580 s tvornički ugrađenom opremom. (Oba kombajna umjesto prednjih guma imaju gumene gusjenice).



Slika 1 Elektronička karta uroda uljane repice na parceli Donji Grabovac

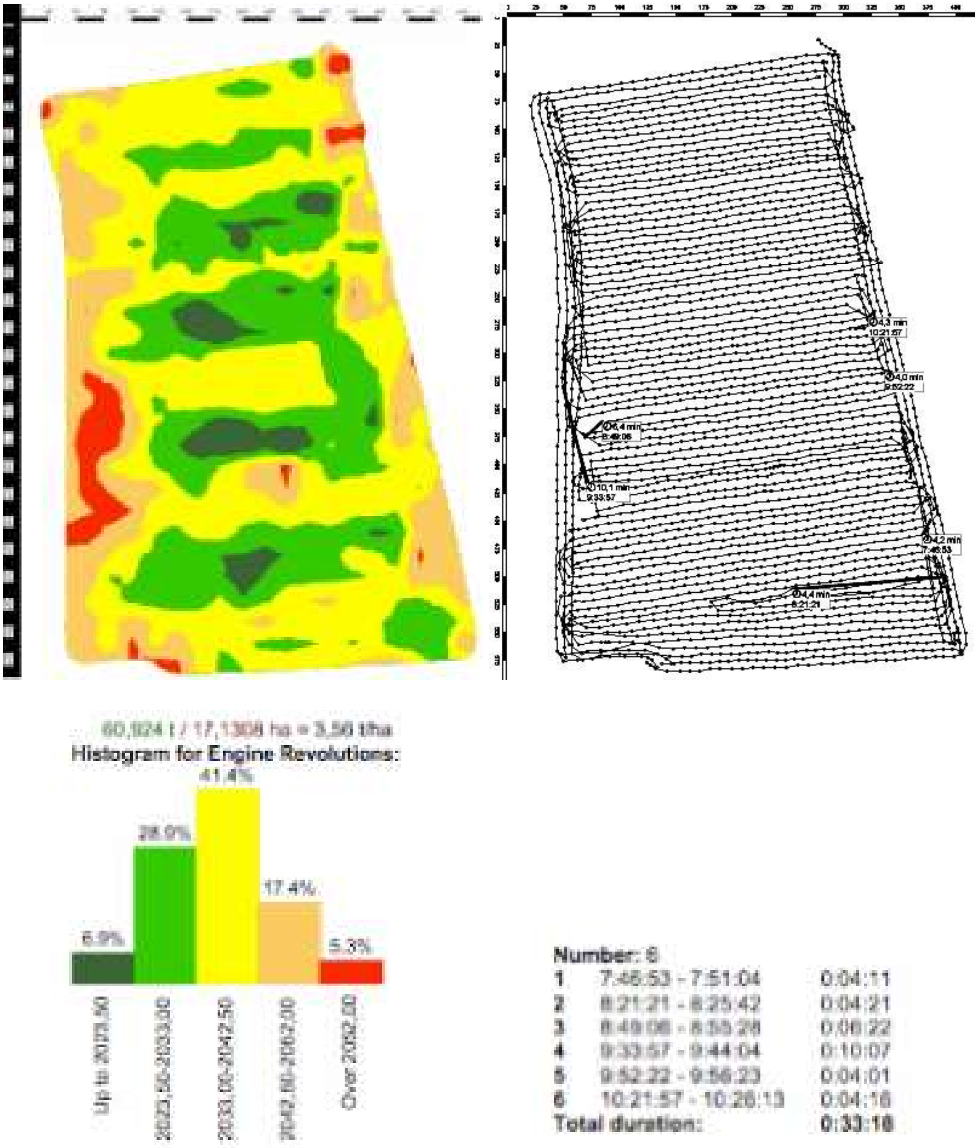
Koristi od izrade karte prinosa su:

- identificiranje razlika prinosa unutar polja (table, njive)
- mogućnosti za ciljano ispitivanje
- točnost nedostatka hranjiva tamo gdje je nizak prinos
- utvrđivanja točne sabijenosti tla
- uočavanje problema dreniranja
- bilježenja i unošenja u kartu zakorovljenosti
- spoznavanje što treba učiniti
- posluživanje izrade karte uroda, karte plodnosti
- potpora odluci: davanje nužne potpore Preciznoj poljoprivredi.

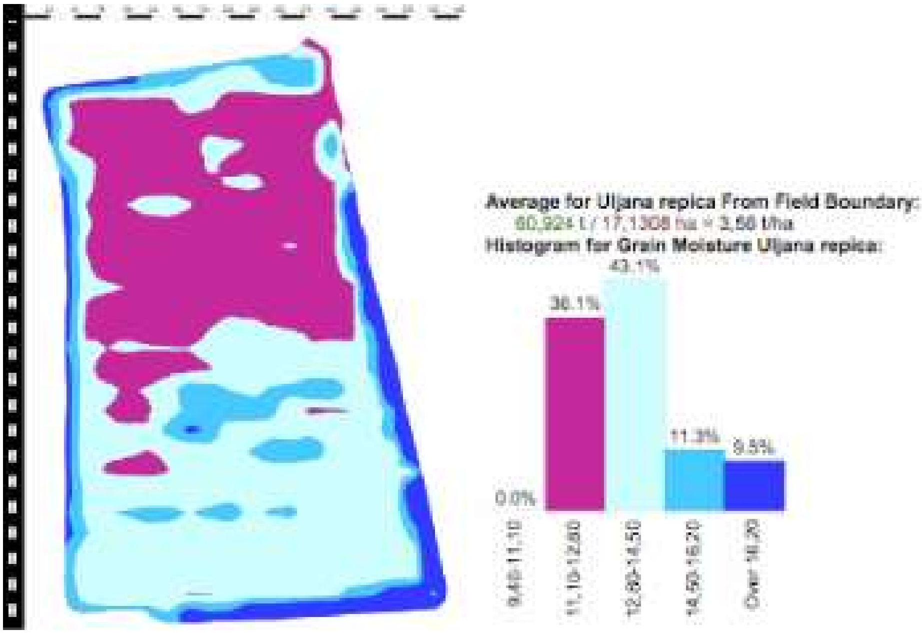


Slika 2 Elektronička karta kretanja kombajna u žetvi

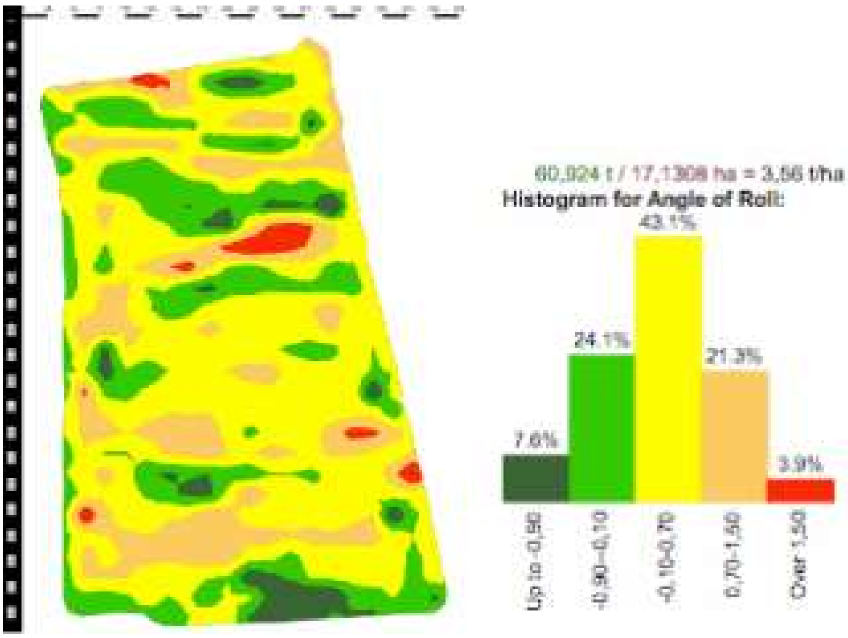
Na drugoj slici iscrtana je putanja kretanja kombajna. Prva tri prohoda su oko table da bi se oslobodio prostor za kretanje. Na ovoj slici moguće je uočavanja racionaliziranja vršidbe, počevši od izbora smjera kretanja kombajna, do uočavanja preklapanja prohoda i potrebe uvođenja tzv. paralelnog vođenja s prvim prohodom, pri čemu bi se uštedjelo oko 10 % vremena.



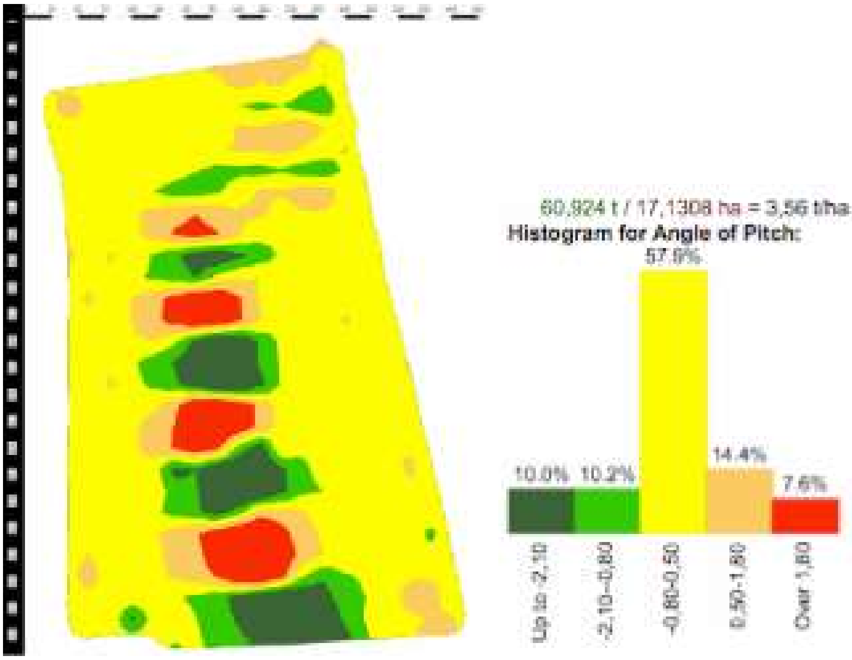
Slika 3 Elektronička karta rada, zastoja i kvarova kombajna



Slika 4 Elektronička karta varijabilnosti vlage zrna uljane repice



Slika 5 Elektronička karta poprečnog mikroreljefa table



Slika 6 Elektronička karta uzdužnog mikroreljefa table

KAKO SE RAZVIJAO SUSTAV MJERENJA URODA

Karte plodnosti tla pokazuju mjesta na kojima treba uzeti uzorke tla za ispitivanje. Do sada se to određivalo na bazi izviđanja terena i zapažanja, ili se površina podijelila na geometrijski pravilne dijelove i uzimali uzorci.

Od ideje do razvoja korisnih instrumenata prošlo je četvrt stoljeća. Danas je to moguće zahvaljujući istraživanjima i razvoju od 1980. g. prikazanom u narednom pregledu.

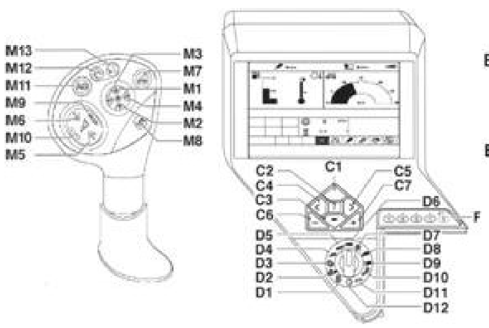
- 1980 prijavljen je prvi "patent" mjerenja uroda (prinosa) korištenjem snopa svjetla
- Claydon (UK): mjerenje uroda s Mjeračem uroda (Claas Dominator)
- 1987 Schueller et. al.: (USA) lokalno mjerenje s Mjeračem uroda kombinirano s položajem
- 1988 Larson et. al. (USA): mjerenje površine polja Global Positionihg System-om (GPS)
- 1991 Auernhammer (D): prvo mjerenje uroda pri vršidbi kombajnom pomoću DGPS
- 1991 Claas & MF zajednički kartiraju prinos
- 1995 ACT s Quantimetrom (snopom svjetla) prilagođenom za kombajn

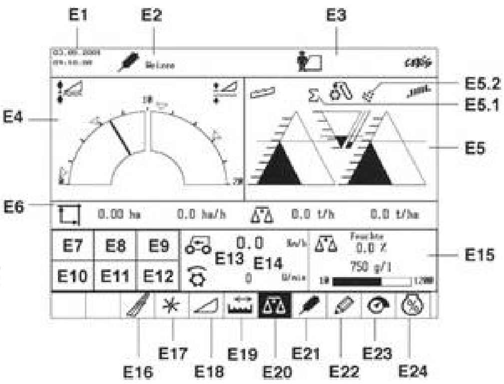
- 1996 Quantimetar kao opcija, neobavezna ponuda uz kombajn Claas Lexion (CEBIS)
- 1997 Agro.map software za mjerenje uroda
- 1988 početak integriranja Sistema precizne poljoprivrede s ACT, to jest sa sistemima Agro-Soil, Agro-Line, Agro-Tag, Agro-Map
- 1999 Agro-Map potpuno primjenjiv za Preciznu poljoprivredu (Precision Farming)
- 2000 Quantimetar pregled za Claas Lexion
- 2001 Pokrenut Agro-Map
- 2002 U tvornici se ugrađuje modul za kartiranje prinosa na Claas Lexion 480
- 2003 Modul kartiranja uroda za Agro-Net NG
- 2004 Od tada se integriraju Precizna poljoprivreda i Agro-Net NG

ŠTO JE CEBIS?

Na kombajnima Claas ugrađena je oprema CEBIS, što je kratica od prvih slova Claas Elektronische Bord Informationssystem (Classov elektronički informacijski sustav na pultu). CEBIS daje odvojeno, rasčlanjeno: sliku vožnje kombajna po tabli (što prikazuje druga slika), sliku žetve u meniju GPS-a, omogućava pred podešavanje vitla, pred podešavanje žetvenog uređaja, unošenje radnog zahvata, podešavanje prema vrsti kulture, mjerenje prinosa, mjerenje vlage zrna, registriranje broja okretaja motora, nagibe terena po kojemu se komgajn kreće i za svaki od ovih mjerenja daje odvojene podatke, njihov grafički prikaz i ispis kakav je prikazan na prve dvije slike.

Proizvodnja i uvođenje ove opreme izdvojena je u tvrtku Agrocom. Naravno mjeri se i vrijeme kao i kalendarsko, što je osnova za proučavanje brzine kretanja, prijeđenog puta, te uz upisani radni zahvat i učinak kombajna. Meni (Menu) je s pod-menijima podijeljen na više ravnina, a u ispitivanom slučaju to je osam ravnina.

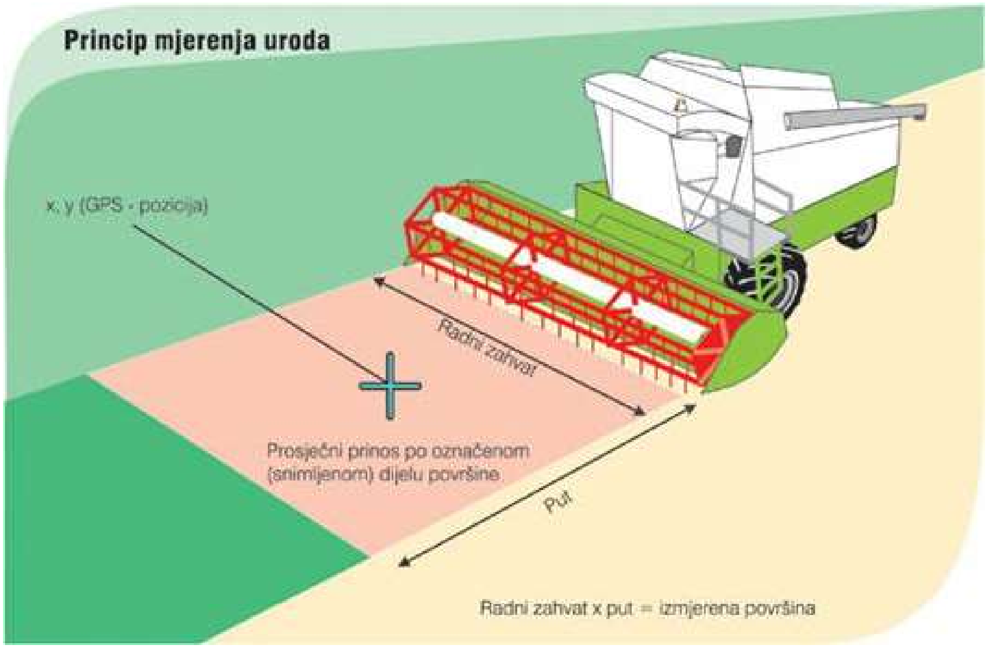




Slike 7 i 8 Prikaz nadzorno-upravljačkog uređaja u kabini kombajna

Dvije slike koje su u vidnom polju vozača kombajna pokazuju čime on sve upravlja, tj. koje informacije ulaze u sustav. Ovdje ne obrazlažemo detalje, jer to se čini kod obučavanja rukovatelja. Polazi se od okretnog šaltera D (lijeva slika). Ako je u položaju D6 pokazuje se na ekranu Meni lista, a vozač preko tipki "C" može pozvati na 10" (25,4 cm) ekran pojedine pod-menije i pomoću + i - tipki podešavati vrijednosti. Okretanjem šaltera "D" poziva se npr. na D 1 = broj okretaja bubnja, D 2 = broj okretaja ventilatora, D 3 = zazor na ulazu korpe u mm, D 4 = osjetljivost, kontrola protoka kroz sita D 7 = otvorenost gornjih sita a D 12 = kontrast na ekranu.

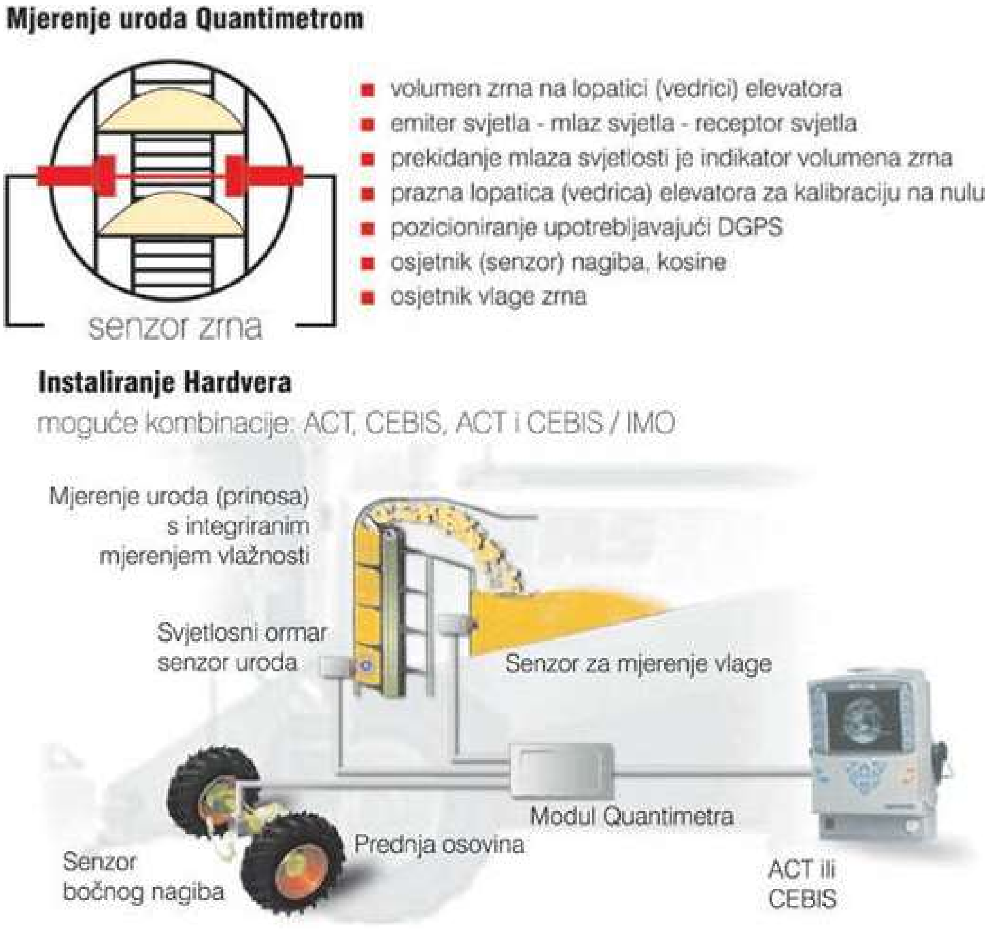
Naredne dvije slike objašnjavaju funkcioniranje snimanja putanje kombajna pomoću GPS sustava, koji se inače koristi u prometu vozilima, kretanju aviona i brodova, a najprije je bio korišten u ratne svrhe. Prinos na mjestu vršidbe utvrđuje se na osnovu brzine, to jest prijeđenog puta za četiri sekunde u kojemu se mjeri količina uroda i radnog zahvata. Taj prinos se "upisuje" točno na tu površinu i unosi u kartu table. Prinos se naravno baždari, to jest kalibrira za pojedine kulture, a na osnovu vaganja prinos uhvaćenog u bunker kombajna. Odstupanja prinosa mogu biti vrlo ma, ispod 0,5 %, što međutim i nije presudno za uočavanje razlika u plodnosti (pogledaj prvu sliku).



Slika 9 Određivanje položaja stroja u prostoru, pređenog puta i stvarnog radnog zahvata

Preciznost lokacije koja se utvrđuje signalima s najmanje tri, a redovito sa četiri satelita i s poznatom referentnom točkom na zemlji je vrlo visoka. Za geodetske potrebe ona je u granicama svega jednog milimetra, a za potrebe rada kombajna i traktora s priključcima zadovoljavajuća preciznost je pet do deset centimetara.

Prikaz instaliranja Hardvera preuzet je iz dokumenata za obuku u kartiranju prinosa kombajnima pomoću CEBIS-a. Slike govore same za sebe dovoljno, a u tome je važno da je to oprema koja se kupuje i samo ju treba naučiti koristiti.



Slika 10 Mjerenje uroda i vlage zrna

ISPLATI LI SE UVOĐENJE OPREME KAO ŠTO JE CLAAS CEBIS?

Sa sustavom i njegovim mogućnostima se najprije trebaju upoznati voditelji posla na većim gospodarstvima, organizatori proizvodnje u Zadrugama, kao i davatelji usluga. Momentom uvođenja kartiranja plodnosti tla mora se promijeniti i organizacija rada. Sada kombajn, osim svojih primarnih funkcija žetve, vršidbe, iznošenja uroda iz table, te sječke i raspodjele slame, postaje instrument. U tome važnu ulogu ima računalna podrška, koja odmah daje obrađene podatke za sve do tada izvedene postupke i omogućava njihovo prenošenje u kućno računalo na daljnju obradu i pripremu čipova za primjenu kod gnojidbe i zaštite bilja.

Cilj izrade karte plodnosti je upoznavanje tla na svakom dijelu table. Nakon laboratorijskih ispitivanja uzoraka tla (fizike i kemije tla) utvrđeni su uzroci niže plodnosti na dijelovima table u odnosu na najvišu plodnost na poznatim dijelovima table. Možda se i na najboljim dijelovima table može stanje plodnosti poboljšati. Prva slika pokazuje da je na 15,7 % površine snimljene table urod repice bio iznad 6,7 t/ha, a da je prosječni prinos bio 3,56 t/ha. Rubni dijelovi table imali su vrlo nizak prinos, što odmah ukazuje na potrebu utvrđivanja razloga – zašto?

ZAKLJUČAK

Za primjenu Precizne poljoprivrede na bazi izrade karata neophodno je kupiti opremu i naučiti ju koristiti. Ova oprema odmah otkriva prinos na mjestu vršidbe, odstupanja od najvišeg prinosa, daje podatke o vlazi zrna po dijelovima table, učinku kombajna u neto radu (pokazuje kakva je organizacija rada) itd. Ova oprema je neusporedivo zanimljivija od bilo koje druge opreme, a ne opterećuje rukovatelja kombajnom. Pače, olakšava mu podešavanje naprijed naznačenih funkcija kombajna.

U razvijenim zemljama prosječni prinos uljane repice je iznad 4,9 t/ha i na toj osnovi se kalkulira s proizvodnjom bio dizelskog goriva. Već ovdje obrađeni primjer pokazuje da su prinosi i iznad 6 t/ha zrna uljane repice mogući i kod nas, ako se ujednače površine na razini najboljih dijelova tabli. U tome poslu najbolje može pomoći izrada karti plodnosti pri vršidbi.

Nedopustivo je odlaganje korištenja mogućnosti, koje u ovom slučaju pruža CEBIS. Ima i drugih mogućnosti, a ovdje je prikazan primjer čije rezultate već koristimo.

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FIRST STEPS OF PRECISION FARMING IN CROATIA ON THE YIELD MAPPING BASIS

SUMMARY

The paper presents results and experience of first yield electronic mapping performed in Republic of Croatia. The mapping was carried out 2006. in oil seed rape harvesting at fields of Kutjevo d.d., Arable & Livestock production Ovčare.

Key words*: Yield electronic mapping, precision farming, harvest, oil seed rape*

35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 004.9
Prethodno priopćenje
Preliminary communication

CONSIDERATIONS REGARDING THE CORRELATION BETWEEN EXPERIMENTAL TESTS AND MATHEMATICAL MODEL

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ABSTRACT

An important step of the any experimental research carried out consists in the mathematical evaluation of the results. In this respect, the mathematical models which describe the test assure a complete evaluation of the observed process of phenomena.

In order to increase the ability of the test evaluation, an own compute program was design by the author using MathLAB software.

The program assure a complete statistical evaluation of the measured values (until 9999 values) by the statistical calculated parameters (mean, mode and standard deviation) are used for cheek the appropriate distribution functions which describe with accuracy the phenomena (exponential, Gauss, Weibull, etc). The concludence of the test is evaluated using the Gamma and Student evaluation model.

The input of initial values can be made by the operator or from a data file with extension txt. The output results will be displayed as values (in table format) or graphic, depending by the operator's option.

This program was test for evaluate the experimental results for the laboratory test carried out in order to evaluate the cleaning process efficiency.

Keywords: *test, cycle, distribution, Weibull, statistic, parameters.*

INTRODUCTION

Any natural or physics phenomena can be describe by a mathematical model. The model shows the tendencies of the modification in time of the observed life work of the test carried out. Based on the probabilistic theory the applied mathematics used with generosity the models able to describe the tendencies of the tests phenomena. Usual the probability is used for reliability evaluations. Also for evaluate some experimental tests this theory may be used as an application for evaluate experimental results.

In order to evaluate the laboratory carried out tests the theory provides some mathematical distributions relations. Most common which assure complete evaluations are: exponential, Gauss Laplace, Weibull and Gamma. All of them make the link between failure rate and the survey probability. Associate with this mathematical probabilistic distribution a generous statistic evaluation must be done, in order to evaluate the relevance of the experimental results.

At the moment, most common software are used in order to evaluate the reliability distribution rate, promoted by RELIASoft, RINO and other companies. A complete soft designed for evaluate the reliability of live cycle of systems and its compound parts is Weibull 7++. The power of the soft consists in it the possibilities to evaluate and verify the assumption distribution function according to the statistic tendency of the considered values.

In order to evaluate and verify the relevance of the estimation, some tests as: Chi Square or Student confirm with more confidence the quality of the evaluation.

An important step consists in a data results collected realistic statistic evaluation of the. In this respect a complete statistic evaluation of the data by tendencies of grouping and the frequency of data distribution represent the most appropriate possibility to perform a correct evaluation.

THEORETICAL ASSUMPTION

As we mention in the first chapter, a correct data statistic evaluation is able to assure a correct distribution function of the carried out tests.

According with the statistic math, the tendencies are evaluated by mean of the events and standard deviation of the events. Bout statistic parameters are described with the relations:

$$m = \frac{1}{N}\sum_{i=1}^{N} x_i \tag{1}$$

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(x_i - m\right)^2} \tag{2}$$

If the mentioned statistic parameters give us information regarding the quality of the collected data, the others statistic characteristics of the distribution of the events inform us about the tendency of the evaluated events.

The Probability Density and Cumulative Distribution Functions Designations are able to offer general information regarding the most appropriate distribution function according with the probability of the event happened (fig. 1).

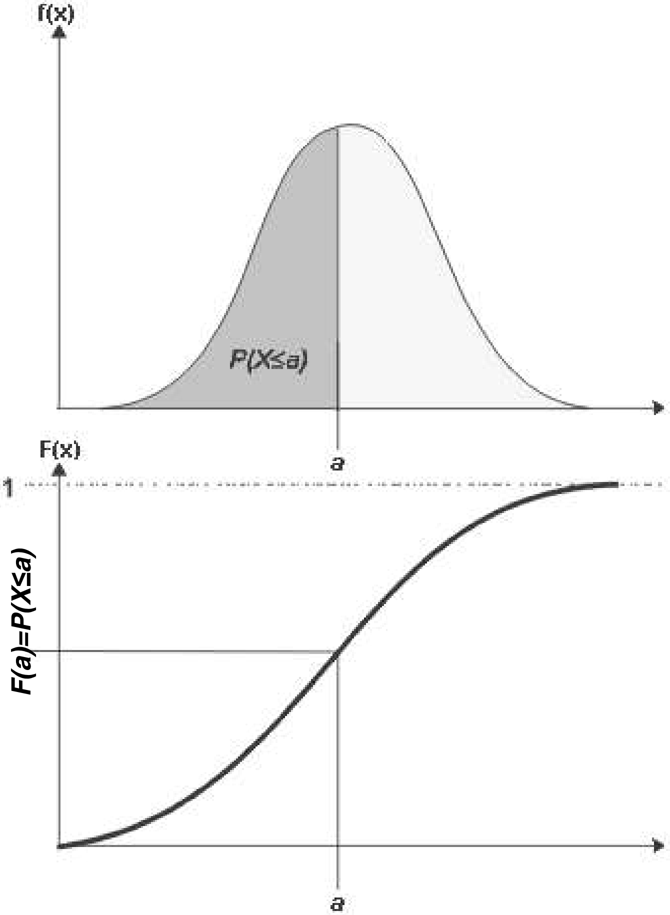

Fig. 1 The distribution function (up) and cumulative distribution of the failures (down), example for normal reliability distribution

In fact bout two statistical functions represents a first distribution approximation, because, the probability density represent by applied math point of view the probability density of the failure (noted with *f(t)*) and the cumulative distribution function (noted with *F(t)*), represent the distribution of the failure.

This assumption was confirmed by probabilistic relation of the considered parameters. In this respect, for Failure distribution function, the probability is give by relation:

$$F(x) = P(X \le x) = \int_{0,-\infty,\gamma}^{\infty} f(s)\,ds \tag{3}$$

where the started point of the evaluation can be the start point of test (0 value), or the entire life cycle of the estimated object, or an other considered point.

For Weibull distribution, we accept the assumptions given by two parameters function [1].

Assuming the theoretical basic equation which the reliability indicators:

- reliability function *R(t)*

$$R(t) = e^{-\left(\frac{t-\gamma}{\eta}\right)^{\beta}}, \tag{4}$$

where: *t* is the variable depending with the time test cycle;

γ is the location parameter;

η is the scale parameter;

β is the shape parameter.

The fault function is:

$$F(t) = 1 - e^{-\left(\frac{t-\gamma}{\eta}\right)^{\beta}} \tag{5}$$

the density probability of time work function:

$$f(t) = \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1} e^{-\left(\frac{t-\gamma}{\eta}\right)^{\beta}} \tag{6}$$

- the rate of fault function is:

$$z(t) = \frac{\beta}{\eta}\left(t - \gamma^{\beta-1}\right) \tag{7}$$

- mean time between failure functions:

$$m = \gamma + \eta\Gamma\left(1 + \frac{1}{\beta}\right) \tag{8}$$

THE ALGORITHM DESCRIPTION

Using the statistics basic parameters obtained from the data evaluation, a mathematical algorithm was proposed in order to evaluate the probabilistic tendencies of the carried tests.

Special attention needs the Weibull distribution in order to obtain the characteristic parameters β and γ.

Considering the basic of the solve procedure proposed by Baron, for two parameters Weibull distribution, the authors describe a program for evaluate the reliability tests [1].

The application described by Baron and used as a basic concept in this work, consist in evaluation of the reliability test results in accordance with Weibull distribution. According with the theoretical assumption, usually, the η scale parameter is in must evaluations neglected, due to it loss influence when it is approximate at value one.

For estimate the distribution γ and β parameters, the follow equation system was considered:

$$\begin{cases} \sum_{i=1}^{n} y_i = n \cdot a + \beta \sum_{i=1}^{n} \lg(t_i) \\ \sum_{i=1}^{n} y_i \cdot \lg(t_i) = a \cdot \sum_{i=1}^{n} \lg(t_i) + \beta \cdot \sum_{i=1}^{n} (\lg(t_i))^2 \end{cases} \quad (8)$$

where:

$$\sum_{i=1}^{n} y_i = \sum_{i=1}^{n} \lg\left(\lg \frac{1}{R_i(t)} \right) \quad (9)$$

For simplify the equation in order to create compute gates for the program, the system (6), was re-write as:

$$\begin{cases} A = n \cdot a + B \cdot \beta \\ C = B \cdot a + \beta \cdot D \end{cases} \quad (10)$$

From the last equation system, the parameters which describe the Weibull distribution are calculated with the equations:

$$a = \frac{A \cdot D - C \cdot B}{n \cdot D - B^2} \quad (11)$$

where a is the anti-log of γ parameter.

$$\beta = \frac{n \cdot C - A \cdot B}{n \cdot D - B^2} \quad (12)$$

For correlate the results and find the approximate value associate to the estimation, the χ^2 test is used

In order to find correlation of the experimental result with Weibull distribution, a test procedure was developed and a programmer was creating using MathLab 6.0 soft.

For exponential and normal distribution, the statistic parameters: mean and standard deviation, assure an appropriate description of the tendencies.

The diagram of the compute steps is presented in figure 2.

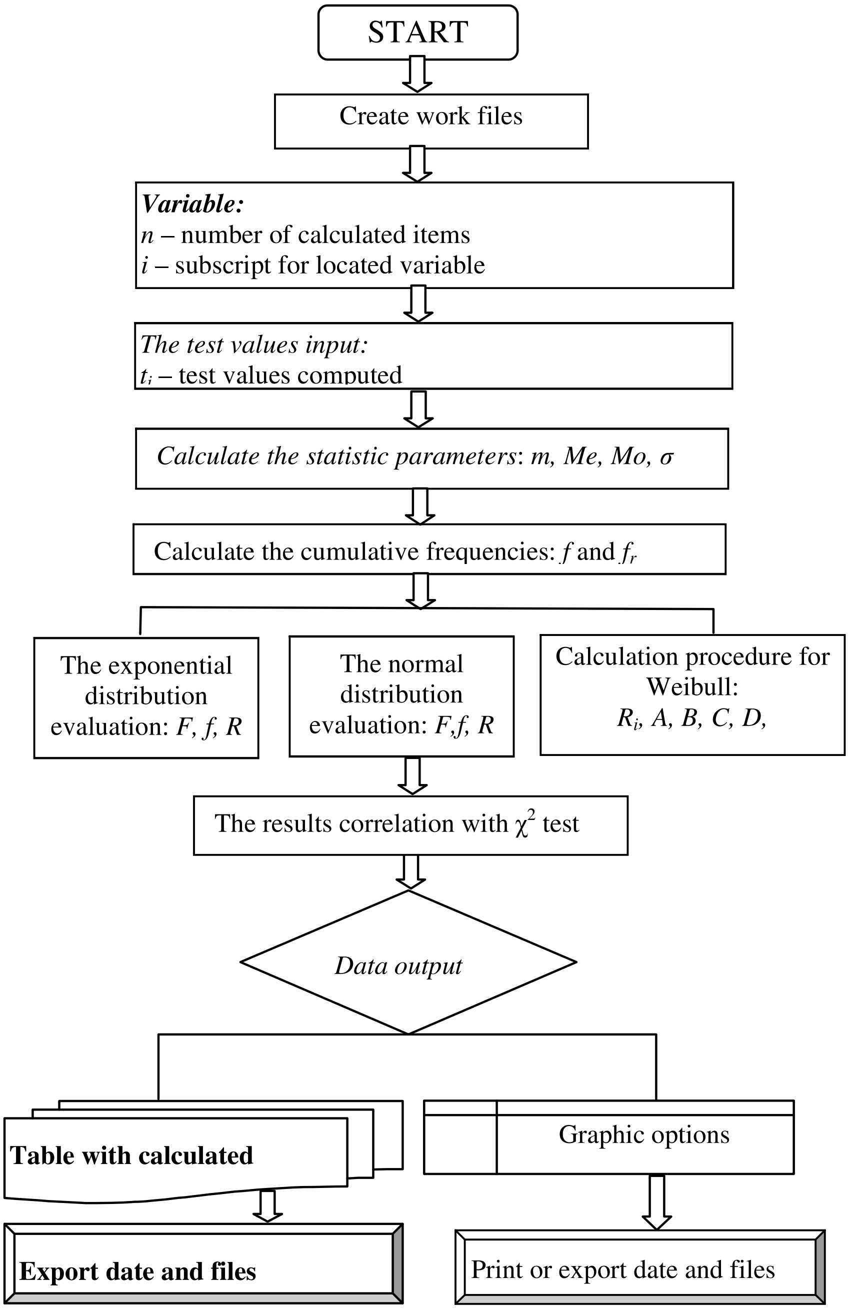

Fig. 2 The diagram of the processing date for calculates the probabilistic distributions

THE SOFT PROCEED PRESENTATION

According with the diagram presented in the second chapter, the soft assure large possibility to develop test and applications.

The dialog boxes are in Romanian, for create a large customers access. The program created is compound by 5 different folders as:

- basic folder that contain de exe. Command;
- data input folder for introduce de values resulted from test;
- mathematical operator folder;
- chi^2 data base folder;
- graphic operator folder.

The save option for new application files are viable from the basic folder.

The programmer was developed and assures an attractive interface for each type of evaluated distribution (fig. 3).

An example of the operated interface of the programmer are presented in figure 4. The demonstration was performed for 9 input parameters. In fact the programmer has the possibility to compute until 105 input parameters.

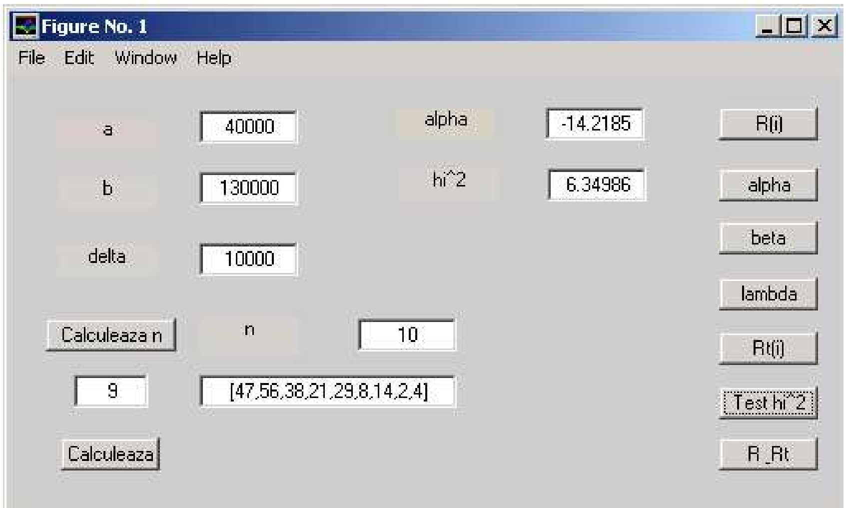

Fig. 4 The example of work with the programme; the operator interface

The graphic interface is available individually and in correlation with hi^2 test.

In the operating mode, the work interface was described in Romanian language, for increase the accessibility for the operators.

CLEANING EFFICIENCY TESTS EVALUATION WITH THE SOFT

The described algorithm was used for evaluate experimental tests carried out for evaluate the grain cleaning process efficiency [3].

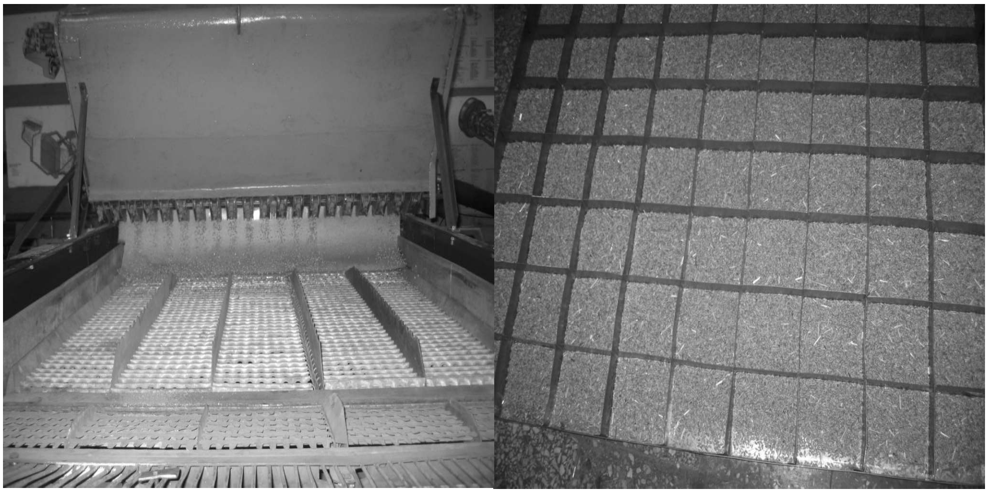

Fig. 5 The experimental stand (left) and the collected box (right)

Using a data acquisition system designed for this purpose the experimental values was collected and some measurements was done in order to evaluate the grain quantity sorted in each considered area unit of the sieve surface (fig. 5). The improve procedure supposes to repeat each test for increase the confidence of the work carried out.

The data collected were evaluated by math point of view using the described algorithm with the proposed soft. The evaluation target consists in the sieve surface separation efficiency. In this respect, a probability of the quantity of the grain sorted in each considered unit area was calculated using the described soft.

In this way the influence of the sieve work frequency was evaluated and some test results show significant details.

Considering the literature in this field most authors describe the sieve work efficiency by some mathematical models considered as a one result of the test. Our results show a complete accordance with the probabilistic distribution low. In this respect, for the medium frequency (corresponding to a 420 rpm), the quantity sorted across the sieve respect the exponential distribution (fig. 6):

For height rotation speed of the sieves action device, the Weibull distribution describes the separation process with an accepted relevance (fig. 7). In this case the characteristic parameters are: β equal with 1,9175 and λ is equal with -10,2826. Bout two coefficients describe tendencies of the separation with height confidence demonstrated also by the chi square test, in accordance with experimental results.

We must mention that the mathematical evaluation of the results was effectuated for a large test number, after a statistical evaluation and selection of the errors occurs under the electronic data collect process.

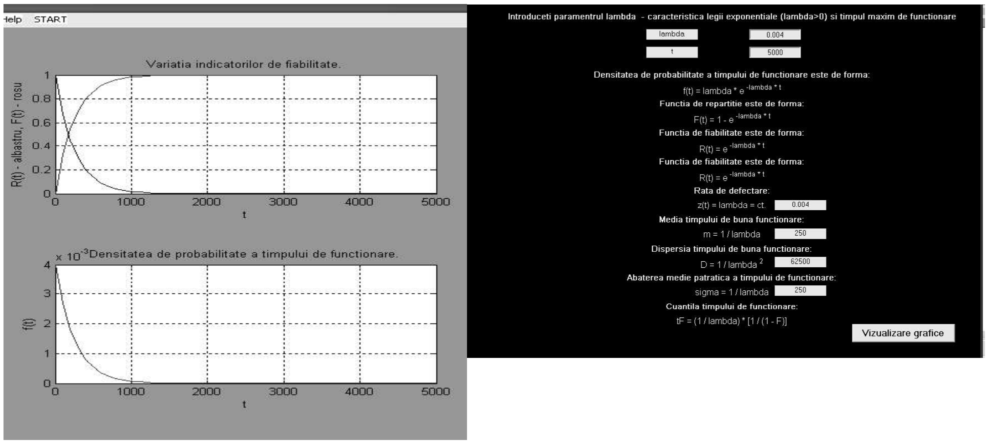

Fig. 6 The operating interface (left) and the exponential graphic results for test values evaluation

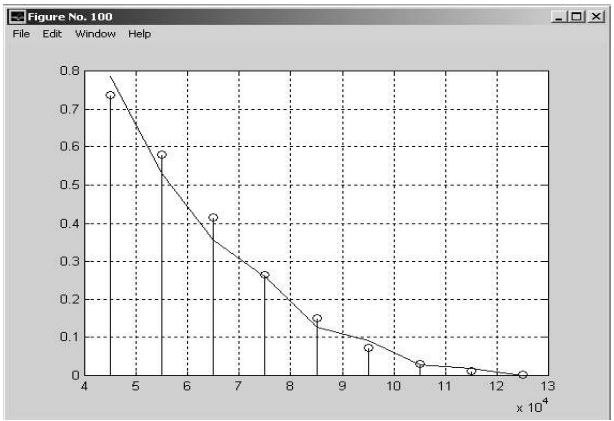

Fig 7 The Weibull distribution of the experimental results and chi square evaluation

CONCLUSIONS

The described program assures a complete and fast test values evaluation. This was used for a large tests carried in laboratory conditions and for various data collected. The possibility to import data from serial interfaces RS 232 using a common soft represent an advantage which increase the work domain possibilities.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.431.73
Prethodno priopćenje
Preliminary communication

FEM MODEL FOR APPRECIATION OF SOIL COMPACTION UNDER THE ACTION OF TRACTORS AND AGRICULTURAL MACHINES

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SUMMARY

The compaction phenomenon of agricultural soil can be defined as an increase in its dry density, respectively in reduction of its porosity, and can result from any natural causes as: rainfall impact, soaking, internal water stress from soil, and other. An important part has the artificial compaction, which is generated by the contact with tires or caterpillars of tractors and agricultural machines. It is very important to know the behavior of soil under the action of these rolling devices because by pressures against the soil, permits to decrease the negative effects of the surface compaction and negative effects of deep compaction. Within the framework of this paper, an original study is presented for the effect referring to soil compaction in the case of two tractors with identical powers, one wheel tractor (U-445) and a caterpillar tractor (SM-445), and in the case of two important harvester-threshers (SEMA 140 and New Holland TX-66). It is create a model of analysis using the finite element method for each case, which permits the analysis of distribution of the equivalent stress and distribution of the total displacements in the soil volume, making evident both of the conditions in which the soil compaction is favor and of the study of graphic variation of equivalent stress and the study of shifting in the deep of the soil volume.

Key words: *Soil compaction, stress, tractor, agricultural machines, finite element method*

INTRODUCTION

The compaction phenomenon of agricultural soil can be defined as an increase in its dry density and the closer packing of solid particles or reduction in porosity [E. McKyes, 1985], which can result from natural causes, including rainfall impact, soaking, and internal water tension. The passage of wheels over agricultural soils, which is usually of short duration in the case of most vehicles, results in soil artificial compaction. Soil compactness is a static state property of agricultural soil. Subsoil compaction may persist for a long time and is hence a threat to the long-term productivity of the soil [Etana & Håkansson, 1994].

The most important factors, which have a significant influence in the process of artificial compaction of agricultural soil, are: the type of soil, moisture content of the soil, intensity of external load, area of contact surface between the soil and the external load, shape of contact surface, and the number of passes.

The soil structures produced by tillage are strongly affected by soil moisture. There exists a water content at which the result of tillage is optimal. Laboratory tests have shown that the changes in density are closely proportional to the logarithm of normal pressure. The number of passes affects the magnitude of change in soil density, and the volume of affected soil.

Because the agricultural soil is not a homogeneous, isotropic, and ideal elastic material, the mathematical modelling of stress propagation phenomenon is very difficult.

THEORETICAL ELEMENTS

Many mathematical models of stress propagation in the soil are based on the Boussinesq equations, which describes, more than a century ago, the stress distribution under a point load (Fig. 1) acting on a homogeneous, isotropic, semi-infinite, and ideal elastic medium. The stress levels are given in cylindrical coordinates as follows [9]:

$$\sigma_z = \frac{3 \cdot P \cdot z^3}{2 \cdot \pi \cdot R^5} \tag{1}$$

$$\sigma_r = \frac{P \cdot z^3}{2 \cdot \pi} \cdot \left[\frac{3 \cdot z \cdot r^2}{R^5} - \frac{1 - 2 \cdot \upsilon}{R \cdot (R + z)} \right] \tag{2}$$

$$\sigma_\theta = \frac{P \cdot (1 - 2 \cdot \upsilon)}{2 \cdot \pi} \cdot \left[\frac{1}{R \cdot (R + z)} - \frac{z}{R^3} \right] \tag{3}$$

$$\tau_{rz} = \frac{3 \cdot P \cdot r \cdot z^2}{2 \cdot \pi \cdot R^5} \tag{4}$$

where P –is the point load, υ -Poisson's ratio, $\sigma_{z,r,\theta}$ –normal stress components, τ_{rz} –shear stress component.

Frohlich developed equations to account for stress concentration around the point of application of a concentrated load for the problem of the halfspace medium subjected to a vertical load P. Introducing the concentration factor ν, was developed the expression for stresses σ_R as:

$$\sigma_R = \frac{\nu \cdot P}{2 \cdot \pi \cdot R^2} \cdot \cos^{\nu - 2} \varphi \tag{5}$$

where $\cos\varphi = z/R$. For the case $\nu=3$ the halfspace medium can be shown to be elastic and isotropic with a constant Young's modulus; for the case $\nu=4$ the Young's modulus E increases linearly with depth z. The ν values of 3, 4 and 5 represent hard, normal and soft soil [8].

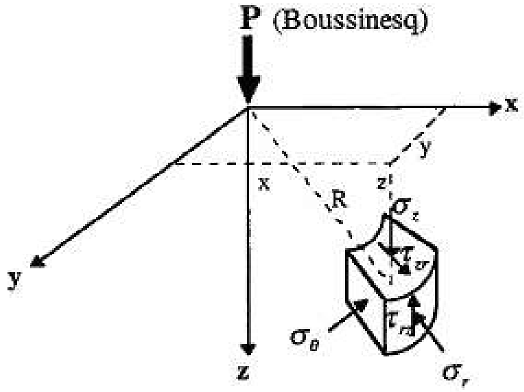


Fig. 1 Stress state produced by a concentrated vertical load [9]

Many models of dynamic soil behaviour use elastic properties of soil, and when the soil is represented by a linearly elastic, homogenous, isotropic, weightless material, the elastic properties required to fully account for the behaviour of the material are Young's modulus (E), shear modulus (G), and Poisson's ratio (υ).

Figure 2 show the stress state in soil, of an infinitely cubic soil element, which can be written in a matrix, termed the matrix of the stress tensors [8]. Stresses acting on a soil element can be described by mechanical invariants, which are independent of the choice of reference axes. The three invariants yield [7]:

$$I_1 = \sigma_1 + \sigma_2 + \sigma_3 = \sigma_x + \sigma_y + \sigma_z \tag{6}$$

$$I_2 = \sigma_x\sigma_y + \sigma_x\sigma_z + \sigma_y\sigma_z - \tau_{xy}^2 - \tau_{xz}^2 - \tau_{yz}^2 = \sigma_1\sigma_2 + \sigma_1\sigma_3 + \sigma_2\sigma_3 \tag{7}$$

$$I_3 = \sigma_x\sigma_y\sigma_z + 2\tau_{xy}\tau_{xz}\tau_{yz} - \sigma_x\tau_{yz}^2 - \sigma_y\tau_{xz}^2 - \sigma_{xy}^2 = \sigma_1\sigma_2\sigma_3 \tag{8}$$

It is useful to define stress measures that are invariant. Such stress is the octahedral normal stress and the octahedral shear stress:

$$\sigma_{oct} = \frac{1}{3}(\sigma_1 + \sigma_2 + \sigma_3) = \frac{1}{3}I_1 \tag{9}$$

$$\tau_{oct} = \frac{1}{3}\sqrt{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_1 - \sigma_3)^2} = \sqrt{\frac{2}{9}\cdot\left(I_1^2 - 3I_2\right)} \tag{10}$$

The critical state soil mechanics terminology uses the mean normal stress p and the deviator stress q. Whereas p=σ_{oct} Eq. (9), q is given as [7]:

$$q = \frac{1}{\sqrt{2}}\sqrt{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_1-\sigma_3)^2} = \sqrt{(I_1^2-3I_2)} \tag{11}$$

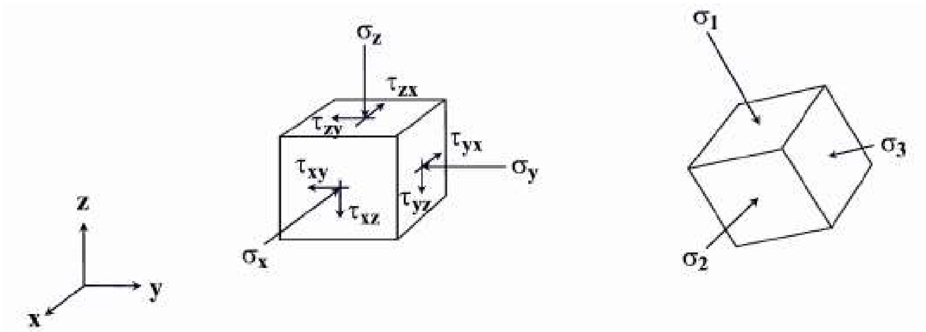


Fig. 2 Stress tensor components [8]

The incremental methods are used to deal with material and geometrically non-linear problems. The basis of the incremental procedure is the subdivision of the load into many small increments. Each increment is treated in a piecemeal linear fashion with the stiffness matrix evaluated at the start of the increment. The tangent stiffness, E_t (Fig. 3) for each element is calculated from the stress-strain curves according to the current stress level of that element. It is worth noting that normally a strain increment, $d\varepsilon$, is defined as the ratio of an incremental length to the original length.

In a FEM calculation when the coordinates are continually updated, the strain increment $d\in$, has the mean of a ratio between an incremental length and the current length.

The relationship between ε and $\in$ has the form [4]:

$$\varepsilon = 1 - e^{-\in} \tag{12}$$

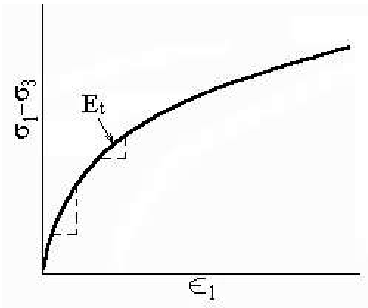


Fig. 3 Stress-strain curve for agricultural soil

According to the relationship between ε and ∈ the following revised stress-strain and tangent stiffness formulae were derived and used in the calculation [4]:

$$\sigma_1 - \sigma_3 = \frac{1 - e^{-\in_1}}{a + b \cdot (1 - e^{-\in_1})} \tag{13}$$

$$E_t = \frac{1}{a} \cdot [1 - b \cdot (\sigma_1 - \sigma_3)] \cdot [1 - (b + a) \cdot (\sigma_1 - \sigma_3)] \tag{14}$$

For saturated soil under an undrained condition, the volume change is generally considered to be negligible. But for FEM calculation purposes, it is common to assume a constant Poisson's ratio slightly less than 0,5 [4].

In terms of the concept of the incremental method, for a soil with nonlinear properties when increments are very small, Hooke's law in which the Young's modulus, E_t, and Poisson's ratio, υ_t, are variables (depending on current stress and strain values) is valid [4]. On the basis of this, for a plane strain problem, a formula for the volume modulus, K_t, can be derived:

$$K_t = \frac{d(\sigma_x + \sigma_y)}{d(\varepsilon_x + \varepsilon_y)} = \frac{E_t}{(1 - \nu_t - 2 \cdot \upsilon_t^2)} \tag{15}$$

where: ε_x, ε_y are strains in *x* and *y* directions; σ_x, σ_y are stresses in *x* and *y* directions.

If υ_t is constant, as E_t decreases (soil failure), K_t also decreases. This means that soil volume changes can be large. Assuming K_t is constant, and the initial values of E_t and υ_t are E_0 and υ_0, respectively, then the Poisson's ratio formula can be derived as in Eqn (16) in which a maximum υ_t and a minimum E_t may be specified to avoid the calculation problem:

$$\upsilon_t = 0{,}25 \cdot \left(\sqrt{9 - \frac{8 \cdot E_t}{E_0} \cdot (1 - \upsilon_0 - 2 \cdot \upsilon_0^2)} - 1\right) \tag{16}$$

METHODS

The Drucker-Prager plasticity model can be used to simulate the behavior of agricultural soil. The yield criterion can be defined as:

$$F = 3 \cdot \alpha \cdot \sigma_m + \overline{\sigma} - k = 0 \tag{17}$$

where α and k are material constants which are assumed unchanged during the analysis, σ_m is the mean stress and $\overline{\sigma}$ is the effective stress, α and k are functions of two material parameters ϕ and c obtained from experiments where ϕ is the angle of internal friction and c is the material cohesion strength.

In using this material model, the following considerations should be noted:

- Strains are assumed to be small.
- Problems with large displacements can be handled provided that the small strains assumption is still valid.

- The use of NR (Newton-Raphson) iterative method is recommended.
- Material parameters ϕ and c must be bounded in the following ranges:

  $90 \geq \phi \geq 0$ (in degrees)

  $c \geq 0$ (in force/unit area)

The required input parameters for the constitutive model of the agricultural soil are:

- Cohesion of soil (c): 18.12 kPa
- Internal friction angle of soil (φ): 30°
- Soil density (γ_w): 1270 kg/m^3
- Poisson's ratio υ_s: 0.329
- Young's modulus E: 3000 kPa

In our model, it was considered a soil volume with the depth of 1-2 meter, the width of 3-4 meter and length of 4-8 meter (Fig. 4) under the act of different tractors and harvester-threshers. The structural nonlinear analysis was made on the ideal model, which was considered the soil as if it were homogeneous and isotropic material. It was used the COSMOS/M 2.95 Programme for FEM modelling.

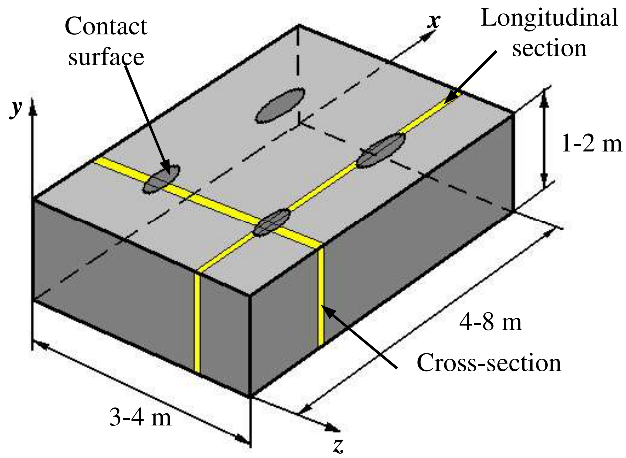


Fig. 4 Analyzed soil volume

RESULTS AND DISCUSSION

Figures 5 and 6 show the results of FEM analysis in cross-section and in longitudinal section for two 45 HP tractors with tires and with caterpillar (U-445 and SM-445), respectively for two harvester-threshers (New Holland TX-66 and SEMA-140). These results are: the stresses distribution in soil, and the graphical variation of stresses along the vertical-axial direction and along to the longitudinal direction.

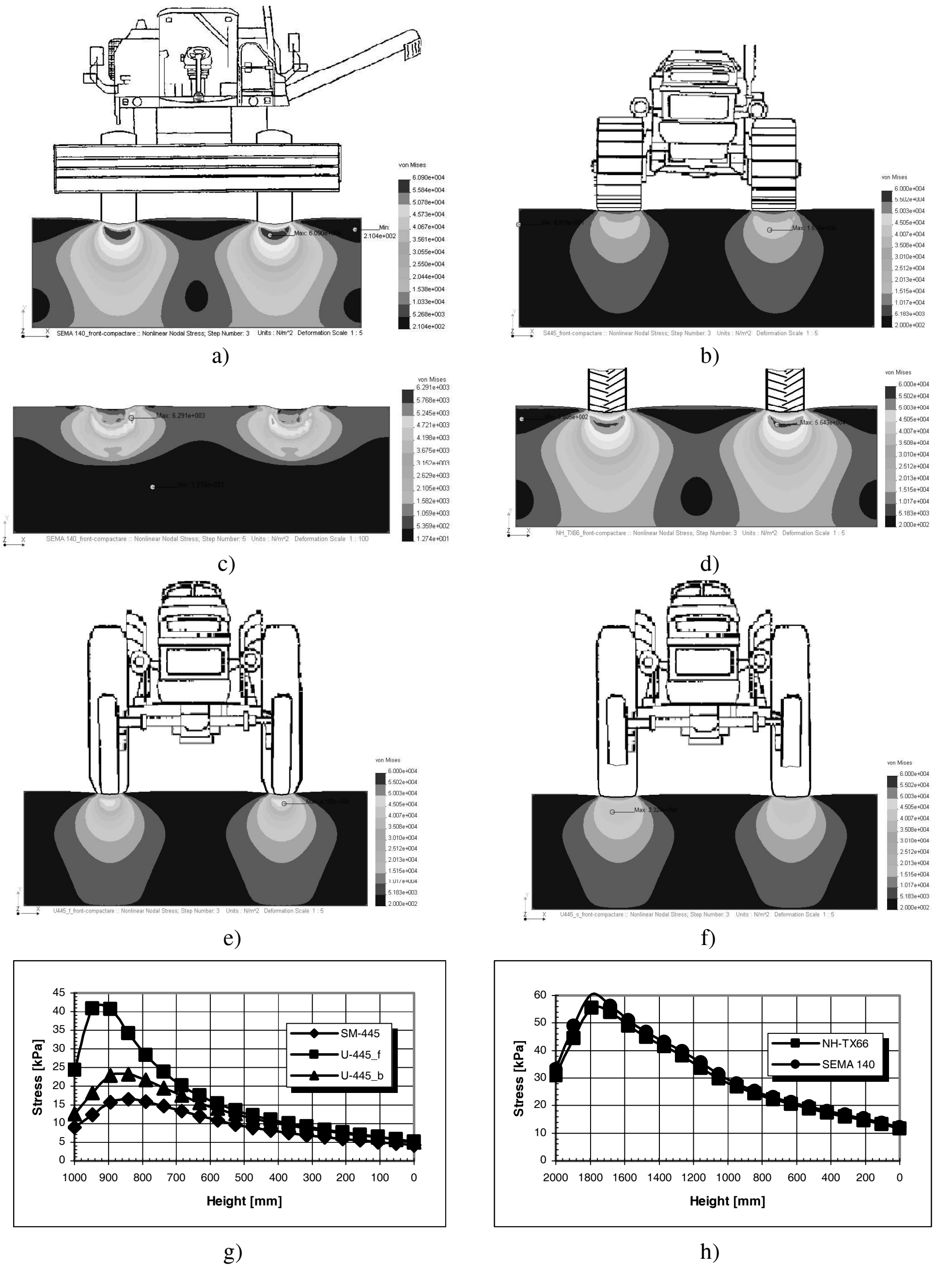
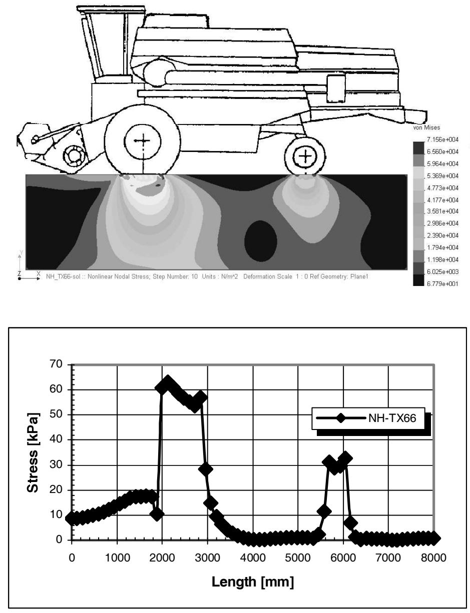
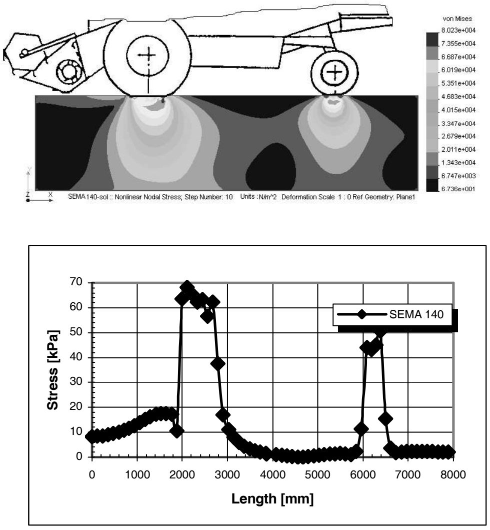
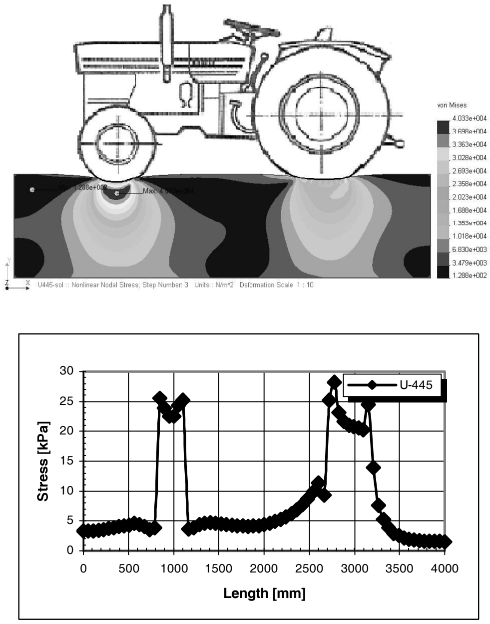


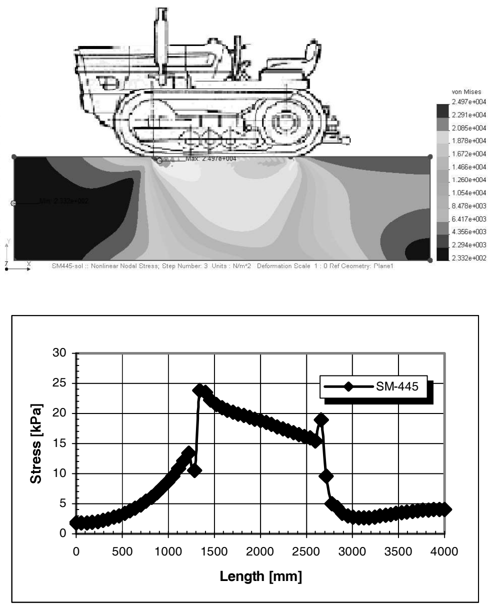
Fig. 5 Stresses distribution in cross-section for: a) SEMA 140 harvester-thresher, b)SM-445 caterpillar tractor, c) SEMA 140 harvester-thresher after the first transit, d) New Holland TX-66 harvester-thresher, e) front wheels of U-445 tractor, f) back wheels of U-445 tractor, g)-h) graphical distribution along the axial-vertical direction





a) b)





c) d)

Fig. 6 Stresses distribution and graphical variation along the longitudinal direction to the top layer of the soil in longitudinal section for: a) New Holland TX-66 harvester-thresher, b) SEMA 140 harvester-thresher, c) U-445 tractor, d) SM-445 caterpillar tractor

CONCLUSIONS

- The Finite Element Method is in present the most advanced mathematical tool which can be used for the study of agricultural soil artificial compaction process. For mathematical modeling the soil is considered as a homogeneous and nonlinear material.
- From this study results that from these analysed tractors and harvester-threshers, the highest artificial compaction of soil there is in the case of the front wheels of SEMA-140 harvester-thresher (see figure 5.h), when the equivalent maximum stress in soil is approx. 70 kPa, and in the case of the front wheels of NH TX-66 harvester-thresher (see figure 5.h), when the maximum equivalent stress is higher then 65 kPa. In these cases is recommended to extend the contact area between the wheel and the soil.
- This study represents a supplementary argument for using the caterpillar for the reduction of artificial soil compaction. The present researches are directed to using the rubber caterpillar, and also to using the reduce-pressure tyres with largest contact area with the soil.

ACKNOWLEDGEMENT

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 004.7:631.356.46/.47
Izvorni znanstveni rad
Original scientific paper

MATHEMATIC MODELLING AND SIMULATION OF THE DISPLACEMENT OF THE MATERIAL ON OSCILLATING IMPURITIES CLEANING SYSTEMS FROM BULB AND POTATO HARVESTERS

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SUMMARY

In this paper is presented a mathematical model of the displacement of the material on the oscillating impurities cleaning systems from the bulb and tubercle harvesters. Based on the mathematical model, it was created a computer simulation program which allows the determination of the optimal values of the constructive and functional parameters of the oscillating impurities cleaning systems, for which the material is shaken with such intensity so no damages appear on the useful products. The determination of the optimal values of the oscillating impurities cleaning system main parameters is related with the mechanical properties linked with the impact comportment of the processed products.

Key words: *bulb and tubercles harvesters, impurities cleaning systems, mathematical modelling, computer simulation, optimizing.*

INTRODUCTION

At the bulb and tubercles mechanized harvesting, the separation of them from the broken up soil bed, resulted after the digging, is a difficult process because the great quantity of soil that must to be removed, which is frequently much greater than the quantity of useful products. The separation process becomes supplementary more difficult because of the presence in the mixture submitted to the separation, excepting the soil fragments, of vegetal remaining impurities or boulders and stones with dimensions and shapes similar with those of the useful products.

At the bulb or tubercle harvesters, there are used several types of impurities cleaning systems like: grate or sieve devices, bitters devices, profiled or eccentric roles devices, and others. To the impurities cleaning systems of grate or sieves type, that are the most usually met impurities cleaning systems at the bulb and tubercle harvesters' construction, the working process is similar with the sifting process on plane sieves. The impurities cleaning systems of grate or sieve type present several constructive variants relatively uniform spread, namely: belt conveyors, oscillating grates and vibrating sieves.

In this paper, it is analysed the working process of the belt conveyor impurities cleaning systems, which constructively, is composed of a succession of metallic bars, articulated one to another by hooks, or fixed on chains or belts (see figure 1), forming a continuous belt. Generally the bars are made of round profile or round wire of steel, which sometimes can be covered with rubber or plastic, for the protection of the useful products submitted to the separation. The pitch between the bars is such established that the space between two consecutive bars corresponds to the minimum admissible dimension limit of harvested products. The conveyor belt moves with a constant speed v_t, in the sense of the material advancement towards the rear of the harvester, the speed of the conveyor belt being greater than the working speed of harvesting agregate (ussualy 1.5 – 2 times bigger), fact which makes that, to the taking over of the mixture that must be submitted to the separation from the digger, on the impurities cleaning belt conveyor device, takes place a spreading of the material, which has a extremely favourable effect on the impurities separation process.

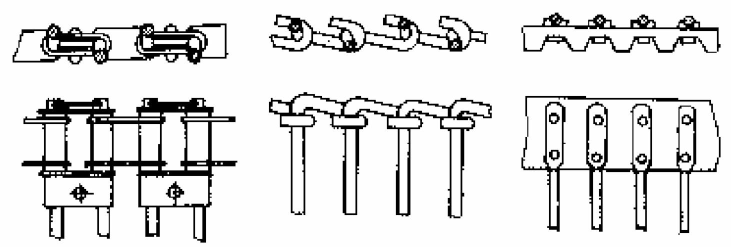


Fig. 1 Constructive variants of belt conveyors [?]

The active surface of the belt conveyor is inclined towards the horizontal with an inclination angle that the value is established in function with the nature of the processed products, which belong to a characteristic range. Inclinations of the active surface over the superior limit of the range can lead to the turn down of the useful product, whereas inclinations under the inferior limit of the range lead to a small soil clearance of the conveyor, and consequently of the harvester.

In order that the separation process takes place, the mixture submitted to the process must to leap on the active surface of the conveyor. For this purpose, in certain zones of the active surface of the belt conveyor, there are induced forced oscillatory movements by shaking devices. Constructively, the shaking devices, from the belt conveyor of the onion and potato harvesters, the most frequently used are with profiled roles or with knocking hammers.

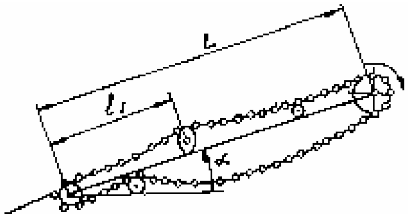


Fig. 2 Impurities cleaning belt conveyor [?]

In figure 2 it is presented a belt conveyor whereat the active surface is shaken through the action of a system of roles with eliptic profile driven in rotary mouvement even by the belt conveyor displacement.

The advantages of the belt conveyor cleaning systems are constructive simplicity and silent working without significant shocks and vibrations transmitted to the machine chassis, while the main disadvantage in a lower efficacy of the impurities separation because of the fact that the separation process takes place mostly in the shaking organs zones of the active surface of the conveyor, being much blurred and practically insignificant on the unshaken rest of the active surface of the conveyor. Is that for, the number and the emplacement of the shaking organs becomes very important. Generally, the lower efficiency of the belt conveyor cleaning systems can be compensate by the enlargement of their active surfaces.

MATHEMATIC MODELLING OF THE MATERIAL DISPLACEMENT ON THE ACTIVE SURFACE OF THE BELT CONVEYOR

According as it was shown in the previous section, during the working process of the impurities cleaning belt conveyor, the material resulted after the digging is taken over and transported on their active surfaces. At the taking over and during the transport, the particles of material with smaller dimensions than the distance between the belt conveyor bars pass through the spaces between bars and fall down on the soil, on the active surface remaining the material particles bigger than the distance between the belt conveyor bars. The material remained on the active surface of the conveyor is prevailingly composed of useful products, which are wanted to be separated of impurities, respectively bulbs or tubercles normally developed, but also soil fragments, boulders, rocks and vegetal offals which were not separated because they have dimensions comparable with those of the useful products or because of their form or position on the conveyor active surface, remain on it whereas their dimensions allow their separation. Therefore, where the separating process would be more efficient, namely to obtain the removal of the majority of separable particles, during the transport on the active surface of the belt conveyor it is necessary that the material would be agitate. It can be intuit that more the material is frequently and intensely agitate, more the efficiency of the separation is higher. Regrettably, the agitation of the material can conduce to the damage of the useful products because their impacts with the active surface of the belt conveyor, as a result of the leaping. So, in the case of the impurities cleaning belt conveyor, the problem consists in the establishment of a optimal working process, that ensure a high efficiency of the impurities separation, but without damaging the useful products.

For this purpose, in the present paper it will be developed a mathematical model of the displacement of the material on the active surface of the belt conveyor in the acting zones of the shaking device, in the case of a profiled roles device with eliptic profile.

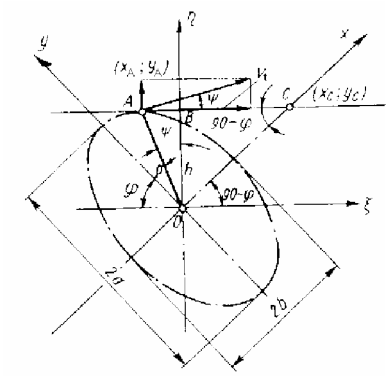


Fig. 3 The kinematical analisys of the conveyor active surface passing over the eliptic roles

The kinematical analysis of the conveyor active surface is made in the acting zone of the eliptic roles (see figure 3) utilising a consacrate mathematical model, taken from the speciality literature [?]. For the analysis there are imposed the following simplifying hipothesis: the belt conveyor, which moves with the speed v_t, drive without sliding the eliptic roles in a variable speed rotary mouvement, the active surface of the conveyor is considered sufficiently rigid so the contact between the conveyor and the eliptic role is punctual (marked with A in the figure), during the working the active surface of the conveyor in contact with the eliptic roles occupies paralel positions.

Attaching a mobile coordinates system $x0y$, solidary to the eliptic role (0 being the rotary center of the role), oriented by its main axes and fixed coordinates system $\eta 0 \xi$, whereat the 0η axe is normal to the active surface of the conveyor and the $O\xi$ axe is parallel with that, it will be determined the mouvement equations of the point of tangency between the conveyor and the eliptic role, on the normal direction to the surface of the conveyor, that have the following expresions:

$$h = a \cdot \sqrt{\frac{b^2}{a^2} + \left(1 - \frac{b^2}{a^2}\right) \cdot \sin^2 \varphi} \tag{1}$$

$$\frac{dh}{dt} = \frac{dh}{d\varphi}\frac{v_t}{h} = v_t \frac{(1-k^2)\sin\varphi\cos\varphi}{k^2 + (1-k^2)\sin^2\varphi} \tag{2}$$

$$\frac{d^2h}{dt^2} = \frac{v_t^2}{a}(1-k^2)\frac{k^2-(1+k^2)\sin^2\varphi}{(k^2+(1-k^2)\sin^2\varphi)^{5/2}} \tag{3}$$

where: h – the distance between the center of the eliptic role and the conveyor surface, on normal direction to that, k – the eccentricity of the eliptic profile of the role (namely the ratio between the small semiaxe b and the big semiaxe a), φ – the current value of the rotary angle of the eliptic role.

It is mentioned that because the symmetry of the role eliptic profile, the period of the function from the expresions 1,2, and 3 correspond to a half of rotation of the roles (namely $\varphi_T = \pi$ radians), and the ulterior studies will be made corresponding to one period.

So, during a period of rotation of the eliptic roles, on a particle of material from the active surface of the conveyor (the active surface of the conveyor being inclined towards the horizontal with the inclination angle α), they act the following forces (see figure 4): the gravity force $m \cdot \overline{g}$, the reaction force $\overline{N}$ of the conveyor upon the particle and the inertial force $m \cdot d^2h/dt^2$ due to the conveyor active surface acceleration.

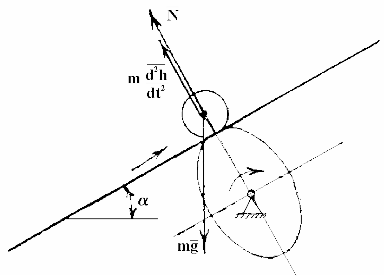


Fig. 4 The forces that act on a particle from the conveyor surface in the eliptic roles zones

From the forces acting on the particle equilibrium conditions (more preccisely of the forces projections on normal directions on the conveyor surface), it can be determined the rotary angle φ_0 of the eliptic role corresponding to the detachment of the particle with mass m from the conveyor surface, by imposing the detachment condition, namely, the annulment of the reaction force of the conveyor upon the particle ($N \le 0$) at limit. So, the value of the φ_0 angle is the following root bigger than 0 of the resulted equation:

$$\frac{v_t^2}{a}\cdot(1-k^2)\cdot\frac{k^2-(1+k^2)\cdot\sin^2\varphi}{(k^2+(1-k^2)\cdot\sin^2\varphi)^{5/2}} + g\cdot\cos\alpha = 0 \tag{4}$$

That is mentioned that corresponding to the detachment angle φ_0, from the conveyor surface they are detaching all the particles with the mass lower or equal to the considered mass m.

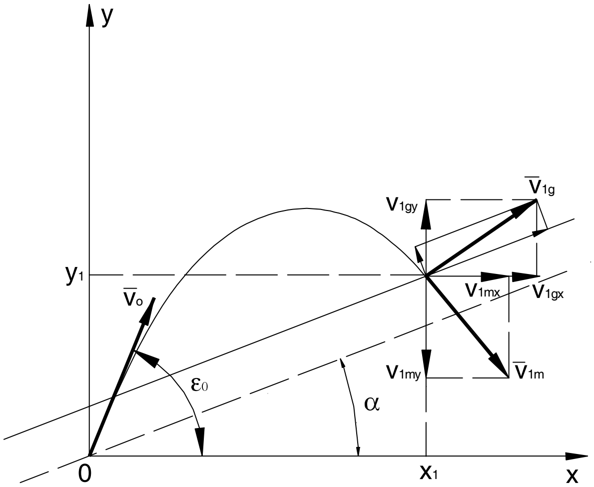


Fig.5 The study of the displacement of the material detached from the conveyor surface

Knowing the value of the angle φ_0 of detachment, they can be determined the elements of the speed of the particle at the detachment from the conveyor surface, that is, in the moment of detachment equal with the conveyor speed corresponding to the φ_0 angle (the coordinates system is that from figure 5), namely:

$$v_{0x} = v_t \cdot \cos\alpha - v_t \frac{(1-k^2)\cdot \sin\varphi_0 \cdot \cos\varphi_0}{k^2 + (1-k^2)\cdot \sin^2\varphi_0} \cdot \sin\alpha \tag{5}$$

$$v_{0y} = v_t \cdot \sin\alpha + v_t \cdot \frac{(1-k^2)\cdot \sin\varphi_0 \cdot \cos\varphi_0}{k^2 + (1-k^2)\cdot \sin^2\varphi_0} \cdot \cos\alpha \tag{6}$$

$$v_0 = \sqrt{v_{0x}^2 + v_{0y}^2} \tag{7}$$

The material detached from the conveyor is displacing in free mouvement, then it comes back on the conveyor active surface after a period of time, having impact with it. The determination of the kinematic parametres of the returnment of the detached material on the conveyor active surface will be done by solving the following system of ecuations, resulted from the condition of intersection between the trajectory of the material in free mouvement and the conveyor surface trajectory. The system of equations is the following:

$$x = v_0 \cdot t \cdot \cos\varepsilon_0$$

$$y = -\frac{g \cdot t^2}{2} + v_0 \cdot \sin \varepsilon_0 \tag{8}$$

$$y = x \cdot tg\alpha + \frac{a}{\cos \alpha} \cdot \left(\sqrt{k^2 + (1-k^2) \cdot \sin^2 \varphi} - \sqrt{k^2 + (1-k^2) \cdot \sin^2 \varphi_0} \right)$$

$$t = (\varphi - \varphi_0) \cdot \frac{a \cdot \sqrt{k^2 + (1-k^2) \cdot \sin^2 \varphi}}{v_t}$$

It is mentioned that in the system of equations 8, t represents the time and ε_0 is the angle between the detachment speed v_0 and the horizontal axe of the coordinate system.

By solving the system of equations, they are obtained the moment t_1 after which the material returns on the conveyor active surface and the rotary angle φ_1 of the eliptic role corresponding to the moment of the material on the conveyor surface, which are parameters imperiously needed for the continuation of the calculus algorithm, as well as the coordinates of the material returning point on the surface of the conveyor. The expressions of moment t_1 and of the angle φ_1 are the following:

$$t_1 = \frac{a}{v_t} \cdot (\varphi_1 - \varphi_o) \cdot \sqrt{k^2 + (1-k^2) \cdot \sin^2 \varphi_1} \tag{9}$$

$$\varphi_1 = \varphi_o + \frac{v_t}{h} \cdot t_1 \tag{10}$$

With the parameters t_1 and φ_1 they can be calculated the elements of the material speed v_{1m}, respectively of the conveyor speed v_{1g}, corresponding to the moment of impact between the material and the surface of the conveyor, with the following expressions:

$$v_{1mx} = v_0 \cdot \cos \varepsilon_0 \tag{11}$$

$$v_{1my} = -g \cdot t_1 + v_0 \cdot \sin \varepsilon_0 \tag{12}$$

$$v_{1m} = \sqrt{v_{1mx}^2 + v_{1my}^2} \tag{13}$$

$$v_{1gx} = v_t \cdot \cos\alpha - v_t \cdot \frac{(1-k^2)\cdot\sin\varphi_1\cdot\cos\varphi_1}{k^2+(1-k^2)\cdot\sin^2\varphi_1}\cdot\sin\alpha \quad (14)$$

$$v_{1gy} = v_t \cdot \sin\alpha + v_t \cdot \frac{(1-k^2)\cdot\sin\varphi_1\cdot\cos\varphi_1}{k^2+(1-k^2)\cdot\sin^2\varphi_1}\cdot\cos\alpha \quad (15)$$

$$v_{1g} = \sqrt{v_{1gx}^2 + v_{1gy}^2} \quad (16)$$

Knowing the elements of v_{1m} and v_{1g} speeds they can be calculated the elements of the speed v_c of impact between the material and the conveyor surface with the following expressions

$$v_{cx} = v_{1mx} - v_{1gx} \quad (17)$$

$$v_{cy} = v_{1my} - v_{1gy} \quad (18)$$

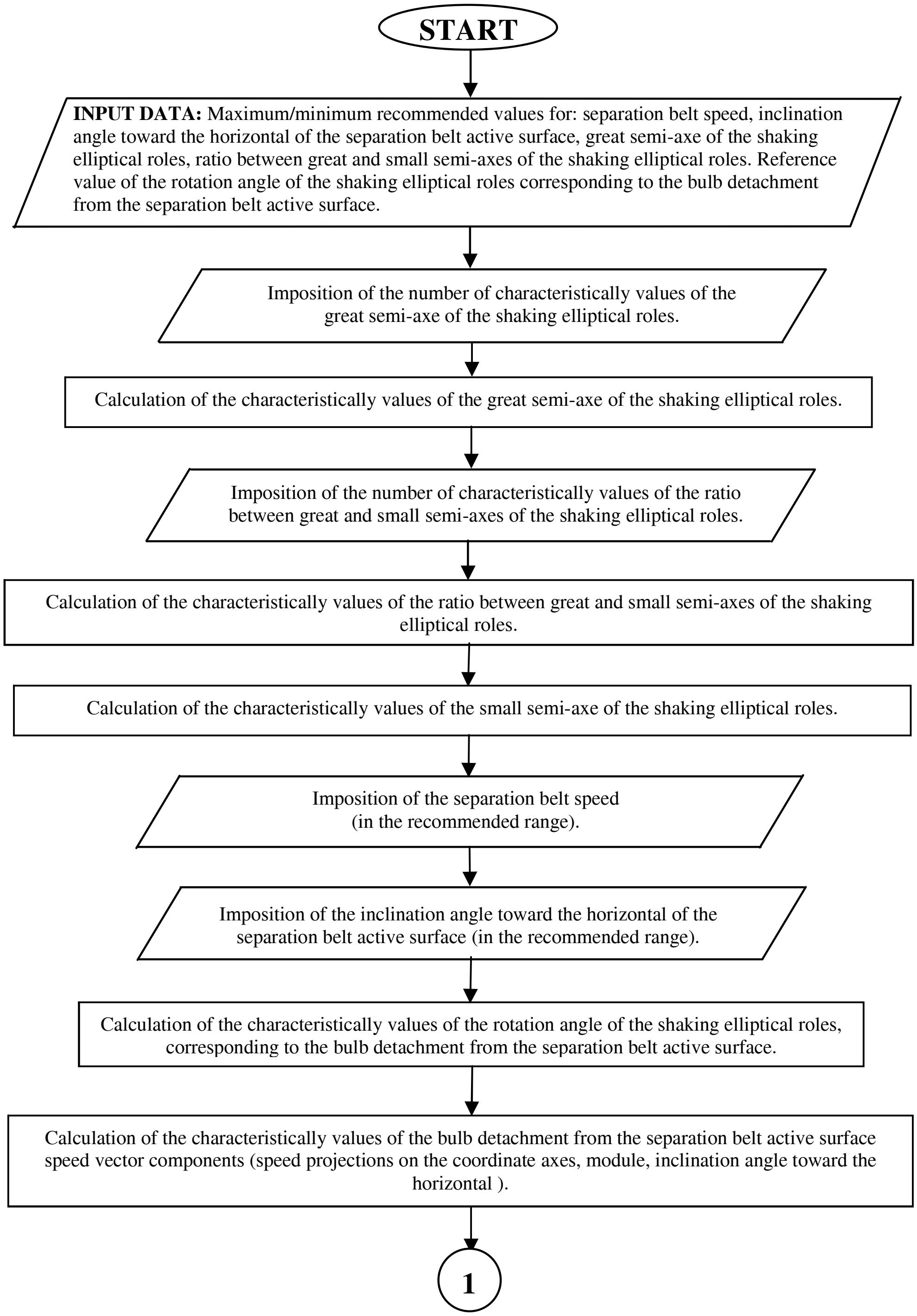
$$v_c = \sqrt{v_{rx}^2 + v_{ry}^2} \quad (19)$$

CALCULUS PROGRAM OF THE SPEED OF IMPACT OF THE USEFUL PRODUCTS WITH THE CONVEYOR ACTIVE SURFACE

Based on the calculus algorithm of the useful products impact speed with the conveyor active surface, it was elaborated a computer program that aloud the determination of the impact speed values if there are imposed the values for the conveyor speed and for the inclination angle towards the horizontal of the conveyor active surface and the ranges of variations of the eccentricity and dimensions of the elliptical roles.

The program is interactive; the operator can introduce, in function with the concrete situation, the adequate values for all the required parameters.

The structural schema of the calculus program is presented in figure 6.


START
INPUT DATA: Maximum/minimum recommended values for: separation belt speed, inclination angle toward the horizontal of the separation belt active surface, great semi-axe of the shaking elliptical roles, ratio between great and small semi-axes of the shaking elliptical roles. Reference value of the rotation angle of the shaking elliptical roles corresponding to the bulb detachment from the separation belt active surface.
Imposition of the number of characteristically values of the great semi-axe of the shaking elliptical roles.
Calculation of the characteristically values of the great semi-axe of the shaking elliptical roles.
Imposition of the number of characteristically values of the ratio between great and small semi-axes of the shaking elliptical roles.
Calculation of the characteristically values of the ratio between great and small semi-axes of the shaking elliptical roles.
Calculation of the characteristically values of the small semi-axe of the shaking elliptical roles.
Imposition of the separation belt speed (in the recommended range).
Imposition of the inclination angle toward the horizontal of the separation belt active surface (in the recommended range).
Calculation of the characteristically values of the rotation angle of the shaking elliptical roles, corresponding to the bulb detachment from the separation belt active surface.
Calculation of the characteristically values of the bulb detachment from the separation belt active surface speed vector components (speed projections on the coordinate axes, module, inclination angle toward the horizontal).
1

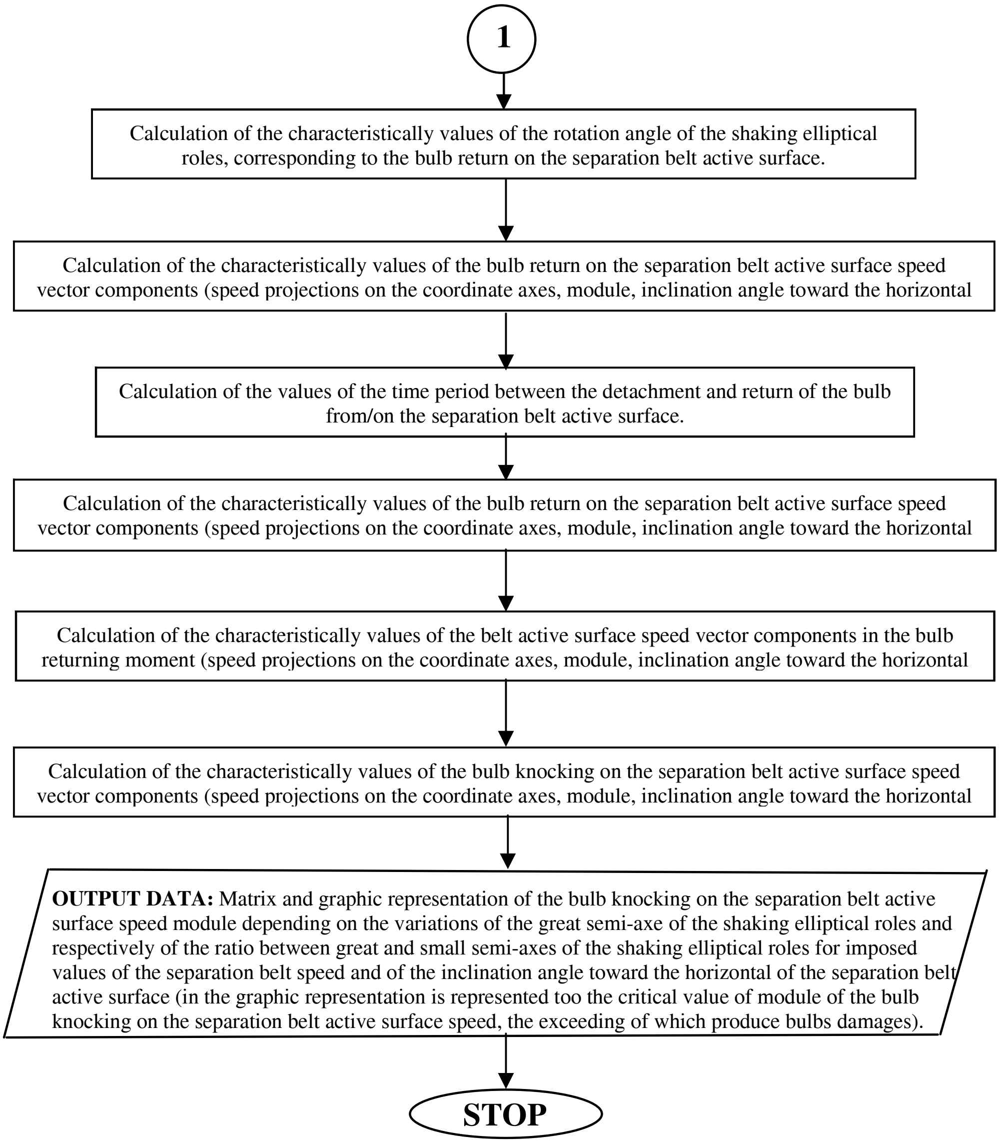


Fig.6 The structural schema of the calculus program

THE IMPURITIES CLEANING MAIN PARAMETERS OPTIMISATION BY INTERMEDIUM OF THE CALCULUS PROGRAM

The outputs of the calculus program are the graphs of useful product impact speed variation, in function with the eccentricity and the dimensions of elliptical roles of the shaking device for imposed values for the conveyor speed and for the inclination angle towards the horizontal of the conveyor active surface.

They were elaborated two variants of calculus program, a variant for the case of belt conveyor with elastic active surface (see figure 7), which, after a short period after the passing over the shaking roles, whereat the oscillating movement of the surface attenuates and have only translation (transport) movement, and a variant for the case of belt conveyor with rigid active surface (see figure 8), acted by elliptic shaking roles, or an elastic active surface acted by pairs of elliptic roles, placed at small distances along the full length of the conveyor active surface, so that all the point of the active surface have the same composed movement, (oscillation and translation) like in the shaking roles action zones.

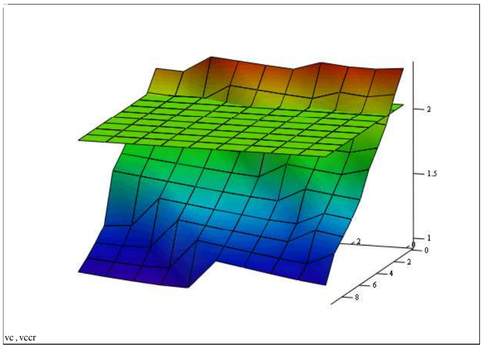


Fig.7 The impact speed variation graph in the case of elastic active surfaces

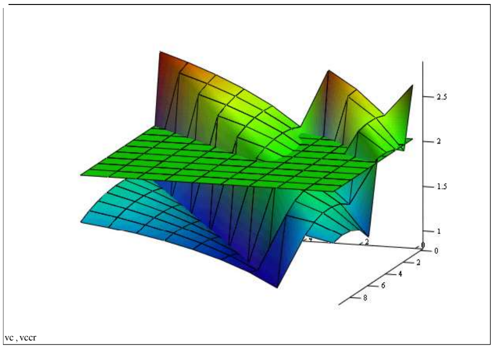


Fig.8 The impact speed variation graph in the case of rigid active surfaces

For the establishment of the impurities cleaning belt conveyor main parameters values, analysed with the calculus program, wherefore the working regime is optimal, namely the shake-up of the material is the most energetically possible without the damage of the useful products, on the impact speed variation graph is introduced the impact speed admissible limit value, which if is exceeded appear the damages to the useful products. In the graph, the impact admissible limit value appears like a plane parallel with the horizontal plane.

The zones from the impact speed variation graph which are above the impact speed admissible limit value plane correspond to working processes whereat the shake-up is very energetically, but the useful products are damaged.

The zones from the impact speed variation graph which are under the impact speed admissible limit value plane correspond to working processes whereat the shake-up is low energetically and the impurities separation is insufficient.

The optimal working processes of the belt conveyor correspond to all the points of intersection between the impact speed variation graph and the impact speed admissible limit value plane, wherefore there are obtained the most energetically shake-up but without the useful products damages.

More precisely, if in the computer calculus program there are imposed certain values for the conveyor speed and for the inclination angle towards the horizontal of the conveyor active surface, after running the program, there are obtained pair of optimal values for the eccentricity and the dimensions of the elliptic role profile, for the optimal separation of the useful products which have the mass beneath a imposed value.

The impact speed admissible limit values for a certain useful product can be determined by experimental researches. For example, for onion bulbs, the impact speed admissible limit takes value between 2 -2.1 m/s (estimations based on the references [?]).

CONCLUSIONS

In the paper is presented an original mathematic model for the determination of the impact speed of the material and the active surface of the impurities cleaning belt conveyor fitted with elliptic roles shaking device, at the material displacement thought the acting zones of the shaking roles.

Based on the mathematic model was elaborated an interactive computer program which aloud the tracing of the impact speed variation graphs when there are imposed the values of the conveyor speed and the inclination angle towards the horizontal of the conveyor active surface, and the characteristic domains of variations of the eccentricity and the dimensions of the elliptic role profile.

Introducing the impact speed admissible limit value, which if is exceed they are produced damages to the useful products, the computer program allows to determine the optimal values of the eccentricity and the dimensions of the elliptic profile of the shaking roles, for imposed values of the values of the conveyor speed and the inclination angle towards the horizontal of the conveyor active surface, corresponding to working regimes of the impurities cleaning belt conveyor with energetically shake-up but without the useful products damages.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 004:63](497.5)
Pregledni rad
Review paper

MJESTO I ULOGA INFORMATIKE U PROCESU RAZVITKA HRVATSKOG POLJODJELSKOG SUSTAVA NA POČETKU 21. STOLJEĆA

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"Informacija je resurs koji se uporabom ne troši, nego oplemenjuje. Imati pravu informaciju znači imati ispravnu orijentaciju u vremenu i prostoru".

SAŽETAK

U radu se istražuje pozicija info osnove hrvatskog poljodjelskog sustava u odnosu na info osnovu suvremenih poljodjelskih sustava razvijenih zemalja, a ukazuje se i na važnost istraživačkog pristupa domeni implementacije standarda informatizacije iz poljodjelskih sustava razvijenih zemalja u hrvatski poljodjelski sustav.

Posebna pozornost posvećena je ponajprije razlozima za donošenje nove strategije razvoja hrvatskog poljodjelstva u kojoj bi na sustavan način trebalo osmisliti i njegovu info osnovu u formi standarda, kao i obrazovne aspekte, u ovom povijesno prijelaznom razdoblju u ovom nadasve važnom području hrvatskog gospodarstva i hrvatske države.

Ključne riječi: *info sustavi, standard informatizacije, poljodjelski sustav, sustav javnog komuniciranja, mrežni informacijski servisi, komunikacijski sustavi, masovnomedijski sustavi, poljodjelskog razvoja.*

UVOD

Činjenica je da su suvremeni poljodjelski sustavi razvijenih zemalja u veliko oplemenili svoju info komponentu kroz akcepciju info tehnologija i na njima temeljenih znanja, te na taj način napravili ogromni jaz u odnosu na poljodjelske sustave nerazvijenih i tranzicijskih država, među koje spada i Hrvatska država. Suočeni s takvim stanjem nužno nam je u strateškom smislu poduzeti adekvatne mjere u cilju kako smanjivanja, tako i premošćavanja nastalog jaza, pa je stoga, nužno potrebito istražiti strukturalne elementne na koje nam valja utjecati. No, pritome također valja imati i na umu činjenicu da paralelno s ovim nakanama dolazi i do novog tehnološkog razvoja poljodjelskih sustava razvijenih zemalja koji zakonito vodi do novog produbljivanja razvojnog jaza s državama u tranziciji, pa je stoga, svako nam vrijeme dragocijeno kako bismo na organizirani način krenuli ka izgradnji info osnove hrvatskog poljodjelskog sustava i modernizaciji hrvatskog poljodjelstva, i to sukladno proklamiranim prioritetima i potrebama, te mogućnostima koje nam stoje na raspolaganju.

Također nam valja imati na umu i činjenicu da je svijest o ovim gibanjima u domeni suvremenog poljodjelstva kod nas izuzetno slaba, pa je stoga nužno potrebita sustavna podrška u širem smislu kako nebi u ovom za nas važnom području zavladala prosječnost ideja i svijesti, što bi imalo nesagledive posljedice u bliskoj budućnosti razvoja hrvatskog poljodjelstva. Naime, iskustvo je pokazalo da nije samo važno nešto proizvesti ili odgojiti nego da treba znati gdje, kada i koliko čega se može plasirati, kako bi na načelima ekonomskih zakonitosti poljodjelski sustav bio bonitentan, a zato su nam nužno potrebne informacije koje mora generirati info komponenta poljodjelskog sustava, što do sada kod nas nije bio slučaj[4)].

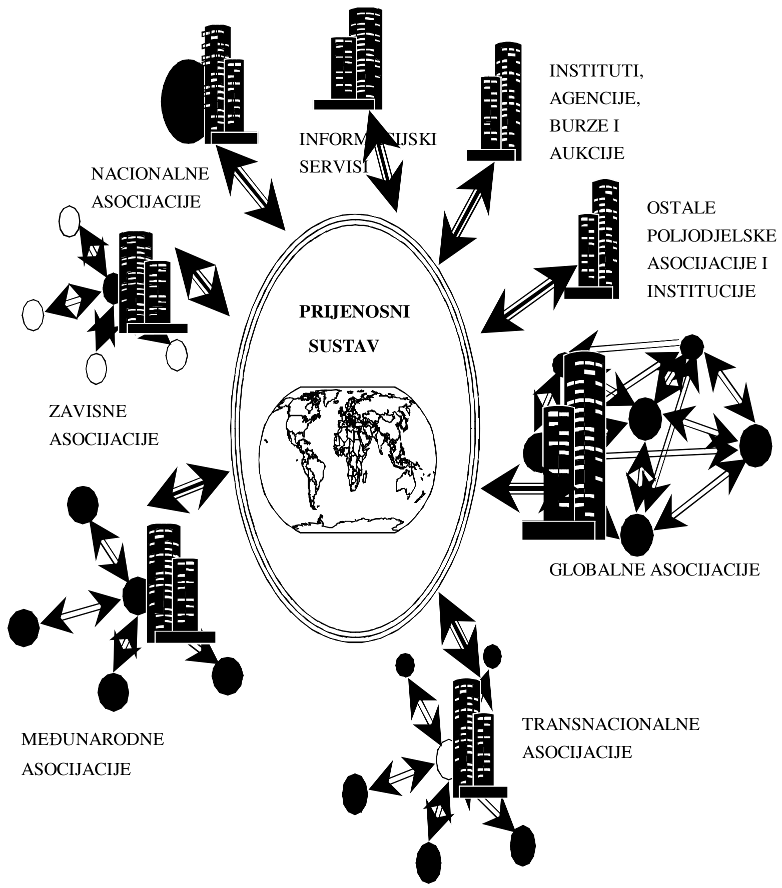
No, također nam valja ukazati na činjenicu da nije moguća niti izgradnja Informacijskih servisa poljodjelskog tipa, kao i da nije niti moguća izgradnja Burze i Aukcije poljodjelskih proizvoda, kao niti nužno potrebiti Baza podataka poljodjelstva, bez koncepcijskog i strateškog osmišljavanja info osnove hrvatskog poljodjelstva, kao i njenog povezivanja s relevantnim domaćim i međunarodnim okruženjem[3)].

Sadašnje stanje pokazuje da se većina strateških, taktičkih i operativnih odluka donosi temeljem iskustva (na konvencionalan način), a ne temeljem info sustava hrvatskog poljodjelstva, podržavanih suvremenim informacijsko-komunikacijskim tehnologijama i na njima temeljenim znanjima (na nekonvencionalan način). Također u usvojenoj Strategiji razvoja hrvatske poljoprivrede nema niti i! od info osnove hrvatskog poljodjelskog sustava, a kamoli da se predviđa njena intenzivnija izgradnja na hrvatskim prostorima.

KARAKTERISTIKE INFO OSNOVA SUVREMENIH POLJODJELSKIH SUSTAVA

Činjenica je da su globalizacijski procesi trenutna preokupacija brojnih svjetskih kompanija poljodjelskog tipa, i da je za takovu koncepcijsku i stratešku orijentaciju nužno potrebna bila akcepcija suvremenih info postignuća i na njima temeljenih znanja u kontekstu povezivanja istih s relevantnim nacionalnim i međunarodnim okruženjem. No, također valja kazati da analiza većine poljodjelskih sustava razvijenih zemalja pokazuje izuzetnu sofistikaciju poljodjelskih proizvodnih i poslovnih procesa u cilju djelotvornijeg funkcioniranja i univerzalnijeg gospodarenja ujedinjenim tržištem na kojem djeluje uravnoteženi sustav vrijednosti. Kazanom valja dodati i činjenicu da razvijene države brojnim poticajnim mjerama djeluju na razvoj svog nacionalnog poljodjelstva, što omogućuje fleksibilnije ponašanje poljodjelskih kompanija na domaćem i međunarodniom tržištu, a ima za posljedicu teškoće opstanka na takovom tržištu onih kompanija čije zemlje iz kojekakvih razloga nisu u mogućnosti pratiti takav trend razvoja.

No, ako bismo htjeli ukratko opisati i shematski prikazati razne organizacijske oblike asocijacija poljodjelskog tipa suvremenih poljodjelskih sustava visoko razvijenih zemalja, ona isti možemo prikazati (vidi: sliku 1.) i razvrstati na: organizacije poljodjelskog tipa, i institucije poljodjelskog tipa.



Slika 1 Prikaz info osnove suvremenih poljodjelskih sustava u institucijsko-organizacijskom smislu.

Organizacije poljodjelskog tipa. U organizacije poljodjelskog tipa kao asocijacije suvremenih poljodjelskih sustava, možemo između ostalih ubrojiti[1)]: *nacionalne asocijacije, međunarodne asocijacije, zavisne asocijacije, transnacionalne asocijacije i globalne asocijacije.*

Nacionalne asocijacije. *Ove asocijacije poljodjelskog tipa djeluju kao jedinstveno poduzeće s jednim sjedištem iz kojeg se strategijski upravlja. Info osnova ovih asocijacija ima zadatak da osigurava relevantne informacije u cilju prosperiteta asocijacije na jedinstvenom nacionalnom tržištu.*

Međunarodne asocijacije. *Ove asocijacije poljodjelskog tipa imaju više sjedišta s više nacionalnih centrala koje djeluju kao nezavisna poduzeća. Info osnova ovih asocijacija ima zadatak da organizira adekvatne informacijske baze, i da omogući neometan tijek informacija između različitih sjedišta asocijacije u cilju njene strateške orijentacije.*

Zavisne asocijacije. *Ove asocijacije imaju više sjedišta gdje moć pripada središnjici, dok podružnice djeluju kao zavisne vanjske jedinice. Info osnova ovih asocijacija ima zadatak da osigurava adekvatne informacijske baze, i da omogući slobodan tijek informacija između različitih informacijskih djelova asocijacije, te da njene informacije budu podloga u donošenju njenih strateških odluka.*

Transnacionalne asocijacije. *Ove asocijacije poljodjelskog tipa imaju više sjedišta i više nezavisnih nacionalnih središnjica s podružnicama koje se strategijski kontroliraju iz središnjice. Info osnova ovih asocijacija ima zadatak da osigura relevantne informacijske baze, i da omogući slobodan tijek informacija kako unutar asocijacije tako i prema relevantnom okruženju, i to u cilju prosperiteta asocijacije na transnacionalnoj razini.*

Globalne asocijacije. *Ove asocijacije poljodjelskog tipa organizirane su na mrežno-relacijskoj osnovi, te nezavisno djeluju kroz jedinstvenu strategiju. Info osnova ovih asocijacija ima zadatak da organizira adekvatne informacijske baze, i da osigurava slobodan tijek informacija u cilju koncepcijskog i strateškog djelovanja asocijacije na svjetskom tržištu.*

Institucije poljodjelskog tipa. Od institucija poljodjelskog tipa koji egzistiraju u suvremenim poljodjelskim sustavima možemo između ostalih ubrojiti: *institute, agencije, burze i aukcije, te informacijske servise.*

Instituti poljodjelskog tipa. *Zadaća ovih institucija je da na lokalnoj, regionalnoj i nacionalnoj razini provode različita ali međusobno zavisna istraživanja u kontekstu razvoja poljodjelstva i njegovog prosperiteta na nacionalnoj i međunarodnoj razini. Info osnova ovih institucija ima zadaću da ih međusobno poveže i da ovisno o njihovoj koncepcijskoj i organizacijskoj logici funkcioniranja osigurava relevantne informacijske baze, kao i slobodan međusobni tijek relevantnih informacija, kao i tijek informacija prema organizacijama i institucijama poljodjelskog i inog tipa. Informacije koje se nalaze u bazama podataka središnjeg nacionalnog instituta poljodjelskog tipa, podloška su raznim državnim i gospodarskim tijelima u njihovim koncepcijskim i strateškim orijentacijama.*

Informacijski servisi. *Zadaća ovih institucija je da osigurava relevantne tržišne i druge informacije, ponajprije za potrebe sve raznovrsnijih organizacija i institucija koje djeluju u suvremenim poljodjelskim sustavima, te da istražuju i prikupljaju relevantne informacije iz okruženja koje su interesantne za nacionalne asocijacije i institucije u cilju njihove orijentacije kako na domaćem tako i na međunarodnom tržištu.*

POLOŽAJ INFO OSNOVE HRVATSKOG POLJODJELSKOG SUSTAVA

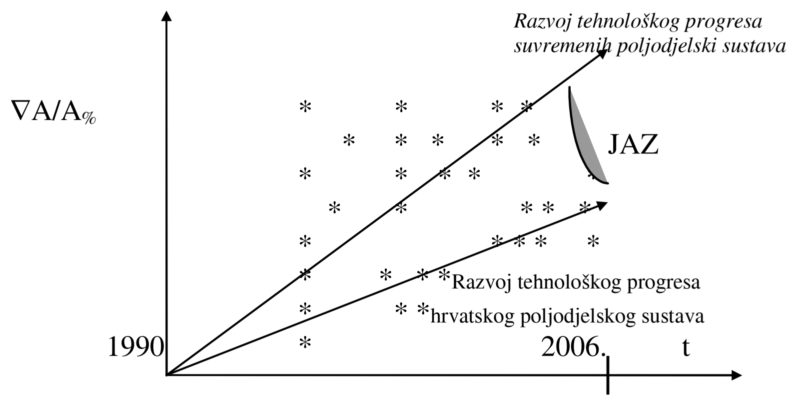
Činjenica je da je hrvatski poljodjelski sustav u koncepciji razvoja bivše države bio niz desetljeća zanemarivan, pa tako s njime bila zanemarivana i njegova info osnova. Također valja naglasiti da se je hrvatski poljodjelski sustav od svih sustava u Hrvatskoj u minulom razdoblju, najsporije kretao ka informatizaciji svoji proizvodnih i poslovnih procesa. No, ovakvo stanje još je više pogoršanodomovinskim ratom i ratnim razaranjima, gdje su ratne štete i pustoš nametnule nov breme hrvatskom poljodjelstvu i tako još više otežalo njegovu poziciju i sposobnost da na ekonomskim načelima funkcionira[2)].

Današnja situacija stanja je takova na na nacionalnoj/državnoj razini nemamo niti jednu poljodjelsku asocijaciju koja bi se mogla nositi s poljodjelskim asocijacijama iz razvijenih zemalja, a i pretvorbeni procesi u domeni poljodjelstva nisu išli ka njegovoj homogenizaciji i na taj način su sustavno doprinjeli njegovoj sve većoj dezintegraciji. Kao rezultat cjelokupnog stanja je i činjenica da danas na početku 21. stoljeća, ne postoje značajnije veze hrvatskog poljodjelskog sustava s relevantnim međunarodnim okruženjem na info osnovi. Također u aktualnoj organizacijskoj koncepciji hrvatskog poljodjelstva nedostaje cijeli niz institucija poljodjelskog tipa, između kojih navodimo: nacionalni poljodjelski institut, burzu i aukciju poljodjelskih proizvoda, kao i agencije poljodjelskog tipa, te poljodjelski informacijski servisi (PIS).

Kao rezultat navedenih nedostataka organizacijskog i institucijskog tipa, je i to, da danas uopće nemamo relevantnih informacijskih baza poljodjelskog tipa na nacionalnoj/državnoj razini, kako bismo mogli uskladiti na razvojne planove sa stvarnim potrebama u određenim vremenskim okvirima.

No, također valja kazati da o info osnovi u usvojenoj Strategiji razvoja hrvatske poljoprivrede nema niti riječi, pa joj stoga valja pridjeliti konvencionalni status preživjelog vremena. Kazanom valja dodati i činjenicu koja pokazuje i nedostatak svijesti u domeni izgradnje info osnove hrvatskog poljodjelstva, što svakako može dovesti do daljnjih negativnih učinaka koji mogu rezultirati kolapsom cjelokupnog sustava. Na situaciju u kojoj se nalazi hrvatsko poljodjelstvo valja dodati i prisutne sustavne tendencije segmentarnog riješavanja problema, i to bez ozbiljnijeg sagledavanja stanja u kojem se nalazi cjelokupni poljodjelski sustav.

Kao rezultat stanja u kojem se nalazi hrvatski poljodjelski sustav u odnosu na suvremene poljodjelske sustave, je i sve veći razvojni jaz kojeg je vrlo teško smanjiti, a kamali premostiti, što je prikazano na slici 2.



Slika 2 Prikaz tehnološkog progresa hrvatskog poljodjelskog sustava

Tehnološki progres prikazan na Slici 2. Iskazan je za područje poljodjelstva po Cobb-Dauglasovoj makroekonomskoj funkciji od osamostaljenja Hrvatske države, i uspoređen sa razvojem nekih suvremenih poljodjelskih sustava kumulativno izraženih veličina. No, radi pojašnjenja osnovni parametara za izračunavanje tehnološkog progresa po Cobb-Dauglasovoj funkciji, istu ćemo prikazati preko slijedeće formule:

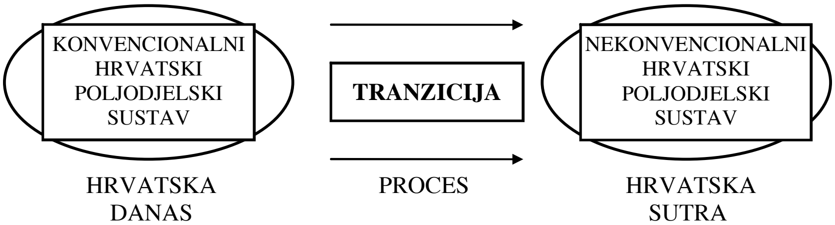
$$\boxed{\Delta \mathbf{A}/\mathbf{A}_{\%} = \Delta \mathbf{Q}/\mathbf{Q}_{\%} - (\Delta \mathbf{R}/\mathbf{R}_{\%} * \alpha + \Delta \mathbf{K}/\mathbf{K}_{\%} * \beta)}$$

gdje je:

1. $\Delta \mathbf{A}/\mathbf{A}_{\%} \Rightarrow$ stopa tehnološkog progresa
2. $\Delta \mathbf{Q}/\mathbf{Q}_{\%} \Rightarrow$ stopa rasta nacionalnog proizvoda
3. $\Delta \mathbf{R}/\mathbf{R}_{\%} \Rightarrow$ stopa rasta zaposlenih
4. $\Delta \mathbf{K}/\mathbf{K}_{\%} \Rightarrow$ stopa rasta fiksnih fondova
5. $\alpha + \beta \Rightarrow$ stope elastičnosti [pretopstavka je da je $\alpha + \beta = 1$, ali nije uvjek jedan(1), pa se tebaju izračunati i za izračunate vrijednosti treba osnovne veličine korigirati].

Temeljem provedenih istraživanja glede analize tehnološkog progresa hrvatskog poljodjelstva po Cabb-Douglasovoj funkciji, između ostalog vidljiv je pad broja zaposlenih, smanjenje udjela prihoda poljodjelskog sustava u nacionalnom bruto proizvodu i zastarjelost/devastiranost tehnologije (fiksnih fondova) gdje oko 87% tehnologije koja egzistira u hrvatskom poljodjelskom sustavu je konvencionalnom dok je 8% tehnologije nekonvencionalno, a svega 5% tehnologija čine info tehnologije. Stoga, ako znamo da se uz određenu tehnologiju primjenjuju i prikladne metode i tehnike rada, jasno nam je gdje je danas hrvatsko poljodjelstvo i njegova info komponenta.

Temeljem kazanog valja nam konstatirati da je hrvatski poljodjelski sustav danas konvencionalan, te da ga kroz tranzicijske procese valja osuvremeniti, što znači da treba postati nekonvencionalan (vidi: slika 3.), te na toj osnovi nastojati smanjiti u odnosu na svijet nastali jaz prikazan na slici 2.



Slika 2 Transicijski procesi u domeni hrvatskog poljodjelstva

No, za orijentaciju prikazanu na slici 3. Nužno su potrebna saznanja o položaju i poziciji hrvatskog poljodjelskog sustava, pa stoga, bi bilo neophodno provesti jedno ciljano razvojno istraživanje kako bismo znali koncepcijski osmisliti takove tranzicijske procese koji će u bliskoj budućnosti hrvatski poljodjelski sustav učiniti suvremenim i partietnim u odnosu na poljodjelske sustave razvijenih zemalja.

VAŽNOST ISTRAŽIVAČKOG PRISTUPA U DOMENI STANDARDA INFO OSNOVE HRVATSKOG POLJODJELSKOG SUSTAVA

Temeljem iznesenih činjenica glede položaja i razvoja info osnove hrvatskog poljodjelskog sustava, smatramo da bi trebalo provesti jedno ciljano razvojno istraživanje kojim se želi utvrditi pozicija standarda info komponente našeg poljodjelskog sustava s organizacijskog, informacijsko-komunikacijskog i personalnog aspekta. No, činjenica je da je osuvremenjavanje info komponente hrvatskog poljodjelskog sustava bilo zbog inih razloga desetljećima zenemarivano u bivšem sustavu, i da ju je sadašnja situacija uvjetovana ratom i ratnim razaranjima bitno i pogoršala, pa je stoga, neophodno provesti određeno istraživanje koje bi sustavno ukazala na ovu problematiku, s ciljem modernizacije iste kroz novu strategije razvoja hrvatskog poljodjelstva. Na taj način bismo spriječili prisutne tendencije segmentarnog pristupa kompletnoj problematici, te na info osnovi integrirali naš poljodjelski sustav. Istraživanje polazi od pozitivne hipoteze koja se bazira na činjenici da hrvatsko poljodjelstvo ima prioritetnu poziciju u razvoju Hrvatske, pa zato, info komonenta tog sustava mora biti i bonitetna i djelotvorna. Stoga, istraživanje ima zadatak da na prihvatljivoj akademskoj razini prezentira modele alokacije i implementacije info komponente hrvatskog poljodjelskog sustava, koji će kroz primjenu suvremenih info resursa i na njima temeljenih znanja integrirati gotovo sve sfere hrvatskog poljodjelskog sustava, te povezati iste s relevantnim internim i eksternim okruženjem. U tom cilju u istraživanjima valja primjenivati kako suvremene info metode i tehnike, tako i alati, te tehnologije vezne uz izgradnju info osnove hrvatskog poljodjelskog sustava. Također se može očekivati da će predloženo istraživanje ukazati na nužnost, pretpostavke i prednosti koje pruža suvremena info tehnologija našem poljodjelstvu.

Svrha, pretpostavke istraživanja

Na temelju spoznaje stanja i problema organizacijsko-komunikacijskog ustroja info komponente hrvatskog poljodjelskog sustava, treba predložiti novi info model hrvatskog poljodjelskog sustava s uklapanjem istog u relevantno domaće i međunarodno okruženje. Prema tome, svrha ovakvog istraživanja je da se na temelju analize i sinteze info komponente sustava, daju preporuke za standardizaciju, optimalizaciju i implementacija raspoloživih info resursa u domene hrvatskog poljodjelskog sustava, u cilju njegove integracije i razvoja iz agrarnog u postagrarno razdoblje. Gledano iz tog uklona pretpostavka (hpoteza) ovakvog istraživanja je pozitivna a bazira se na suvremenim trendovima razvoja info osnove suvremenih poljodjelskih sustava razvijenih zemalja, koji su u znatnijoj mjeri akceptirali relevantna info postignuća i na njima temeljena znanja.

Stoga, možemo kazati da kod nas info osnovu svremenog poljodjelstva tek treba sustavno osmisliti i u koncepcijskom i strateškom obliku oblikovati, te kroz model implementirati, u cilju daljnjeg razvoja hrvatskog poljodjelstva.

Značaj istraživanja i način njegovog uklapanja u prioritete

Istraživanje info komponente hrvatskog poljodjelskog sustava svakako treba biti razvojno, a valja ga temeljiti na analizi postojećeg stanja info osnove hrvatskog poljodjelstva, te sukladno ocjeni postojećeg stanja, signirati najracionalnije moguće puteva razvoja glede transformacije i tranzicije hrvatskog poljodjelskog sustava, po uzoru na poljodjelske sustava razvijenim zemljama u kojima info komponenta ima dominantnu ulogu glede razvoja.

No, također info komponenta hrvatskog poljodjelskog sustava mora dati odgovore koliko čega ima i koliko čega treba u sferi poljodjelstva, kako bi se ista mogla na djelotvoran način postaviti spram poljodjelskih potreba koje ima ili će imati Hrvatska Država. Zato, bez bonitetne info komponente hrvatskog poljodjelskog sustava nije moguće niti njegovo optimalno funkcioniranje sukladno mogućnostima i potrebama.

Stoga, imali se na umu činjenica da je hrvatski poljodjelski sustav u prošlim vremenima najsporije kretao ka informatizaciji svoji proizvodnih i poslovnih procesa, i da isti predstavlja glavni prioritet u razvoju Hrvatske Države, onda bi ovakvo istraživanje, bilo ujedno i temeljno istraživanje koje bi na sustavan način istražilo njegovu info osnovu.

Gledano s tog uklona može se kazati da bez adekvatne i suvremene info infrastrukture, nema niti adekvatnih informacijskih baza, nema niti specijaliziranih informacijskih servisi, info burze i aukcije poljodjelskog sustava …, što je sine qua non ulaska u Europske i svjetske integracije i komunikacije u kontekstu uklapanja našeg poljodjelstva, kako bi isti mogao na paritetnoj osnovi pronalaziti svoje probitke i perspektive uz adekvatnu nacionalnu svijest o luvanju i saluvanju nacionalne poljodjelske suverenosti i identiteta.

No, dodamoli kazanom i činjenicu da je pred nama vrijeme velikih transformacijskih i tranzicijskih procesa koje se odnose na poljodjelski sustav, stoga, hoćemoli to izvesti na adekvatan način ovisi i o tome koliko smo ih i suštinski svijesni da bi ih proveli.

Ciljevi istraživačkog pristupa

Ciljeve istraživačkog pristupa u domeni info osnove hrvatskog poljodjelskog sustava možemo klasificirati na: *opće ciljeve istraživanja i posebne ciljeve istraživanja.*

Opći ciljevi istraživanja. Ovi ciljevi istraživanja mogu se sagledati kroz potrebu da treba istražiti i spoznati info osnovu hrvatskog poljodjelstva, te sukladno trendovima razvoja predložiti novi model info komponente poljodjelskog sustava na početku 21. stoljeća. Predloženi model info komponente hrvatskog poljodjelskog sustava trebao bih sadržavati organizacijeske, informacijsko-komunikacijske i personalne elemente/pretpostavke koje su nužno potrebiti pojedinim agro institucijama i poduzećima radi djelotvornog organiziranje info funkcije, kao i preporuke za međusobno povezivanje istih u jednu zavisnu ali međusobno različitu informacijsko-komunikacijsku cjelinu.

Posebni ciljevi istraživanja. U posebne ciljeve istraživanja info osnove hrvatskog poljodjelskog sustava valja ubrojiti:

a) utvrđivanje stanja i selektiranje problema vezanih uz info osnovu hrvatskog poljodjelstva.

b) utvrđivanje utjecaja vlasničkih i transformacijskih procesa na uspostavu info osnove hrvatskog poljodjelstva.

c) istraživanje suvremene profilacije info komponente hrvatskog poljodjelskog sustava
d) utvrđivanje organizacijskih, informacijsko-komunikacijskih i tehničkih pretpostavki za realizaciju info sustava hrvatskog poljodjelstva.
e) istraživanje personalne i obrazovne problematike vezane uz info komponentu poljodjelskog sustava.
f) istraživanje zakonodavne regulative glede info komponente poljodjelskog sustava.
g) istraživanje utjecaja sustava obrade podataka, sustava obrade informacija, komunikacijskih sustava i masovnomedijskih sustava poljodjelskog tipa, na razvoj i djelotvornost poljodjelskog sustava kao cjeline.
h) perspektive razvoja hrvatskog poljodjelskog sustava na info osnovama.

Metode istraživanja

U realizaciji ovog istraživačkog zadatka stoje nam na raspolaganju razne info metodologije funkcionalne i konceptualne orijentacije.

Funkcionalne metodologije. To su fazne metodologije koje cjelokupni proces izgradnje info sustava dijele na faze, podfaze, korake i zadatke.

Konceptualne metodologije. Ove metodologije karakterizira sustavna filozofija u kojoj info sustava je sastavni dio konkretnog organizacijskog sustava koji svojim funkcioniranjem omogućuje njegov djelotvorni rast i razvoj. U te metodologije ubrajama: metodologije za izgradnju sustava baziranih na podacima (metodologija Informacijskog inženjerstva i metodologija SSADM-Structured System Analisys and Design Method), metodologije za izgradnju sustava baziranih na znanju, i metodologije za izgradnju komunikacijskih sustava i masovno medijskih sustava (kao što je kvalitativna i kvantitativna analiza, genetsko-strukturalna i funkcionalna metodologija, te metodologija implementacije novih medija), kao sustav javnog komuniciranja iz domene hrvatskog poljodjelstva.

Istraživanja će sigurno zahtjevati kombinirani pristup primjene metodologija, što se s obzirom na specifičnost njihove primjene u domeni poljodjelskih sustava može reflektirati na pouzdanijoj izgradni info osnove hrvatskog poljodjelstva.

Plan istraživanja

U koncepcijskom i strateškom smislu ovaj istraživački zadatak moguće je realizirati u određenim vremenskim okvirima kroz tri (3) istraživačke faze, i to:

1. Faza. U ovoj istraživaćkoj fazi treba izvršiti analizu info komponente na uzorku više poljodjelskih asocijacija i institucija, ocjena rezultata istraživanja i konceptualizacija problema kroz studij adekvatne literature i sličnih istraživanja u svijetu, kao i praksoloških rješenja.

2. Faza. U ovoj istraživačkoj fazi treba izvršiti strukturiranje elemanata za oblikovanje modela info komponente hrvatskog poljodjelskog sustava. Također bi se trebale dati adekvatne preporuke vezane uz alokaciju i implementaciju modela s organizacijskog, informacijsko-komunikacijskog, tehničkog i personalnog aspekta.

Faza 3. U ovoj istraživaćkoj fazi treba dati preporuke za alokacija i implementacija novi institucijskih organizacijskih oblika koji su nužno potrebni za djelotvirno funkcioniranje hrvatskog poljodjelskog sustava, a sukladno tome i strukturalni elementi ustroja info komponenta tih sustava. Naglasak treba biti na poticanju izgradnji adekvatnih Informacijskih baza, komunikacija, relevantnog povezivanja, meržnih informacijskih servisa poljodjelskog tipa, kao i povezivanja istih u nacionalnu i svjetske mreže za prijenos podataka (Internet, CARNet..).

Primjena istraživanja

Rezultati istraživanja trebali bi biti od aplikativnog značenja i kao takovi trebali bi pomoći nadležni tjelima i resornom Ministarstvu, te agro institucijama u Hrvatskoj, da lakše izvrše nužnu transformaciju hrvatskog poljodjelskog sustava u cilju modernizacije istog prema suvremenim info kriterijima i standardima.

To znači, da bez izgrađene info osnove na suvremeni način nije moguća niti nužno potrebna transformacija hrvatskog poljodjelstva, jer bez informatizacije bazičnih i poslovnih procesa i njihovih sveza međusobno i s relevantnim okruženjem nije niti moguće provesti istu. Stoga, ovo istraživanje bi išlo u pravcu signiranja na modularan naćin adekvatnih rješenja u formi preporuka, a u kontekstu izgradnje info osnove poljodjelskog sustava, s ciljem uklapanja istog na bonitetan i paritetan način u prestojeće europske inetgracije.

Istraživanje bi trebalo ponuditi načine međusobnog informacijsko-komunikacijskog uvezivanja različitih poljodjelskih asocijacija i institucija, kao i preporuka u tom kontekstu, koje bi resorni organi i tjela nadležnih agencija i Ministarstava poduprli u smislu adekvatne implementacije.

Preporuke bi se odnosile i na redefiniranje poljodjelskog sustava na razini institucijskih formi, jer je sada već jasno da u našem poljodjelskom sustavu nedostaje niz institucija koje treba implementirati da bi isti mogao udovoljiti spomenutim zadaćama i potrebama u perodu koji nam prestoji.

Zakonodavne i etičke forme istraživanja

Predloženo istraživanje valjalo bi provesti u skladu sa svima Zakonim iz domene poljodjelstva, Zakonom o telekomunikacijama, Zakonom o HRT, Zakonom o HINI, Zakonom o javnom priopćavanju, kao i drugim pozitivnim pravnim propisima Hrvatske države. Istraživanje također treba biti u skladu s važećim rezolucijama i konvencijama Vijeća Europe, kao i Belmont Reportu (1979) koji govori o nužnosti poštivanja osoba, dobrohotnosti i pravednosti istraživanja.

No, na temelju kazanog vidljivo je da istraživanje počiva na dobrohotnosti i da ima za cilj unapređenja hrvatskog poljodjelskog sustava kroz osmišljavanje i alokacije njegove info osnove.

Očekivani rezultati istraživanja

Činjenica je da je ostvarljivost ovog istraživačkog zadatka dobrim djelom moguća u određenim vremenskim granicama, i u istraživačkim etapama, a sigurno očekivani rezultati su:

- Točno saznanje o stanju i problemima info osnove hrvatskog poljodjelstva.

- Točno saznanje o stanju i problemina info osnove nekih suvremenih poljodjelskih sustava.
- Izrada koncepcije modela info komponente hrvatskog poljodjelskog sustava.
- Davanje preporuka za alokaciju i implementaciju info modela, kao i preporuka vezanih za standardizaciju i sustave komuniciranja.
- Utvrđivanje info elementata za integraciju info komponente hrvatskog poljodjelskog sustava.
- Davanje preporuka za komunikacijsko povezivanje poljodjelskih asocijacija i institucija, te davanje elemenata za povezivanje naših institucija sa tangiranim poljodjelskim međunarodnim okruženjem putem svjetskih informatičkih mreža.

OBRAZOVNI ASPEKTI U DOMENI INFO OSNOVE HRVATSKOG POLJODJELSTVA

Temeljem opisanog stanja razvoja info osnove suvremenih poljodjelskih sustava razvijenih zemalja, te položaja u kojem se nalazi info osnova hrvatskog poljodjelskog sustava, kao i nužni istraživanja koje treba provesti, valja nam konstatirati da u domeni obrazovanja valja izvršiti radikalne promjene kako bi se budući stručnjaci iz domene poljodjelstva što više upoznali s relevantnim info postignućima i na njima temeljenim znanjima.

Na taj način bismo na kvalitetan način pripremili personalnu komponentu koja bi u određenom vremenu mogla odigrati važnu ulogu u tranzicijskim procesima hrvatskog poljodjelstva. No, kako sada stvari stoje na poljodjelskim visoko obrazovnim institucijama hrvatskih sveučilišta obrazovni info modul je neadekvatno zastupljen, a početni obećavajući impuls s početka 90-ih godina, gotovo je u potpunosti anuliran putem odnosa snaga i argumenta moći uz potpunu indiferentost Sveučilišta i resornog Ministarstva.

No, imajući na umu poziciju info modula na našim visokoškoliskim institucijama poljodjelskog tipa, može se konstatirati da bi isti valjalo redefinirati kako bismo po uzoru na razvijene zemlje i mi dali našim budućim poljdjelskim stručnjacima nužno potrebita znanja iz ove domene, kao što se takvim stručnjacima daje u razvijenim zemljama svijeta. No, za takovu orijentaciju nužno je potrebna pomoć Sveučilišta i resornog Ministarstva, koja je prema dosadašnjim iskustvima potpuno izostala.

PRETPOSTAVKE POVEZIVANJA HRVATSKOG POLJODJELSKOG SUSTAVA S RELEVANTNIM OKRUŽENJE NA INFO OSNOVAMA

Stvarnost u koju smo došli nam ukazuje na činjenicu da Hrvatska mora voditi jednu konstruktivnu politiku u strategiji razvoja hrvatskog poljodjelstva na početku 21, stoljeća, i to s ciljem uklapanja istog u međunarodnu podjelu rada prema suvremenim standardima među koje spadaju i info standardi.

No, za takovu orijentaciju hrvatskog poljodjelstva nužno je i na državnoj razini implmentirati adekvatnu informacijsku infrastrukturu za slobodan tijek informacija kako iz sustava u okruženje, tako i iz okruženja u sustav.

No, također je prema našim saznanjima potrebno u organizacijskom smislu redefinirati hrvatski poljodjelski sustav, te u organizacijsku strukturu tog sustava implementirati organizacijske institucijske oblike koji u suvremenim poljodjelskim sustavima funkcioniraju i nosioci su njihovog razvoja.

Stoga, znademo li da su u suvremenim uvjetima privređivanja institucije nosioci razvoja, onda s obzirom na nedostatke istih u našem poljodjelskom sustavu, je ujedno i rezultat razvojnog stanja u kojem se nalazimo, a ne mjenjanje ovog stanja može dovesti do novog pogoršanja cjelokupnog sustava i izostanka njegovog povezivanja s relevantnim okruženjem na info osnovi.

Temeljem kazanog, valja nam konstatirati da promjene koje valja nužno provesti u okviru hrvatskog poljodjelskog sustava ovise o činjenici koliko smo u osnovi svijesni tih promjena koje treba provesti.

ZAKLJUČAK

Temeljem prikazanog stanja info osnove suvremenih poljodjelskih sustava i položaja info osnove hrvatskog poljodjelskog sustava, te opisanih istraživačkih potreba u ovoj domeni, valja nam kazati da se po svemu sudeći hrvatski poljodjelski sustav nalazi na pragu svojeg novog razvoja, i da na taj izazov valja kvalificirano odgovoriti i to ponajprije snagom vlastitog uma, koji će na profinirane načine i brojne turbulencije na paritetan način nas povezati s tangiranim domaćim i međunarodnim okruženjem.

No za takvu orijentaciju nužno je potrebno usvojiti novu koncepciju i strategiju razvoja hrvatskog poljodjelstva, i to na interdisciplinarnoj osnovi, kako bi ista bila u funkciji poticanja, a ne spoticanja razvoja hrvatskog poljodjelstva, a to znači da se nikako da se nikako ne pretvori u svoju suprotnost i da bude kočnica svekolikog razvoja našeg poljodjelstva i da tako u koncepcijskom smislu doprinosi njegovom strateškom nazadovanju, a ne razvitku..

Doista, mogućnosti koje nam danas pruža moderna znanost i tehnologija, su takove da se s njima možemo uspješno nositi u odnosu na probleme s kojima se suočava naš poljodjelski sustav, no hoćemo li te mogućnosti i iskoristiti ponajprije ovisi o našim htijenjima dali određene promjene u istinu i želimo provesti.

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PLACE AND ROLE INFORMATIC'S IN PROCESS DEVELOPING CROATIAN AGRICULTURAL SYSTEMS AT THE BEGINNING OF THE 21.ST CENTURY

SUMMARY

This paper deals with info base of Croatian agricultural systems it with info base Croatian agricultural systems as in developed countries and also shows the importance of a research approach in domene implementation standards informatization from agricultural development country in Croatian agricultural system.

Special attention is paid to reasons of broughting up new strategies of Croatian agricultural system development which would handle its info base a systematical way. The attention is also paid to educational aspects in the Croatian agricultural domain in this historic transitional period.

Key words: *info system, standards informatization, agricultural system, public communication system, information service, communication systems, massmedial systems, strategy agricultural development*

35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Prethodno priopćenje
Preliminary communication

WORKING ENVIRONMENT OF ROTARY MILKING PARLOUR

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SUMMARY

Building of big farms with uninsulated cowshed, using rotary type of milking parlour will be more popular. In Estonia, there are already four that type of farms with 450...1000 milking cows. Farm's inside working environment climate on milking parlour is greatly influenced, especially in wintertime, by outside climate and works, carried out on waiting area. Because of milking, cleaning, manure disposal and large number of cows on waiting area, there will be much higher content of relative moisture and noxious (noisome) gases in the air. The cows spend relatively short time on waiting area and milking parlour compared to milker, who's period of duty is much longer, 7...8 hours per day.

The aim of the paper was to study the influence of works carried out on rotary milking parlour and outdoor climate to the parlour and to the workers energetic load in farm with uninsulated cowshed during winter and summertime and to determine time, spent for milking of cows. Indoor temperature, relative humidity, air velocity, carbon dioxide and ammonia content were measured for that purpose on rotary milking parlour with 24 cow places (farm with 636 cow places). In addition, all work operations performed were observed in chronological order and the workers' pulse rates were measured and taken as a basis to calculate the work energy load. Measuring device named Data Logger with respective sensors and computer program AMR WinControl were used to examine indoor climate. At the same time outdoor air temperature and relative moisture were observed, using Rotronic measuring device.

Present paper includes results of research about works carried out on rotary milking parlour, outdoor climate influence to indoor climate, milker's work load rate and work expense.

Key words: *milker, herdsman, rotary milking parlour, waiting area, outdoor climate, indoor climate, temperature, relative moisture, oxygen, carbon dioxide, ammonia, pulse rate, work load rate, work expense.*

INTRODUCTION

Construction of large farms with uninsulated cowsheds, in which cows are milked on a carousel type of milking parlour, is becoming increasingly frequent. As of today, there are already four such farms with 450...1000 dairy cows in use in Estonia. The quality of climate in the milking parlour of these farms and the waiting area pertaining to it as well as the performance of the workers is affected by outdoor climate and the works made in these premises. Due to the milking and cleaning works, and especially the high concentration of cows in the waiting area, there is an increase in relative humidity and carbon dioxide content of indoor air (Mikson et al., 2006). There are no substantial researches on working environment of milking technology used in the rotary milking parlour carried out. Consequently, there is a need to study indoor climate of these premises and the impact of the working environment on the energetic workload of workers.

The objective of the present research was to study the impact of works performed in the milking parlour and waiting area as well as outdoor climate of uninsulated cowsheds with resting stalls on indoor climate of these premises and on the level of physical effort for work of workers, and to determine milking duration in summer and in winter. For that purpose, indoor air temperature, relative humidity, velocity and contents of oxygen, carbon dioxide and ammonia were measured. Simultaneously, outdoor air temperature and relative humidity were measured. Works performed in the premises were monitored and chronometrically measured, and also workers' pulse rate was measured, which was used as a basis for determining the level of physical effort for work.

METHODS

Working environment in a farm with 636 cows was studied. The farm comprises of one uninsulated cowshed with 619 dairy cows in summer and 617 dairy cows in winter that were milked in four groups according to their productivity. Milking was carried out twice a day with a fish bone rotary milking device "Impulsa" with 24 lots, milking duration was on average 6.5 hours.

Cows are kept in cubicles without bedding. The area of the waiting area is 305 m^2 for 160 cows.

The floor of the waiting area is sloped ascending towards the milking parlor. Milking parlour has open hollow and natural ventilation through a hole in the roof and openings in the walls covered with roller blinds. In the milking parlour floor heating and forced ventilation was used. There were two milkers who, in turn, prepared cows for milking, placed milking device to udder and disinfected udder after milking. After milking the workers cleaned the platform of the rotary device and the walls and floor of the milkers hollow with water jet and a brush.

A herdsman was responsible for driving cattle from the cowshed to the waiting area and from there on to the milking parlour, and for cleaning the waiting area with a mini loader AVANT after milking.

Indoor air temperature, relative humidity, velocity and contents of oxygen, carbon dioxide and ammonia in waiting area and at milking parlour were measured at the height of 1.5 m from the floor of the platform (http..., Karhunen, 1992) and at the height of 3.0 m from the floor of the waiting area during twenty-four hours. Simultaneously, outdoor temperature and relative humidity were measured and the work of milkers and herdsman was monitored and measured chronometrically. The study was carried out in the summer of 2005 and the winter of 2006.

ALMEMO Data Logger 8990-8 equipment with computer program AMR WinControl was used for studying the parameters of indoor climate. Indoor air temperature and relative humidity were measured with AMR company sensor FH646-1 with measurement area –20…+80°C (measuring accuracy 0.01°C) and 5…98% (measuring accuracy 0.1%). Oxygen and carbon dioxide content were measured with sensor ZA 9000-AK2K (measurement area 0…100%, measuring accuracy 0.01%) and FY A600 (measurement area 0…2.5%, measuring accuracy 0.01%) respectively. For measuring ammonia content a measuring device Dräeger PAC III was used (measurement area 0…100 ppm and measuring accuracy 1.0 ppm. Air velocity was measured by using thermo-anemometer FHA645TH2 with measurement area 0…2 m/s and resolution 0.001 m/s. HygroLog device with HygroClip S sensor were used for measuring the temperature and relative humidity of outdoor air (measurement area -40…+85°C and 0…100%, measurement accuracy ±0.3°C and ±1.5% respectively). Measurement results were analysed by using computer programmes AMR WinControl, HW3 and MS Excel (Kiviste, 1999).

The level of physical effort for work was determined according to the average and highest pulse rate of milkers and the herdsman, based on the Classification of Workload approved by World Health Organization (WHO) (Tuure, 1991) and according to the data of the authors (Andersen et al., 1978) determining the level of physical work: pulse rate less than 100 beats per minute - light (L); pulse rates 100…124, 124…150 and pulse rate over 150 represent moderate (M), heavy (H) and very heavy (VH) level of physical effort for work respectively.

Workers’ pulse rate was measured with „Polar Sport Tester” equipment consisting of sender (sensor) and receiver (tester) (Mikson et al., 2005). Sender was attached to the pulse area and the receiver on the hand. Receiver recorded the information concerning pulse rate in every 5 seconds.

After processing the data computer programme Polaris produced statistical series and diagrams of workers’ pulse rate, identified chronologically, as well as minimum, maximum and average values of pulse rates. Diagram print-outs were supplemented with additional scales facilitating the observance of changes in the level of physical effort for work during work performed (Figure 1).

Working hours of the two milkers and the herdsman were measured chronometrically during 24 hours. The actual working hours of the workers were determined according to the structure scheme (Maatalouden työnormit, 1988), which considers total working hours as consisting of steady supporting time (10 minutes for dressing, washing, etc.) and time for fulfilling the production work. The latter comprised both the time spent on performance and the time spent on preparations and finishing. Pictures were taken of each work operation, pause, etc. of a worker to enable to determine the time spent on these activities, describe the activities and make entries into the monitoring diary. Simultaneously, "Polar Sport Tester" was used. Comparing the results of the measurements gave information about the time spent on a particular task and the pulse rate the employee had while performing these tasks.

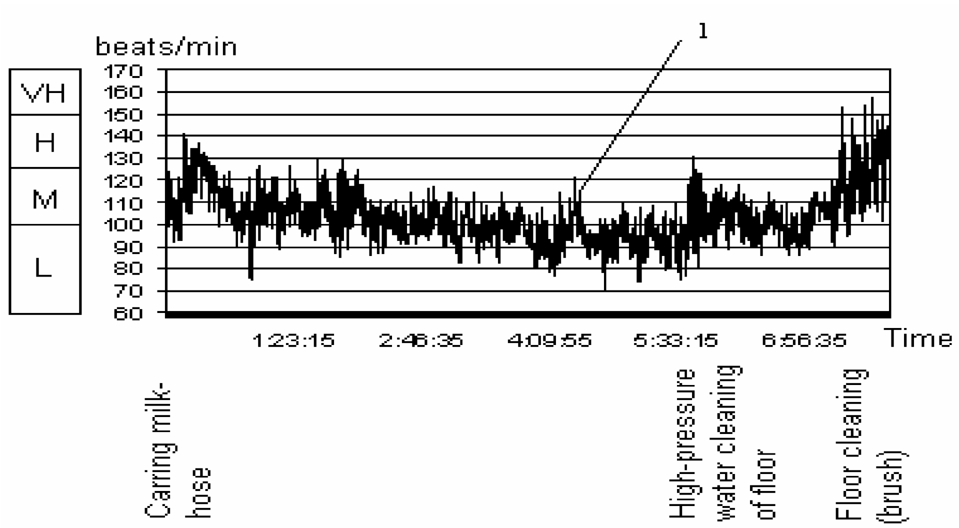


Figure 1 Pulse rate of milker 1 (1), works performed and the level of physical effort for work at a morning milking in summer; L – light; M – moderate; H- heavy; VH – very heavy level of physical effort for work

Daily unit cost in human minutes per one cow and one ton of milk was determined, considering the number of cows milked in the parlour and the amount of the gathered milk in tons.

RESULTS

The results of the study of summer indoor climate reveal that at the outdoor temperature of 1.9...15.6°C, the temperature in the premises of the milking parlour was between 14.01...19.77°C, with the average daily temperature being 17.41°C (Table 1, Figure 2A).

In case of lower outdoor temperatures at nights, the lowest indoor temperature was 13°C at the beginning of morning milking, by the end of the milking the temperature had risen up to 19.1°C. Despite the higher outdoor temperature (up to 15.6°C at daytime), indoor temperature rose only up to 19.77°C due to the intensive ventilation of the room.

Relative humidity of air in milking parlour was, on average (74.88%), lower than the humidity of outdoor air (82.36%), which was achieved with the floor heating used also in summer. Relative humidity rate of indoor air (92.2%) exceeded allowed limits only at the time the parlor was processed with water jet.

The average oxygen and carbon dioxide content (19.91% and 0.21%, respectively) remained within the allowed limits. Only at the beginning of morning milking, as the cattle were driven to the milking parlour with lower indoor temperature and insufficient ventilation, the carbon dioxide content of the air (0.26%) exceeded the allowed limit (0.25%).

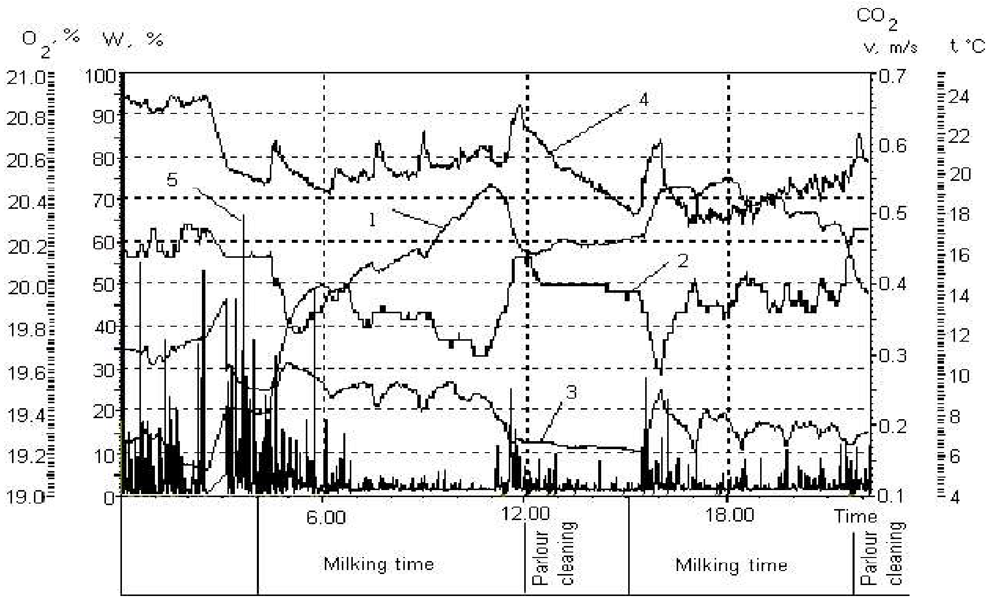
As the results of the winter study of indoor climate reveal, at the outdoor temperature and relative humidity of -2.5...+6.6 °C and 50.8%...90.3%, respectively, the temperature and relative humidity in the premises of the parlour was between 10.7...21.71 °C and 60.0...88.3%, which constituted average of 16.38 and 74.21% being within the allowed limits (Table 1, Figure 2B). A higher carbon dioxide content (0.19%) was measured only at the end of both morning and evening milking and a higher relative humidity (88.3%) at the time the parlour was processed with water jet. In general, good indoor climate is ensured by intensive heating and ventilation of the room. Content of ammonia in the air was measured only in winter and the level did not exceed 10 ppm.

At the time indoor climate of the waiting area was studied in summer, the outdoor temperature and relative humidity were between 2.9...18.0°C and 50.12...89.23%, which constituted average of 7.40°C and 82.60% (Table 2). In case of open sidewalls of the waiting area, the measured values were lower on average, being 6.85°C and 8.11% respectively, but the indoor air humidity increased up to 100% while manure was removed from the floor. Due to the high concentration of animals in the waiting area, the concentration of carbon dioxide in the air was high, measured between 0.20...0.35%, which caused the decrease in the contents of oxygen down to 17.71...19.89%. Consequently, in case of a mild weather when the velocity of air (wind) is little in summer, a supplemental air ventilation system should be exploited to improve ventilation in the waiting area.

Table 1 Numerical values of the milking parlour and indoor and outdoor climate parameters in summer and in winter during 24 hours ($\bar{x}$ - average)

Parameters	**Summer**			**Winter**		
	Min	**Max**	$\bar{x}$	**Min**	**Max**	$\bar{x}$
Temperature, °C	14.01	19.77	17.41	10.07	21.71	16.38
Relative humidity, %	63.3	92.2	74.88	60.0	88.3	74.21
Oxygen O_2, %	19.57	20.25	19.91	18.25	19.45	18.70
Carbon dioxide CO_2, %	0.161	0.26	0.21	0.09	0.19	0.145
Ammonia NH_3, ppm	_	_	_	0	10.0	3.0
Air speed, m/s	0.09	0.26	0.11	0.09	0.57	0.12
Outdoor temperature, °C	1.9	15.6	6.25	-2.5	6.6	2.75
Outdoor relative humidity, %	70.56	95.94	82.36	50.80	90.30	71.63

A.



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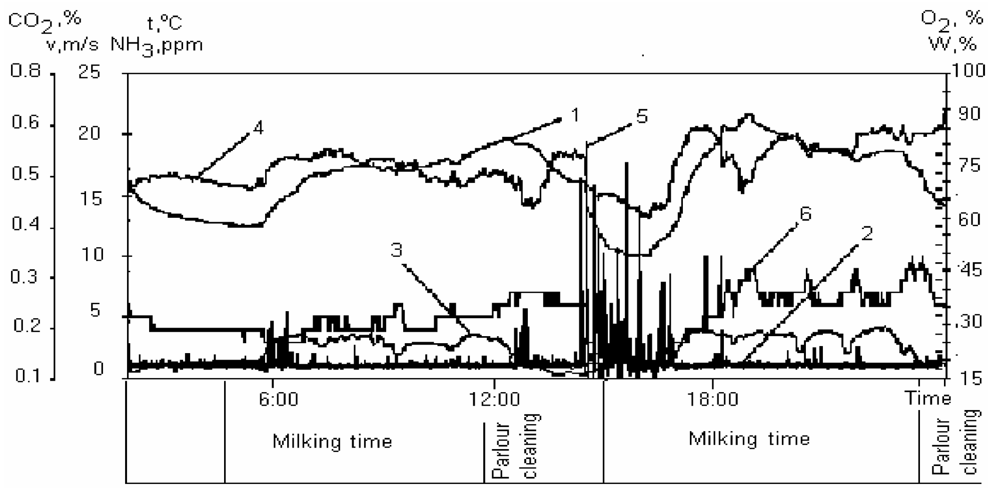

Figure 2 Diurnal change of measured air parameters values of milking parlour in summer (A) and winter (B): 1-temperature; 2-oxygen; 3-carbon dioxide; 4-relative humidity; 5-air speed; 6-ammonia.

As there is no wall separating the milking parlour from the uninsulated cowshed, the lower temperature in winter (measured between -9.0...+8.0°C) affected the indoor temperature of the waiting area, with daily average of 5.44°C (Table 2). While indoor temperature was -5.63°C before morning milking, at the time of the fourth group of animals being in the waiting area, the temperature rose up to +0.1°C (Figure 3) and by the time of evening milking the temperature was already as high as 11.5°C. Relative humidity of air was on average 79.72% remaining within the allowed limits. However, due to the comparatively low indoor temperature in the morning, relative humidity rose up to 100% during morning milking. Also, the average carbon dioxide content (0.20%) in air remained within the limits. Based on the measurements, it can be concluded that indoor climate of waiting area in winter with its lower temperature is more favourable for the animals than indoor climate in summer when higher air temperatures cause an increase in gasping of animals and a higher concentration of carbon dioxide, thus decreasing the content of oxygen in the air.

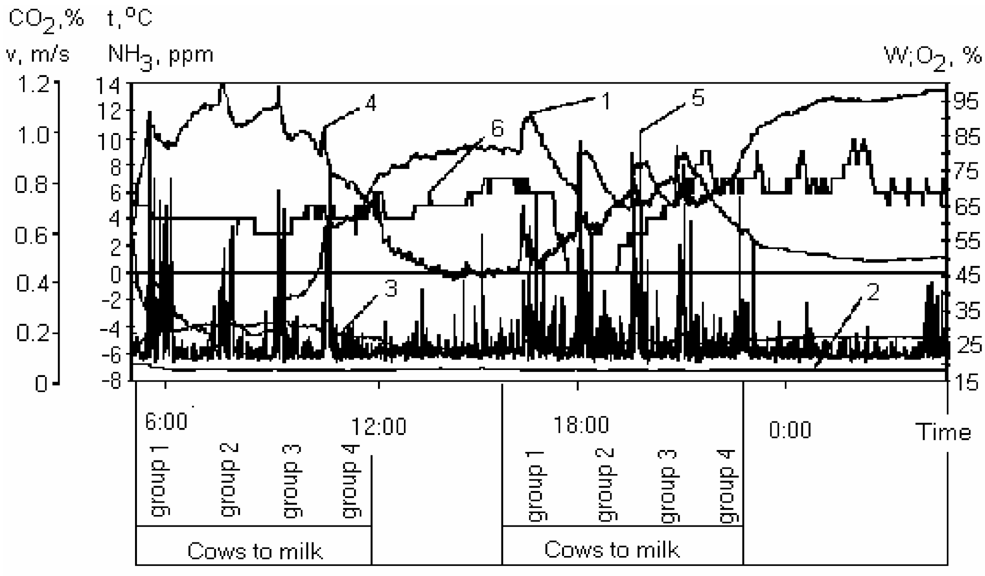

Figure 3 Diurnal change of measured air parameters values of waiting area in winter: 1-temperature; 2-oxygen; 3-carbon dioxide; 4-relative humidity; 5-air speed; 6-ammonia

It appeared that in summer and in winter the physical effort for work of milkers was, measured during a shift by the average pulse rate, light (L) and moderate (M) (Table 3). However, some tasks, like displacing long milk hoses, cleaning the platform of the parlour and the floor of the hollow, became classified as heavy and very heavy, increasing the pulse rate frequency up to 140...157 beats per minute (Figure 1, Table 3).

As the milkers were working in a heated room with forced ventilation, low indoor temperature of waiting area in winter did not affect significantly their energetic load. In case of routine tasks, the work of milker 2 was easier as compared to that of milker 1, which could be attributed to the longer employment history and proficiency of the older woman.

Considering the average pulse rate, the work of the herdsman was generally moderate (Table 3).

Table 2 Numerical values of indoor and outdoor climate parameters in waiting area in winter and in summer during 24 hours ($\overline{x}$ - average)

Parameters	**Summer**			**Winter**		
	Min	**Max**	$\overline{x}$	**Min**	**Max**	$\overline{x}$
Temperature, °C	6.63	16.45	6.85	-5.63	11.55	5.44
Relative humidity,%	60.3	100	81.1	60.3	100	79.72
Oxygen O_2,%	17.71	19.89	19.4	17.76	20.24	18.06
Carbon dioxide CO_2,%	0.20	0.35	0.25	0.10	0.26	0.20
Ammonia NH_3, ppm	–	–	–	0	6.0	2.5
Air speed, m/s	0.080	0.87	0.150	0.083	0.172	0.125
Outdoor temperature, °C	2.9	18.0	7.4	-9.0	8.0	3.5
Outdoor relative humidity,%	50.12	89.23	82.6	74.21	86.81	76.38

Table 3 The level of physical effort for work of workers (L – light; M – moderate; H-heavy; VH – very heavy level of physical effort for work)

Parameters	**Herdsman 1**	**Milker 1**	**Milker 2**	**Milker 1**	**Milker 2**
	Winter	**Summer**		**Winter**	
	Morning	**Morning**	**Evening**	**Morning**	**Evening**
Sex	Female	Female	Female	Female	Female
Age, years	43	36	51	36	51
Pulse rate, beats/min:					
-average	103	103	94	104	94
-highest	155	155	140	157	141
Work load rate					
-acc. to average pulse rate	M	M	L	M	L
-acc. to highest pulse rate	VH	VH	H	VH	H

Very heavy physical effort for work was required for opening and closing the gates of fences in the cowshed and for emotional communication with a disobedient animal while driving it to the milking parlor or back to the cowshed.

Studying the time of milking revealed that daily working hours per one cow and one ton of milk were longer in winter (4.93 and 219.39 human minutes) as compared to those in summer (4.42 and 184.67 respectively) (Table 4). It appeared that with the same size of cattle and same amount of milk gathered (20 liters), milking time increased by 308 human minutes per day in winter.

Table 4 Time of milking in human minutes per one cow and one ton of milk during 24 hours

Parameters	**Summer**			**Winter**		
	Morn.	**Even.**	**24 h**	**Morn.**	**Even.**	**24 h**
Number of herdsmen		1			1	
Number of milkers		2			2	
Number of cows		619			617	
Milk, t	7.54	7.26	14.81	7.85	6.02	13.87
Prepare-finish time, human minutes	84	69	153	79	61	140
Main work, human minutes	1320	1182	2502	1428	1395	2823
Const, help time, human minutes	30	30	60	30	30	60
Sum. work time, human minutes	1444	1291	2735	1547	1496	3043
Work expense per cow, human minutes	2,33	2.09	4.42	2.51	2.42	4.93
Work expense per milk ton, human minutes	191.51	177.82	184.67	197.07	248.50	219.39

CONCLUSIONS

In the present study, indoor air temperature, relative humidity, velocity and contents of oxygen, carbon dioxide and ammonia were measured in milking parlour and waiting area of a dairy farm with an uninsulated cowshed during 24 hours in summer and in winter. Simultaneously, outdoor air temperature and relative humidity were measured. Works performed in the premises were monitored and chronometrically measured. During the working hours pulse rate of the milker and the herdsman were measured. Also workers' level of physical effort for work and daily time of milking per one cow and one ton of milk was determined.

The study revealed that the change in numerical values of indoor climate parameters is dependent on the works performed in these premises (driving animals to the waiting area and to the milking parlour, milking, removing manure and cleaning floors) and, especially in case of waiting area, on outdoor climate.

Studying indoor climate of milking parlour in summer proved that at outdoor temperature level of 1.9...15.6°C, the temperature in the premises of the milking parlour was between 14.01...19.77°C, with the average temperature being 17.41°C. Despite the higher outdoor temperature (up to 15.6°C at daytime), indoor temperature only rose up to 19.77°C due to the intensive ventilation of the room, which remains within the allowed limits (17…21°C).

Relative humidity of air in milking parlour was, on average (74.88%), lower than the humidity of outdoor air (82.36%), which was achieved with the floor heating used also in summer, however, relative humidity rate of indoor air (92.2%) exceeded allowed limits only at the time the floor was cleaned with water jet.

Average oxygen and carbon dioxide content of air remained within the allowed limits both in summer and in winter.

The results of the winter study of indoor climate revealed that due to intensive heating of the room and appropriate ventilation good indoor climate was achieved. As the values of outdoor air temperature and relative humidity were -2.5...+6.6°C and 50.8%...90.3% respectively, the respective numerical values of indoor air parameters of milking parlor were 16.38 and 74.21% respectively.

As indoor climate of the waiting area was studied in summer, outdoor temperature and relative humidity were within the allowed limits, being in case of open sidewalls of the waiting area on average 6.85 and 8.11% respectively; indoor air humidity increased up to 100% only while manure was removed from the floor. It appeared that due to the high concentration of animals in the waiting area, the concentration of carbon dioxide in the air was high, measured up to 0.35%, which caused the decrease in the contents of oxygen. Hence, beside the natural ventilation, the waiting area needs to be equipped with forced ventilation.

For the waiting area being directly connected with (without a separating wall between) an uninsulated cowshed, significant impact of outdoor climate on indoor climate can be felt. Thus, in case of outdoor temperature in winter being between -9.0...+8.0°C, temperature in the waiting area was measured -5.63…+11.55°C, which constituted average of 5.44°C. Relative humidity of air, on average 79.72%, rose up to 100% during morning milking, change caused by the low indoor temperature (-5.63°C); average carbon dioxide content (0.20%) in air remained within the limits (up to 0.25%).

Temperature and relative humidity at the milking parlour and waiting area increased at the time of milking as compared to the respective values measured at the time between milking shifts. At the same time, also an increase in the velocity of air in these premises could be perceived.

In winter, supplemental heating would raise the temperature and application of an additional ventilation system would decrease humidity in the waiting area.

Proceeding from the average pulse rate measured during work performance in summer and in winter, the physical effort for work of milkers was light (L) and moderate (M), shifting to heavy (H) and very heavy (VH). Displacing long milk hoses, cleaning the platform of the parlour and the floor became classified as heavy and very heavy, increasing the pulse rate frequency up to 140...157 beats per minute.

According to the average pulse rate, the work of the herdsman was generally moderate (M). Very heavy physical effort for work was required for removing gates of fences in the cowshed and for emotional communication with a disobedient animal.

Working hours per one cow and one ton of milk a day were 4.83 and 215.6 human minutes respectively. In winter, milking time took the workers ca 1.5 hours more than that in summer.

ACKNOWLEDGEMENT

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.223.2:636.2.083.312.1
Prethodno priopćenje
Preliminary communication

THERMAL AND HUMIDITY ENVIRONMENTAL CONDITIONS IN UNINSULATED COWSHED

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SUMMARY

Having carried out the literature analysis it has been established that the relative air humidity in spacious cowsheds is often high and even exceeds the relative air humidity outside by 15 %. It is considered that the reason for high humidity is inadequate ventilation in the cowshed. The work objective is to substantiate reasoned values of environmental conditions (i.e., air temperature and relative humidity) in a cowshed which are necessary in designing and operating a ventilation system. Analytical and experimental research methods have been applied using the principles of thermophysics. An equation relating relative humidity in a cowshed with the temperature difference between the inside and outside air has been drawn. Another equation showing the biggest allowed temperature difference to prevent condensation of water vapour on the internal surface of external barriers has been drawn. Analytical and experimental research has substantiated that probable minimum relative humidity in a cowshed is about 5 % lower than relative humidity outside. The reasoned temperature difference between the inside and outside air during cold season is about 4 ^oC, when the heat transfer rate of walls and roof was 4.5 $W/(m^2 \cdot K)$.

Key words: *cowshed, thermal charakteristics, temperature difference, air humidity*

INTRODUCTION

Up to the mid sixties of the last century the recommended inside air temperature for milking cows was 10–15 ^oC (Horntvedt 2000). Therefore, in the zones of cool and temperate climate insulated (warm) cowsheds were built. Later as cow productivity became higher, recommended temperature was constantly reduced because it had been established that a productive cow released much heat and low temperatures protected the animal from overheating. The research of recent years (Epinatjeff 1997) showed that the most suitable temperature for a productive cow yielding 20 kilograms or more milk per day ranged from plus 5 ^{o}C to minus 10 ^{o}C. The milk yield decreases only when the temperature exceeds plus 24 ^{o}C or when it drops down to minus 27 ^{o}C.

Having reviewed the research literature it can be stated that the temperature and humidity regime of naturally ventilated cowsheds has been analysed experimentally under production conditions. An assumption can also be made that due to insufficient ventilation relative humidity often exceeds the outside air humidity in spacious cowsheds (Janni et al 2001; Pajumagi et al 2005).

The work objective is to substantiate reasoned values of temperature and humidity schedule in a cowshed which is necessary in designing and operating the ventilation system in an analytic and experimental way.

METHODS

Analytical and experimental research methods have been applied using the principles of thermophysics.

Analytical research is applied to achieve dependence of cowshed relative air humidity on the difference between the inside and outside air temperatures, the analysis being related to thermal characteristics of promising cowsheds in Lithuanian climatic conditions. The results achieved have been compared with the experimental data.

A cowshed's thermal characteristics are described by the modulus of heat losses which points out a proportion of the animals' total heat flow that is lost through the external barriers when the difference between the inside and outside air temperatures is one degree. The total modulus of the heat losses x_o assesses losses through all external barriers, and the partial x assesses losses through walls and roof. Total modulus of heat losses $x_o = \left(\sum UA + \psi P\right) / \sum Q_o$ and partial modulus $x = \sum UA / \sum Q_o$, 1/K. Here U – heat transfer rate of barrier (walls and roof), W/(m^2·K); A – barrier area, m^2; ψ – factor heat losses through floor and foundations, W/(m·K), (when foundations and floor area insulated ψ = 0.9, when not insulated – ψ = 1.5 W/(m·K); P – foundation perimeter, m; $\sum Q_o$ – animals' total heat flow, W.

Experimental research was carried out in an uninsulated 200-place cowshed of 21 m in width. The average heat transfer rate of cowshed walls and roof was 4.5 W/(m^2·K). The total modulus of heat losses was 0.057 1/K and the partial modulus was 0.056 1/K. Fresh air came into the upper part of the cowshed through 15 mm wide gaps between longitudinal wall planks and the polluted air was removed through 0,6 m wide rooftop gap. The overall area of air removal gap was 42 m^2. The overall area of air inlets during cold season was 17 m^2. During warm season the cowshed's doors are opened. In that case the overall area of wall inlets is equal to the area of the rooftop inlet.

During the research the inside and outside temperature, relative humidity and air velocity in the rooftop inlet were measured. The air temperature and humidity were registered every hour during one entire keeping in barn period from November to April. A computerized gear TRACER COX for temperature and humidity measuring-memory was used for that purpose. Air movement and wind velocity were measured by ALMEMO–2290–3 device.

RESULTS AND DISCUSIONS

Analysis

Relative inside air humidity and sweating of external barriers in winter, estimated parameters of ventilation system depend on the difference between the inside and outside temperatures. The latter indicator depends on heat and water vapour flows inside the building, the building's thermal characteristics and climatic conditions outside.

Relation between the inside relative air humidity and difference of temperatures is achieved by solving house's heat and water vapour balance equations together. The final expression is as follows:

$$\varphi_i = \frac{1}{d_i}\left[\frac{ce}{\dfrac{\varepsilon + \eta I x}{\Delta t} - x_o} + \varphi_o d_o\right], \tag{1}$$

where: φ_i, φ_o – inside and outside relative air humidity, parts of unit;

d_i, d_o – inside and outside absolute air humidity in set point, g/kg;

c – specific air heat capacity, kJ/(kg·K);

e – specific water evaporation intensity (amount of water vapour released by animals and evaporated in building per unit of total animal heat), g/kJ;

ε – ratio of animal sensible heat with total heat;

$\eta = \beta/\alpha_o$ – rate to assess sun irradiance, m^2·K/W (β – rate of sun energy absorption of external surface; α_o – rate of heat transfer of external barrier surface, W/(m^2·K));

I – average flow density of sun energy on overall external barrier surface, W/m^2;

Δt – difference between inside and outside air temperatures, ^{o}C.

Dependence of the average specific intensity of water evaporation on the building air temperature t_i, ^{o}C,

$$e = 0.085 \times 10^{0.02 t_i} \;. \tag{2}$$

Value $\varepsilon = 1 - 2.5e$, here 2.5 – specific heat of water vapour, kJ/g.

The optimum value of temperature difference Δt is such at which the building relative air humidity φ_i is the lowest. In analysing the following was selected:

- Relative humidity of outside air φ_o, %, depends on air temperature t_o, ^{o}C, (Anonymous 1995) in the following way:

$$\varphi_o = 86.6 - 0.535 t_o - 0.0368 t_o^2 \;; \tag{3}$$

- Rate to assess sun irradiance η=0.022 m^2·K/W (Kavolelis 2004);

- Density of sun irradiance on building's barriers depending on outside air temperature (Kavolelis 2004):

when t_o, °C	–5	0	10	≥15
here I, W/m^2	20	130	145	190

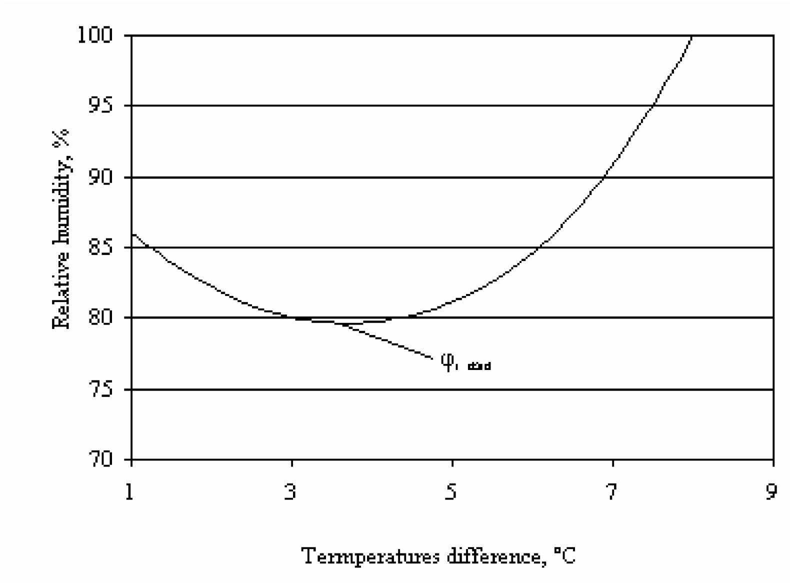

Figure 1 The dependence of the relative humidity of the inside air on the difference temperature between inside and outside air, when outside air temperature is minus 5 °C, relative humidity – 88 %, and the modulus of heat losses through external barriers of the cowshed – 0.057 1/K; $\varphi_{i\,\min}$ – likely minimum relative humidity of the inside air

The analysis results show that in cold season when the outside air temperature is lower than 0 °C the optimum difference between the inside and outside air temperatures is about 4 °C. In that case the relative air humidity is the lowest and about 5 % lower that the relative air humidity outside. When the temperature difference increases or decreases compared with the optimum value, the relative humidity inside air increases (Figure 1).

In order to prevent condensation of water vapour on the internal surface of external barriers the permissible temperature difference between the inside and outside air can be established by the following equation (Kavolelis 2004):

$$\Delta t_p = -\frac{260}{U} \lg \varphi_i \ . \tag{4}$$

In recent years cowsheds' roofs are often covered with asbestos-free slating, heat transfer rate of which is U = 3.7 W/(m^2·K) and tin (U = 6.6 W/(m^2·K). When the air relative humidity is multiannual average and the cowshed is ventilated in an appropriate way, in the first case the permissible temperature difference is about 7 ^{o}C and in the second case – 4 ^{o}C.

Knowing the optimum temperature difference the reasoned ventilation intensity and ventilation system parameters can be calculated. In the most common case the air flow coming through the ventilation system (ventilation intensity):

$$G = \frac{\sum Q_o}{c}\left[\frac{\varepsilon + x\eta I}{\Delta t} - x_o\right] = \rho_o v_1 \sum A_1 = \rho_i v_2 \sum A_2 \ , \qquad (5)$$

where: G – reasoned ventilation intensity, kg/s;

$\sum Q_0$ – total heat flow of animals, kW;

ρ_i, ρ_o – density of inside and outside air, kg/m^3;

v_1, v_2 – air velocity in inlets and outlets, m/s;

$\sum A_1$, $\sum A_2$ – total areas of inlets and outlets, m^2.

Experimental Results

Experimental research results and its comparison with analytical research are presented in Figure 2. The points correspond to average daily experimental values. During the research the average daily temperature varied from minus 15.2 ^{o}C to plus 8.3 ^{o}C and relative humidity varied from 78.1 to 98.1 %.

The experimental dependence of relative humidity of the inside air, %, on the outside temperature can be expressed by the following regression equation:

$$\varphi_i = 0.0085 t_o^2 - 0.582 t_o + 81.72 \ . \qquad (6)$$

The difference between the experimental and analytical relative humidity values of the inside air was insignificant and made about 2 %.

The experimental dependence of the difference between the inside and outside air temperatures on the outside temperature can be expressed by the following regression equation:

$$\Delta t = -0.0027 t_o^2 - 0.0983 t_o + 3.96 \ . \qquad (7)$$

During the cold season the average daily temperature in the cowshed was 4.6 ^{o}C ($p \leq 0.05$) higher than that outside and the experimental temperature difference was about 1 ^{o}C higher that the analytical value.

The ventilation intensity of the cowshed varied from 450 to 760 m^3/h per cow and exceeded the recommendation for EU countries: minimum in winter – 80 m^3/h per cow and maximum in summer – 500 m^3/h per cow. It can be stated that the ventilation system of the cowshed has been designed and equipped properly and it maintains microclimatic parameters close to the optimum ones.

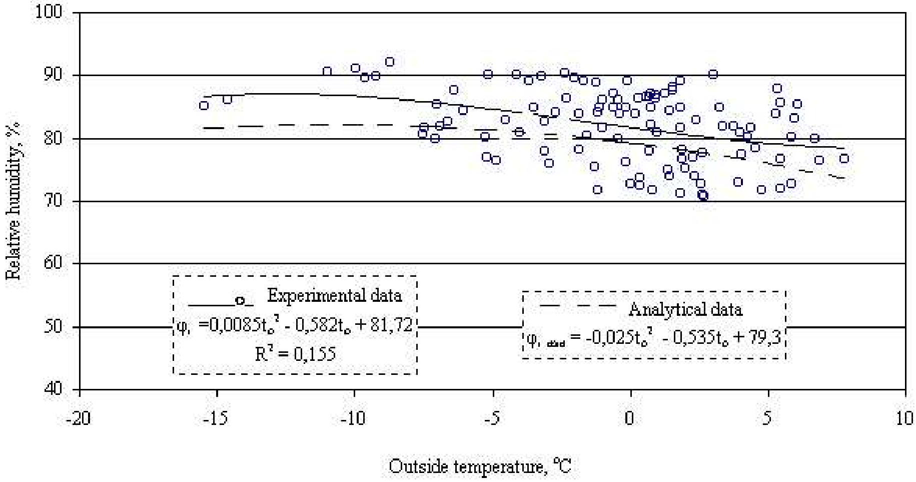

Figure 2 The experimental and analytical dependence of relative humidity of the inside air φ_i on outside temperature t_o, when the modulus of heat losses through external barriers of the cowshed is x_o=0.057 1/K

CONCLUSIONS

1. Having performed analytical research an equation (1) has been drawn which relates the inside relative air humidity with the difference between the inside and outside temperatures describing the intensity of the cowshed's ventilation.
2. The analytical and experimental research has substantiated the fact that permissible minimal relative air humidity in a cowshed is about 5 % lower than that outside.
3. The reasoned difference between the inside and outside temperatures of an uninsulated cowshed (average heat transfer rate of walls and roof is – 4.5 W/(m^2·K)) in cold season (lower than 0 °C outside) is about 4 °C.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 665.334.9
Pregledni rad
Review paper

MOGUĆNOSTI DECENTRALIZIRANE PROIZVODNJE ULJA IZ ULJANE REPICE ZA BIODIZEL NA OBITELJSKIM GOSPODARSTVIMA

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SAŽETAK

Potpisom Kjotskog protokola (potpisan 1998. godine, ratificiran 2002. godine) Slovenija namjerava do razdoblja 2008-2012 ispuštanje plinova, koji prouzrokuju takozvani efekt „staklenika“ smanjiti za 8 % (obzirom na stanje u 1986. godini). Upotreba biogoriva predstavlja jednu od mjera Strategije i kratkoročnog akcijskog plana smanjenja emisija spomenutih plinova. Promjenom zakona o trošarinama na goriva krajem 2003. godine biogoriva kao pogonska goriva opredijeljena su kao trošarinski proizvodi sa 0 % trošarinskim stupnjem. Slijedeći korak u poticanju upotrebe biogoriva učinjen je prijenosom Direktive EU u slovenski pravni poredak (EU direktiva o promociji uporabe biogoriva i drugih obnovljivih goriva za promet koja države članice potiče ka povećanju udjela biogoriva u ukupnoj potrošnji goriva za transport na 5,75 % do kraja godine 2010). U sklopu strateškog cilja Slovenije za povećanje stupnja samoopskrbe energijom, poljoprivreda bi mogla odigrati značajnu ulogu na području opskrbljivanja sirovina za biogoriva. Za slovenske i europske prilike (klimatski uvjeti, tehnologija proizvodnje, cijena biogoriva, poljoprivredna problematika, itd.) od tekućih biogoriva iz biomase trenutačno je najprimjerenije gorivo biodizel proizveden iz biljnih ulja, odnosno biodizel iz uljane repice. Za domaće prilike u budućnosti biti će zanimljiva decentralizirana proizvodnja ulja iz uljane repice pošto je moguće proizvoditi kvalitetno ulje, koje predstavlja sirovinu za biodizel te uljanu pogaču, koja je zanimljiva kao bjelančevinasto krmivo visoke vrijednosti. Decentralizirana proizvodnja moguća je i na većim obiteljskim gospodarstvima koja su raspršena po cijeloj državi, zbog toga što male proizvodne jedinice mogu poslovati ekonomično kao i prihvatljivo za okoliš *uslijed jednostavne i jeftine tehničke opreme i jednostavnog radnog procesa povezanog sa niskom potrošnjom energije.*

Ključne riječi*: biogoriva, biodizel, uljana repica, decentralizirana proizvodnja ulja*

UVOD

Transport producira 28 % emisija ugljičnog dioksida u EU, a cestovni transport će prema ocjenama stručnjaka proizvesti 90 % novih emisija ugljičnog dioksida do 2010. godine, zbog čega je uvođenje goriva, koja će doprinijeti ka smanjenju ugljičnog dioksida od vitalnog značaja za dosezanje ciljeva Kjotskog protokola. Potpisom Kjotskog protokola Slovenija namjerava do razdoblja 2008-2012 smanjiti ispuštanje takozvanih „stakleničkih plinova“ za 8 % (obzirom na stanje u godini 1986).

Ugljični dioksid, koji se stvara kod izgorijevanja biomase, ne daje svoj doprinos ugrožavanju podneblja, pošto se radi o ugljiku kojeg su biljke vezale iz zraka i ponovno se vraća natrag u zrak. Biomasa, koja nastaje u poljoprivredi, upotrebljava se kao izvor ljudske ili životinjske hrane, za preradu u sirovine, proizvode ili goriva dok se jedan dio u obliku otpadaka neposredno vraća u tlo. Pored čvrstih i plinskih produkata biomase postoje i tekuća goriva iz biomase ili biogoriva. Biogoriva je moguće upotrebljavati kao nadomjestak ili dodatak gorivima naftnog izvora za upotrebu u transportu i izvan njega. Od tekućih goriva iz biomase najznačajnija biogoriva su: bioetanol, biometanol te biodizel. U sklopu strateškog cilja Slovenije za povećanje stupnja samoopskrbe energijom, poljoprivreda bi mogla odigrati značajnu ulogu na području alternativnih izvora energije, naročito biogoriva na osnovi ulja iz uljane repice. Promjenom zakona o trošarinama u Decembru 2003 biogoriva kao pogonska goriva definirana su kao trošarinski proizvodi sa 0 % trošarinskim stupnjem. Slijedeći korak pri daljem poticanju upotrebe biogoriva učinjen je prijenosom Direktive EU o promociji uporabe biogoriva i drugih obnovljivih goriva za promet, koji potiče članice ka povećanju udjela biogoriva u ukupnoj potrošnji goriva za transport na 5,75 % do kraja 2010. godine, u slovenski pravni poredak. To je ostvareno Pravilnikom o sadržaju biogoriva u gorivima za pogon motornih vozila (Službeni list RS, br. 108/2005). U pravilniku je definiran minimalan godišnji prosječni sadržaj biogoriva u svim gorivima, koja su uključena u promet za pogon motornih vozila na području Republike Slovenije, i to najmanje 1,2% 2006. godine, najmanje 2% 2007. godine, najmanje 3% 2008. godine, najmanje 4% 2009. godine i najmanje 5% 2010. godine. Zajamčivanje minimalnih sadržaja biogoriva postalo je obveznost distributera motornih goriva.

Biodizel proizveden iz uljane repice

Za europske i slovenske prilike (klimatski uvjeti, poljoprivredna problematika, tehnologija proizvodnje, cijena biogoriva itd.) od tekućih biogoriva iz biomase trenutačno je najprimjerenije gorivo biodizel proizveden iz biljnih ulja.

Proizvodnja biodizela iz uljarica predstavlja najjednostavniji od svih produkcijskih lanaca za biogoriva, a osim toga što je vrlo značajno je da su i troškovi proizvodnje najniži u usporedbi sa drugim biogorivima. Trenutačno se u svjetskom mjerilu 80 % biodizela proizvede iz uljane repice, 13 % iz suncokreta, a ostatak iz drugih biljnih ulja. Iz sjemena različitih biljnih vrsta moguće je proizvesti biljna ulja, koja se mogu neposredno upotrijebiti za pogon dizelskih motora prerađenih posebno u te svrhe. Ako pak izvršimo proces esterifikacije, dobivamo biodizelsko gorivo koje je po svojim karakteristikama slično dizelskom gorivu iz mineralnog ulja (plinskom ulju) i koje je prikladno za pogon dizelskih motora. **Vrlo je značajno da je moguće biodizel proizveden postupkom esterifikacije iz ulja uljane repice, suncokreta, soje, itd., upotrijebiti za već postojeće izvedbe dizelskih motora na vozilima i drugim strojevima, koji se upotrebljavaju u svim segmentima ljudske djelatnosti**. To mu daje ogromnu prednost pred nekim drugima energetskim resursima, za koje je potrebno zasnovati potpuno nove motore, npr. gorive ćelije za iskorištavanje vodika itd. Biodizel se može upotrebljavati za pogon većine osobnih i gospodarskih vozila sa dizelskim motorom. Budućnost biodizela nije sporna jer već sada neke korporacije iz automobilske industrije odobravaju upotrebu biodizela na budućim dizelskim motorima oznake EURO 5.

Jedna od mogućnosti za energetsko vrednovanje biomase, odnosno biogoriva, je upotreba koeficijenta njihove energetske bilance, koji predstavlja razmjer između energije, koja se dobiva iz energetske biljke (finalnog produkta) i energije koju upotrijebimo za proizvodnju spomenute biljke (N.El Basam 1998). Biodizel, odnosno esterificirano repičino ulje ima energetski razmjer 1 : 5,5 uključivo sa slamom, kao energentom i 1 : 3,2 bez uključene slame (slama kao energent). Za usporedbu: etanol iz pšenice ima energetski razmjer 1 : 3,6, etanol iz šećerne repe ima energetski razmjer 1 : 2,46 do 1 : 2,53. (N.El Basam 1998). Iz podataka vidi se visoka pozitivna energetska bilanca biodizela. Energetska bilanca je omjer između uloška fosilne energije neophodne za proizvodnju specifičnog energijskog nosioca i sadržane uporabne energije (Mittelbach et al. 2004). Energijska bilanca za biodizel je pozitivna i u izvještajima drugih autora (istraživanja obavljena u razdoblju 1991 – 2003) i kreće se od 1 : 2,3 do 1 : 3,2 (Mittelbach et al. 2004). Proizvodnja biodizela zahtijeva unos fosilne energije u različite faze: proizvodnja mineralnih gnojiva, uporaba poljoprivredne mehanizacije pri proizvodnji uljane repice, sušenje zrnja uljane repice, ekstrakcija ulja iz sjemena na mehanički ili kemijski način, proizvodnja metanola za transesterifikaciju itd. (i za spomenute faze moguće je upotrijebiti unos energije biogoriva). U slučaju upotrebe rabljenih jestivih ulja energetski omjer je još pozitivniji zbog toga jer otpada faza proizvodnje mineralnih gnojiva i proizvodnja zrnja uljane repice.

Predviđa se da će se u budućnosti proizvodnja biodizela skoro u cjelini odvijati prema postupku Fischer - Tröpsch. Do 2020. godine (neki autori pomiču taj datum na 2030. godinu), kada će prema predviđanjima znanstvenika spomenuta tehnologija biti osvojena za širu komercijalnu upotrebu, proizvodnja biljnog ulja proizvedenog pomoću mehaničke ekstrakcije sjemena uljarica biti će još uvijek prevladavajuća tehnologija za proizvodnju osnovne sirovine za biodizel.

U 2005. godini na području biogoriva u EU opažen je najveći porast proizvodnje biodizela. Glavni razlog za tako snažan razvoj predstavlja prihvaćanje Direktive o pospješivanju uporabe biogoriva i drugih obnovljivih resursa u sektoru prijevoza (2003/30 ES), koji od članica EU zahtijeva osiguravanje određenog udjela primjene biogoriva u prometu i određivanje ciljne vrijednosti udjela goriva. Proizvodnja biodizela u EU – 25 članica u godini 2004 porasla je od 1,9 milijuna tona na 3,2 milijuna tona. 65 % rast proizvodnje biodizela bio je dosta veći nego prije godinu dana, kada je iznosio 35 %. U državama EU 15 još uvijek se odvija 90 % proizvodnje biodizela, a broj država, koje su u

EU proizvodile biodizel u godini 2005 se je udvostručio. Danas se biodizel proizvodi već u 20 država, a to je 9 država više nego 2004. godine.

U sklopu strateškog cilja Slovenije za povećanje stupnja samoopskrbe energijom, poljoprivreda bi mogla odigrati značajnu ulogu na području alternativnih resursa energije, prije svega biogoriva na osnovi ulja iz uljane repice. U Sloveniji se uljana repica trenutačno uzgaja na približno 4000 ha, što omogućuje teoretski proizvodnju 4000 t/godinu biodizela. Prema ocjenama stručnjaka u dugoročnom razdoblju uljanu repicu mogli bi uzgajati na približno 15 000 ha – 18 000 ha (zemljišta u zarastanju, plodored, zamjena radi napuštanja proizvodnje određenih kultura itd.). Dodatne rezerve su moguće i u sklopu proizvodnje uljane repice za energetske svrhe - biodizel na površinama koje zbog propisa EU moraju biti inače u mirovanju. Za proizvodnju manje kvalitetnog biodizela moguće je upotrijebiti i otpadna jestiva ulja, kojih se godišnje nakupi oko 12000 – 14000 t i životinjske masti kojih se godišnje sakupi oko 8000 t. Teoretski potencijal spomenutih sirovina omogućuje proizvodnju dodatnih približno 20000 – 22000 t biodizela/godinu.

U 2005. godini biodizel je počela proizvoditi i Slovenija. Službeni podaci o proizvodnim količinama još nisu poznati, ali prema ocjenama European Biodiesel Bord-a i na osnovu ankete izvedene u okviru projekta EurObserver slovenska proizvodnja ocjenjuje se trenutno na 8000 – 9000 tona. Za proizvodnju biodizela u Sloveniji korištena je domaća i uvozna sirovina. Na žalost biodizel proizveden u Sloveniji skoro u cjelini ide za izvoz a vrlo malo se ga potroši za domaće svrhe (trenutno biodizel upotrebljava u manjem opsegu ljubljanski gradski prijevoz, manji prijevoznici i obrtnici te nešto u poljoprivredi preko kompenzacije za uljanu repicu). Proizvodnja biodizela u većem opsegu u Sloveniji trenutačno se odvija na nekoliko lokacija (postoji i nekoliko desetina mikro proizvođača, koji trenutno nemaju uređeni status proizvođača). Prema dostupnim podacima od većih jedinica u godini 2005 radila je jedna jedinica za decentralizirani oblik proizvodnje biodizela kapacitete do 2000 t/godini (bazira na domaćoj sirovini – uljanoj repici) te jedinica za proizvodnju u većem opsegu na industrijski način u Pinusu, Rače, i u Tovarni olja Gea, Slovenska Bistrica. U planu su i neke veće proizvodne jedinice, koje bi trebale započeti radom ove, odnosno slijedeće godine. Proizvodnja svih novih jedinica bazirati će se u manjoj mjeri na domaćoj sirovini – uljanoj repici - i u najvećoj mjeri na uvoženim uljima te otpadnim jestivim uljima i mastima životinjskog porijekla.

Decentralizirana proizvodnja ulja za biodizel

Proizvodnja biljnih ulja, koja predstavljaju osnovnu sirovinu za proizvodnju biodizela, danas se odvija na osnovi ekstrakcije ulja pomoću mehaničkog prešanja - stiskanja sjemena ili pomoću topiva (npr. heksan). Proces ekstrakcije zavisi od količine ulja u sjemenu (za sjemena sa niskim sadržajem ulja primjerena je samo ekstrakcija pomoću topiva). Mehaničko stiskanje sjemena obavlja se mehaničkim kontinuiranim presama vijčanog tipa u jedno ili dvofaznom procesu. Stiskanje sa prethodnim grijanjem omogućuje odstranjenje 95 % ulja iz sjemena dok je bez prethodnog grijanja ova količina nekoliko niža. Ekstrakcija pomoću topiva je još učinkovitija, pošto omogućuje odstranjenje i do 99 % ulja iz sjemena. Uljana pogača, koja ostaje nakon ekstrakcije topivima zbog prisutnosti organskih topiva manje je primjerena za životinjsku krmu nego uljana pogača, koju dobivamo kod mehaničkog procesa stiskanja.

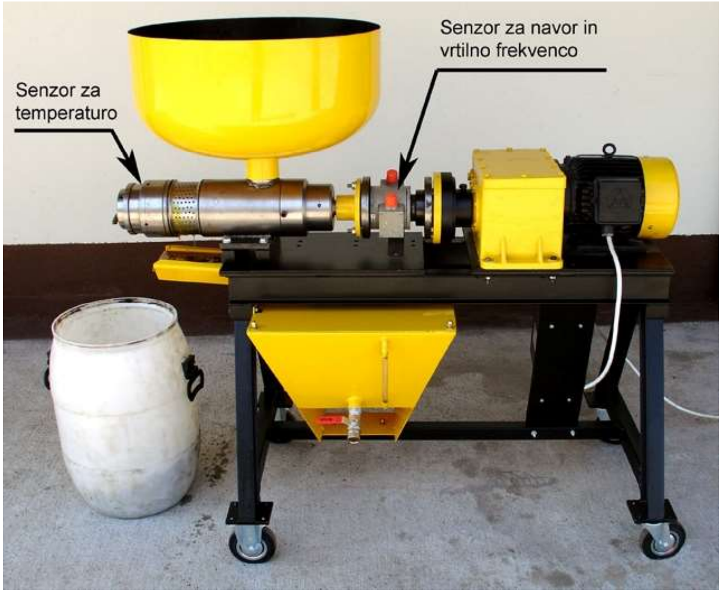
Trenutačno postoji slaba mogućnost poboljšanja postojećeg procesa mehaničkog stiskanja uljane repice. Moguće su samo manje uštede na energiji pri samom procesu stiskanja. Zato će u budućnosti značajnu ulogu odigrati trženje nusproizvoda (buduća istraživanja morati će se odvijati i u smjeru bolje iskoristivosti spomenutih nusproizvoda).

Dodatni poticaj za decentraliziranu proizvodnju biljnog ulja predstavlja spoznaja da je proizvodnja biodizela iz uljarica najjednostavniji od svih produkcijskih lanaca za biogoriva a pored toga su i troškovi procesiranja najniži u usporedbi sa drugim biogorivima.

U posljednje vrijeme u Njemačkoj i u nekim drugim državama EU pojavljuju se decentralizirani proizvođači ulja za biodizelsko gorivo. O decentraliziranoj proizvodnji ulja radi se onda kada jedinice za preradu stisnu od 0,1 do 5 t sjemena uljane repice na dan (Tack 2003). Neki autori navode da je za decentralizirane jedinice potrebno preraditi čak do 25 t sjemena na dan (Widmann 2005). Decentralizirani proizvođači ulja locirani su pored samoga izvora sirovina i povezani su direktno ili indirektno sa poljoprivrednom proizvodnjom. U slovenskom prostoru također se zauzimamo za decentralizirani oblik proizvodnje biljnog ulja za biodizelsko gorivo u manjim proizvodnih jedinicama, koje se mogu nalaziti na različitim lokacijama po državi (značaj raspršenosti proizvodnih jedinica). Decentralizirane proizvodne jedinice za stiskanje sjemena repice mogu raditi ekonomski i prihvatljivo za okoliš, jer su njihova tehnička oprema i radni proces što je moguće jednostavniji i povezani sa niskom potrošnjom energije. Npr. decentralizirana jedinica potroši za hladno stiskanje 80 kWh/t sjemena, a velika jedinica, koja vrši ekstrakciju sjemena pomoću topiva čak 470 kWh/t sjemena, što predstavlja skoro šest puta veću potrošnju energije! Takva proizvodnja je također visoko fleksibilna, jer se može izvršiti brzu promjenu stiskanja iz jedne vrste sjemena uljarice na drugu. Decentralizirana proizvodnja je zbog kraćih transportnih putova (transportni putovi do 50 km) a time i manjih troškova, koji terete cijenu proizvodnje, primjerenija od centralne proizvodnje u velikim jedinicama. Ekonomičnost takve proizvodnje uvjetovana je strukturom tržišta u smislu dobave sirovine kao i mogućnosti prihvaćanja produkata (ulja i krmne pogače). Profitabilnost decentralizirane proizvodnje ulja ovisna je od: visine investicije u opremu, trajanja radne sezone, troškova za sjeme, prodajne cijene uljanih pogača i uloženog ljudskog rada (Tack 2003). Vrlo je značajna činjenica da decentralizirana proizvodnja ulja ne opterećuje okolinu jer joj ne trebaju topiva za ekstrakciju i toplotna obrada sjemena, a u procesu proizvodnje, što je vrlo značajno, ne nastaje otpadna voda (pri proizvodnji ulja na industrijski način pomoću topiva stvaraju se velike količine otpadne vode).

U Sloveniji su proizvođači koji uljanu repicu proizvode za ulje i koji su u 2003. godini postigli prosječni prinos od 3 t/ha, usprkos njihovoj srednjoj uspješnosti, privređivali neučinkovito. Pri prosječno postignutoj otkupnoj cijeni uljane repice nisu uspjeli pokriti sve neposredne troškove proizvodnje. Dosezanje pokrića omogućeno im je preko državnih subvencija (Vadnal at al. 2004). Prema naših zaključcima bi proizvođač, koji bi uljanu repicu za biodizel stiskao na vlastitom gospodarstvu mogao ostvariti dodatan prihod, što bi ujedno bila i dodatna motivacija za gajenje uljane repice u većem opsegu i širenje decentraliziranog načina proizvodnje ulja u slovenskom prostoru.

Sirovo ulje, koje se dobiva stiskanjem, potrebno je očistiti od različnih nečistoća kao što su bjelančevine, fosfati, aldehidi, ketoni, gume (Riva et al. 1999). Zbog zahtjevanosti kod čišćenja spomenutih nečistoća sirovo ulje na gospodarstvu, koje se bavi stiskanjem sjemena repice, samo bi očistili od mehaničkih primjesa i to postupkom sedimentacije te fine filtracije. Tako pripravljeno ulje preuzimali bi veći proizvođači biodizelskog goriva – biorafinerije - koji bi izvršili postupak daljeg fizikalno odnosno kemijskog čišćenja, koje je tehnološki zahtjevnije te proces same esterifikacije ulja odnosno proizvodnje biodizela.



Slika 1 Eksperimentalna preša za kontinuirano prešanje – stiskanje sjemena uljane repice, (maksimalni kapacitet prešanja iznosi 50 kg/h sjemena) omogućuje variranje brzine vrtnje i okretnog momenta te geometrije dijela za prešanje; opremljena je s senzorima za brzinu vrtnje, okretni moment i temperaturu; preša je razvijena na Kmetijskom inštitutu Slovenije, Odjelu za poljoprivrednu tehniku

Na gospodarnost proizvodnje uljane repice namijenjene za proizvodnju goriva značajno utječe i prodaja i uporaba sačme uljane repice, koje ostaju nakon stiskanja ulja i predstavljaju bjelančevinasto krepko krmivo. Zabrana hranjenja krmivima životinjskog izvora snažno je smanjila svjetsku ponudu bjelančevinastih krmiva niske razgradivosti. Za europsku poljoprivredu karakterističan je veliki manjak bjelančevinastih krmiva. Vlastitom proizvodnjom EU pokrije tek približno 30 % potreba stočarstva. Sačma i pogače repice predstavljaju približno 10 % bjelančevinastih krmiva i čak 90 % potrošenih količina proizvede sama EU. Očekujemo da će se povećavanjem proizvodnje repice za potrebe proizvodnje biodizela, njihov udio u strukturi potrošenih krmiva povećati. Pogače iz uljane repice mogle bi predstavljati značajan izvor bjelančevina za ekološko stočarstvo. Europska uredba o ekološkoj poljoprivredi (EC No. 1804/1999) zabranjuje hranidbu svim nusproizvodima industrije ulja, koji su dobiveni uz pomoć otapala, dakle i sačme soje. Na tu uredbu se nadovezuje i slovenski Pravilnik o ekološkoj proizvodnji i preradi poljoprivrednih proizvoda, odnosno životnih namirnica (Službeni list, br. 31/2001). U usporedbi sa sačmom soje vrijedilo bi kod domaćih uljanih pogača iskoristiti i prednost, koju donosi nadzirana proizvodnja i zabrana uporabe sjemena genetski modificiranih biljaka u Sloveniji. Potencijalni korisnici uljanih pogača bile bi mješaonice krmiva i poljoprivrednici, koji sami pripremaju krmne smjese. Kako Slovenija pretežni dio bjelančevinaste stočne hrane uvozi, postoji prilično veliki interes mješaonica stočne hrane za domaću sirovinu. Predviđa se da će se zbog aktualnih događaja u poljoprivredi (mesno koštano brašno i pojava BSE, veći dio prinosa soje potiče od genetski modificiranih sorti) interes za domaću proizvedenu stočnu hranu ubuduće još povećavati. Domaćom proizvodnjom ulja iz uljane repice otvara se mogućnost proizvodnje pogača repice posebne kakvoće. Za prodaju uljanih pogača postoji mogućnost upotrebe već postojećeg načina prodaje npr. trgovine sa repromaterijalom za poljoprivredu.

Slika 2 Jednostavna tehnička rješenja omogućuju decentraliziranu proizvodnju ulja na obiteljskim gospodarstvima a kao nusproizvod stiskanja sjemena uljane repice ostaju uljane pogače bogate bjelančevinama; preša na slici namijenjena je za kontinuirano hladno prešanje sjemena različitih uljarica, kapacitet preše iznosi 25 – 120 kg sjemena/h (temp. sjemena na ulazu 15 – 25 °C), kapacitet preše je povezan sa brzinom vrtnje dijela za prešanje (variranje broja okretaja pužnice za transport i prešanje sjemena pomoću frekvencijskog regulatora), snaga elektromotora za pogon preše 4 kW, broj okretaja pužnice za dovođenje i prešanje sjemena 5 – 50 okr./min. (ovisno o uljarici), preša je opremljena sa rezervoarom za prihvat ulja i grubo predčišćenje ulja od mehaničkih primjesa, postupkom sedimentacije ulja

ZAKLJUČAK

U slovenskim prilikama u budućnosti biti će zanimljiva decentralizirana proizvodnja ulja iz uljane repice na obiteljskim gospodarstvima jer postoji mogućnost proizvodnje kvalitetnog ulja, koje predstavlja sirovinu za biodizel i uljanu pogaču, koja je zanimljiva kao bjelančevinasto krmivo visoke vrijednosti. Decentralizirana proizvodnja može se odvijati na obiteljskim gospodarstvima koja su raspršena po cijeloj državi, jer manje proizvodne jedinice mogu raditi ekonomski i prihvatljivo za okoliš zbog jednostavne i jeftine tehničke opreme i jednostavnog radnog procesa povezanog sa niskom potrošnjom energije. Poticanje proizvodnje uljane repice za biodizel u slovenskom poljoprivrednom prostoru u budućnosti će omogućiti i stimulaciju razvoja decentraliziranih proizvodnih jedinica za stiskanje ulja.

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POSSIBILITIES OF DECENTRALIZED OIL PRODUCTION ON FAMILY FARMS FROM RAPE SEED FOR BIODIESEL

SUMMARY

By signing the Kyoto Protocol (signed in 1998, ratified in 2002) Slovenia resolved to lower the emissions of greenhouse gases by 8 % (with regard to the situation in 1986) in the period 2008-2012. The use of biofuels is one of the measures conceived by the Strategy and Short-Term Action Plan of Decrease of Emissions of Greenhouse Gases. Alteration of the Law on Excise Duty in December 2003 determined biofuels used as engine fuels to become excise products with a 0 % excise rate. The next step to stimulate the use of biofuels was undertaken by including in the Slovene legal system the EU Directive on the Promotion of the Use of Biofuels or Other Renewable Fuels for Transport, which encourages the EU member states to increase the share of biofuels in the total use of fuels for transport to 2 % by the end of 2005 and to 5.5 % by the end of 2010. In frame of the strategic goal of Slovenia to increase the self-sufficiency rate in energy, agriculture may play an important role in the field of providing raw material for biofuels. For the present Slovene conditions (climatic conditions, production technology, price of biofuels, agricultural problems, etc.) biodizel made of plant oils or biodizel made of oil seed rape is considered to be the most appropriate fuel among the liquid biofuels made of biomass. Decentralised oil production from rape seed will be of interest for the Slovene conditions in future since quality oil can be obtained, which is a raw material for biodizel, and oil cake which is interesting as a high quality protein feed. Decentralised production may be carried out on larger farms which are dispersed throughout the country, since small production units can operate economically and environmentally friendly due to a simple and cheap technical equipment and simple working process connected with low energy use.

***Key words**: biofuels, biodizel, oil seed rape, decentralised oil production*

35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Expert paper

THE BIOFUEL, A GLOBAL APPROACH

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ABSTRACT

The paper present the work carried out by a research group from Technical University of Cluj-Napoca, Road Vehicles and Agricultural Machinery Department.

According with the energetic demand of the society, new sources must be explored at the beginning of the new millennium. In this respect, the fuel obtained from vegetable oil represents an alternate option with few benefits.

Regarding the research carried a vision through the research target was promote. It consists in a sustainable energetic demand approach which must respond to the European conditions, in particularly, regarding the appropriate conditions from our country.

In this respect, the work was developed in the following directions:

- *rapeseed oil crop in order to determine the must efficient biologic variety of it which respond to the soil conditions from our country; also the must appropriate cultivation technology was determine according with the soil demands; a special attention was focused in harvesting process due to the risk to loss an important production fraction;*
- *rap seed oil production and the biofuel technology production from crude oil; this parts consist in a seeds press evaluation regarding the efficiency of the process in order to evaluate the oil quantity obtained in different press condition (with or without material heating);*
- *tests results carried out in laboratory conditions in order to evaluate the energetic efficiency and the pollution effect;*

an evaluation of the benefits and of the constraint regarding the rapeseed oil used as a fuel for Diesel engines.

Keywords:*biofuel, rapeseed oil, statistic, test, evaluation.*

INTRODUCTION

The new vegetable fuels obtained from agriculture and organics materials assure significant advantages in the transportation field and for agriculture. These fuels present some advantages as:

- pollution reduction with ecological benefits;
- a continuous possibility to increase the land crop efficiency;
- a strong energetic reason for all European countries.

According with the engagement of European Union stipulated in the Kyoto agreement, the pollutants reduction or more specific to decrease the contribution of the internal combustion engines at the green house effect, represent an important demand.

At the same time, the new vegetable fuels assure a more independence of the nationals transportation systems (at the moment more then 98% of fuel is obtain from mineral oil), by diversification of products and improving the safety of engines fueled processes. A plus benefit consists in a new market for agricultural products of the farmers. For the next years the European Union schedule is to increase the biofuels quantity used in transportation especially regarding road transportation and for the own farmers need (for farm tractors and harvesting machines) [4].

Fig 1 The sustainable approach links for biofuel production

Based in European Community Directives, in all countries members will be promote in the next years actions for replace the mineral fuel with vegetable one in 5,75% proportion (until 2010).

This will be happened after if until 1996 only 0,25% from fuel consumption was based on biofuel. Almost ¾ from biofuels was produced and used in France, Austria and Germany (2002), and at that moment it represent only 0,45% of the fuels used in transportation. In this countries the taxes policy encouraged the biofuels production and utilization.

This fact represents for the farmer and chemical industry a challenge in order to increase the biofuel production and energetic efficiency.

At the moment due to the significant impact of this new ecological fuel, a sustainable approach must be done. In this respect, there are few links with particularly contribution to the biofuel technology (fig. 1).

CROP TECHNOLOGY

Crop technology presents some particularly aspects for the cultivated plants in order to be used as a fuel. The harvest production represent an economic criteria for evaluate the culture profitableness. According with the oil quantity obtained for one rapeseed kilo the crop production limit which assures a reasonable price of the biofuel and which cover the production farmer costs is 2.5 tones/hectare in accordance with the all agricultural and technological operations cost.

In accordance with the climacteric particularity of our region, the most efficient culture is the spring rapeseed, due to the damage produced by the loss temperature of the winter and in absence of snow through the autumn rape culture.

If the average production of the autumn rapeseed is better then spring rape culture the risk of freezing in the winter determinate the farmers to choose the rapeseed spring culture.

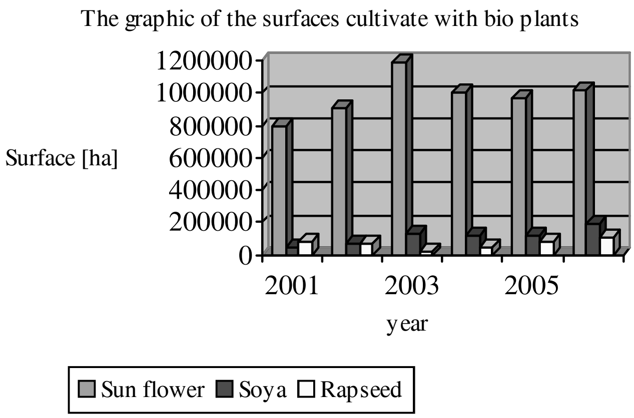

Fig. 2 The evolution of bio plants crop surface. [4]

Regarding the land surface cultivated with bio plants, in figure 2 is presented the evolution of the cultivated surfaces started with 2000 year. Also the medium production obtained in this years represent an indicator of the crop technology applied for these cultures (fig. 3).

The experience of the last five years in the absences of the snow and considering the average winter temperature for our region, the risk of the autumn culture is high. The spring culture is quoted with a medium production. The results obtained by farmers involved in our project are presented in table 1.

Table 1 The characteristics of the rapeseed culture

Location	**Land surface [ha]**	**Seed used**	**Fertilization and herbicide applied**	**Average production [tone/ha]**
Alba region	2,75	HEROS	yes	2875
Turda region	2,1	BOLERO	Partially	1745
Campia Turzii	2,2	HEROS	Inadequate	1462
Alba region	1,45	BOLERO	Yes	2175

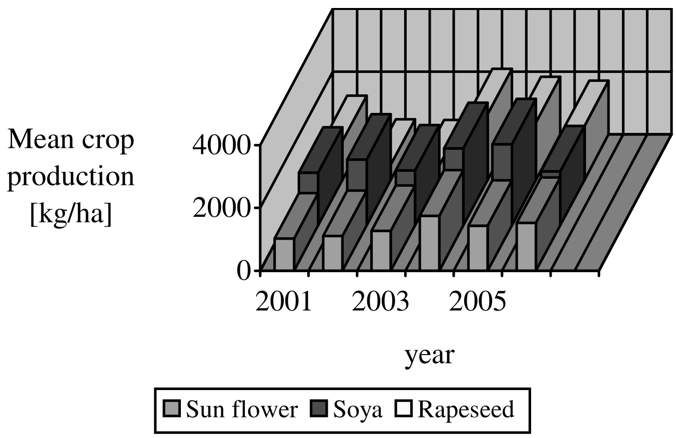

Fig. 3 The mean productions for years 2001 – 2006. [4]

The rapeseed plants were observed during the entire crop process, in different vegetation stages (fig. 4).

Considering the data reports from figure 3, regarding the mean production obtained for parsed crop, there are some important remarks about rapeseed technology: according with our country conditions, autumn rapeseed represent a height risk crop due to the winter conditions (freezing and the absences of the snow which protect the plants).

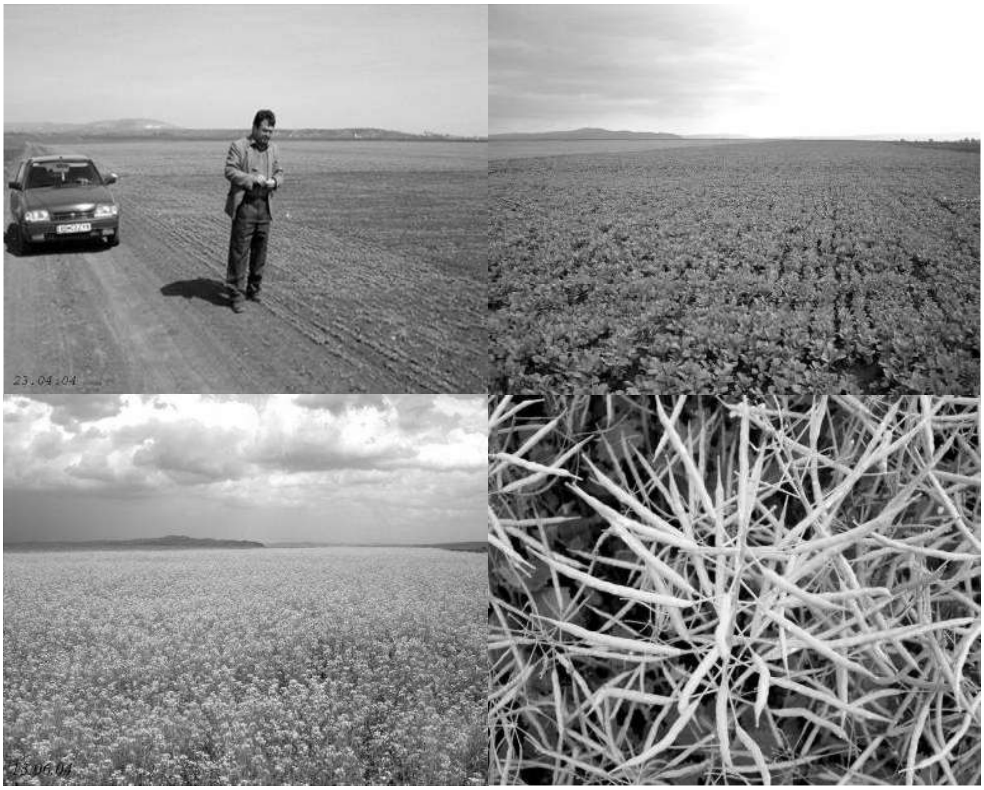

Fig. 4 The spring rapeseed cultivated in different vegetation stages observed for the same land

RAPESEED OIL AND BIOFUEL EFFICIENCY

In order to evaluate the biofuel efficiency few laboratory tests were carried out. The tests were carried out for D 118 diesel engine (80 HP at 2200 rpm) used for most popular Romanian tractors.

The test stand is compounded by: Diesel engine, hydraulic engine dynamometer, transducers and a serial 232 data acquisition system connected to a PC (fig. 5). The comparative tests carried out for Diesel fuel and biofuel, were able to conduit at the effective parameters variation: power and torque developed by the engine for the similar functioning conditions (fig. 6).

Regarding the fuel consumption and specifique fuel consumption, these parameters increase with average values: 4,5% for crude oil and 2,8% for biofuel.

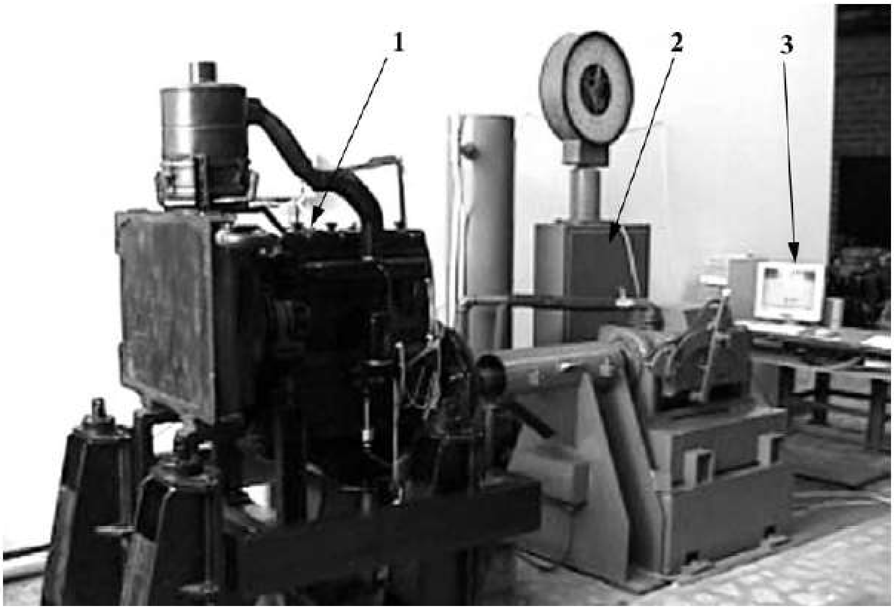

Fig. 5 The experimental stand: 1 – D118 diesel engine; 2 – hydro dynamometer; 3 data acquisition PC

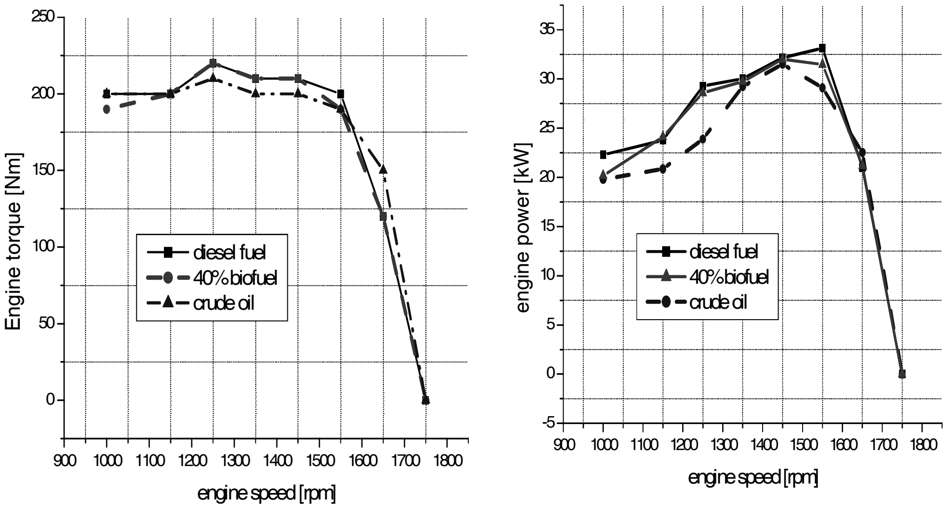

Fig. 6 The engine torque (left) and power (right), measured for diesel fuel and biofuels (laboratory tests)

SUSTAINABLE ENERGETIC AND ENVIRONMENTAL APPROACH

According with present energetic demands biofuel obtained from vegetable oil represent and a challenge for European farmer, at the same time with a strong requirement regarding the future energetic sources. The biofuel represent a sources to increase the pollution produced by internal combustion engine. The test carried out in our laboratory confirm that the average pollution produced by biofuel decrease with 4 – 8 %.

According with research grant developed by our department, the work direction consist in evaluation of the biofuel efficiency in real work conditions. In this respect two urban buses run with biofuel produced in the laboratory two weeks in last year (fig. 7).

Fig 7 Urban bus fueled with biodiesel, in testing area

The measurements realized show an similar fuel consumption at the same time with significant pollutant reduction.

CONCLUSIONS

The biofuel and crude oil used as a fuel for Diesel engine represent a future opportunity for European countries. If the energetic parameters decrease the average rate is acceptable and the benefit consist in a serious pollutants reduction. Also by economic point of view the energetic culture (rapeseed, sun flower, soya.) represent an opportunity to increase the farms efficiency.

Some particularities were observed regarding the engine functioning condition in the winter due to the rapeseed oil height viscosity.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 620.97
Stručni rad
Expert paper

JAPONSKI DRESNIK, PLEVEL KOT OBNOVLJIVI VIR ENERGIJE (OVE)

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POVZETEK

Delna rešitev problema, pomanjkanje energije in zmanjševanje emisij toplogrednih plinov je izkoriščanje obnovljivih virov energije (OVE), med katere spada tudi pridobivanje bioplina iz biomase. V svetu in tudi pri nas ta problema rešujemo z izkoriščanjem kmetijske zemlje za namene proizvodnje biomase. Večinoma se za ta namen prideluje koruzo. Ena od možnosti je izkoriščanje plevelov ali raznega rastlinja z zemljišč z omejenimi dejavniki pridelovanja, kot biomaso za proizvodnjo bioplina ali kot surovino za kurjenje. Japonski dresnik (Reynoutria japonica), je plevel, ki se nenadzorovano širi na vsa možna za rast primerna zemljišča. Weendska in CNS analiza sta pokazali alternativo rabe japonskega dresnika za namene pridobivanja biomase, kot dodatka osnovnemu substratu gnojevki v proizvodnji bioplina. Na osnovi kemičnih analiz smo izračunali teoretično količino proizvedenega bioplina.

Ključne besede: *energija, obnovljivi viri energije, bioplin, japonski dresnik,*

UVOD

Tehnologija pridobivanja bioplina je poznana, ne poznamo pa še vseh možnih mešanic različnih substratov za tehnološko in ekonomsko optimalno proizvodnjo bioplina. Izkoriščanje poti in uporaba biomase z območij z omejenimi možnostmi pridelovanja hrane, predstavlja eno od niš, za pridobivanje organske mase. Na taka zemljišča se nenadzorovano širi japonski dresnik in izpodriva razne avtohtone rastline ter ruši naravno ravnotežje. Japonski dresnik lahko izkoriščamo kot biomaso in s tem omejimo nenadzorovano širjenje te rastline.

Rastlina je zelo velika in nima naravnih sovražnikov. Iz vidika nadzorovanja širjenja japonskega dresnika, smo ga vključili v raziskavo, kot potencialno rastlino za pridobivanje biomase, v našem primeru za proizvodnjo bioplina.

Japonski dresnik je neavtohtona rastlina, ki je k nam prispela iz Azije, kot okrasna rastlina. V sto letih je pobegnila iz nadzora in se nenadzorovano širi na vsa prosta zemljišča. V Evropi se razmnožuje predvsem vegetativno z rizomi. Regenerira se že iz zelo majhnega dela rizoma. V Evropi nima naravnih sovražnikov, kar vpliva še na lažje širjenje. Po lastnih opazovanjih smo ugotovili, da se uspešno širi s pomočjo vode vzdolž vodotokov.

MATERIALI IN METODE

Japonski dresnik (Reynoutria japonica)

Rastlino smo opazovali na nekmetijskem zemljišču, na obrežju reguliranega potoka Gradaščice. Brežina na kateri smo spravljali dresnik je bila obrnjena na jug. Na sliki 1 je japonski dresnik.

Slika 1 Japonski dresnik *(Reynoutria japonica*) ob potoku v času cvetenja

Slika 2 Rastlina japonskega dresnika *(Reynoutria japonica*)

Spravilo

Naključno smo izbrali 10 m^2 japonskega dresnika na brežini potoka Gradaščice. Pridelek smo v različnih zrelostnih fazah poželi z ročno s srpom ga stehtali in vzorčili. Prva faza spravila je bila v sredini meseca maja, takrat je bila rastlina v največji fazi rasti in je že vidno prehitevala z rastjo ostale obrežne rastline v bližini. Visoka je bila 1,5 m do 1,7 m. Druga faza spravila je bila v sredini meseca junija. Dresnik je bil že velik 2,5 m in je zadušil večino rastlinja pod njim. Tretja faza spravila je bila v sredini meseca julija. Japonski dresnik je dosegel maksimalno velikost na tem rastišču ki je bila 2,7 m do 3 m. Začela se je tvorba gnerativnih delov.

Označene vzorce smo 14 dni sušili v sušilni komori pri temperaturi 35ºC. Posušene vzorce smo stehtali, nato smo jih zmleli z mlinom, ki je imel vstavljeno sito z luknjami premera 2 mm. Zmlete vzorce smo shranili v plastične vreče. Vsak vzorec smo shranili za morebitne nadaljnje analize.

Določitev C, N, S in Weendska analiza

Kemično analizo za določitev C, N in S so opravili na Gozdarskem inštitutu Slovenije na Oddelku za gozdno ekologijo, po metodi za določitev:

C: ISO 10694 **N:** ISO 13878 **S:** ISO 15178

V vseh primerih določitev je šlo za sežig pri 1350 °C in analizo sežignih plinov – elementna analiza.

Na vzorcih so opravili Weendsko analizo na Kmetijsko veterinarskem zavod Murska Sobota.

REZULTATI IN RAZPRAVA

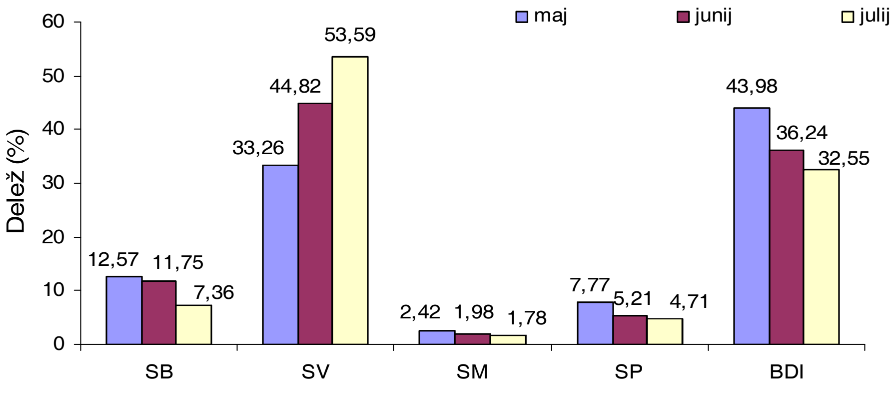
Pridelek japonskega dresnika je naraščal s starostjo rastline. Naraščal je tudi delež surove vlaknine in s tem suhe snovi. Kot vidimo iz preglednice 2 je razmerje C:N v tretji zrelostni fazi v juniju zelo neugodno. Japonski dresnik, kot dodatek k gnojevki bi v tej zrelostni fazi bil primeren, ampak če pogledamo preglednico 1 vidimo, da je vsebnost surove vlaknine 53,59 %. Sklepamo lahko, da se je povečal delež celuloze in lignina, ki sta v procesu fermentacije slabo razgradljiva do nerazgradljiva.

Preglednica 1 Pridelki in Weendska analiza japonskega dresnika v različnih zrelostnih faza

	zelinje (t/ha)	SS (%)	SS (t/ha)	SB (%)	SV (%)	SM (%)	SP (%)	BDI (%)
Japonski dresnik maja	46	18,80	8,65	33,26	33,26	2,42	7,77	43,98
Japonski dresnik junija	62	21,32	13,22	44,82	44,82	1,98	5,21	36,24
Japonski dresnik julija	90	23,28	20,95	53,59	53,59	1,78	4,71	32,55

Preglednica 2 Deleži ogljika, dušika in žvepla v različnih zrelostnih fazah pri japonskem dresniku

	C	N	S	C:N
Japonski dresnik maja	43,40	1,830	0,194	23,71585
Japonski dresnik junija	44,20	1,730	0,186	25,54913
Japonski dresnik julija	45,40	1,115	0,161	40,71749



Slika 1 Delež surovih beljakovin (SB), surove vlaknine (SV), surovih maščob (SM), surovega pepela (SP) in brez dušičnega izvlečka (BDI) v različnih zrelostnih fazah japonskega dresnika

Kot temelj za maksimalno proizvodnjo bioplina smo upoštevali razmerje C : N, ki je med 25–30 : 1, navaja Polprasert (1986). Kot lahko vidimo se je temu razmerju najbolj približal dresnik v juniju, takrat je imel še tudi dokaj zadovoljiv delež surovih maščob in surovih beljakovin.

Žveplo je moteč faktor v bioplinski tehnologiji, saj na strojne elemente deluje korozivno (Đulbić, 1986). Največ žvepla je bilo pri dresniku požetem maja, takrat je bilo tudi največ surovih beljakovin, na kar lahko sklepamo, da je žveplo bilo vezano v beljakovinah.

Pretvorba rastlinske suhe snovi v bioplin

Eden od ciljev naše raziskave je določitev količine proizvedenega bioplina iz posameznih rastlin. Različni avtorji navajajo različne količine proizvedenega bioplina iz rastlin z znanimi deleži posameznih skupin (SB, SP, SM, BDI in razmerje C:N) . Tako smo na osnovi Weendske analize in CNS analize različnim zrelostnim fazam japonskega dresnika določili faktor pretvorbe za proizvodnjo bioplina.

Preglednica 3 Količina proizvedenega bioplina iz kg SS po različnih avtorjih in uporabljen faktor za preračun iz naših rastlin

Surovina	Količina bioplina/kg SS	
	Doseženi izpleni biolplina po drugih avtorjih (m^3/kgSS)	Upoštevan izplen bioplina (m^3/kgSS)
Koruza	0,3-0,4 Medved in Novak (2000), 0,41 Beck (1997), Dulbić (1986) , Zver (2005)	0,4
Ljuljka	0,28-0,55 Medved (2000), 0,41 Beck (1997)	0,4
Črna detelja	0,43-0,52 Đulbić (1986), Zver (2005)	0,45
TDM	0,28-0,55 Medved (2000), 0,41 Beck (1997)	0,45
Japonski dresnik maj	določitev	0,39
Japonski dresnik junij	določitev	0,42
Japonski dresnik julij	določitev	0,35

ZAKLJUČEK

Japonski dresnik je invazivna rastlina, ki se nekontrolirano širi na vsa razpoložljiva zemljišča. V našem okolju še nima naravnega sovražnika, kar še dodatno pospešuje njegovo širjenje. Zaradi našega podnebja se večinoma razmnožuje le vegetativno s pomočjo korenike. Vodna erozija, ki odnaša tudi to korenino vpliva na hitrejše širjenje japonskega dresnika, zato je njegovo širjenje najbolj opazno ob vodotokih, kjer zavzame vsako prazno mesto.

Letni prirast japonskega dresnika v našem klimatu je zelo velik, zato bi bilo dobro to rastlino na nek način izkoristiti. Glede na rezultate Weendse analize in CNS analize je rastlina primerna za uporabo v bioplinski industriji in to meseca junija, ko je razmerje hranil najugodnejše tudi za mikroorganizme v fermentorju. Košnja japonskega dresnika sredi poletja bi poleg pridobljene biomase še zaustavila nemoteno širjenje in dominacijo te rastline nad drugimi rastlinami v okolici.

V prihodnje nameravamo rastlino še vključiti v postopek fermentacije v bioplinskem reaktorju.

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JAPANESE KNOTWEED AS RENEWABLE ENERGY SOURCE

Human civilisation try to find solutions for insufficient energy supply and decreasing emission of green house gases is renewable energy sources utilization. Biogas production from biomass is surely one of the possible solutions. Japanese knotweed (Reynoutria japonica) although a weed could become an energy source. Weenden and CNS analysis showed that it could be additive to basic liquid manure substrate for bio gas production.

***Key words**: Energy, renewable energy sources, biogas, japanese knotweed*

35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

dTDR AS AN OPTIMIZATION TOOL FOR ADVANCED PROCESS MONITORING IN BIOWAST TREATMENT

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SUMMARY

The funding of the German Federal Ministry of Education and Research brought up a collaborative project amongst IMKO and AgEng of Hohenheim University. With that dTDR has been developed, to quote soil water conditions on the go. But the technique holds a larger potential. First experimental setup showed good results of dynamic readings for biological residuals. The sensor instantly enables to quote the volumetric proportion of water within a porous material (1Hz). Gravimetric reference and stationary TDR readings matches the dynamic detection with high correlation. Baseline test series of the novel sensor proved a broad potential for dynamic moisture content quantification by dynamic TDR (dTDR). The findings represent a basic potential for a feasible control tool for biological waste processing. An implementation concept was compiled for composting plant processes and sewage sludge drying.

***Key words**: Biomass, biowaste, biogenous residual drying, composting, dynamic, precision farming, process monitoring, sewage sludge, soil moisture, Time Domain Reflectometry (TDR), TRIME*

INTRODUCTION

The detection of soil moisture is an essential parameter of assessing actions in plant production. But an accurate and fluent detection of moisture is absent for agri - systems by now. Therefore a joint project of Agricultural Engineering at Hohenheim University and IMKO Micromodultechnik started under foundation of the German federal ministry of education and research (BMBF, FKZ 0330107) in 2002. The main focus of the project was the development of a dynamic field moisture gauge. It is supposed to feed decisive data bases for either irrigation management or cultivation-, process- and trafficability decisions (Jantschke, 2005). IMKO launched its TRIME (Time Domain Reflectometry with Intelligent Microelements) in 1990. With that an autonomous TDR interpretation was realized. The system works with basic or specific calibrations to enhance an automatic interpretation of TDR readings. The implemented algorithm numerically translates the findings into accurate volumetric moisture proportions. The project was finished successfully with the novel introduction of a 1Hz resolution measuring device. This fresh development provides a valuable technique to control diverse processes over prevailing water contents.

Therefore, it represents one of the main process variables for drying or watering of biogenous residual substrates. The basic specification of TRIME allows an accurate interpretation of soil moisture to a maximum of 15mS/cm. The use of appropriate noise reduction and electro-sensitive adaptation of damping further leads to a tolerance of electrical conductivities of ca. 40mS/cm for TRIME. The sensor was designed, using VDI-guidelines of systematic construction (see VDI 2221, 1993), eliminating bleak approaches by means of detailed requirement analysis and a systematic conduit of material and design parameters. The probe body was specified as IP 55 (protected against the powder and against water jets; DIN EN 60529) under monolithic implementation. The rugged sensor holds a potential for waste management and process control of biogenous residual drying or controlled moistening in compost plants.

METHODS

Time Domain Reflectometry (TDR)

Common determination of soil moisture is based on several methods, dealing with a direct and indirect data acquisition in order to conclude on actual substrate moisture (Stacheder, 1996). The techniques mostly require soil contact or even soil extraction from its location. Among the most accurate methods, gravimetrical determination, neutron probe and Time Domain Reflectometry are favoured as standard or reference methods, even. Instant process regulation requirements eliminate standard oven drying (DIN 18121 part 1 and 2) for a fluent control of process parameters, even though it is the most common practice to evaluate soils moisture, drying samples at 105°C for 24h. DIN 18121 - standard method delivers static data, evaluating input and output magnitude of the sample taken (weight). In contrast to the aforementioned, fluent regulation of processes is based on constant data acquisition on a high resolution scale.

The basis for the dynamic integrated electronic measuring device (TRIME) consists of signal generator, sampler and the sensor waveguide. Similar to TDR, the signal generator is capable of producing a rapidly escalating voltage surge. Commonly used TDR instruments like the TRIME-EZ (IMKO) or the laboratory TDR instrument Tektronix Cabletester 1502 B generate a surge of 200 mV in a time of 20 ps (1 ps = 10^{-12} s). The voltage surge causes the propagation of an electromagnetic wave. With every measurement cycle, the pulse starts to propagate along the transmission line, which is characterized as coaxial HF-cable. The wave pulse is decelerated at the waveguide, where it is introduced to the surrounding porous material. The pulse is being reflected at the waveguide end and returns back on to the electronic measuring implements, where the interference of emitted and reflected pulse is recorded by a sampler unit (runtime). For laboratory TDR instruments the result is quoted visually. Soil and other porous materials can be described as a mixture of solid proportion, water and air. Its characteristic permittivity forms the basis of the measurement. The permittivity of air ($\varepsilon_r = 1$) and dry porous substrate ($\varepsilon_r < 5$) is significantly lower than the permittivity of water ($\varepsilon_r = 81$). Molecules of water are strong dipoles, which are aligning up within an introduced electromagnetic field. These dielectrics are effectively decelerating propagation speed of electromagnetic waves. Roth gives an equation, regarding soil physical properties (porosity and bulk density), Topp formulates an empirical equation in order to derive the volumetric water content (Roth, et al., 1990; Topp, et al., 2000). Based on these findings, an automatic detection of TDR traces is commonly realized, scanning the appearing curve in defined steps (Δ t). The detected current voltage is recorded for the entire expressive part of the TDR signal. In contrast, TRIME gauges time over predefined voltage steps at a resolution of about 10 ps. The system implies the aforementioned calculations within the handheld instrument, which results in accurate readings for soils within the normal range of electrical permittivity (Jantschke, 2004). This results in a fast evaluation of the signal (15 sec.). With the altering of the voltage grades, the expressive part of the TDR curve is quoted accurately. High ionic conductivity leads to a lowering of the signal's amplitude (Stacheder, 1996). TRIME gives an accurate volumetric material proportion up to 40mS/cm. Besides basic electronic demands, the size of the measuring field is the most important requirement for a successful measurement. It is defined by the sensor's layout and specific material (Jantschke, et al., 2005).

Effects on TDR detection

To quantify the potential effects on probe design and the measurement, a baseline study has been conducted, dealing with stationary measurements. Air filled gaps and water filled gaps interfere a correct reading, though they are representing a respectively false value of bulk density. Thus they are not represented with substrate average porosity. The effect of a large pore proportion within the measuring field has been investigated, using screened silt with a particle size of 0.5 mm. The substrates field capacity was determined 50%. The initial moisture for the experiments was set to 25% and raised by steps of 5% until field capacity was reached. The applied probe was a constructive 3 prong sensor. The probe dimensions were chosen to 8 cm prong length and a 2/3 prong/spacing ratio. It was used in context with a Tektronix Laboratory HF-Oscilloscope. The measured volume showed 0.92 litres. The first trial was set up, dealing with up to three artificial large pores (Ø 3 mm) within the range of the measured volume. The case showed no significance. Neither it did while saturating, nor at attained water contents. Therefore it might be concluded, that large pores do not interfere the TDR measurement, regarding a usual field measurement set up. Whereas further scenarios (Table 1) showed a high potential to cause faulty readings due to probe distortion. Dynamic movements are likely to cause probe distortion at a prong setup. The monolithic probe prevents false readings o this basis.

Table 1 Trial setup to evaluate effects on TDR sensor ambience

	Objective	**Substrate**
Setup 1	Air filled large pores, water filled large pores	Screened silt (0.5 mm)
Setup 2	Sensor distortion influence, measuring field modulation	Sandy clay, gravel admixture
Setup 3	Verification	Glass beads, Dragonit (Ø 0.45 mm)

RESULTS

Systematic development of dTDR-technology

The dTDR device is based on TRIME technology, which has been firstly introduced by IMKO 1990. TRIME translates TDR traces into numbers of volumetric water content. Further development to provide a dynamic TDR technique has been funded since 2002 by the German Federal Ministry of Education and Research (FKZ 0330107). The design and production of the prototype gauge has been conducted using VDI-guidelines (VDI 2221, 1993). Two modules define the functional components of the gauge. The head-cone of the gauge vertically divides the soil, to facilitate a direct sensor/soil-contact. The sensor body provides the waveguide bearing which holds the actual probe. Modified TRIME electronics are embedded within the sensor body. Various PVC (Polyvinyl Chloride) elements are used to brace the setup and protect the embedded electronics

First measures to further reveal the most appropriate technical setup were to place distinct design components of the dTDR gauge into numerical modelling context of the conducted electromagnetic field (Matlab, Maxwell 2D). Resulting, the designed depth of the gauge could be minimized, identifying an air notch within the PVC to buffer the electromagnetic field.

A second step provided an integration of the aforementioned geometrical suggestions into the design of the sensor body. Therefore the engineering software *CATIA* (Dassault Systems) was used for the 3D-embodiment design. Further development was iteratively conducted for the module *Product Function Optimizer*. For finite-elements method (FEM) analysis, material parameters of Steel and PVC were defined to simulate construction. A potential load scenario (Fig. 1; top) displays assumed area-loads onto the sensor-body within 3D-space. Findings of Verschoore (2003) showed loads of 0.1-0.7 N/mm² (soil bin trials) and 0.3-1.0 N/mm² (field trials) for a comparatively similar shaped setup. Investigations of Froeba (1991) and Getzlaff (1953) are backing up this statement. Steiner (1979) declares a maximum load of 2.3 N/mm² at 16 % vol. water content, which is found reduced to 0.2 N/mm² at 25 % vol. water content.

The progression angle α was variegated for different operating conditions. Accordingly resulting forces are changing. The load scenario shown, clarifies a specific sensor-load while proceeding within the topsoil at 2 m/s. The predicted resulting maximum deformation is found to appear at the sensor's head-cone. Deformation d has been calculated 0.04mm.

The waveguide bearing appears with unverifiable distortion, which underlines a save insert of a ceramic waveguide cover (material strain, fissure). “Van-Mises equivalent stress band” σ_v was computed maximum $3.7x10^7$ N/m^2 at the joint of head-cone and sensor-body.

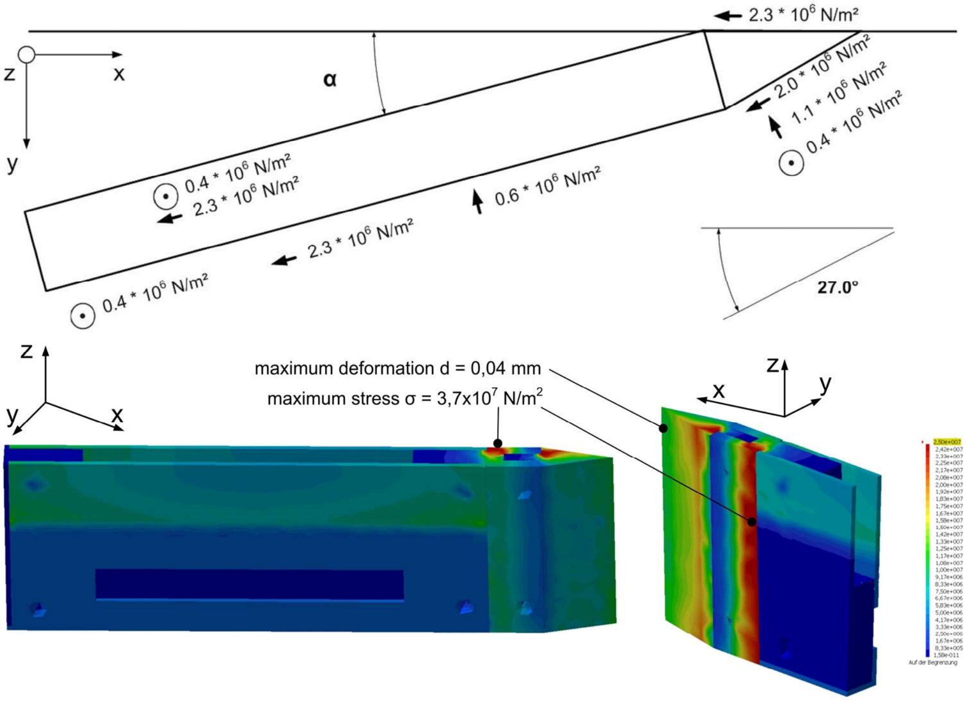

Figure 1 Momentary load scenario for altering progression angles (top); FEM components under structural analysis for the aforementioned load scenario (bottom).

The resulting ready gauge is specified under economically optimized setup conditions as stabile and rugged. Distortion and appearing stress of PVC components are negligible. Embedded electronics are specified protected IP 55 and higher (DIN EN 60529).

Dynamic measurement verification

To test dynamic moisture acquisition a soil bin set up was equipped. Static measurements of prevailing water content were carried out, using a TRIME standard P2G. To quote the TDR trace visually conventional 3 prong sensors were introduced in the respective depth. The dTDR sensor was mounted on a chassis frame, which was driven by steel wire ropes to a maximum pace of 5 m/sec.. The vertical penetration depth was adjusted by 2 crank levers. It is controlled by 2 ultrasonic position encoders. Distance is recorded in mm-scale over a rev-meter at the wheel. Simultaneously the current draft force is being recorded in 3 dimensions (x; y; z). Penetration depth varies from -30 mm to -160mm for soil bin tests. It can be boosted by an accordant vertical mount for an implementation in process engineering. Fills of optional depth can be measured catching up with force and mounting requirements. The dynamic probe has been tested for standard soil substrate. The maximum progression pace appeared at 5m/sec and a vertical penetration depth of - 10cm. Moisture assessment resolution was clearly provided with 1 Hz. The gained values are verified, using stationary TDR and simultaneous gravimetrical evidence.

Quantification of potentialities for process engineering of waste treatment

Soil moisture content varies in space and time, thus a sensor technique has to be introduced in order to provide basic data, documenting and evaluating the prevailing conditions of drying or re-moistening. This goal can be achieved for precision agriculture applications and for a control of moisture in processes treating biogeneous materials. DTDR is characterized by a defined measuring tolerance to prevailing conductivity conditions. The basic specification can be broadened, modifying the sensors setup concerning waveguide damping and calibration. The newly developed dTDR sensor produces exact and automatic moisture readings at a high temporal resolution of 1 Hz and a spatial resolution of h=3cm in adjustable vertical penetration depths. Consequently a shallow soil layer at defined penetration depth is evaluated by the system. This provides an approximation of the concurrent moisture over defined layers. These specifications are sound to improve process control of composting plants and the drying of biogenous residuals (sewage sludge, biowaste, biowaste blend, e.g.; see table 2)

Table 2 Specifications of soil, sewage sludge, compost, biowaste and a blend of biowaste blend (abridged comparison)

		Soil	**Biowaste**	**Compost**	**Sewage Sludge***	**Biowaste Blend****
pH		3.0 - 7.5	7.55	5.0 - 8.5	8.0 - 8.5	7.5
Bulk density	[g/cm³]	1.1 - 1.8	0.7	0.35 - 1,1	0.7	0.5 - 0.7
Electrical conductivity	[mS/cm]	0. – 0.9	2 - 5	2 - 7	3	2 - 3
Appearing moisture	[% Vol]; wet	50	55	90	60 - 90	40
Appearing moisture	[% Vol]; dry	2	50	30	10-25	20
Temperatur e range	[°C]	-10 – 30	< 75	< 755	> 55	> 55

* sewage sludge drying
** biowaste/ paper blend (52/48)

The abovementioned substrates display an abridged physical outline of potential materials to be monitored. The given scale is covered by dTDR specifications. Therefore an application in biogeneous materials treatment processes is promising. The prevailing process water contents (input moisture vs. output moisture) are fitting within the measuring range of dTDR. The influence of temperature (Müller, 2004) to the reading is compensated electronically by the implementation of an advanced evaluation algorithm (Stacheder, 1996). The reliance of this pre-examination has to be proofed in further test series on measurement accuracy for the designated substrates. A potential dTDR monitoring is displayed for compost plants (moistening; see figure 5) and solar sewage sludge drying (see figure 6). The respective applications provide a high potential of process documentation and beneficial effects by means of advanced immediate process modulation.

Implementation concept for composting plants

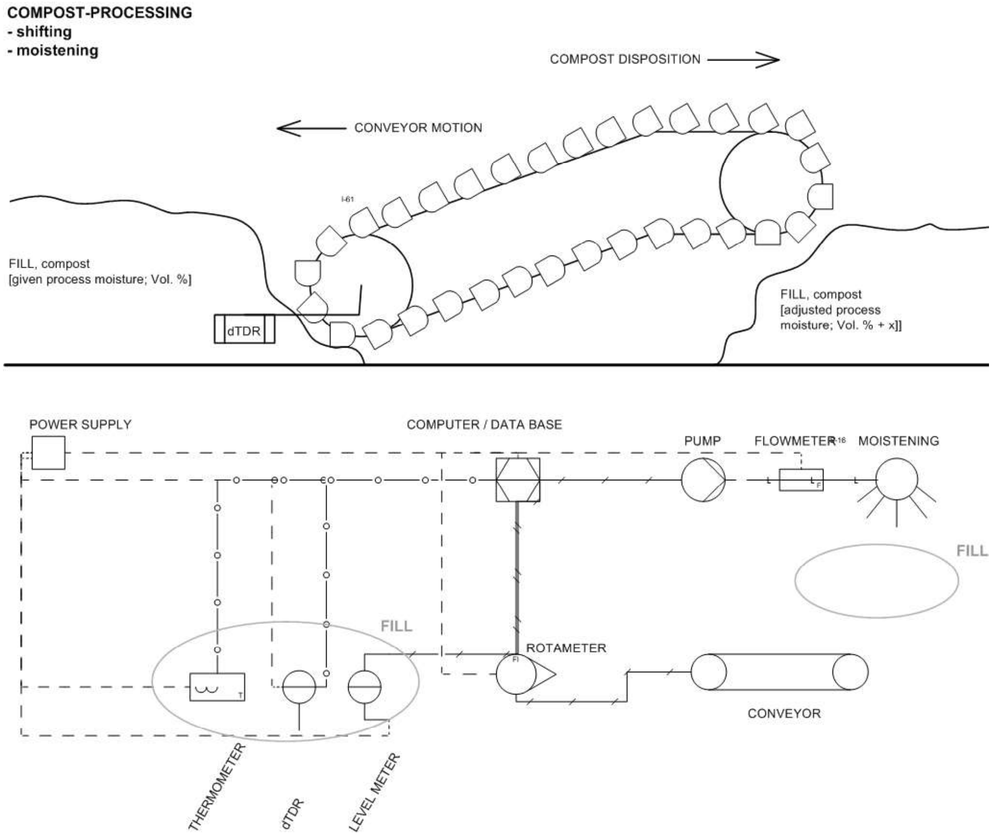

Figure 2 Structural sketch & structural system of a compost plants conveyor with implemented moisture detection.

With the implementation of dTDR, areas of required moistening can be identified accurately. Unlike common practice, this gives a clear objective rating of prevailing water contents. Present practice mainly deals with a subjective evaluation of moistening quantities by the operators of respective plants. Therefore an objective process control enables an instant regulation of demanded moisture intermixture to achieve the desired water content. The link-up to process technology can be realized by an implementation of system-dependent PROFI-BUS, ISO-BUS or CAN-BUS interfaces. A re-adaptation to 30% Vol. water content defines the process modicum for microbiologic activities in composting plants. The control of additional process variables such as progression pace and admixture of aggregates can be actuated as well. Microbiological processes are intended to be optimized for compost plants in order to produce an optimal specification of compost (Kraft, 2001; Zaied, 1999; Reloe, 1993).

Implementation concept for sewage solar sludge drying

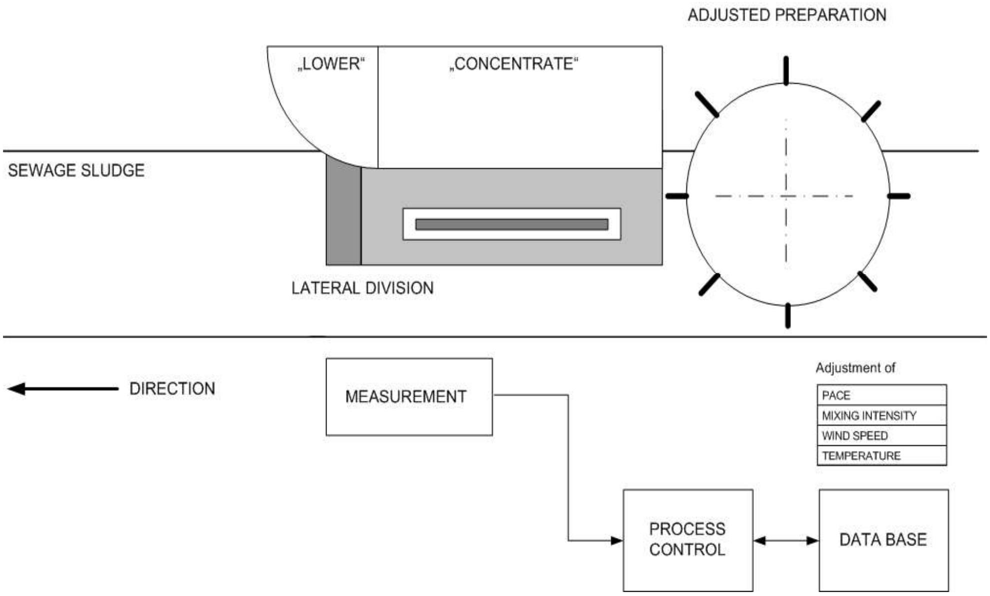

Figure 3 Structural sketch of a sewage sludge moisture control device, dynamic.

In contrast to the abovementioned composting plant implementation, solar drying of sewage sludge aims to suppress microbiologic activities and prepares the substrate for further process sequence. Either combustion or transport requires a preferably dry product, to gain economic benefits. For sewage sludge drying the problem of unequal moisture distribution is widespread. Current process monitoring is realized by heat balance equations, which cause a high failure potential due to unequal moisture distribution in the fill. Substrate moisture variation can range from 20-50%. Targeted operations of shifting and turning form a potential application for dTDR. The other main actuator of the process is represented by climate control parameters. Rapid and equal drying is determined as an activity objective.

OUTLOOK

After first studies the aim of transferring the recently developed dTDR probe to related applications of agricultural production seems potential. Most notably, beneficial economic effects are to be assumed for alternative energy production from biogenous residuals, which rely on an accurate detection of concurrent water contents. Consequently an instant process control via data alignment of process variables is requested. Furthermore clear and fluent process documentation is enabled. Therefore mathematical models have to be generated. Further tests are intended.

First stationary results showed excellent results, predicting process water status for defined conditions. The novel dynamic soil moisture sensor (dTDR) enables a fluent data acquisition at a resolution of 1 Hz. Therefore the evaluation of process variables is facilitated. Limitations of dTDR are revealed in a shallow penetration depth. A single sensor represents one horizontal layer of 3 cm size. The alignment of more datasets is promising. Substitute values verify the recorded moisture proportions (penetration force, temperature, bulk density; e.g.). Therefore the dynamic measurement delivers a substantial advance of application as a supportive information module for process regulation. The applications mentioned are analytic surveys, to quantify potential benefits from the novel introduced technique. A technology transfer to related fields of agriculture is desired.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

ANAEROBIC DIGESTION OF ENERGY CROPS WITHOUT MANURE ADDITION

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SUMMARY

For Germany, the number of biogas plants using energy crops in a manure-free-fermentation is increasing. Simultaneously the number of process disturbances rose as well. In contrast, co-fermentation-plants in which liquid manure is used, indicate stability and higher load capacities. Current approaches at the University of Hohenheim should clarify on laboratory scale which elements of liquid manure are to be found responsible for its process stability. Further test series focus on a stable manure-free-fermentation using the industrial kind of substances found responsible for process stability of this specific fermentation.

***Key words**: Anaerobic fermentation, biogas, liquid manure-free, energy crops, energy production, trace elements, maize silage*

SITUATION

Germany has defined the ambitious goal, to increase the portion of the renewable energy of current electricity-consumption from 10% to at least 12.5% and 20% by year 2010 and 2020, respectively (BMU, 2006). In the course of this development, a law novella of the renewable energy law (EEG, 2004) was launched September 2004. It stipulates a higher remuneration entitlement to biogas plant owners, if only energy crops and manure are used as input material.

Up to now, biogas from regenerating sources has predominantly been produced in the co-fermentation-procedure via liquid manure. Untilled farmland which is likely to be used for a production of energy crops is mainly located in regions with low cattle populations. Transport of slurry over longer distances is costly, an establishment of liquid manure free fermentation plants governmentally promoted. However, field reports indicate that biogas producers are experiencing process-disturbances when manure free fermentation method is used. The goal of the ongoing research is to determine the essential processing parameters for a liquid manure free conversion of energy crops into biogas.

METHODS AND MATERIAL

In a trial, at the State Institute of Farm Machinery and Farm Structures Baden-Württemberg, University of Hohenheim, an investigation was conducted to find out the effects on the stability of the manure free fermentation process. The experiments were done in horizontal, continuously stirred digesters with a fermenter volume of 17 litres (Figure 1). To begin with, maize silage and liquid manure were fed daily in digesters at an organic loading rate of 2.5 g of organic dry mater (ODM) per litre in the mesophilic range (37°C) for more than three retention times. The average retention time was limited by addition of tap water to 35 days. The transfer into a manure-free fermentation process was done by substitution of manure with tap water. The retention time remained unchanged. The loading rate was reduced from 2.5 oTS l-1 d-1 to 2.2 g oTS l-1 d-1 due to substitution by water.

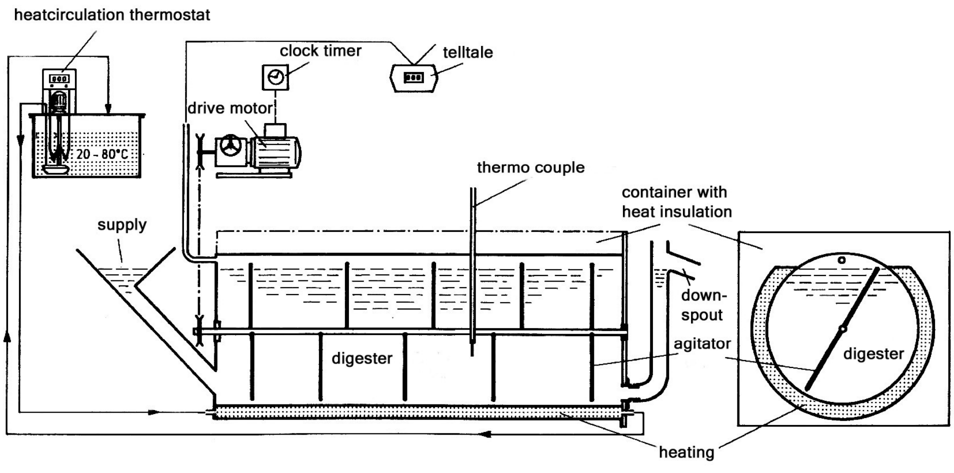

Figure 1 Scheme of a horizontal 17 l digester

In order to achieve identical conditions, digesters were emptied and cleaned previous to subsequent experiments. Thereafter the digesters were filled with substrate from biogas plant and further fed with maize silage and liquid manure for 2.5 retention times. The average retention time was limited by addition of tap water to 40 days. The initial loading rate amounted in 2.86 g of ODM l^{-1} d^{-1}, of which 0.36 g ODM l^{-1} d^{-1} originated from manure and 2.5 g ODM l^{-1} d^{-1} maize silage, respectively. The transfer into a manure-free fermentation was conducted as the preceding trial by substitution of the liquid manure with tap water, consequently reducing the organic load rate to 2.5 g ODM l^{-1} d^{-1}.

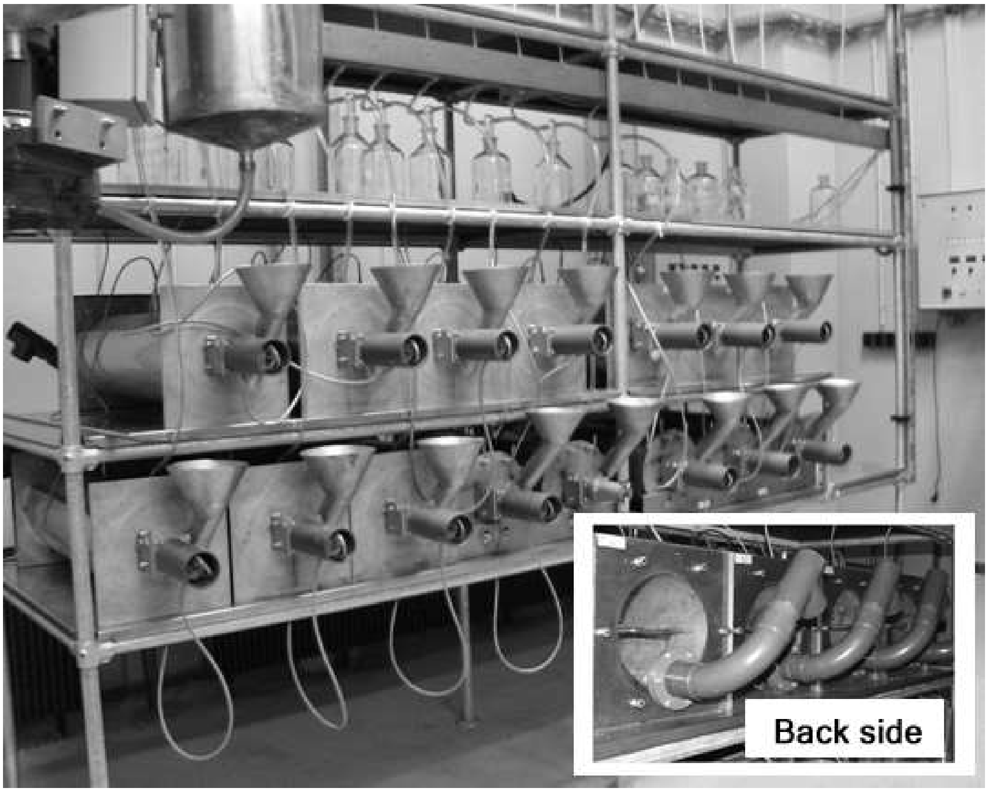

Figure 2 Experimental setup with 15 horizontal lying digesters

Consequently following the assumption that the stabilization of the process is based on substances contained in the liquid manure, five runs with two repetitions, in each case containing different elements, were set up as shown in Table 1. The quantities of the substances addition corresponded to respective concentrations of the liquid manure used before. Additionally, a sixth run only fed with maize silage was set up. This was prepared to generate a relation to the "continous solid-phase digestion" which has been increasingly utilised in Germany since 2005. A control run was set, for which maize silage and water was exclusively nourished.

Table 1 Fermenter constituences

run	appelation	input					
1	B+TE+N+ODM	maize silage	water	buffer	trace elements	nitrogen	wood fibre
2	B+TE	maize silage	water	buffer	trace elements		
3	B	maize silage	water	buffer			
4	B+ODM	maize silage	water	buffer			wood fibre
5	TE+N+ODM	maize silage	water		trace elements	nitrogen	wood fibre
6	SF	maize silage					
control	C	maize silage	water				

Trace elements: were added as solution.

Buffer: a phosphate buffer was added as solution to stabilize the optimal pH range required by methanogenious bacteria.

Nitrogen: was fed as urea.

Non degradable ODM: was fed as industrial wood fibre, this avoids quick ODM reduction which was observed in the preceding trial and thus providing a settling surface for micro organisms.

RESULTS

Results of the pre-test

Process-disturbances occurred in the first retention time during the fermentation of maize silage. The process could not be stabilized by halving the maize silage input to 1.1 g ODM l^{-1} d^{-1}. Within the first three retention times, the buffer capacity of the digester-substrate was reduced by 63%, the ODM-content by 50%, ammonia concentration by 52% and trace element concentrations (selected/essential) between 25-75%. It should be noted that the aforementioned changes of the fermentation output were based exclusively on the absence of manure content. No dilution was done - the liquid manure was solitude substituted by water.

Preliminary results of the main attempt

Before the manure-free fermentation was started, the pH-values of all runs were 7.21-7.23 and therefore within the optimal range required by methanogenious bacteria. The control run (C), run 3 (B) and 4 (B+ODM) resulted in the space of 25-30 days below the neutral range of pH 6.8-7.5, which is necessary for acetic methanogenious bacteria (Braun, 1982). At this time the acid-concentration reached 2870 - 5070 ppm acetic acid equivalents. After the first retention time these runs were cut off. Forty-three days after the trials launch acid-concentration-level amounted 8830 - 10150 ppm acetic acid equivalents. The daily formed gas quantity decreased to 0.6 liters, the methane concentration declined below 45%.

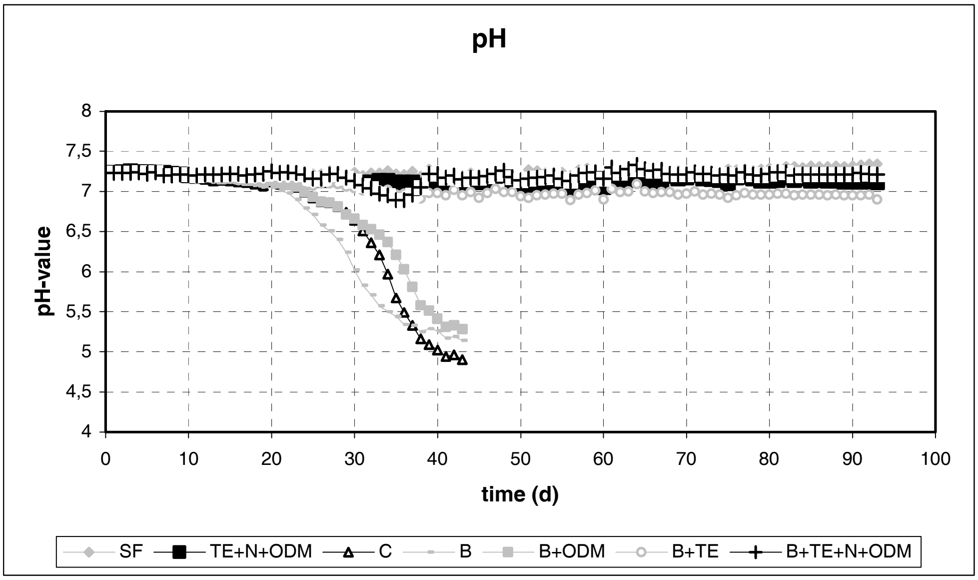

Figure 3 Development of the pH values

The remaining four on-going trial runs designate a stable process. 110 days after manure exclusion, all digesters supplied with a trace element mixture, show acid concentration of less than 300 ppm acetic acid equivalent. Run 1 (B+TE+N+ODM) shows the same pH-levels as the beginning of the trial, run number 2 (B+-TE) went stabile at almost pH 7.0 (Figure 3). The specific methane productivity of both runs amounted 1.4 litres per litre digester volume (Figure 4) and a methane yield of 0.30 litres per gram organic substance added (Table 2). All remaining runs indicate a methan content of about 53-54% (Figure 5). The runs 5 (TE+N+ODM) and 6 (SF) result with an identical 1.6 litres fermentation gas per litre of fermenter volumes and a methane yield of 0.32 l/g oTS and a more than 12% elevated gas yield than the runs 1 (B+TE+N+ODM) and 2 (B+-TE), buffered by phosphate. The solitary maize silage run (SF), a slight continuous rise of pH could be observed to a level of pH 7.35. Due to an interim addition of acid enhancement up to a level of 1800ppm acetic acid equivalent, the acid concentration at is currently found 630 ppm acetic acid equivalent.

Table 2 Methane yield in litres per gram of organic dry matter

run	methan yield
	l/g ODM
1 B+TE+N+W	0,295
2 B+TE	0,295
5 TE+N+W	0,335
6 SF	0,333

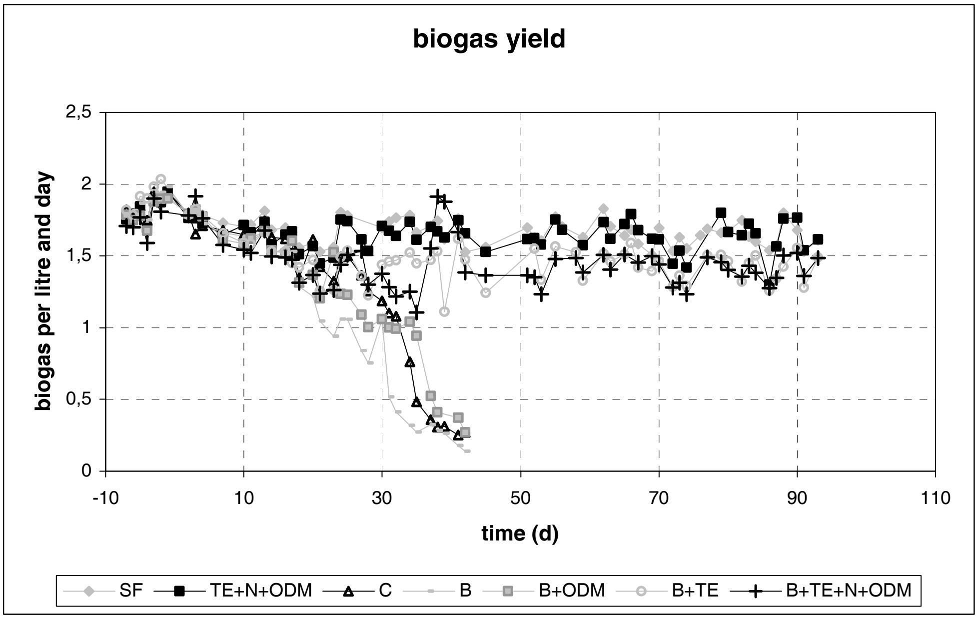

Figure 4 reactor-specific biogas yield

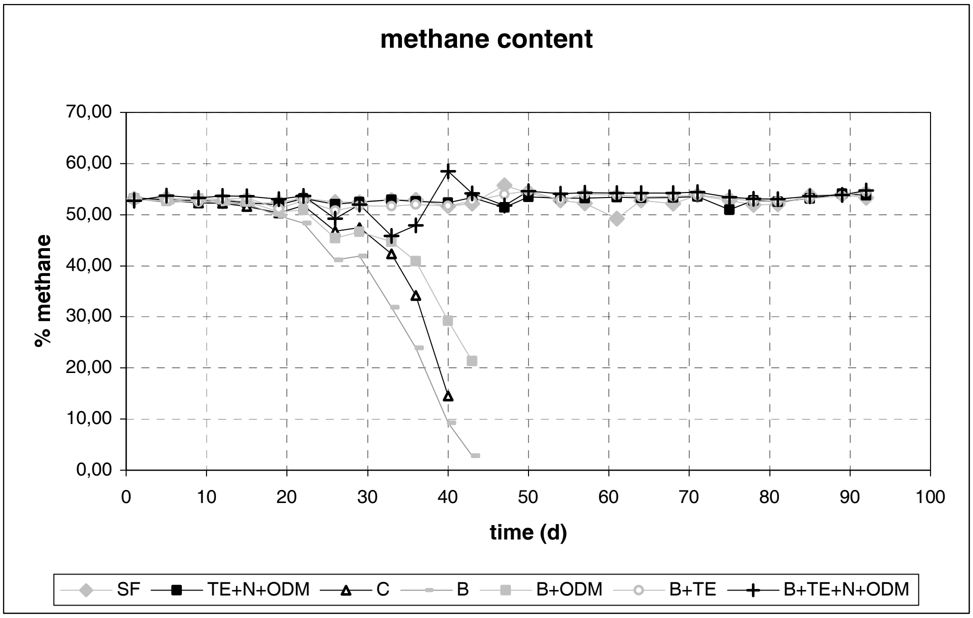

Figure 5 methane-content of biogas

DISCUSSION

Since a stable process is identified after a period of 3-5 retention times (VDI 4630), still no final statements are prospective for the ongoing approaches (currently 2 ¾ retention times). Although, clear positive tendencies appear. Two runs, to which no trace element mixture was added (B; B+ODM) and which were limited due to the addition of water to a retention time of 40 days, showed substantial process disturbances up to the almost complete succumb of biogas formation (alike control C). Process stabilization could not be achieved by addition of a phosphate buffer. An exclusive inhibition of the process by the absence of buffer capacity seems to be improbable. Subsequent approaches are to show this effect on a basis of various buffer systems. Comparing run 5 (TE+N+ODM) to run 1 (B+TE+N+ODM) and 2 (B+TE) 12-13 % lower methane yields were observed which could be caused by the phosphate buffer used (process inhibition). A process-stabilizing manipulate of wood fibres could not be underlined with run 4 (B+OBM). Run 2 (B+TE) performs stable, even without the addition of heavy degradable organic substance (microbial settling surface). The preceding attempt (1.1 oTS l^{-1} d^{-1}) showed a substantial decrease of the dry matter in the fermenting substrate to partially under 1%. Current test series result in a slight increase of organic matter content in the fermenter due to the organic loading rate of 2.5 g oTS l^{-1} d^{-1} (without addition of heavily degradable organic matter). The addition of wood fibres or similar structures was found non-essential for maize silage. The decrease of ammonium concentration within the fermenting substrate as observed in the preceding attempt was not found evident for a destabilization of the fermenting process. For run 2 (B+TE), to which no urea is added, the ammonium concentration is found lowered within the fermenting substrate after 110 days, 50% less than in the preceding attempt. Run 6 (SF) showed a stable trial process until today, whereas higher fatty acid concentrations could be stated. Since no water is added, this option exhibits a very long retention time - consequently solitary a small part of the liquid manure added in advance is displaced by adding maize silage from the digester. due to the retention time wich is three times as long as the other variants are, only after a considerable time process disturbances are to be expected. The runs 1 (B+TE+N+ODM), 2 (B+TE) and 5 (TE+N+ODM) shifted with a trace element mixture, presently perform stable. Single types show a stable process, without an addition of ammonium, addition of the buffer and with heavily degradable organic matter contents. The low concentrations of volatile fatty acids indicate all three variants to a undisturbed conversion of the organic substance into biogas.

CONCLUSIONS

A goal of this approach is to unveil the reason of frequently observed process disturbances for liquid manure-free biogas plants in practice. Preconditioned knowledge described liquid manure to enhance the biogas process positively; solitary the chemical definition of contained substances remained unknown. Technically pure substances were set into liquid manure-free laboratory tests. Provisional results indicate trace elements to be a major reason for process stability. The next attempt is to define if trace element contents of maize silage and other energy crops are sufficiently for a stable biogas process. Additionally the role of trace element supplies and other process auxiliary materials has to be clarified in order to result to a comparable level of gas yields alike the co-fermentation with liquid manure.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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THE FERMENTATION PROCESS AS A POTENTIAL INACTIVATION OPERATION

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SUMMARY

Fusarium (pathogen of Fusarium Head Blight) and its toxic intermediate catabolic product, the so called Mycotoxins, DON (Deoxynivalenol) are prominent for their high grade of deterioration on cereal products. A current research project at the State Institute of Farm machinery and Farm structures at the University of Hohenheim was launched to clarify the terms and conditions for a potential intermixture of Fusarium-contaminated substrate in agricultural biogas plants. Primary results of the interdisciplinary approach showed a reasonable potential deactivating Fusarium within inoculated cereals. A supplementary analysis of the metabolic procedure and its aforementioned parameters is imperative. Thus the authorized maximum levels of contaminants are expected to be performed due to this innovative alternative of a contaminant disposal under suitable biogas production. For Germany an infected quantity of approximately 3.8 Mio. t/a at a six fold higher annual yield of cereals (FAOstat, 2005) are potential to be decontaminated adapting the promising approach. It could be stated, that the aimed biogas process was found stable in respect to the addition of contaminated charges. The two different experimental setups are described in the following paper. Both systems were operated in batch process, varying in their content of total solid and agitation. Several times the Hohenheim Biogas Yield test has been specified in detail. In below the Laboratory solid phase digesters are displayed.

Key words*: Mycotoxins, Fusarium , biogas process, batch fermentation, solid phase digestion*

SITUATION

Almost every crop is supporting an indigenous population of moulds. Regarding various appearances, the most significant plant pathogenic fungus is Fusarium. An infected quantity of approximately 3.8 Mio t/a is listed for Germany. Furthermore 25% of the world's crops are estimated to be contaminated with intermediate catabolic products (FAOstat, 2005). Fusarium spores within cereals are consequently problematic and to be inactivated. One of the commanding toxins produced is Deoxynivalenol (DON).

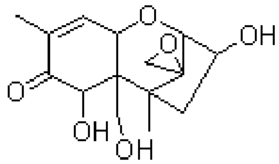

Fig. 1 Deoxynivalenol (DON)

Occurrence of DON in feed materials is almost exclusively associated with cereals, and the levels of occurrence are in the order of hundreds of µg/kg upwards. DON appears as a field (pre-harvest) rather than a storage contaminant, and almost always co-occurs with other Fusarium toxins. Preventive measures are difficult to implement and even the effect of fungicide treatment on DON levels is controversial (Edwards et al., 2001). As seasonal variations significantly influence the extent of Fusarium infections, levels of DON tend to vary from year-to-year making it difficult to generalise as to typical levels of occurrence.

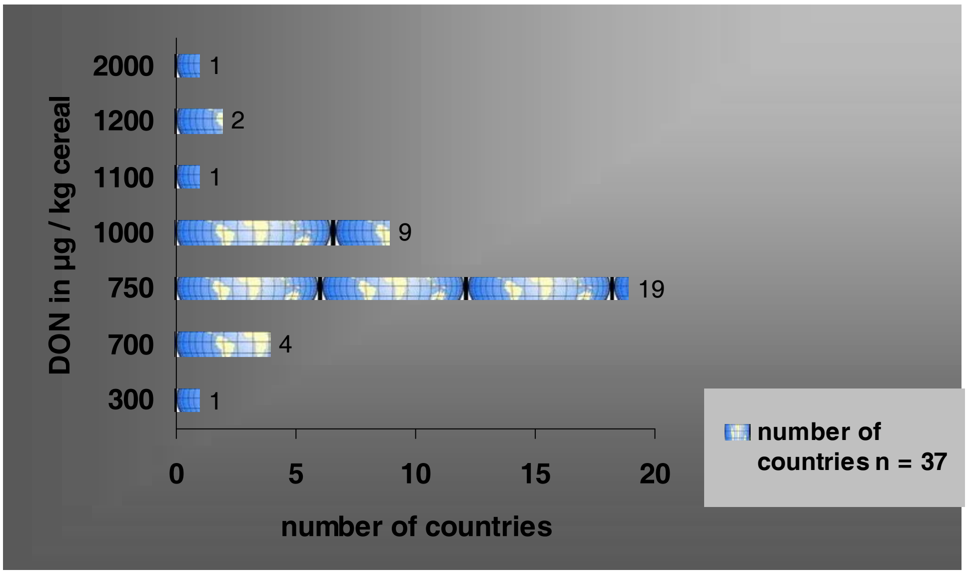

Fig. 2 Concentration of wheat flour determined in 37 countries (after van Egmond 2004)

A recent review of worldwide contamination of cereal grains and animal feed with Fusarium mycotoxins (Placinta et al., 1999) has tabulated the finding of DON in wheat, maize, oats, barley, rye and feeds in Bulgaria, Finland, Germany, the Netherlands, Norway and Poland at levels ranging from a few µg/kg to more than 30 mg/kg. The highest reported levels were in maize cobs from Poland. The following chart shows the allocation of the DON concentration in cereals (wheat flavour), measured in 37 countries.

The main toxic effect of DON is the inhibition of protein synthesis, binding to the ribosome. So it's known to provoke harmful anorexia and emesis caused by short- or long-term administration, diagnosed with humans and livestock animals. Therefore risk assessments for DON have been performed by differencing organisations like: Scientific Committee on Food (SCF, 2002), the Joint Expert Committee on Food Additives (JECFA) (WHO, 2001) and the Nordic Working Group (Eriksen and Alexander, 1998). In 2002 a temporary tolerable daily intake (TDI) of 1µg/kg body weight was established by the EU Scientific Committee on Food (SCF, 2002). No more than a year ago the European Commission launched a regulation, providing maximum levels of contaminants ((EC) No. 856/2005), to prevent these toxins from being spread into the human food chain The amendment is basically focusing on Deoxynivalenol (DON), Zearalenone (ZEA) and Fumonisins. For DON, the following maximum loads are authorized:

Unprocessed cereals: 1250µg/kg

Cereal flour: 750µg/kg

Cereal based baby food: 200µg/kg

Fig. 3 Fusarium infected spike and moulded wheatgrains

Thus the regulation demands a disposal of the concerning wheat charges. One of the chances lies in cereal combustion, which has to be authorised by regional authorities due to the creation of unfavourable emissions. Due to this, the most feasible, environmentally compatible and economical option has to be revealed in order to get rid of the contaminated batches, which inspires current research to create innovative routines of a save disposal. One current research approach at the state Institute of Farm machinery and Farm structures at the University of Hohenheim is to investigate the prerequisites of a potential deactivation of Fusarium spores in a fermenting process. A subsequent reduction of the contained mycotoxine (DON) under fermentation conditions is desired.

Varying parameters of temperature, infection rate and time created surrounding conditions which performed a convenient potentiality of spore deactivation. The process is attended by a simultaneous production of biogas. This appears as an alternative way of disposal creating clean high grade energy simultaneously.

OBJECTIVE TARGETS

Since the implementation of the "Act on Granting Priority to Renewable Energy Sources" the predominant agricultural biogas techniques are in a flux. As slurry was over many decades the principally used digested substrate, now a days solid- phase fermentation of energy plants are in a great demand. Less reactor volume, less process energy, less transport capacity and less outdoor emissions are some of the considerable advantages (Schäfer, 2005). Admittedly the state of the art of the installation engineering is subjected to restrictions. The mixing strategies and the loading as well as the unloading techniques are not negotiable with liquid digestion systems. Therefore the applied research as well as the industry is focused on special technologies allowing a high total solid (up to 50 % TS) content digestion.

The whole purpose of the task specification, in close collaboration with the institute of animal nutrition, is to ensure the plant operators an unobstructed biogas generation.

Therefore several test series have been conducted according to VDI directive 4630. The determination of microbiological activity rate was proved at bench scale unit for charges of contaminated wheat in appearance of entire grains and ground flour in batch processes in slid as well as in liquid fermentation processes.

To get a fine grasp of the current experimental design, task specifications are proposed following:

- Potential of biogas generation: to detect microbiological inhibition of the fermentation process by contaminated substrates
- Germination capacity of the *Fusarium* spores: to abate the infectious field load by the deploy of residues on new crops
- Monitoring of toxins: to abate the path of infection, reinfection can not be excluded ("carry over-effect")

An appraisal of the biogas generation was set up in two different lab scale units.

The mini-batch fermentation based on the Hohenheim Biogas yield test has been described in detail [Helfrich and Oechsner; 2003]. The Laboratory solid phase digesters have been built up in 2004 [Kusch] and provided a basis for pure research pertaining solid phase fermentation. The 10 cylindrical lined reactors are fabricated of stainless steel. The comprehensive faculty is about 60 L; the content of solid material concludes around 50 L. Two Water benches for the circulated arrangement for maintaining temperature are installed. Temperature in the reactor is determined per repeat determination twice per hour by PT 100. To avoid loosing thermal energy, polystyrene insulation is mounted on the reactors and all relevant tubes. The process water is collected in a hopper reservoir on the reactor ground, and sprinkled over the biomass bed by an electrical pump. To disburden sample drawing a three-way cock is added in the percolate recirculation tube and after at least 15 minutes of recirculating the liquid can be sampled. According to descriptive literature pertaining anaerobic fermentation processes the blending of free lechate and the liquid phase in the substrate is advantageous for the methane production. To assume and evaluate the toxin concentration continually was one of the major aspects of our experimental setup.

For a better understanding the two different scales are tabulated in the next figure. Special solid-phase laboratory-scale reactors were constructed (figure 3).

		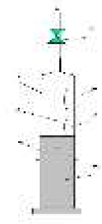
typecast	Based on testing sanitary landfill process (Heyer, 1997) developped by Kusch (2005)	Hohenheim Biogas Yield Test Helfrich, Oechsner (2003)
Volume test cell	50 l stainless steel	100ml hermetic bins out of glas,
Operation	Heated with water bench, connected in series	130 bins are set up in an incubator
Mixing element	Not necessary	an integrated wheel, rotating vertically with a slow and constant speed
Substrate in % of total amount	75 % solid inokulum 25 % chopped green cut 5 % moulded wheat + 10 liter process water	98% liquid inokulum 2% moulded wheat
TS %; VS/TS %	Solid inokulum: 36 %; 54 % Chopped green cut : 46 %; 60% Moulded wheat: 88 %; 94 % Process water: 0,9 %; 0,42%	Liquid manure: 4 %; 60% Moulded material: 88 %; 94 %
Temperature	35 ° C	35°C; 53°C
Duration of fermentaiton	0,5 – 35 days	0,5 – 35 days
Gas measurement	Reservoir in an aluminium coated PE/ PFTE gas-bags; CH4 , CO2 detection by infrared spectorscopy	Reservoir in dead storage capacity; CH4 detection by infrared sensor

Fig. 4 Tabulated data of the two different laboratory scale units

RESULTS

Biogas interpretation

Neither the fermentation in solid-phase digestion systems, nor the mini batch fermentation showed any microbial inhibition. To peer the fermentation of the mini batch Fermenter processes conclude as follows: With the start of the fermentation trial the population of common anaerobic bacteria is marginal and solitary fractionally adapted. Until the fourth day the development phase is found secluded. Therefore the micro organisms reach the highest grade of their performance, until their activity slows down due to the exhausted nutrition status in the ambient media. Using the specific methane yield as an indicator to reveal potential interactions of contaminated substrates, profit cuts are consequently used for identification. According to other curve progressions, the set of "certified reference material, ground" shows a relatively higher yield, see Figure 2.

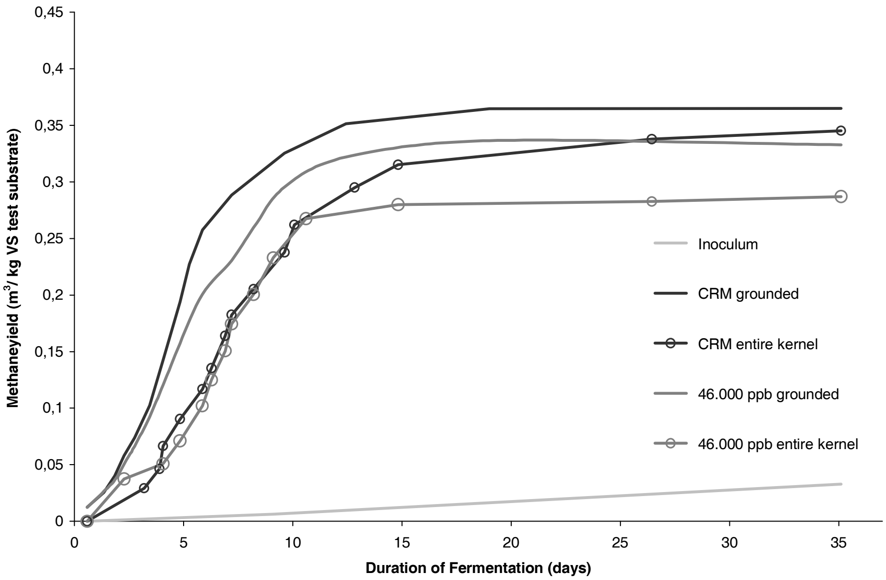

Figure 5 Fermentation of Fusarium infected substratum

This effect can partly be explained by conditions of an eased enzymatic activity when ground material is decomposing. Another explanation can be found in the decline of germane ingredients: Thousand-seed weight differs from mean by 43g (regular kernel), from contaminated kernels by 30g from mean.

The Weender/van Soest analysis showed reduced contents of starch and sugar for contaminated substrates. Under the authority of a present fungus the biogas forming process is not affected adversely. The addition of microbiological contaminated charge showed max. loads of 46.000µg/kg by the moulded wheat.

WEENDER & VAN SOEST ANALYSIS	DM	CA	EE	STC	SUG	CP	CF	NfE
Unit	g/kg FM	g/kg DM	g/kg DM	g/kg DM	g/kg DM	g/kg DM	g/kg DM	g/kg DM
Reference Material	880	19	20	662	33	138	29	794
Moulded material	900	24	15	640	28	150	27	776

Fig. 6 Ingredients of the two fermented substrates

Microbiological interpretation

An aborticide of Fusarium by means of the biogas fermentation in the two temperature sets and the different TS content loads can be underlined from first results. The infection of unfermented material comprises a rate of 100 percent, caused by an expeditious domination of Fusarium on inoculated kernels. This was found evident after a retention time of 0.5 days by means of aforementioned extraction and examination. The inactivation of Fusarium can be explained by the absence of oxygen. Concurrent moulds were billed to the group of total moulds (Aspergillus flavus, Penecillium rouqueforti and others).

Mycotoxin monitoring

The decomposition of the routine toxine DON by specific conversation to the less deepoxylated derivative (DOM-1) is displayed in figure 3. Thus the bias of a potential inactivation of cereal mycotoxines can be assumed. To define the entire microbiological process as a complete record, will evaluate.

DISCUSSION

After fermentation of the contaminated grain, neither *Fusarium hyphea* nor their germinable spores could be detected due to terms and conditions prevailing in biogas vessels. Moulds and yeasts are proved to fill a comparatively inferior position to micro organisms, which is inevitable for the biogas process. The conditions of growth and reproduction are differing relative to water activity and the availability of oxygen. The acquired pH value of 8.36 was discovered to high for effective growth. The thermal treatment of temperatures beyond 30° C and a particular absence of oxygen deleted germination capacity.

Fusarium needs a consistent surface in order to grow in hydrogenous ambiance (Kaltwasser, 1980). These requirements were not to be implicated by liquid manure. Anaerobic and liquid phase are favoured by yeasts in contrast to moulds. The retention time showed no effect on the further appearance of *Fusarium*. The *Mycelium* and the residues of the *hyphea* were found nonviable in the disposing milieu and probably abolished by hydrolytic bacteria.

Another aspect is given by the negative effect of escharotic substances, emerging from the biogas process, hydrosulphide e.g., which affects the sensitive conidia. Confirmed permanent moulds (like *Ascospores*) are capable to outlast, or even re-germinate after exposure on culture media. The mesophile fungus performs its optimum of growth at 22°C - 28°C.

OUTLOOK

Primary results of the interdisciplinary approach showed a reasonable potential deactivating *Fusaria* within inoculated cereals. By means of the HBT and the solid phase batch trial it could be stated, that the desired biogas process was found stable in respect to the addition of contaminated charges. The analogy of the currently driven trials to the natural activity of a rumen is to be underlined concerning an effective handling of the contaminants. These first results have to be verified further basic process parameters (temperature, fermentation process alternatives). A supplementary analysis of the metabolic procedure and its aforementioned parameters is imperative. Thus the authorized maximum levels of contaminants are expected to be performed due to this innovative alternative of a contaminant disposal under suitable biogas production. For Germany an infected quantity of approximately 3.8 Mio. t/a at a six fold higher annual yield of cereals (FAOstat, 2005) are potential to be decontaminated adapting the promising approach.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 331.101:631.372:62-51
Prethodno priopćenje
Preliminary communication

NEKE ERGONOMSKE ZNAČAJKE KABINE TRAKTORA *IMT 549 DV*

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SAŽETAK

U radu se iznose rezultati mjerenja buke vibracija koje se sa malog poljoprivrednog traktora prenose na ruke i tijelo vozača tijekom rada. Mjerenja buke su obavljena uz uho vozača kod približno nazivnog okretnog momenta dok su mjerenja vibracija obavljena na dvije mjerne točke. Na volanu su mjerene vibracije koje se prenose na ruke rukovatelja, a na sjedalu su mjerene vibracije koje se prenose na čitavo tijelo. Sva su mjerenja obavljena pri kontroliranim frekvencijama vrtnje motora u praznome hodu. Frekvencija vrtnje motora je varirala u rasponu od 1 500 do 2 200 min^{-1}. Vibracije su mjerene u sve tri koordinatne osi istovremeno u frekvencijskom rasponu propisanom međunarodnim normama. Mjerenja su analizirana, vrednovana u skladu s preporukama, a rezultati su iskazani tablično i u grafičkom obliku.

***Ključne riječi**: buka, vibracije, mjerenja, vrednovanje vibracija*

UVOD

U mnogim je radovima i znanstvenim raspravama istican problem kako buke tako i vibracija koje se s mehaniziranih sredstava rada prenose na rukovatelje. Nedvojbena je činjenica da kako buka tako i prenesene vibracije smanjuju komfor rukovatelja, umanjuju sveukupnu učinkovistost, a izlaganje iznad određenih granica može izazvati trajna oštećenja kod vozača. Naime, opće je poznata činjenica da izloženost buci i vibracijama iznad dopuštenih granica izaziva trajna oštećenja organizma. Sve su to razlozi zbog kojih je potrebno objektivno mjeriti razine buke i vibracija, na svrsishodan način ih vrednovati te odrediti stvarnu opasnost na pojedinim radnim mjestima. Svaka je uređena sredina dužna posvetiti odgovarajuću pozornost problemu zaštite od utjecaja kako buke tako i vibracija.

I u Hrvatskoj se ovom problemu posvetila dužna pažnja na formalno-pravnoj razini. Tako se primjerice u *Zakonu o zaštiti na radu* kao i u *Zakonu o inspekciji rada* radi izbjegavanja neželjenih posljedica po zdravlje na većem broju mjesta posredno ili neposredno nalaže mjerenje razine buke i vibracija te ograničavanje vremena izlaganja pojedinaca. Slabo ili necjelovito poznavanje utjecaja buke i vibracija, nedostatak primjerene mjerne opreme čije značajke trebaju udovoljavati zahtjevima međunarodnih normi pogoršava i inače lošu stvarnost u našim uvjetima.

PROBLEMATIKA

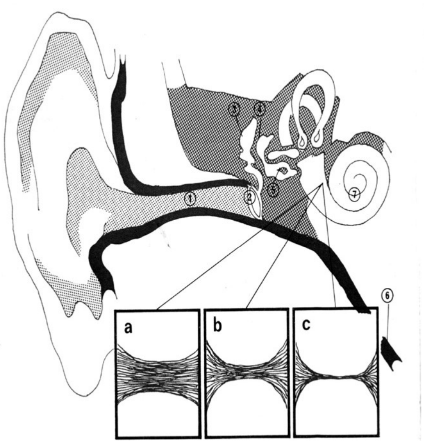
Rukovatelji svih mehaniziranih sredstava rada izloženi su utjecaju buke i mehaničkih vibracija. Isti je slučaj i s putnicima u svim prometnim sredstvima. Pri tome se ljudsko tijelo ponaša kao vrlo složen fizikalni i biološki sustav. Uz mehaničke utjecaje u obzir valja uzeti i psihološke utjecaje.

Djelovanje buke

Ljudsko je uho složen i izuzetno osjetljiv organ. njegove bi se osnovne značajke mogle sažeti u sljedeće postavke:

a) uho je selektivan akustički analizator
b) određuje smjer zvučnog izvora
c) indikator je glasnoće
d) indikator je visine i boje tona e) omjer najmanjeg i najvećeg zvučnog tlaka koje uho može podnijeti iznosi $1{:}10^6$
e) u području najveće osjetljivosti uho reagira na zvučni tlak koji izaziva titranje bubnjića amplitudom koja je jednaka 1/10 promjera najmanjeg atoma, tj. amplitudom manjom od 10^{-11} m.

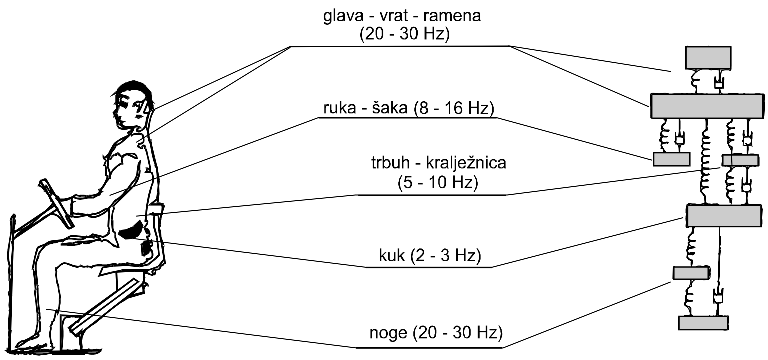
Presjek uha:
1 – bubnjić
2 – čekić
3 – nakovanj
4 – stremen
5 – Eustahijeva tuba
6 – pužnica
7 – Cortijev organ



Slika 1 Cortijev organ: a) pun nervnih stanica; b) nagluhost; c) konačna gluhoća

Iz toga proizlazi da je zdravo uho izuzetno osjetljivo te da valja uložiti puno pažnje da se ta osjetljivost sačuva. Dugotrajna izloženost buci previsokog intenziteta izaziva trajnu nagluhost (Pražić1975). Razlozi nagluhosti treba tražiti uvijek u degenerativnim promjenama osjetilnih stanica kako to prikazuje sl. 1.

Mehanički utjecaj vibracija na ljudsko tijelo može se pojednostavljeno prikazati kao mehanički titrajni sustav s koncentriranim masama, prigušnim i elastičnim elementima kako je to učinjeno na sl. 2. Različiti dijelovi organizma, kako je to pokazano na sl. 1 imaju različite rezonantne frekvencije. Stoga vibracije određene razine i frekvencije predstavljaju različitu opasnosti za pojedine dijelove tijela (Goglia et.al. 1999., Somek 1975., Henich 1981). Izmjerene vrijednosti treba zbog toga ispravno vrednovati te na taj način vršiti stvarnu procjenu opasnosti (13, 14 i 15).



Slika 2 Pojednostavljeni prikaz mehaničkog utjecaja vibracija na ljudsko tijelo.

Mjerenja koja se iznose u ovome radu obavljena su na mjestima koja mogu izazvati različite efekte na tijelu vozača. Vrijednosti dobivene mjerenjem su iz tog razloga i tretirane različito, kako to i preporučuju međunarodne norme (13, 14 i 15). Postupak mjerenja, rezultati i analiza rezultata mjerenja se navode u daljnjem tekstu.

MJERENJA

Mjerenja buke

Buka je mjerena kod približno nazivnog okretnog momenta (¾ majvećeg broja okretaja motora ~1800 min^{-1}). Mjerenja buke u kabini traktora obavljeno je u skladu s dolje navedenim nacionalnim i međunarodnim normama:

a) HRN ISO 5131:2000EN

   Akustika – Traktori i strojevi za poljoprivredu i šumarstvo – Mjerenje buke na mjestu rukovatelja – Pregledna metoda (ISO 5131:1996)

   Acoustics – Tractors and machinery for agriculture and forestry – Measurement of the noise at the operator's position – Survey method (ISO 5131:1996)

b) HRN ISO 6394:2000EN

Akustika – Mjerenje buke strojeva za zemljane radove na mjestu rukovatelja – Uvjeti ispitivanja pri stajanju (ISO 6394:1998)

Acoustics - Measurement at the operator's position of airborne noise emitted by earth-moving machinery – Stationary test conditions (ISO 6394:1998)

Mjerenja kojih se rezultati iznose u ovome radu, su provedena u skladu s *Pravilnikom o načinu ispitivanja određenih sredstava rada i radne okoline te sadržaju , obliku i načinu izdavanja dozvola*. Tijekom mjerenja korištena je dokumentacija s uputstvima za upotrebu i održavanje ispitivanoga tipa traktora, a postupak mjerenja bio je u skladu s postupkom propisanim u međunarodnim normama.

Za mjerenje razine buke u kabini kao i za sva ostala mjerenja razine zvuka korištena je oprema popisana u tablici 1.

Tablica 1 Oprema korištena za mjerenje buke

Red. br.	Naziv	Proizvođač	Tip	Serijski br.
1	mikrofon	Bruel&Kjaer	4145	375569
2	zvukomjer	Bruel&Kjaer	2209	669972
3	magnetofon	Bruel&Kjaer	7003	778754
4	kalibrator	Bruel&Kjaer	4220	656775
5	analizator	Bruel&Kjaer	2131	769777
6	računalo	Hewllet&Packard	Vectra	3011F07105

Izmjerena razina buke je vrednovana pomoću A- filtera i u prethodno navedenim uvjetima je iznosila 81 dB(A). Prema Pravilniku o najvišim dopuštenim razinama buke u sredini u kojoj ljudi rade i borave – NN 145/2004, s obzirom na oštećenje sluha kada izmjerena ekvivalentna razina buke na radnome mjestu prelazi 80 dB(A), kao ocjenska razina buke za pojedinog radnika primjenjuje se normalizirana dnevna osobna izloženost buci LRE,8h. Ako je buka tijekom radnog tjedna promjenjiva, primjenjuje se normalizirana tjedna osobna izloženost LRE,w. Najviša dnevna ili tjedna osobna izloženost buci radnika iznosi 85 dB(A). Istodobno najviša vršna C-vrednovana razina buke ne smije biti viša od LC, peak = 140 dB(C). Prema tome izmjerena razina buke u kabini traktora od 81 dB(A) upućuje na to da bi trebalo odrediti normaliziranu dnevnu izloženost buci. Ako se pretpostavi da je operater tijekom rada izložen cijelo radno vrijeme izmjerenoj ili manjoj razini buke, može se ustvrditi da nema opasnosti za oštećenje sluha jer razina buke ne prelazi vrijednost najviše dnevne ili tjedne razine od 85 dB(A).

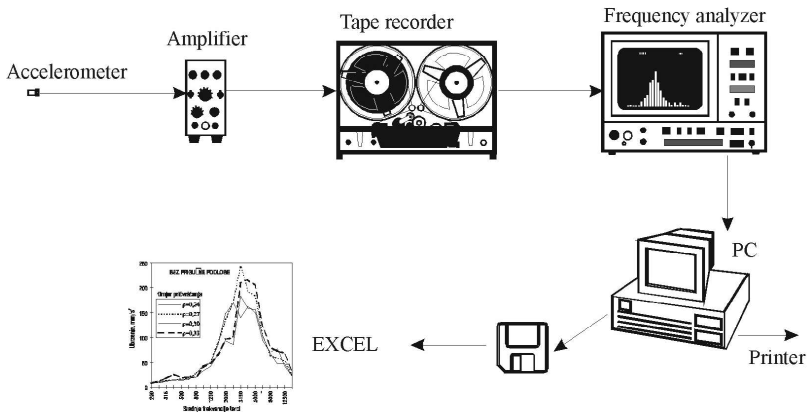
Mjerenja vibracija:

Mjerenja vibracija koje se sa volana prenose na ruke vozača su napravljena u skladu s normom HRN EN ISO 5349: *Mechanical vibration – measurement and evaluation of human exposure to hand-transmitted vibration*.

Za mjerenja i analizu podataka korištena je oprema popisana u tablici 2.

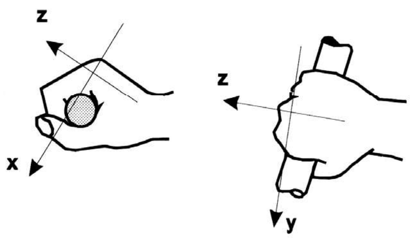
Tablica 2 Oprema korištena za mjerenje vibracija

Red.br.	Naziv	Proizvođač	Tip	Tvorn. br.
1.	akcelerometar	Bruel & Kjaer	4326 A 001	11645
2.	pojačalo	Bruel & Kjaer	2635	777442
3.	pojačalo	Bruel & Kjaer	2635	777443
4.	pojačalo	Bruel & Kjaer	2635	777434
5.	kalibrator	Bruel & Kjaer	4291	775742
6.	magnetofon	Bruel & Kjaer	7003	778754
7.	analizator	Bruel & Kjaer	2131	769777
8.	računalo	Hewlett Packard	Vectra ES	3011F07105



Slika 3 Mjerni lanac korišten za mjerenje i analizu vibracija

Mjerenja su istovremeno vršena u tri osi prema koordinatnom sustavu definiranom normom sukladno slici 4.



Slika 4 Koordinatni sustav za mjerenje vibracija koje se prenose na ruke prema ISO 5349

Mjerenja razine vibracija koje se prenose s volana traktora na ruke operatera obavljena su stupnjevito pri raznim brojevima okretaja motora (700, 900, 1100, 1300, 1500, 1700, 1900 i 2200 min^{-1}) u mirovanju te je za svaki napravljena frekventna (tercna) analiza na temelju pet uzoraka iz kojih je određena srednja vrijednost, iz podataka tercne analize izračunato je vrednovano ubrzanje u sve tri osi (a_{hwi}) i određena ukupna razina vibracija (a_{hv}) .

Vrednovane razine ubrzanja izračunate su prema:

$$a_{h,w} = \left[\sum_{j=1}^{n} (w_j \cdot a_{wj})^2 \right]^{1/2}$$

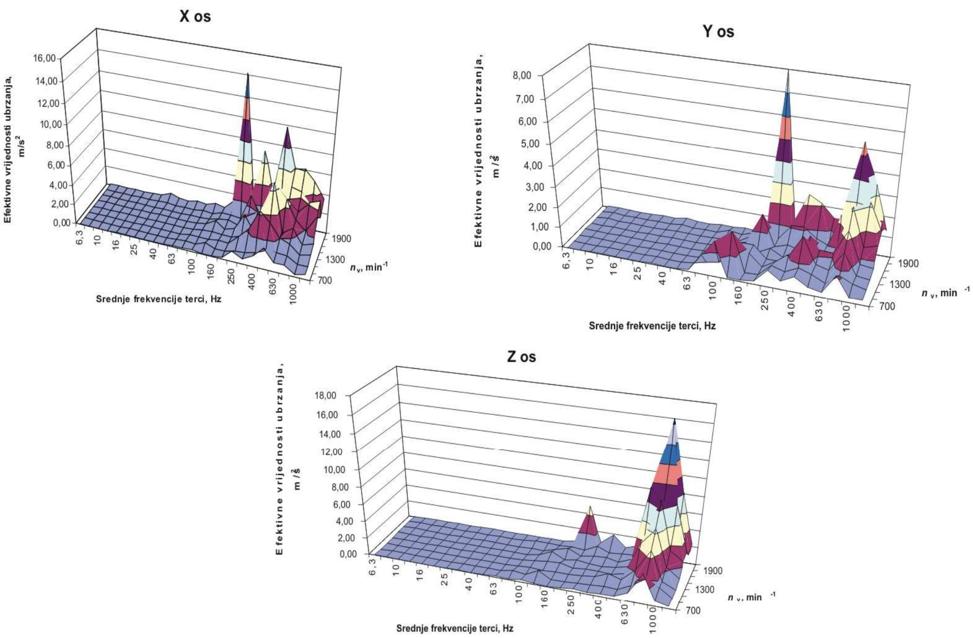
gdje je w_j – faktor za vrednovanje pojedine terce, a_{wj} – efektivna vrijednost ubrzanja u pojedinoj terci (m/s^2).

Iz vrednovanih razina ubrzanja u sve tri osi određena je ukupna razina vibracija prema:

$$a_{hv} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2}$$

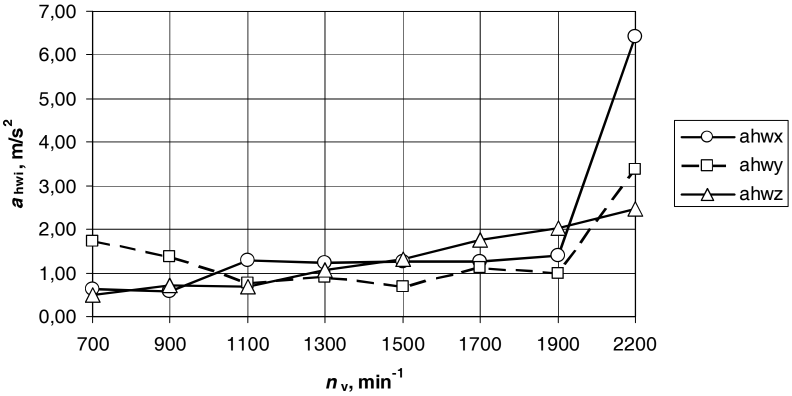
gdje su a_{hwi} – vrednovane efektivne vrijednosti ubrzanja u pojedinim osima (m/s^2).

Rezultati tercne analize prikazani su na slici 5.



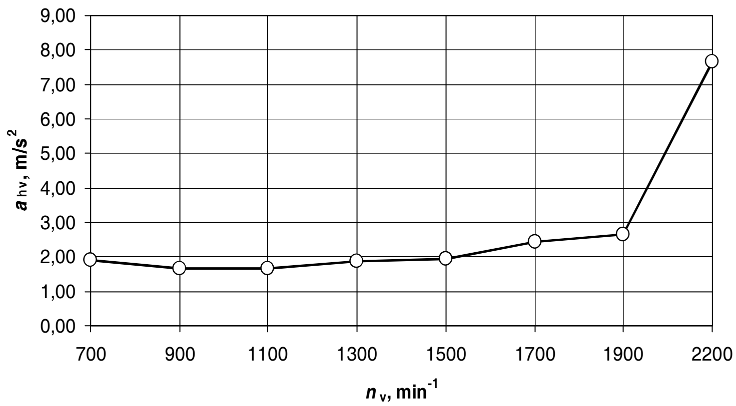
Slika 5 Rezultati tercne analize u sve tri osi pri raznim vrijednostima nv

Rezultati dobivenih vrednovanih razina ubrzanja u sve tri osi prikazani su na slici 6.



Slika 6 Vrijednosti vrednovanih razina ubrzanja po osima

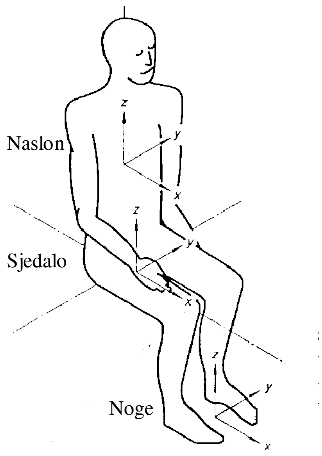
Rezultati ukupne razine vibracija prikazani su na slici 7.



Slika 7 Ukupna razina ubrzanja pri stup- njevitoj promjeni broja okretaja motora

Mjerenja vibracija koje se prenose na tijelo operatera sa sjedala su napravljena u skladu s normom HRN EN ISO 2631: *Evaluation of human exposure to whole body vibration.* Korištena je već ranije navedena oprema za mjerenje i analizu podataka.

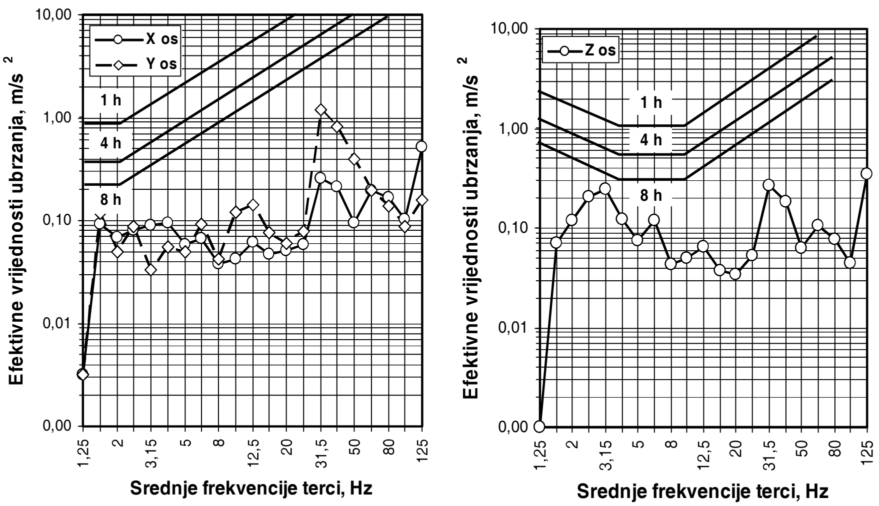
Istovremeno su vršena mjerenja u tri osi prema koordinatnom sustavu definiranom normom sukladno sl. 8.



Slika 8 Shematski prikaz osnovnih smjerova koordinatnog sustava prema ISO 2631 za sjedeći položaj

Mjerenja su obavljena pri vožnji traktora po terenu pri frekvenciji vrtnje motora od 1800 min^{-1}. Na temelju izmjerenih vrijednosti napravljena je analiza po srednjim frekvencijama terci te su izračunata vrednovana razina ubrzanja za svaku pojedinu os. Na temelju tih podataka određena aritmetička sredina podataka koja je onda unašana u dijagrame i uspoređivana s ograničenjima za 8; 4; 2,5 i 1 satno dnevno izlaganje danima u ISO 2631-1-1986.

Rezultati tercne analize prikazani su na slici 9.



Slika 9 Rezultati tercne analize vibracija koje se prenose sa sjedala traktora

Vrijednosti vrednovanih razina ubrzanja u pojedinim osima određene su temeljem analize vremenskog zapisa pomoću tercne analize i relacije:

$$a_w = \left[\sum_i (W_i \cdot a_i)^2 \right]^{\frac{1}{2}}$$

gdje je a_w – vrijednost vrednovanih ubrzanja (m/s^2), W_i – faktor vrednovanja pojedinih terci za odgovarajuću os, a_i – efektivna vrijednost ubrzanja pojedine terce (m/s^2).

Rezultati vrednovanih razina ubrzanja u sve tri osi dane su u tablici 3.

Tablica 3 Rezultati vrednovanih razina ubrzanja u sve tri osi

a_{wx} m/s^2	a_{wy} m/s^2	a_{wz} m/s^2
0,166	0,189	0,373

Vektorski zbroj ubrzanja u sve tri osi a_v iznosi 0,45 m/s^2.

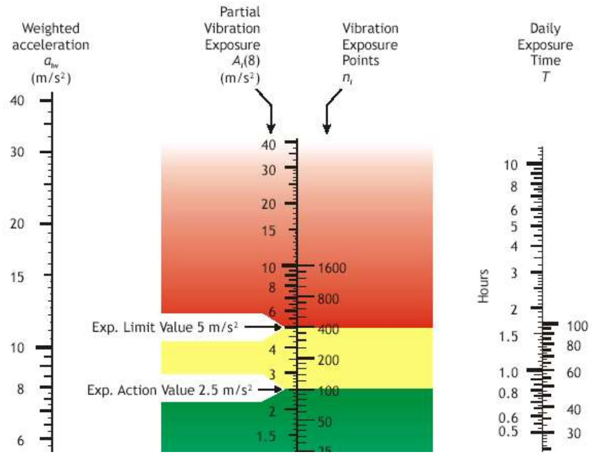
ZAKLJUČAK

Prema *Pravilniku o najvišim dopuštenim razinama buke u sredini u kojoj ljudi rade i borave* – NN 145/2004, s obzirom na oštećenje sluha kada izmjerena ekvivalentna razina buke na radnome mjestu prelazi 80 dB(A), kao ocjenska razina buke za pojedinog radnika primjenjuje se normalizirana dnevna osobna izloženost buci $L_{RE,8h}$. Ako je buka tijekom radnog tjedna promjenjiva, primjenjuje se normalizirana tjedna osobna izloženost $L_{RE,w}$. Najviša dnevna ili tjedna osobna izloženost buci radnika iznosi 85 dB(A). Istodobno najviša vršna C-vrednovana razina buke ne smije biti viša od $L_{C,peak}$ = 140 dB(C). Prema tome izmjerena razina buke u kabini traktora od 81 dB(A) upućuje na to da bi trebalo odrediti normaliziranu dnevnu izloženost buci. Ako se pretpostavi da je operater tijekom rada izložen cijelo radno vrijeme izmjerenoj ili manjoj razini buke, može se ustvrditi da nema opasnosti za oštećenje sluha jer razina buke ne prelazi vrijednost najviše dnevne ili tjedne razine od 85 dB(A).

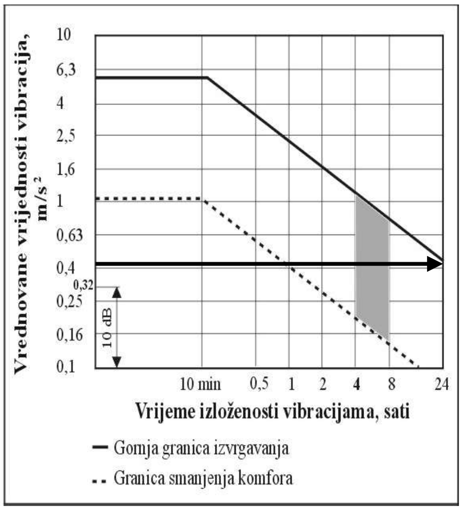
Iz rezultata mjerenja vibracija na volanu traktora ne može se utvrditi da li ima opasnosti za zdravlje operatera jer bi bilo potrebno utvrditi vremensku izloženost operatera pojedinim razinama vibracija. Tek na temelju tih podataka moguće je odrediti ukupnu dnevnu, tjednu ekvivalentnu razinu vibracija kojima je operater izložen. Kao orijentacijski pokazatelj dopuštenih granica može se koristiti nomogram prema The 'Vibration Directive' (Directive 2002/44/EC) prikazan na slici 10.

Na temelju određenih vrijednosti ukupne razine vibracija (a_{hv}) može se vidjeti da u većini promatranih radnih opterećenja traktora razina vibracija ne prelazi vrijednost od 2,5 m/s^2 kada bi trebalo poduzeti neke mjere zaštite, a jedino pri maksimalnom broju okretaja prelazi maksimalno dopuštenu razinu vibracija od 5 m/s^2.

Iz analize vibracija koje se prenose na tijelo operatera u sjedećem položaju može se vidjeti na temelju tercne analize i graničnih krivulja da najvjerojatnije nema nikakve opasnosti po zdravlje operatera pri danom opterećenju i načinu rada traktora. Prema važećoj ISO normi bilo bi potrebno odrediti dnevnu ekvivalentnu razinu ubrzanja ukoliko se radni dan sastoji od više različitih perioda izloženosti vibracija i na temelju njih vršiti procjenu. Ukoliko se vrši procjena prema izmjerenih a_v = 0,45 m/s^2 tada se može reći da nema opasnosti po zdravlje operatera, ali nakon jednog sata rada u takvim uvjetima dolazi do narušavanja komfora.



Slika 10 Minimalni standardi za kontrolu rizika od vibracija koje se prenose na ruke



Slika 11 Procjena utjecaja vibracija koje se prenose na tijelo na zdravlje čovjeka (HRN EN ISO 2631: Evaluation of human exposure to whole body vibration)

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 621.693:629.114:631.372
Stručni rad
Expert paper

COMPLEX TESTS OF THE RESISTANCE STRUCTURES IN SIMULATED AND ACCELERATED REGIME ON HYDROPULSE INSTALLATION

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SUMMARY

The paper presents the conditions and the performing method of some complex tests under simulated and accelerated regime of the resistance structures (such as vehicle seats, their anchorages, cabins, etc.) on a special installation of Hydropulse type. There will be pursued the special conditions in which the test is performed, conditions imposed by the European directives and regulations for all the member states of EU and for those associated, as well as the results obtained following the respective tests. The paper conclusions will emphasize not only the necessity of such an installation – of hydropulse type, but also the possibility of performing other complex tests which could replace the classical methods, who need a larger testing period, many employees and high costs.

***Key words**: testing equipment, complex tests, hydropulse type*

INTRODUCTION

One of the most complex tests that had been realized on hydropulse installation is the resistance frame test of the tractor. This was performed with the roof removed from the tractor and it was performed in complying with the Directive 86/298/CEE, referring to the protection devices in case of overturning, mounted behind the operator, at agricultural and forestry wheeled tractors, with narrow - gauge line, with the latest modification no. 89/692/CEE and SEE Agreement in 1992.

The operator's protection device, in endowment of the tractor, is a metallic construction placed behind the chair and it is provided in order to avoid or to remove the risks to which the tractor operator is subdued when overturning, in normal use conditions.

The frame is fixed on the protection wings of the rear wheels by means of 16 screws M12 x 30, and each wing, in its twin, is fixed to the tractor rear axle by means of a plate and 4 screws M16 x 1.5; l = 220 mm.

The frame test was performed with the roof removed from the tractor and it was performed complying with the requirements of the Directive 86/298/CEE.

Consequently, the results of the following test refer to the behaviour at stresses of the assembly made up of a welded frame, protection wheels of the rear axles on which it is mounted and their attachments on the tractor rear axle.

The resistance test of the welded frame was performed complying with the provisions of the Directive 86/298/CEE regarding the protection devices in case of overturning, mounted behind the operator's chair at the agricultural and forestry wheeled tractors, with narrow-gauge line, with the latest modification no. 89/682/CEE and SEE Agreement in 1992.

The welded frame was tested in the Laboratory of Simulated and Accelerated Tests "Hidropulse" within the National Institute of Research - Development for Machines and Food Industry (INMA) – Bucharest.

The main dimensional characteristics of the frame are presented in table no. 1.

Table 1

Den. no.	Measured subassembly	Name of measured element	Value before testing	Value after testing	Obs.
1.	Welded frame	Frame height	825	829	Vertically measured values
		Frame width	1220	1219	Measured at the upper side
		Distance between the right and the left beams	996	995	-
		Frame pitch	4^o 15’	4^o 20’ right beam 2^o 30’ left beam	Inclined to the rear side of the tractor
		Frame lateral tilt	-	2^o 55’ right beam 3^o 45’ left beam	Inclined to the left
2.	Beam	Dimensions: L x B x H	1220x60x51	1220x60x51	-
		Error of straightness on beam length	-	10	Vertical deformation after the last test
		Cross section	Pipe 60x60x5	-	-
3.	Plate	Dimensions	775x165x7	775x165x7	-
4.	Left wall	Dimensions	630 198 128	630 198 128	-

TESTING CONDITIONS

The frame tests have been performed being mounted on a tractor, the tractor being fixed on the testing platform through the agency of a system of universal and specific devices, according to the arrangement presented in fig. 1, 2 and 3.

For the tests a 100 kN hydraulic cylinder was used (for the tests regarding the input power at longitudinal and lateral drive tests) and two 25 kN cylinders (for the test of pressing from upwards downwards).

The deformations suffered by the assembly frame-wings along the longitudinal and lateral drive tests can exceed the value of 200 mm, which corresponds to the maximum stroke the hydraulic cylinder can ensure.

That is why it was used a mounting of stroke amplifying made up of a cable roller and a traction cable, as it results from figures 1 and 3.

Figure 1 Mounting performed an "HIDROPULSE" installation for testing the welded frame, drive from the rear side to the front side

Figure 2 Mounting performed an "HIDROPULSE" installation for testing the welded frame, drive from the up to down

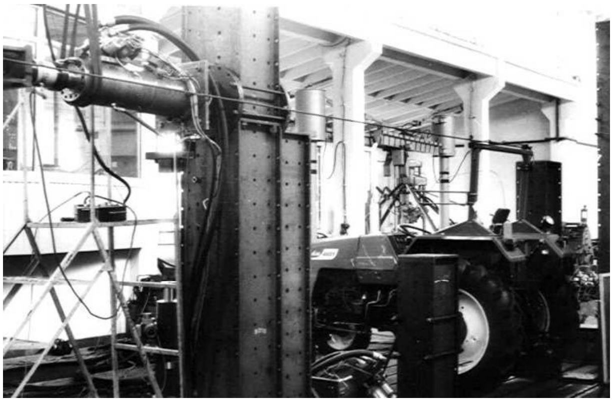


Figure 3 Mounting performed an "HIDROPULSE" installation for testing the welded frame, drive from the lateral side

The testing parameters and their values are presented in table 2 and have been established complying with the product technical documentation and Directive 86/298/CEE.

Table 2

Test Type		Testing parameters		
		Name	**M.U**	**Minimum values calculated according to D 86/298/CEE**
Horizontally	Drive from rear to front	power	J	2162
	Drive from front to rear	power	J	1560
	Lateral drive	power	J	3710
Vertically	Pressing from up to down	power	N	42.400 (2 x 21.200)

For measuring the product input parameters the following gauges have been used:

- Measuring chain for force - LMF 03 / ±25 kN;
- Measuring chain for stroke – LMC 09 / ±100 mm;
- Measuring chain for force – LMF 05 / ±25 kN;
- Measuring chain for stroke – LMC 11 / ±100 mm;
- Measuring chain for force – LMF 08 / ±100 kN;
- Measuring chain for stroke – LMC 04 / ±100 mm;
- Hydraulic cylinder switch cabinet – DCCH - 06;
- Hydraulic cylinder switch cabinet – DCCH – 07;
- Hydraulic cylinder switch cabinet – DCCH – 08.

TEST RESULTS

The results of the tests for the welded frame are shown in table no. 3 and nomograms in figures 4÷11.

Table 3

Den. no.	Tests Successions	Testing Parameters			
		Denomination	**M.U.**	**Measured or resulted values**	**Minimum values calculated according to D 86/298/CEE**
1.	Drive from rear to front	power	J	2183	2162
		force	kN	22,7*	-
		total deformation	mm	205,3	-
		remanent deformation	mm	62	-
2.	Up to down pressing	power	J	76	-
		force	kN	42,62 (2x21,31)*	42,4 (2x21,2)
		total deformation	mm	6,6	-
		remanent deformation	mm	0,2	-
3.	Drive from front to rear	power	J	1582	1560
		force	kN	18,8*	-
		total deformation	mm	159	-
		remanent deformation	mm	45,5	-
4.	Side drive	power	J	3797	3710
		force	kN	21,29*	-
		total deformation	mm	329,5	-
		remanent deformation	mm	146	-
		elastic deformation	mm	183,5	-

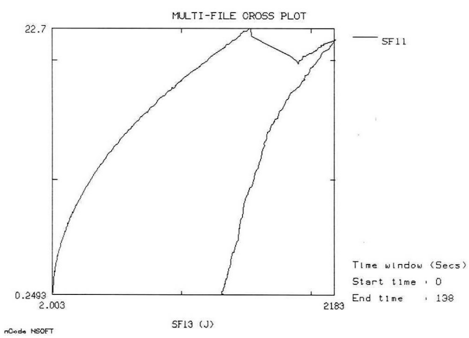


Figure 4 Test of the welded frame
FORCE - POWER. Drive from rear to front

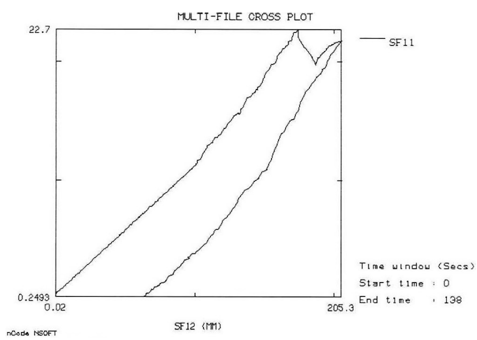


Figure 5 Test of the welded frame
FORCE - DISPLACEMENT. Drive from rear to front

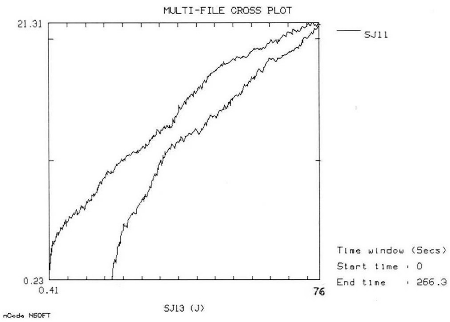


Figure 6 Test of the welded frame
FORCE - POWER. Drive from upwards to downward

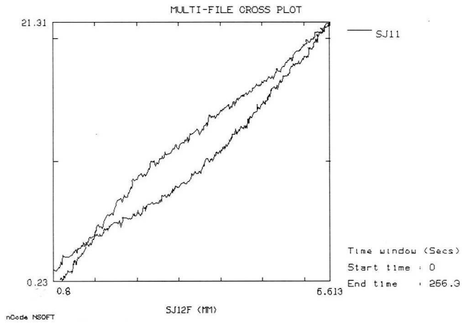


Figure 7 Test of the welded frame
FORCE - DISPLACEMENT. Drive from upwards to downwards

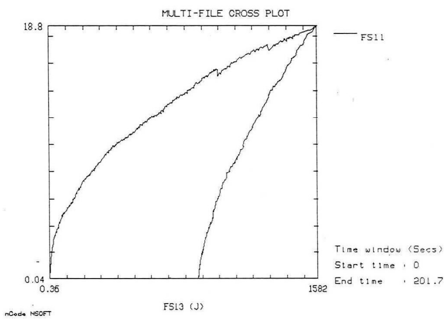


Figure 8 Test of the welded frame
FORCE - POWER. Drive from front to rear

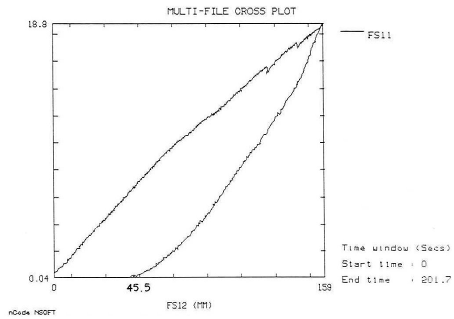


Figure 9 Test of the welded frame
FORCE - DISPLACEMENT. Drive from front to rear

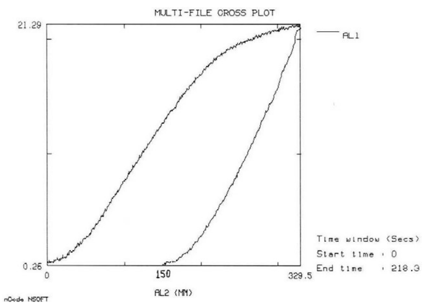


Figure 10 Test of the welded frame
FORCE - POWER. Side drive

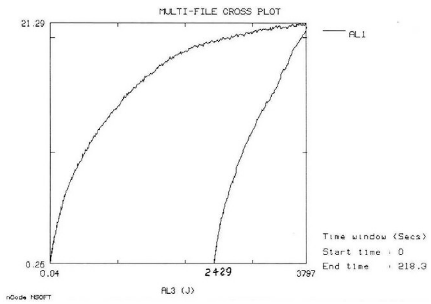


Figure 11 Test of the welded frame
FORCE - DISPLACEMENT. Side drive

The frame deformation during the tests was produced simultaneously with the deformation of the wings on which it is mounted; consequently the values of the deformations and power (energies) presented in the table are values characterizing the behaviour of the assembly frame - wings mounted on the tractor transmission.

The welded frame equipment the tractor is designed to protect the tractor driver from those dangers which may occur by overturning the tractor or limiting their effect, in the case of a normal use.

The tests were performed on the installation for dynamic tests, hidropulse - type, with the roof removed from the frame and after all these, the following have resulted:

- the protection frame has not presented any visible breaks or cracks;
- not any part of the protection device has penetrated, the releasing area, according to Annex III, item 3.2 in the Directive 86/298/CEE;
- the elastic deformation at the side test, measured at 900 mm over the reference point of the chair in a vertical plane, was 134 mm, being under the value of 250 mm provided in Annex II, item 3.1.8 in the Directive 86/298/CEE;
- the maximum remanent deformation was 146 mm.

OTHER EQUIPMENTS TYPES WHICH CAN BE TESTED ON HYDROPULS INSTALATIONS

Equipments and technique devices which can be tested on the complex installation in simulated and accelerated mode and Hydropuls:

- anti-wedging bars and lateral protection devices for trailers;
- tie-devices between vehicles;
- protection devices in turning over case of agricultural and lumber wheels tractors;
- dampers for motor vehicles and especial utilizations;
- towage devices;
- electric transducers;
- electric converters;
- tractors and trailers frames;
- tractors and trailers axles;
- agricultural machines;
- resistance frames for agricultural machines;
- anchoring points of motor vehicles safety belts;
- chairs and anchoring points meant for persons transport;
- subsystems which form the suspension system of elevators booth;
- components and subsystems for aeronautic industry;
- components and subsystems for energy industry etc.

TEST ON CHAIRS AND ANCHORING POINTS OF VEHICLES MEANT FOR PERSONS TRANSPORTATION

- Test object, application domain

The object of this test is checking the mechanic resistance, in accordance with international norms for chairs and anchoring points of vehicles meant for person's transportation. Resistance tests on chairs are made in accordance with *R 80 ECE-ONU.*

Reference documents: PSpI - 01.00.44; PSpI - 01.00.48 and IL SM - 01.00.04

- Test conditions

The test is executed with chairs mounted on a fixed platform, using a special stand. Testing forces required are made by 4 hydraulic cylinders, belonging to the complex test installation in simulated and accelerated mode as Hydropuls type, mounted on the mentioned stand.

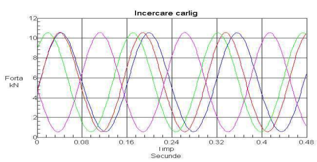
The forces and displacements measuring is realized using force and displacement transducers, in view of reduction.

The values for the forces and displacements measured are registered in data files. Force and displacement diagrams result after data processing.

TRACTORS AND AGRICULTURAL TRAILERS TIE-DEVICES TEST

- Test object, application domain

The tie-devices are simple subsystems as lacing eye type, hook, fork, traction bar or coupling lap which realize the connection between a tractor vehicle and the vehicles towed by this. Seeing that the serious implications which an eventually breakage of such a device could have on the road traffic participants, their test is categorical obligatory. The tie-devices tests are made in dynamic mode, in accordance with the provisions of *D 89/173/EC, D 2000/1/EC* and of *R 55 ECE-ONU*. Reference documents: PSpl – 01.00.37.



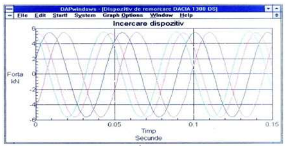
- Test conditions

In terms of circumstance, may be done the test for the device detached from tractor vehicle or mounted on it, its attachment on the test platform is realized by a specific devices system. The test presumes covering a number of $2x10^6$ loading cycles with alternating or pulsating force in terms of the device type, force variation during one cycle being sinusoidal.

TOWAGE DEVICES TEST

- Test object, application domain

The towage devices mounted on motor vehicles is realized at caravans warping and soft trailers. The object of this test is checking the mechanic resistance of these devices by subjecting them to some endurance tests, in accordance with internal standards and European Directives. The towage devices tests are made in accordance with the provisions of *D 94/20/EC*, *SR ISO 1103:1999* and *SR ISO 3853:1997*. Connected and reference documents: PSpl - 01.00.35 and IL SM - 01.04.



- Test conditions

The device is mounted on the test platform by a mediate structure identical with the attachment system on motor vehicle. The force is applied by a hydraulic cylinder which belongs to the complex tests installation in simulated and accelerated mode as Hydropuls type.

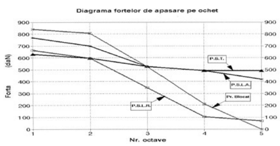
The force variation is sinusoidal and maintains itself till covering 2.000.000 cycles. Until the test end on the towage device surface must not appear crashes, breaks or external visible deteriorations.

The testing force time variation is registered in data files which are ulterior worked.

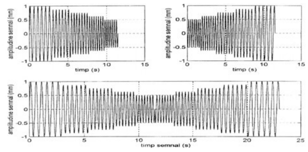
THE TEST FOR THE HITCH WITH SUSPENSIONS OF AGRICULTURAL SEMI-BORNE BIG CAPACITY TRAILERS

- Test object, application domain

The hitch is the trailer part which makes the connection between trailer and the tractor vehicle and its action in exploitation depends by trailer, tractor vehicle characteristics and roads condition on which the trailer passes. The test has as object the damp effect determination, by using this hitch type, the negative influences transmitted to the tractor vehicle and to the vehicle operator chair by the high capacity semi-borne trailers and is made in accordance with the provisions of *D 89/173CEE*, *R 55 ECE-ONU* and with the product technique documentation. Connected and reference documents: PGI – 01.14; PSpl – 01.00.41; PSpl – 01.00.44.



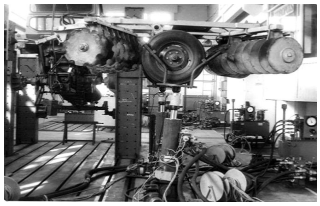
- Test conditions



The test is made on Hydropuls installation with control signals (generated on computer by a program realized in MATLAB) frequency-shift, with variable linear amplitude. The control signals are duplicated helping the hydraulic cylinders and applied to the trailer wheels.

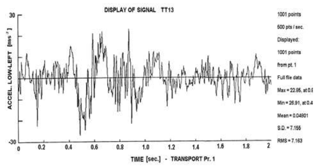
TESTS FOR SIMULATION IN TRANSPORT COMPORTMENT OF THE DISKS HARROWS

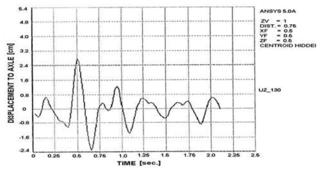
- Test object, application domain



The test has as object to show-down the disks harrows comportment during test in simulated and accelerated mode (simulating the transport conditions) with determination of stresses which can appears in the low resistance points of harrows frame. The test is made in accordance with the firm standard and product technique documentation. Connected and reference documents: PSpl – 01.10.29.

- Test conditions





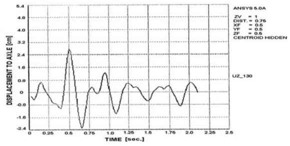
For the test conditions determination was used an analysis program with finite element ANSYS, determining the maximum deformations and stresses in the harrow resistance frame structure. The disks harrow was subjected to the tests in simulated and accelerated mode on the Hydropuls installation (see the figure), using as entrance data the maximum stresses values which were previous determinate. In this way the harrow was subjected to the maximum stresses values, in conditions which simulated the harrow transport comportment.

TEST FOR SIMULATION THE WORK COMPORTMENT OF THE PLOUGH WITH BREAST

- Test object, application domain

The test object is the ploughs designed for ploughing works. In terms of the beneficiary requirement, the test may contain the plough frame, the shovel, the plough body resistance control. The tests are made for the appreciation of resistance which ploughs (parts – especially working orga-ns) insure, in time, at shocks, vibrations, resistance forces, bending moments etc. The test is made in accordance with the the product technique documentation previsions and firm standard. Reference documents: PSpl - 01.00.32; PSpl -

01.00.41; PSpl - 01.00.42; PSpl - 01.00.44; PSpl - 01.00.48.

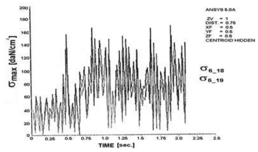


- Test conditions

The plough is tested mounted on the tractor three points attachment triangle, thus may simulate correctly the real situation during work. For driving are used 3 hydraulic cylinders which belong to the test installation in simulated and accelerated mode as Hydropuls type.

TESTS FOR SIMULATION OF TRANSPORT COMPORTMENT OF AGRICULTURAL SEMI-TRAILERS AXLES

- Test object, application domain



The test object is the two axis semi-trailers axles. The tests are made for checking the resistance which the axles insure at shocks, vibrations, loading forces etc. The test is made in accordance with the product technique documentation previsions and firm standard. Reference documents: PGI - 01.14; PSpl - 01.00.41; PSpl - 01.00.42; PSpl - 01.00.44; PSpl - 01.00.48.

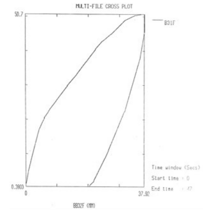
- Test conditions

The four wheels of roller train are backed on four hydraulic cylinders (one for every wheel), thus simulate correctly the stresses which appear in exploitation.

THE TRAILERS ANTI-WEDGING BARS AND LATERAL PROTECTION DEVICES TEST

- Test object, application domain

The anti-wedging bars have the object to avoid wedging of another vehicle, in the event of a beat received at the back side by the trailer. The trailers are equipped with lateral protection devices for the diminution of the risk whereon undefended traffic participants are exposed, in the event of an accidental fall (not to be caught under wheels). The tests are achieved for the object of protection appreciation which these structures insure, in accordance with the international rules. The anti-wedging bars and lateral protection devices tests are made in accordance with the previsions of *R 58 ECE-ONU*, respectively *R 73 ECE-ONU*. Connected and reference documents:



PSpl - 01.00.50 and PSpl - 01.00.51.

- Test conditions

The devices fixation on the tests platform is realized by a specific devices system. Forces are applied in a prescribed order, according to Regulations, by hydraulic cylinders and Hydropuls installation. The forces and displacements values measured are registered in data files for plotting the variation in time graphs of these items.

CONCLUSIONS

With the test installation in simulated and accelerated mode as Hydropuls type can be realized complex tests for a various area of equipments, among few examples were presented above. The tests are made in accordance with operative European directives and regulations, as for these to be recognized to entire European level, the laboratory, in which the installation works, has been accredited at national level by RENAR - body that is recognized of ILAC-MRA. The utility of such installation – Hydropuls type - results from the possibility for realization of other complex testings that could replace classical methods who need a larger testing period, many employees and high costs.

ACKNOWLEDGEMENT

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 534.84:628.517
Stručni rad
Expert paper

TEST OF AN EQUIPMENT WHICH WORKS IN OPEN AIR ACCORDING TO THE REQUIREMENTS OF D 2000/14/EC

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SUMMARY

The implementation of the D 2000/14/EC requirements has started quite recently the last 2 years and it was has been a necessity of complying Romania to the EU requirements in the field (2004-2005). The paper will present the mode in which the sound emission level has been found up, according to the directive 2000/14/EC and the results obtained following the test of a motor hoes (< 3KW).

Key words*: noise, emission, test, motor hoes, acoustic power, directive*

INTRODUCTION

The Directive 2000/14/EC makes mention of the member states alignment legislation towards obstructions elimination for the open traffic of the equipments. It establishes disposals (noise limits, public information on the noise emitted by the equipments, procedures for conformity appreciation etc.) relative to the noise emissions of the equipments designed to be used outside the buildings.

The noise produced by the equipments used outside the buildings and their effects on the attached health and well-being are in the main felt by the citizens on local level. Towards insurance of a security high level, the noise level emitted in the environment by the equipments used outside the buildings must be reduced, for citizens' health and well-being protection and for public interest information delivery on the noise emitted by these equipments.

Table with boundary values for equipments constrained to the noise limitations

Equipment type	**Net installed power P (kW)** **Electric power P_{el} (kW)** **Mass m (kg)** **Cutting width L (cm)**	**The admitted sound power level dB/1pW** **Stage I** **From 3.01.2002**	 **Stage II** **From 3.01.2006**
Compaction machines, only vibrating and non-vibrating rollers, vibratory plates and vibratory rammers;	$P \leq 8$	108	105
	$8 < P \leq 70$	109	106
	$P > 70$	$89 + 11 \lg P$	$86 + 11 \lg P$
Bulldozers, loaders, caterpillar excavator-loaders	$P \leq 55$	106	103
	$P > 55$	$87 + 11 \lg P$	$84 + 11 \lg P$
Bulldozers, excavator-loaders on tires; Dumpers; Graders, Compaction machines for dust hole, loader type; Tower cranes, combustion-engine driven, counterbalanced, Mobile cranes, Compaction machines only non-vibrating rollers, paver-finishers; Hydraulic power packs	$P \leq 55$	104	101
	$P > 55$	$85 + 11 \lg P$	$82 + 11 \lg P$
Excavators; Builders' hoists for the transport of goods; Construction winches; Motor hoes	$P \leq 15$	96	93
	$P > 15$	$83 + 11 \lg P$	$80 + 11 \lg P$
Concrete-breakers and picks, hand-held	$m \leq 15$	107	105
	$15 < m < 30$	$94 + 11 \lg m$	$92 + 11 \lg m$
	$m \geq 30$	$96 + 11 \lg m$	$94 + 11 \lg m$
Tower cranes		$98 + \lg P$	$96 + \lg P$
Electric power packs; Welding generators	$Pel \leq 2$	$97 + \lg Pel$	$95 + \lg Pel$
	$2 < Pel \leq 10$	$98 + \lg Pel$	$96 + Pel$
	$Pel \geq 10$	$97 + \lg Pel$	$95 + \lg Pel$
Compressors	$P \leq 15$	99	97
	$P > 15$	$97 + 2 \lg P$	$95 + 2 \lg P$
Lawn mowers; Lawn trimmers/lawn edge trimmers	$L \leq 50$	96	94 (2)
	$50 < L \leq 70$	100	98
	$70 < L \leq 120$	100	98 (2)
	$L \leq 50$	105	103 (2)

(1) P_{el} for welding generators: the welding conventional current multiplied with the loading conventional voltage, at the lowest value of the active time showed by the producer

(2) These are only indicative digits. The final digits will depend on the posterior amendments of this decision. In default of such posterior amendments, digits from stage I will still be applied in the 2nd stage. The admitted sound power level will round at the nearest full number (smaller than 0.5 at the bottom number, bigger or equal with 0.5 at the top number).

The area for which this Directive is addressed is the one of the outside working equipments, being formed of 22 equipments categories (*constrained to the noise limitations*); builders' hoists for the transport of goods (combustion-engine driven); compaction machines (only vibrating and non-vibrating rollers, vibratory plates and vibratory rammers); compressors (< 350 kW); concrete-breakers and picks, hand-held; construction winches (combustion-engine driven); dozers (< 500 kW); dumpers (< 500 kW); excavators, hydraulic or rope-operated (< 500 kW); excavator-loaders (< 500 kW); graders (< 500 kW); hydraulic power packs; landfill compactors, loader-type with bucket (< 500 kW); lawnmowers (excluding agricultural and forestry equipment, and multi-purpose devices, the main motorized component of which has an installed power of more than 20 kW); lawn trimmers/lawn edge trimmers; lift trucks, combustion-engine driven, counterbalanced (excluding "other counterbalanced lift trucks", with a rated capacity of not more than 10 tonnes); loaders (< 500 kW); mobile cranes; motor hoes (< 3 kW); paver-finishers (excluding paver-finishers equipped with a high-compaction screed); power generators (< 400 kW); tower cranes; welding generators and 41 equipments categories (*constrained only to the noise level marking*): aerial access platforms with combustion engine; brush cutters; builders' hoists for the transport of goods (with electric motor); building site band saw machines; building site circular saw benches; chain saws, portable; combined high pressure flushers and suction vehicles; compaction machines (explosion rammers only); concrete or mortar mixers; construction winches (with electric motor); conveying and spraying machines for concrete and mortar; conveyor belts; cooling equipment on vehicles; drill rigs; equipment for loading and unloading silos or tanks on trucks; glass recycling containers; grass trimmers/grass edge trimmers; hedge trimmers; high pressure flushers; high pressure water jet machines; hydraulic hammers; joint cutters; leaf blowers; leaf collectors; lift trucks, combustion-engine driven, counterbalanced (only "other counterbalanced lift trucks with a rated capacity of not more than 10 tonnes); mobile waste containers; paver-finishers (equipped with a high-compaction screed); piling equipment; pipelayers; piste caterpillars; power generators (≥ 400 kW); power sweepers; refuse collection vehicles; road milling machines; scarifies; shredders/chippers; snow-removing machines with rotating tools (self-propelled, excluding attachments); suction vehicles; trenchers; truck mixers; water pump units (not for use under water)

MEASUREMENT METHOD OF NOISE EMITTED IN THE OPEN AIR BY THE EQUIPMENTS USED OUTSIDE THE BUILDINGS

A establishes for each equipment type working in the open air::

- basic standards regarding noise emissions (SR EN ISO 3744:1997 and SR EN ISO 3746:1998);
- additional general disposals at these basic standards regarding the noise emissions for acoustic pressure level measurement produced by the source.

B establishes for each equipment type working in the open air:

1) a basic standard regarding acoustics emissions, recommended, including:

   - a reference to the basic standard regarding the noise emissions, chosen from A part;
   - testing surface;
   - the value of constant K(2A);
   - the measurement surface shape;
   - the number and the position of the microphones which will be used;

2) the working conditions, including:

- the reference to a standard, if exists;
- the requests regarding the equipment setting;
- a method for calculation the result acoustic power levels, when it is necessary to make several tests in different working conditions;

3) other informations.

The motor hoes 400B type (<3kW) tested is a machine driven by a pedestrian operator, with or without support wheel (wheels) whose working parts action as hoeing tools for insure the motor hoe propulsion and power-operated by one or several driven wheels, equipped with hoeing tools (motor hoe with driven wheel(s)).

The tests of motor hoe 400B type were executed in accordance with following standards and papers: PSpI - 01.00.06; IL - 01.00.19; HG 539/2004; D 2000/14/EC; SR ISO 3744:1997; SR ISO 11094:2003.

The tests of motor hoe 400B type were executed at INMA on a grass field, in the open air.

Figure 1 Motor hoe 400B

TEST CONDITIONS

Preparation of motor hoe 400B type for tests

Toward the acoustic power level determination, on executed following operations for product tests preparation:

- on measured the noise source dimensions;
- on disjointed the additional equipments which were not noise generators;

- previous the determination of the acoustic power level the motor hoe worked 3 hours;
- previous starting determination test of the acoustic power level, the motor hoe worked 10 min, for stabilization.

Tests equipment

Table 3

Crt. no.	Device name	Measurement domain	Precision
1.	Measuring tape	3 m	cl. 1
2.	Measuring tape	60 m	cl. 3
3.	Thermo hygrometer	20 - 40°C; 5 – 95 % humidity	0,3; cl. 2
4.	Barometer	600 – 790 mm Hg	1
5.	Anemometer	0,4 – 40 m/s	0,25
6.	PULSE System and microphones	100 – 10.000 Hz	1

Microphones position on the measurement surface

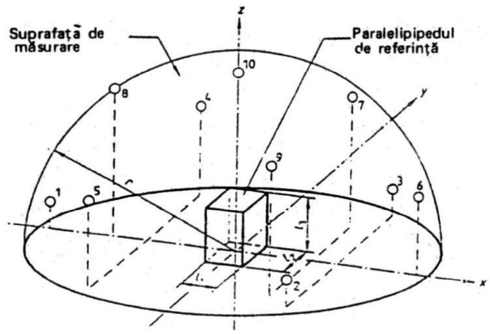


Fig. 2 Microphones key position on the hemispherical measurement surface with 10 microphones

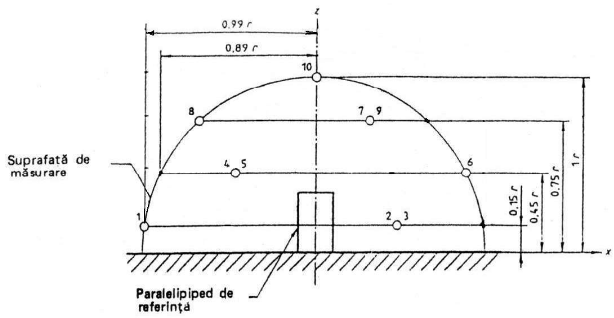


Fig. 3 Microphones placement on hemisphere

REZULTATELE DETERMINATION RESULTS

Global acoustic parameters recorder (in point of measuring and on surface)

	Meas. Time [s]	Lp 1 dB(A)	Lp 2 dB(A)	Lp 3 dB(A)	Lp 4 dB(A)	Lp 5 dB(A)	Lp 6 dB(A)	Lp 7 dB(A)	Lp 8 dB(A)	Lp 9 dB(A)	Lp 10 dB(A)	Average Lp dB(A)	K1 dB(A)	Corrected Lp dB(A)	**Lw dB(A)**
Background	10	41.5	41.7	40.5	43.5	44.1	43.7	44.4	44.4	44.6	44.8	**43.3**			
Background Check	10	41.9	41.7	41.1	44	44.8	44.1	44.9	45	45.3	45.3	**43.8**			
1	10	75.1	75.7	73.6	74.1	75.5	74.2	75	75.4	77.1	77.6	***75.5***	0	75.5	89.5
2	10	75.2	75.7	73.6	74.1	75.6	74.3	75.2	75.5	77.3	77.7	***75.6***	0	75.6	89.6
3	10	75.3	75.9	73.7	74.2	75.7	74.5	75.2	75.6	77.3	77.8	***75.7***	0	75.7	89.7
Mean of the two highest															**89.65**

Acoustic parameters recorder on domain of frequencies (in point of measuring and on surface)

Operation mode	**Measurement**	**Frequency**	**M 1**	**M 2**	**M 3**	**M 4**	**M 5**	**M 6**	**M 7**	**M 8**	**M 9**	**M 10**	**Average Lp [dB]**	**K1 [dB]**	**Corrected Lp [dB]**	**Lw [dB]**
no-load operation	1	100	77.39	79.4	77.19	76.66	77.87	78.21	75	75.28	76.8	74.03	77.05	0	77.05	91.1
no-load operation	1	125	77.36	79.2	76.7	75.37	78.49	75.92	72.77	73.38	74.78	70.1	76.12	0	76.12	90.1
no-load operation	1	160	71.65	72.65	70.65	68.74	70.78	68.53	62.95	64.83	64.37	65.38	69.16	0	69.16	83.2
no-load operation	1	200	76.56	76.61	75.45	72.19	73.69	70.77	64.4	68.19	68.08	74.14	73.42	0	73.42	87.4
no-load operation	1	250	72.68	73.9	70.56	65.34	67.31	64.11	66.9	68.55	70.59	74.07	70.6	0	70.6	84.6
no-load operation	1	315	70.83	72.75	70.47	67.27	65.8	59.99	70.01	70.56	71.5	73.39	70.4	0	70.4	84.4
no-load operation	1	400	64.02	68.2	63.47	63.46	66.27	60.71	66.52	68.57	69.45	66.58	66.44	0	66.44	80.4
no-load operation	1	500	61.61	61.95	58.81	64.21	65.79	64.62	64.6	65.39	64.82	66.63	64.33	0	64.33	78.3
no-load operation	1	630	60.4	57.84	55.73	64.47	66.59	65.52	65.36	61.69	67.37	68.68	64.88	0	64.88	78.9

Continuation

no-load operation	1	800	56.52	54.29	56.14	63.16	63.59	63.63	65.42	63.21	65.97	65.84	63.25	0	63.25	77.3
no-load operation	1	1000	59.18	60.32	58.88	62.42	62.51	65.51	63.51	65.62	66.74	68.47	64.38	0	64.38	78.4
no-load operation	1	1250	66.86	65.05	62.87	65.33	66.81	67.34	67.49	67.33	68.15	68.72	66.87	0	66.87	80.9
no-load operation	1	1600	66.73	66.5	65.4	64.7	63.94	62.99	64.04	64.82	65.96	67.38	65.45	0	65.45	79.5
no-load operation	1	2000	62.71	62.85	62.27	61.97	63.35	60.08	64.25	63.63	65.17	65.24	63.39	0	63.39	77.4
no-load operation	1	2500	59.37	59.88	58.12	60.56	63.43	60.01	61.22	62.16	64.29	63.3	61.65	0	61.65	75.7
no-load operation	1	3150	58.23	58.64	55.25	58.72	60.19	56.69	58.62	59.99	62.37	60.71	59.35	0	59.35	73.4
no-load operation	1	4000	56.55	59.36	55.79	56.62	60.16	55.96	57.76	57.88	60.75	60.27	58.48	0	58.48	72.5
no-load operation	1	5000	55.27	58.45	53.06	54.33	57.86	53.95	55.17	56.55	62.27	58.25	57.41	0	57.41	71.4
no-load operation	1	6300	55.02	58.02	51.14	53.09	58.49	54.08	53.99	56.49	61.55	56.96	56.87	0	56.87	70.9
no-load operation	1	8000	54.44	56.94	50.47	52.21	58.25	53.68	53.19	56.23	61.34	55.79	56.36	0	56.36	70.4
no-load operation	1	10000	54.63	56.33	50.36	52.41	58.54	52.47	53.37	56.68	60.95	55.99	56.25	0	56.25	70.3
no-load operation	2	100	77.18	79.58	77.24	76.59	77.65	78.37	75.01	75.13	76.79	74.01	77.04	0	77.04	91
no-load operation	2	125	77.11	79.01	76.56	75.13	78.29	75.75	72.69	73.12	74.63	69.84	75.93	0	75.93	89.9
no-load operation	2	160	72.01	73	71.04	69.1	71.06	68.85	63.47	65.1	64.61	66.02	69.52	0	69.52	83.5
no-load operation	2	200	76.73	76.96	75.47	72.25	74.05	70.97	64.32	68.29	68.03	74.07	73.58	0	73.58	87.6
no-load operation	2	250	72.95	74.02	70.82	65.44	67.22	64.04	66.67	68.68	70.75	74.3	70.76	0	70.76	84.8
no-load operation	2	315	70.95	72.83	70.37	67.16	65.87	60.06	70.11	70.9	71.83	73.68	70.56	0	70.56	84.6
no-load operation	2	400	64.21	68.12	63.63	63.51	66.23	60.86	66.96	68.75	69.69	66.75	66.59	0	66.59	80.6
no-load operation	2	500	61.97	62.38	58.94	64.22	66.2	64.97	65.12	66.04	65.43	66.73	64.7	0	64.7	78.7
no-load operation	2	630	60.28	57.85	56.15	64.57	66.83	65.69	65.4	62.06	67.45	69.16	65.1	0	65.1	79.1
no-load operation	2	800	56.59	54.53	56.08	63.38	63.92	63.72	65.65	63.29	66.51	65.76	63.46	0	63.46	77.5
no-load operation	2	1000	59	60.09	58.85	62.3	62.58	65.37	63.72	65.76	66.71	68.49	64.38	0	64.38	78.4
no-load operation	2	1250	66.78	65.12	63.08	65.33	66.6	67.37	67.7	67.43	68.14	68.77	66.9	0	66.9	80.9
no-load operation	2	1600	66.78	66.56	65.46	64.78	64.05	62.95	64.05	64.86	66.14	67.3	65.49	0	65.49	79.5
no-load operation	2	2000	62.83	63.09	62.3	62.04	63.52	60.05	64.25	64	65.62	65.31	63.57	0	63.57	77.6

Continuation

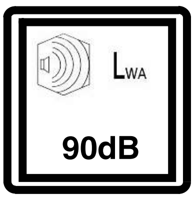
no-load operation	2	2500	59.48	59.56	58.28	60.75	63.46	60.07	61.48	62.54	64.45	63.41	61.78	0	61.78	75.8
no-load operation	2	3150	58.63	58.72	55.46	58.99	60.66	56.59	58.92	60.26	62.75	60.97	59.64	0	59.64	73.6
no-load operation	2	4000	56.84	58.94	56.14	56.77	60.46	55.84	57.98	58.11	60.94	60.53	58.63	0	58.63	72.6
no-load operation	2	5000	55.31	58.05	52.98	54.57	58.01	53.74	55.27	56.53	62.25	58.45	57.4	0	57.4	71.4
no-load operation	2	6300	55.08	57.71	51.33	53.28	58.55	53.81	54.17	56.66	61.43	57.09	56.85	0	56.85	70.9
no-load operation	2	8000	54.62	56.77	50.53	52.43	58.21	53.83	53.44	56.35	61.36	56	56.41	0	56.41	70.4
no-load operation	2	10000	54.51	55.61	50.28	52.37	58.55	52.5	53.29	56.54	60.92	56.06	56.15	0	56.15	70.2
no-load operation	3	100	77.2	79.48	77.17	76.59	77.62	78.3	74.95	75.1	76.71	73.93	76.99	0	76.99	91
no-load operation	3	125	77.06	78.99	76.65	75.14	78.32	75.8	72.82	73.11	74.66	69.91	75.95	0	75.95	90
no-load operation	3	160	71.81	72.76	70.8	68.84	70.86	68.66	63.13	64.96	64.48	65.73	69.29	0	69.29	83.3
no-load operation	3	200	76.78	77.04	75.51	72.28	74.11	71.04	64.29	68.45	68.03	74.24	73.65	0	73.65	87.7
no-load operation	3	250	72.9	74.09	70.84	65.55	67.39	64.14	66.78	68.75	70.82	74.37	70.81	0	70.81	84.8
no-load operation	3	315	70.96	73.06	70.54	67.36	65.85	60.03	70.06	70.87	71.7	73.75	70.61	0	70.61	84.6
no-load operation	3	400	64.3	68.5	63.7	63.76	66.33	61.06	66.7	68.84	69.72	66.77	66.68	0	66.68	80.7
no-load operation	3	500	61.92	62.33	59.36	64.15	66.12	65.27	65.17	66.08	65.27	66.96	64.75	0	64.75	78.8
no-load operation	3	630	60.34	57.99	56.35	64.6	66.79	65.76	65.55	61.98	67.42	69.02	65.08	0	65.08	79.1
no-load operation	3	800	56.66	54.78	56.17	63.28	63.92	63.7	65.59	63.41	66.68	65.95	63.53	0	63.53	77.5
no-load operation	3	1000	59.02	60.45	59.18	62.4	62.51	65.66	63.62	65.78	66.65	68.61	64.46	0	64.46	78.5
no-load operation	3	1250	67.02	65.07	63.11	65.51	66.98	67.74	67.58	67.71	68.23	69.05	67.08	0	67.08	81.1
no-load operation	3	1600	66.73	66.69	65.62	64.84	64.16	63.25	64.09	65	65.95	67.43	65.56	0	65.56	79.6
no-load operation	3	2000	62.96	63.11	62.46	62.12	63.58	60.43	64.45	64.04	65.45	65.41	63.64	0	63.64	77.6
no-load operation	3	2500	59.58	59.94	58.18	60.62	63.39	60.06	61.29	62.51	64.33	63.57	61.77	0	61.77	75.8
no-load operation	3	3150	58.89	58.78	55.37	58.94	60.55	56.8	58.88	60.28	62.65	61.06	59.65	0	59.65	73.7
no-load operation	3	4000	56.98	59.37	56.24	56.84	60.46	56.26	58.06	58.22	60.78	60.72	58.74	0	58.74	72.7
no-load operation	3	5000	55.37	58.47	53.07	54.56	58.32	54.19	55.47	56.7	62.42	58.54	57.6	0	57.6	71.6
no-load operation	3	6300	54.93	58.23	51.41	53.17	58.83	54.09	54.11	56.57	61.7	57.04	57.02	0	57.02	71
no-load operation	3	8000	54.33	57.31	50.58	52.19	58.45	53.67	53.34	56.21	61.71	56.02	56.57	0	56.57	70.6
no-load operation	3	10000	54.84	57.1	50.3	52.3	58.79	52.33	53.22	56.87	61	56.04	56.41	0	56.41	70.4

SOURCE SPECIFICATIONS			
Type	Motor hoe 400B		
Engine capacity (HP)	4		
Dimensions	Length: 400 mm	Width: 300 mm	Hight: 700mm
Serial number	M001746		
Manufacture year	2006		
Working conditions	no-load operation, stationary		
Equipment pre-conditioning	working period before test: 2h		
	stabilization period before the measurements series: 10min		
Measurement surface and microphones number	hemispherical with 10 microphones		
Sphere radius (m)	2		
Measurement surface area (m^2)	25,12		
ENVIRONMENT CONDITIONS			
Temperature (°C)		20	
Environment pressure (bar)		1013	
Relative humidity (%)		46	
Wind speed (m/s)		1,2 m/s	
Adjustement for ambient noise K_1 (dB)		0	
Environment adjustement K_2 (dB)		0	
INSTRUMENTATION			
Name		PULSE System	
Type		3569 C	
Serial number		2550560	
Producer		Bruel & Kjaer	
Calibration		Data: 21.08.2006	
		Place: INMA Bucharest	
		Method: calibration with gauge source	

CONCLUSIONS

The motor hoes 400B was the object for the type verifications and tests for determination of noise emissions level in the open air (in accordance with D 2000/14/EC) and the conformity insured by it establishment. The tests report contains the type verifications results in the open air, marking out the motor hoe 400B acoustic power level in accordance with working rules (D 2000/14/EC and HG 539/2004).

The acoustic power level result: 90 dB(A).



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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

INFLUENCE OF PASTEURISATION PARAMETERS ON THE POTASSIUM SORBAT SHARE IN DRIED PLUMS

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SUMMARY

This works presents results of research in influence of pasteurization parameters to the K-sorbat share in pasteurized dried plumb. Control of the K-sorbat share is important for the effect of preservation on one hand and for its influence on health on the other - or for satisfaction of regulations which limited this part in the conservation.

During the wet pasteurization the plumb is treated with hot solution of K sorbat with aim of additional protection from spoiling. The K sorbat part in final product is measured by HPLC method. Achieved results enable defining the input parameters of wet pasteurization and establishment of legally determined critical limits.

Key words*: dried plums, pasteurisation, potassium sorbat*

INTRODUCTION

Pasteurized dried plumbs are fruit with demands on market for its organoleptic characteristics and for nutritive contents. The fruit crops contain ingredients important for human nutrition, which participate in prevention of different regenerative processes. Various kinds of antioxidant components in plums may play important roles in the combinative or synergistic contribution to total antioxidant activity(5). Beside vitamins and carotenoids, the plumbs contain several important fito-ingredients like flavonoids and phenolic acids which have high anti-oxidation capacity. (1)

A plumb drying is traditional way of conservation which provides relatively stable products that are less subjected to spoiling. A traditional plumb drying is conducted in driers located on orchards or nearby. Dried plumb has very low activity of water and relatively high share of dry matter. The initiation of spoilage process is possible during and after drying for possible air contamination, dust, animal contamination and other types of infestation and those of microbes. In order to eliminate influences of consequent infestation and microbiological contamination of the dried plumbs, the pasteurization and chemical conservation are conducted. (2)

The main goal of this work is to determine the influence of pasteurization parameters on the share of **K-sorbat** in the dried plumbs as final product and therefore defining the dependence of pasteurization conditions in satisfying the legally limited content of the K sorbat.

The K sorbat share in final products is stipulated by law where maximum allowed concentration is 0,1%.

MATERIALS AND METHODS

The material used in the research is the Stanley plumb, from local market.

Before the experiment the plum samples were washed with splash of water for three minutes The samples are treated with hot solution of K-sorbat in proportion of 1, 2 and 3% lasting 3, 4 and 5 minute. The sample treated with the 3% solution for 5 minutes is after pasteurization washed in order to determine the share of K sorbat absorbed in the product. The zero samples are treated for 3 minutes in water of 100 C^0 temperature. After this process the analysis of K -sorbat share is conducted by HPLC method.

The analysis condition are λ = 235 nm , t = 7 min, flow = 2,0 ml/min,p = 186 atm

Mixture for conservans determination

- 125 ml H_2O
- 146 ml O-phosphorus acid
- recharge with ethanol to 500 *ml*

Mobile phase: 2,5 g KH_2PO_4 and 25 g KH_2PO_4 x $3H_2O$ in solution 1 *l* H_2O

Stationary phase: Supelco™ column LC-8 25 cm + precolumn for ballast and waist mater.

Calculation:

$$C(k.s.) = (\bar{A}_{sample} / \bar{A}_{standard}) \cdot C_{standard} \cdot F$$

Where are:

$\bar{A}$ = average surface

$C_{standard}$ = 93 mg/*l*

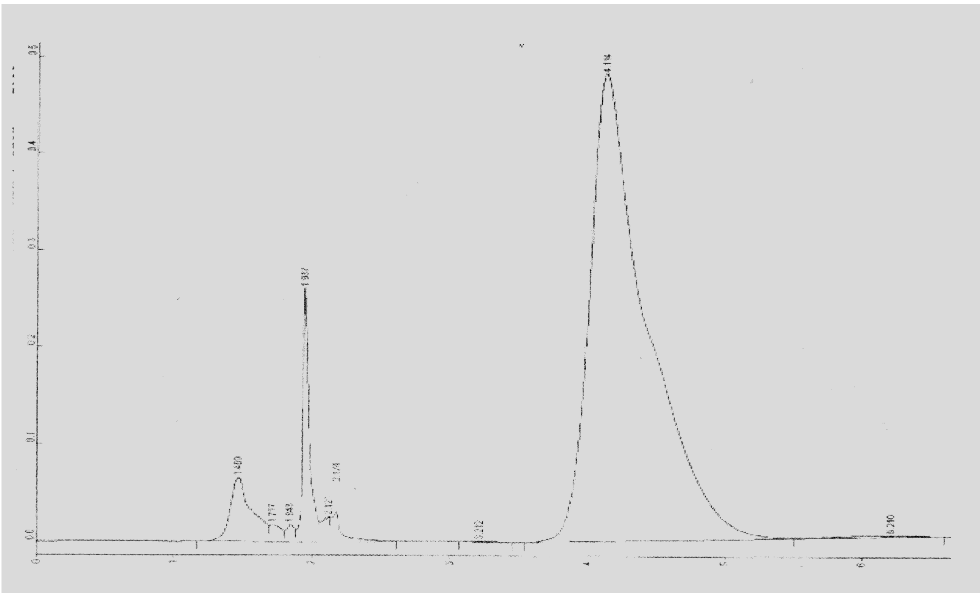
F = factor of dissolution (volume/mass)

RESULTS AND DISCUSSION

Ripe plumb can contain a layer of **cuticula** made of waxes. Cuticula on plumbs is extra cellular, unlived and lipoid membrane, which stops water penetration and solution to and out of plumb. Cuticula is actually biopolymer **cutin** with inhomogeneous structure. (3)

Table 1 Influence of concentration K- sorbat and pasteurization time on share of K sorbat in dried plump

Parameters	**1% K-sorbat solution**			**2% K-sorbat solution**			**3% K-sorbat solution**			
The sample number	1	2	3	4	5	6	7	8	9	10
Time of treatment (sec)	180	240	300	180	240	300	180	240	300	300
Washing after pasteurization	no	no	no	no	no	no	no	no	no	yes
Washing time after pasteurization (sec)	-	-	-	-	-	-	-	-	-	180
Washing time before of pasteurization (sec)	180	180	180	180	180	180	180	180	180	180
Share of K sorbet in final product (%)	0.0288	0.0195	0.0252	0.0752	0.0526	0.0348	0.115	0.0761	0.0516	0.0182



Picture 1 Chromatogram for sample number 7

C**uticula** before drying, is removed by washing but sometime in traditional technology the washing is skipped. However, the cuticula influences dehydration in drying process and also slows down the dehydration during the wet pasteurization.

Based on results from the Table 1 it is visible that the share of K-sorbat in the dried plumb treated by wet pasteurization depends above all on the solution concentration. Namely, it is visible that processing time does not have significant influence to the content of conserves in final product.

This occurrence is logical taking in mind that only a part of K sorbat is absorbed in the product whereas the rest of it stays on the surface and its content depend on density of wrinkles on the surface. This occurrence is therefore directly dependant on method of drying, the quality and sort of the plumb.

It is visible that the share of conserves in final product is in accordance with allowed, except for sample treated by the 3% solution of the K sorbat for period of three minutes.

CONCLUSIONS

- Processing the plumbs with pasteurization and with additional chemical conservation of 1, 2, and 3% K sorbat solution lasting for 3, 4 and 5 minutes finally results in product with K sorbat content that is legally permissible, except for the 3% solution process lasting 3 minutes.
- Of the total amount of the K-sorbat, 1/3 is absorbed to the product and the rest is kept on the surface.
- In order to prevent development of mould on the surface it is recommendable to keep the conservation material on the surface.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

IZRAVNO SPEKTROFOTOMETRIJSKO ODREĐIVANJE L-ASKORBINSKE KISELINE U PRISUSTVU STABILIZATORA

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SAŽETAK

Razvijena je jednostavna, brza i točna metoda za izravno spektrofotometrijsko određivanje L-askorbinske kiseline u preparatima vitamina C. Za stabilizaciju askorbinske kiseline u vodenim otopinama korištena je smjesa etilendiamin-tetraoctene kiseline ($5,37x10^{-4}$ mol/dm^3) i natrijeva acetata ($1,13x10^{-3}$ mol/dm^3) u fosfatnom puferu. Molarna apsorptivnost predložene metode iznosi $1,41x10^4$ dm^3 mol^{-1} cm^{-1} na 266 nm. Određivanje askorbinske kiseline je moguće u opsegu od 0,45 do 12,0 µg/cm^3. Granica dokazivanja iznosi 0,14 µg/cm^3, a relativno standardno odstupanje 0,63 % za 8,0 µg/cm^3 askorbinske kiseline (n = 7).

Mnogi sastojci obično prisutni u produktima vitamina C ne smetaju određivanju L-askorbinske kiseline. Smetnju mogu predstavljati drugi vitamini, limunska kiselina i benzoat. Predložena metoda je uspješno primijenjena za određivanje askorbinske kiseline u preparatima vitamina C. Dobijeni rezultati se slažu sa rezultatima titrimetrijske metode s jodom kao titrantom.

***Ključne riječi**: L-askorbinska kiselina, spektrofotometrija, stabilizatori*

UVOD

Za određivanje L-askorbinske kiseline (vitamin C) razvijen je veliki broj analitičkih metoda, kao što su titrimetrija (AOAC 1995, Fritz i Schenk 1987), fluorimetrija (Wu *i sur.* 2003), spektrofotometrija (Fujita *i sur.* 2001, Lau *i sur.* 1987) i kromatografija (Kacem *i sur.* 1986, Louisi *i sur.* 1998). Osnovni problem kod određivanja L-askorbinske kiseline je njena brza oksidacija, te prisustvo pratećih tvari u realnim uzorcima, naročito reducirajućih agensa, kao što su tanini i ioni prijelaznih metala.

L-Askorbinska kiselina je veoma nepostojana u vodenoj sredini, naročito u prisustvu metalnih iona, kao što su Cu(II) i Fe(III), koji kataliziraju njenu oksidaciju molekularnim kisikom u dehidro-L-askorbinsku kiselinu. Stoga je cilj ovog rada bio da se odaberu pogodni stabilizatori koji će inhibirati kataliziranu oksidaciju L-askorbinske kiseline u vodenim otopinama i time omogućiti njeno kvantitativno određivanje. Za ovu svrhu predložena je smjesa etilendiamintetraoctene kiseline (EDTA) i natrijeva acetata u fosfatnom puferu. Prisustvo pufera je bilo neophodno zbog činjenice da položaj apsorpcijskog maksimuma za L-askorbinsku kiselinu ovisi o pH vrijednosti vodene sredine. Koncentracija L-askorbinske kiseline u otopini odabranih stabilizatora nije se mijenjala najmanje 4 sata nakon priprave. U ovom radu je također ispitan utjecaj nekih kationa, aniona, šećera, organskih kiselina i aminokiselina na izravno spektrofotometrijsko određivanje vitamina C u prisustvu odabranih stabilizatora.

MATERIJALI I METODE

Za pripravljanje otopina korišćeni su reagensi analitičkog stupnja čistoće.

Otopina smjese EDTA ($5,37x10^{-4}$ mol/dm^3), natrijeva acetata ($1,13x10^{-3}$ mol/dm^3), kalijeva dihidrogenfosfata (0,03 mol/dm^3) i dinatrijeva hidrogenfosfata ($9,21x10^{-4}$ mol/dm^3) pripravljena je otapanjem 0,20 g $C_{10}H_{14}N_2Na_2O_8 \cdot 2H_2O$ (Fluka), 0,15 g $CH_3COONa \cdot 3H_2O$ (Merck), 4,08 g KH_2PO_4 (Fluka) i 0,16 g $Na_2HPO_4 \cdot 2H_2O$ (Fluka) u destiliranoj vodi i razblaživanjem vodom do 1 dm^3.

Otopina L-askorbinske kiseline koncentracije $1,13x10^{-3}$ mol/dm^3 pripravljena je otapanjem 0,05 g L-askorbinske kiseline (Riedel-de Haën) u 250 cm^3 otopine stabilizatora.

Otopine koegzistirajućih tvari pripravljene su otapanjem odgovarajućih količina čvrstih ili tekućih tvari u otopini stabilizatora.

Za mjerenje apsorbancija korišćen je spektrofotometar Cecil 2021.

Alikvotni dio otopine uzorka koji sadrži 100-300 µg L-askorbinske kiseline prenese se u volumetrijsku tikvicu od 25 cm^3 i razrijedi otopinom stabilizatora do oznake. Apsorbancija ovako pripravljene otopine se mjeri na 266 nm prema otopini stabilizatora kao slijepoj probi.

REZULTATI I RASPRAVA

Linearnost je definirana odnosom koncentracije L-askorbinske kiseline (mol/dm^3) i vrijednosti apsorbancija pri 266 nm. Baždarni pravac, dobijen metodom najmanjih kvadrata, je linearan do koncentracije L-askorbinske kiseline od 12,0 µg/cm^3. Granica dokazivanja, molarna apsorptivnost i druge analitičke karakteristike predložene metode date su u Tablici 1. Vrijednost koeficijenta korelacije pokazuje da postoji jaka linearna veza između apsorbancije i koncentracije L-askorbinske kiseline. Preciznost postupka je provjerena analizom otopine koja je sadržavala 8,0 µg/cm^3 L-askorbinske kiseline i izračunavanjem relativnog standardnog odstupanja (n = 7).

Selektivnost predložene metode je provjerena određivanjem L-askorbinske kiseline u prisustvu tvari koje se obično nalaze u preparatima vitamina C. Utjecaj nekih kationa, aniona, organskih kiselina, aminokiselina, šećera i vitamina na određivanje L-askorbinske kiseline ispitan je dodavanjem poznatih količina ovih tvari standardnoj otopini L-askorbinske kiseline koncentracije 8,0 μg/cm^3. Usvojeno je da koegzistirajuća tvar u dodanoj količini ne predstavlja ozbiljnu smetnju predloženoj metodi ukoliko pri određivanju L-askorbinske kiseline ne uzrokuje relativnu pogrešku veću od ±5,0 %

Kationi su u prirodnim i komercijalnim produktima prisutni uglavnom u količinama znatno manjim od količine L-askorbinske kiseline. Mnogi kationi, naročito Cu(II) i Fe(III), predstavljaju dobre katalizatore oksidacije L-askorbinske kiseline kisikom iz zraka, te su česta smetnja spektrofotometrijskim i drugim metodama analize vitamina C.

Tablica 1 Analitičke karakteristike predložene metode

Nagib baždarnog pravca	14125,70
Odsječak baždarnog pravca	0,0084
Standardna pogreška nagiba	76,04
Standardna pogreška odsječka	0,0036
Koeficijent korelacije (r)	0,999957
Granica dokazivanja	0,14 μg/cm^3
Granica određivanja	0,45 μg/cm^3
Linearni opseg	0,45 – 12,0 μg/cm^3
Molarna apsorptivnost	1,41x10^4 dm^3 mol^{-1} cm^{-1}
Standardno odstupanje	2,88x10^{-7} mol/dm^3
Relativno standardno odstupanje	0,63 %

Tablica 2 Utjecaj kationa na određivanje L-askorbinske kiseline

Kation	Maseni odnos (Kation: askorbinska kiselina)	Relativna pogreška (%)
Fe(III)	0,02	2,08
Fe(II)	0,02	1,86
Cu(II)	0,033	0,95
Ca(II)	5	-5,46
Mg(II)	2	-1,39
Zn(II)	1	-0,92
Mn(II)	1,3	-0,95
P(V)	4,5	0,00
Mo(VI)	0,2	2,78
Pb(II)	2	2,50
Ni(II)	0,4	0,00
Na(I)	10	0,00

Rezultati ispitivanja utjecaja kationa na određivanje L-askorbinske kiseline predloženom metodom prikazani su u Tablici 2. Ioni kalcija, magnezija, cinka i mangana dovode do negativnih pogrešaka, jer u njihovom prisustvu L-askorbinska kiselina pokazuje nešto slabiju apsorpciju. Smanjenje vrijednosti apsorbancije otopina L-askorbinske kiseline može se u ovim slučajevima pripisati smanjenju pH otopina prilikom dodatka Ca(II) iona u obliku kalcijeva nitrata i Mg(II), Zn(II) i Mn(II) iona u obliku sulfata. Ovo je u skladu s činjenicom da apsorpcijska svojstva L-askorbinske kiseline ovise o vrijednosti pH vodene sredine (Eitenmiller i Landen 1999). Bakar(II), molibden(VI), olovo(II) i joni željeza dovode do pozitivnih pogrešaka koje nastaju uslijed promjene apsorbancije otopina stabilizatora nakon dodatka metalnih iona.

Rezultati ovih istraživanja su pokazali da odabrani stabilizatori učinkovito inhibiraju oksidaciju L-askorbinske kiseline kataliziranu metalnim ionima. Upotrijebljeni stabilizatori s metalnim ionima grade postojane komplekse, čime se sprječava građenje kompleksa L-askorbinska kiselina-metalni ion, a nastali kompleksi nisu učinkoviti katalizatori oksidacije L-askorbinske u dehidro-L-askorbinsku kiselinu.

Rezultati ispitivanja utjecaja aniona na određivanje vitamina C predloženim postupkom dati su u Tablici 3. Uočeno je da u prisustvu većih količina hidrogenkarbonata, sulfita i acetata L-askorbinska kiselina pokazuje nešto jaču apsorpciju, što dovodi do pozitivnih pogrešaka u njenom određivanju. Eksperimentalno se pokazalo da se pH otopina L-askorbinske kiseline neznatno povećava dodavanjem ovih aniona, zbog čega se jača apsorpcija L-askorbinske kiseline može pripisati promjeni pH. Nitrit, oksalat i benzoat u dodanim količinama dovode do pozitivnih pogrešaka, jer apsorbiraju pri 266 nm. Benzoat ozbiljno ometa određivanje L-askorbinske kiseline, s obzirom da uzrokuje pogrešku znatno veću od 5,0 %.

Tablica 3 Utjecaj aniona na određivanje L-askorbinske kiseline

Anion	Maseni odnos (Anion: askorbinska kiselina)	Relativna pogreška (%)
Cl^-	10	0,00
NO_3^-	2,5	0,00
SO_4^{2-}	10	0,00
CO_3^{2-}	5	0,00
HCO_3^-	10	0,87
$H_2PO_4^-$	14	0,00
SO_3^{2-}	10	1,23
PO_4^{3-}	5	0,00
NO_2^-	2	0,61
Tartarat	5	0,00
Acetat	10	1,14
Oksalat	4	0,77
Citrat	20	0,00
Benzoat	2	> 5,00

Relativne pogreške pri određivanju L-askorbinske kiseline predloženom metodom u prisustvu nekih organskih kiselina date su u Tablici 4. Iz prikazanih rezultata je vidljivo da jedino limunska kiselina prisutna u 10 puta većoj količini može ozbiljnije smetati određivanju vitamina C. L-Askorbinska kiselina pokazuje slabiju apsorpciju pri 266 nm u prisustvu limunske, oksalne, vinske i octene kiseline, zbog čega se u svim slučajevima pojavljuju negativne pogreške u njenom određivanju. Promjena apsorbancije otopina L-askorbinske kiseline može se pripisati smanjenju pH njenih otopina nakon dodatka organskih kiselina.

S obzirom da veliki broj farmaceutskih preparata sadrži limunsku kiselinu i natrijev hidrogenkarbonat, ispitan je i utjecaj smjese ovih spojeva na određivanje L-askorbinske kiseline. Eksperimentalni rezultati su pokazali da smjesa koja sadrži 10 puta veću količinu HCO_3^- i 24 puta veću količinu limunske kiseline u odnosu na L-askorbinsku kiselinu nije utjecala na određivanje vitamina C predloženom metodom.

Tablica 4 Utjecaj kiselina na određivanje L-askorbinske kiseline

Kiselina	Maseni odnos (Kiselina: askorbinska kiselina)	Relativna pogreška (%)
Limunska	10	-5,65
Oksalna	5	-1,48
Vinska	5	-2,83
Octena	10	-2,23

Eksperimentalno je utvrđeno da 200 puta veće količine saharoze, D(+)-glukoze i D(–)-fruktoze, 100 puta veće količine D(+)-laktoze i D(+)-maltoze, te 10 puta veće količine L-prolina, DL-alanina, L-leucina, L-arginina i L(+)-asparagina ne smetaju određivanju vitamina C. Smjesa vitamina B_1, B_2, PP, B_5, B_6 i B_{12}, zbog apsorpcije u ultraljubičastom području, ozbiljno smeta određivanju L-askorbinske kiseline predloženim postupkom.

Predložena spektrofotometrijska metoda je uspješno primijenjena za određivanje L-askorbinske kiseline u tabletama vitamina C (Tablica 5). Kao referentna metoda korišćena je titrimetrijska metoda s jodom kao titrantom (Fritz i Schenk 1987).

Pored koegzistirajućih tvari za koje je eksperimentalno utvrđeno da ne interferiraju u predloženoj metodi, određivanju L-askorbinske kiseline nisu smetale ni mnoge druge tvari prisutne u analiziranim realnim uzorcima, kao što su natrijev ciklamat, natrijev saharin, aspartam (izvor fenilalanina), kukuruzni škrob, tiourea i stearinska kiselina. Predloženi postupak se nije mogao primijeniti za određivanje vitamina C u multivitaminskim preparatima, zbog smetnje od strane drugih vitamina, kao ni u produktima koji sadrže acetilsalicilnu kiselinu i paracetamol.

Rezultati određivanja L-askorbinske kiseline u tabletama vitamina C dobijeni primjenom predloženog postupka slažu se sa rezultatima dobijenim titrimetrijskom metodom i s koncentracijama deklariranim na preparatima. Preciznost i točnost predložene metode provjerene su primjenom F i t-testa na rezultate dobijene referentnom i predloženom metodom. Utvrđeno je da između metoda ne postoji značajna razlika u preciznosti, s obzirom da su eksperimentalno dobijene vrijednosti *F* u svim slučajevima bile manje od kritične vrijednosti. *t*-Test je pokazao da razlika između srednjih vrijednosti rezultata dobijenih primjenom predložene i referentne metode nije značajna pri 95%-tnoj razini vjerojatnosti.

Tablica 5 Određivanje L-askorbinske kiseline u komercijalnim preparatima

Naziv produkta	Koncentracija L-askorbinske kiseline (mg/tableta)			F [b]	t [c]
	Deklarirana na produktu	Titrimetrijska metoda[a] (n = 5)	Predložena metoda[a] (n = 5)		
Upsavit (Laboratoires UPSA)	1000	992,94 ± 8,51	992,51 ± 10,18	1,43	0,09
Plivit C (Pliva)	500	498,33 ± 5,12	501,74 ± 4,48	1,31	1,39
Cevitbos (Bosnalijek)	500	490,89 ± 4,81	485,97 ± 3,93	1,50	2,19
CalciumvitaC (Krka)	500	490,67 ± 5,59	494,85 ± 3,25	2,95	1,79
Hermes Cevitt (Hermes Arzneimittel)	1000	1018,90±10,77	1031,04±10,65	1,02	2,22
Vitamin C (PEZ)	60	60,95 ± 0,89	61,13 ± 0,37	5,69	0,53

[a] 95% Granice pouzdanosti za srednju vrijednost
[b] Teorijska vrijednost za F = 6,39 (95%-tna razina vjerojatnosti)
[c] Teorijska vrijednost za t = 2,306 (95%-tna razina vjerojatnosti)

ZAKLJUČCI

Smjesa EDTA i natrijeva acetata u fosfatnom puferu učinkovito stabilizira L-askorbinsku kiselinu u vodenoj sredini i omogućuje njeno kvantitativno određivanje. Mnoge tvari obično prisutne u komercijalnim produktima ne smetaju određivanju L-askorbinske kiseline predloženom metodom. Smetnju mogu predstavljati drugi vitamini, limunska kiselina i benzoat. Predložena metoda je jednostavna, brza, precizna i točna i može se primijeniti za određivanje L-askorbinske kiseline u preparatima vitamina C.

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DIRECT SPECTROPHOTOMETRIC DETERMINATION OF L-ASCORBIC ACID IN THE PRESENCE OF STABILIZERS

SUMMARY

A simple, rapid and accurate method was developed for the direct spectrophotometric determination of L-ascorbic acid in vitamin C products. A mixture of ethylenediaminetetraacetic acid ($5.37x10^{-4}$ mol/dm^3) and sodium acetate ($1.13x10^{-3}$ mol/dm^3) in phosphate buffer was used to stabilize ascorbic acid in aqueous solutions. The molar absorptivity of the proposed method was $1.41x10^4$ dm^3 mol^{-1} cm^{-1} at 266 nm. The determination of ascorbic acid is possible in the range 0.45 – 12.0 µg/cm^3. The detection limit was 0.14 µg/cm^3 and the relative standard deviation 0.63 % for a concentration of 8.0 µg/cm^3 of ascorbic acid (n = 7).

Many of the ingredients commonly found in vitamin C products do not interfere with the determination of L-ascorbic acid. Other vitamins, citric acid and benzoate can interfere. The proposed method was successfully applied to the determination of ascorbic acid in vitamin C preparations. The results obtained by the method agree with those obtained by the titrimetric method using iodine as titrant.

***Key words**: L-ascorbic acid, spectrophotometry, stabilizers*

35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 664.8.037:664.95
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EFFECT OF *K* -CARRAGEENAN ON INITIAL FREEZING POINT OF SURIMI

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ABSTRACT

Initial freezing points (T_i) of surimi samples mixed with sodium tripolyphosphate (w = 0.3%) and different mass fractions of κ-carrageenan (w = 0.3 - 3%) were determined by use of differential thermal analysis (DTA). Surimi was prepared from Adriatic philchard (Sardina philchardus). Water content in surimi was 79.05% before mixing with added substances. Relations between decrease of the initial freezing point (T_i) as function of mass fractions (w) of the κ-carragennan were determined by linear regression. Coefficients of determination R^2 = 0.89 were obtained. The most effect of cryoscopic depression of initial freezing point T_i were exhibited by the samples of surimi with added 3% κ-carrageean. There were differences in the T_i values for samples of surimi and water solution of κ-carragennan as a function of the mass fraction of κ-carrageenan calculated on the total mass of water. These findings support the assumption that κ-carragennan interacts with surimi proteins, resulting in an increase in the mass fraction of bound water, which depresses T_i. The results are compared and discussed with the Pham model for prediction of T_i

***Key words**: initial freezing point, DTA, surimi, κ-carrageenan*

INTRODUCTION

The initial freezing point (T_i) determines a food's thermal properties in frozen state. Most mathematical models for predicting thermal properties of frozen food are based on equation for freezing point depression, T_i (Heldman, 1982; Schwartzberg, 1976; Chang and Tao, 1981; Chen, 1985; 1986; Fikiin 1998; Miles et al., 1997; Pham 1996; van der Sman, 2004, James C., Lejay I., Torosa N., Aizpurua X., James S. J. 2005) wich states that, $\Delta T = K_k \cdot \gamma$, where ΔT is the temperature decrease, K_k is cryoscopic constant, and γ is molality. The lower the initial freezing point, the more microbiologically stable the food, the lower the water activity, the higher its boiling point and the slower the ice content increases as the temperature is lowered (Miles et al., 1997). To protect myofibrillar proteins from freeze-denaturation during frozen storage, cryoprotectants are generally added (Park et al., 1996). The most effective cryoprotectants for myofibrillar proteins are carbohydrates, such a sucrose, sorbitol, maltodextrins and polydextrose (Tomaniak et al., 1998, Herrera J.R. and Mackie I. M. 2003). κ-carrageenan is an anionic sulphated polysaccharide, extracted from certain species of red algae with a composition that consists of alternating 1,3-linked D-galactose-4-sulphated and 1,4-linked 3,6-anhydro-D-galactose monomers. The aim of this work is to investigate cryoprotective effects of *κ*-carrageenan. In this work, laboratory design of DTA apparatus was applied to determine the relative effects of different mass fractions of *κ*-carrageenan on the T_i of samples of surimi.

MATERIAL AND METHODS

Samples of surimi were prepared in the laboratory from Adriatic philchard (*Sardina philchardus*) according to the technique by Lee (1984). Samples were mixed with sodium tripolyphosphate (w = 0.3%) and different mass fractions of κ-carrageenan (w = 0.3 – 3%). Mass fractions were determined as percent of total mass. Moisture content was 79.05% and ash content was 1.09% determined by the A.O.A.C. method (1980) for meat products before addition of the added components. Total protein mass fraction was 17. 56% determined with samples by the Kjeldahl method; (Kjeltec System, model 1002 Distilling Unit, Tecator Inc., Boulder, CO, U.S.A.). Samples were packaged in polyethylene bags and quickly frozen in liquid nitrogen and stored at - 25 °C. Average storage time was 1 week before DTA experiments.

DTA apparatus was constructed in the laboratory (Kovačević and Kurtanjek, 1993) and was used for measurement of initial freezing point T_i. Thermocouples were made from Alumel-Chromel wire (0.07 mm diameter). The thermocouples were calibrated using a standard platinum resistance thermometer, Pt-l00 (Riddle et al., 1976) in the temperature range of -30 to 25 °C. The instruments were interfaced with a standard PC and a sampling rate of 3.5 kHz was used. All data were prefiltered with at +/-3σ rule for noise rejection prior to data analysis (Mendenhall and Sinchic, 1988). From statistical analysis of the measurement signal the calibration error of 50 mK and sensitivity of 10 mK were estimated. An aqueous solution of $CaC1_2$, w($CaC1_2$) = 30%, was used as reference substance for DTA measurement. Distilled water was used as calibration substance for the static correction of the initial freezing point.

RESULTS AND DISCUSION

DTA measurements of samples of surimi mixed with the added substances were conducted in temperature range from -25 to 5 °C. ln Fig. 1 are presented results of DTA. The DTA curves have a low level of measurement noise, which is a result of statistical data filtering and rejection of outliers by +/-3σ rule, and is due to high frequency of data sampling. Drift from the base line in the temperature range from 0 to 0.2 °C is due to difference of thermal properties of samples and the reference substance. From DTA diagrams the peak points were read off as the initial freezing points. Data for the initial freezing points T_i are given in Table 1. In Fig. 1 can be observed systematic shifts of the initial freezing points toward lower temperatures with increased concentration of κ-carrageenan. Below the initial freezing points DTA diagrams for all samples show systematic increase in the temperature difference with increased level of the κ-carragennan. Each DTA diagram is corrected only for constant error of +0.1235355 °C which was determined from calibration with distilled water. By the method of linear correlation of T_i with mass fraction of the κ -carrageenan the parameters of the regression equation were determined:

$$T_i = -0.16554 \cdot w - 0.31016 \tag{1}$$

were standard errors $e(T)$ = 0.0617 coefficient of determination R^2 = 0.89. The most effect of cryoscopic depression of initial freezing point T_i are exhibited by the samples of surimi with added 3% κ-carrageenan.

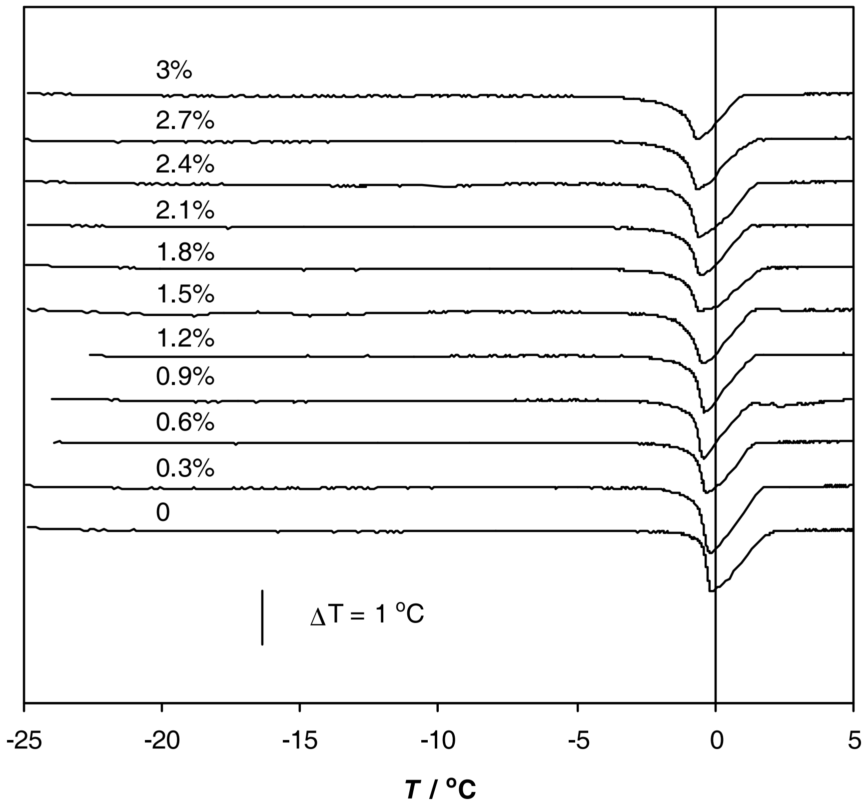

Fig. 1 DTA curves of surimi as a function of w (%) of κ-carrageenan ΔT is temperature difference between sample and reference substance.

Table 1 Experimental data of initial freezing point (Ti) of surimi.

Mass fractions of κ-carrageenan (%)	T_i (ºC)	
	Experimantal data	Linear regression
0	-0.2333	-0.31016
0.3	-0.30505	-0.359822
0.6	-0.44951	-0.409484
0.9	-0.54267	-0.459146
1.2	-0.51085	-0.508808
1.5	-0.55392	-0.55847
1.8	-0.70932	-0.608132
2.1	-0.68481	-0.657794
2.4	-0.6537	-0.707456
2.7	-0.74583	-0.757118
3	-0.75419	-0.80678

The observed values of T_i are presented in Fig. 2 along with the values predicted by the Pham model (Pham, 1996), given by the regression equation with respect to the mass fraction of water *(w_w)*, ash (w_a), other components (w_o) and mass fraction of added component (x_s),:

$$T_i = -4.66 w_o / w_w - 46.4 w_a / w_w \qquad /2/$$

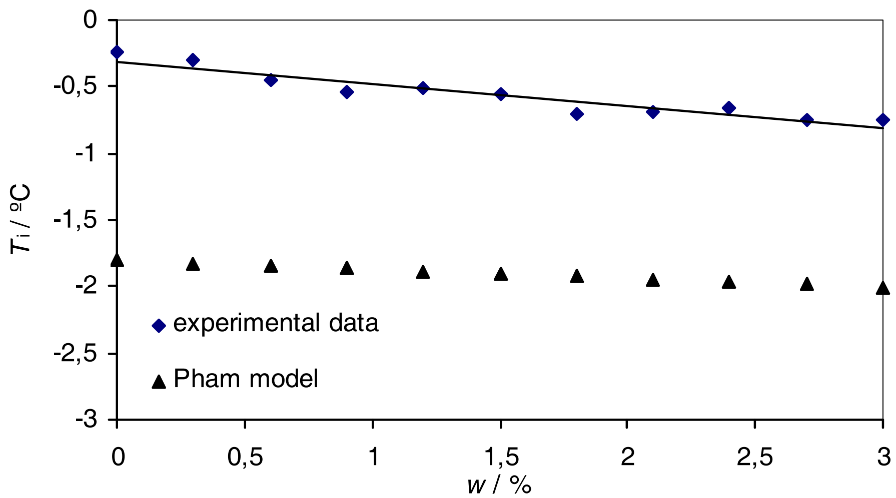

Fig. 2 Initial freezing point (T_i) of surimi as a functions of mass fraction (w) of κ – carragennan.

The experimental value for T_i and results by the Pham model /2/ show large deviations. It can be concluded that the effect of mass fraction is not the only parameter, but also specific components are important. A deviation of initial freezing points T_i confirm that κ-carrageenan acts in accordance with the cryoprotecting mechanism and interacts with protein in surimi, and therefore increases the amount of bound water and decreases the initial freezing point.

In Fig. 3 is presented a comparison of dependencies of T_i for surimi and water solution of κ – carrageenan on mass fraction of κ-carrageenan calculated on total mass of water. Deviations of initial freezing points T_i confirm that κ-carrageenan acts in accordance with the cryoprotecting mechanism and interacts with protein in surimi.

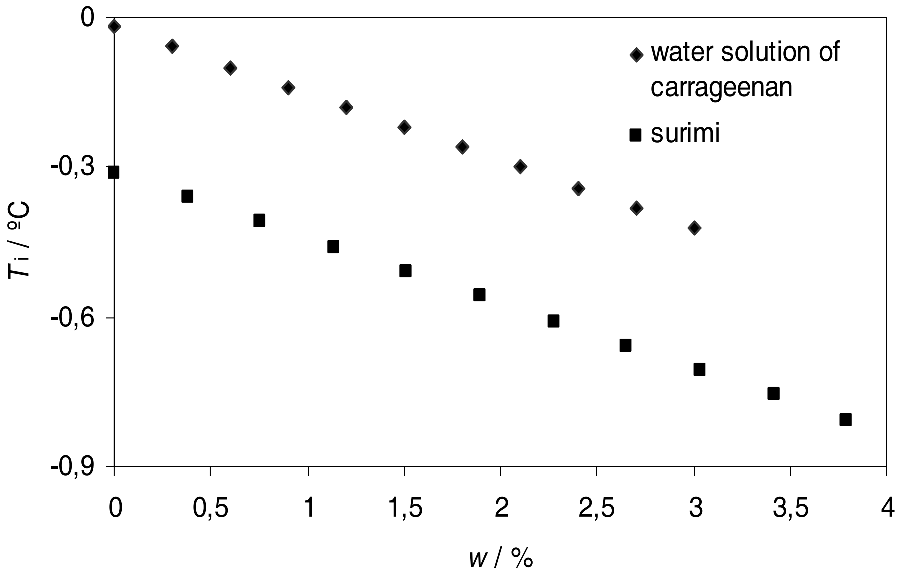

Fig. 3 Comparison of dependencies T_i for surimi and water solution of κ – carrageenan on mass fraction (w) of κ-carrageenan calculated on total mass of water.

CONCLUSIONS

Freezing point depression of surimi is a linear function of the increased mass fraction of κ - carrageenan. The maximum decrease of the initial freezing point was observed with surimi mixed with 3% κ - carragennan. Deviations of experimental value for initial freezing points T_i, and results by the Pham and James model confirm that κ-carragennan acts in accordance with the cryoprotecting mechanism and interacts with protein in surimi. The T_i values for samples of surimi and water solution of κ-carrageenan as a function of the mass fraction of κ - carrageenan calculated on the total mass of water were different for all the samples. The results support the assumption that κ - carrageenan interacts with the protein of surimi, increases the mass fraction of bound water and lowers the T_i.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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THE ECONOMIC SURVEY OF THE MECHANISATION OF FIELD CUCUMBER PRODUCTION AND POST HARVEST TECHNOLOGY

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SUMMARY

The cucumber is one our most important vegetable crops, not only the home consumption but the exported quantity is also remarkable. In view of the production area and the quantity produced pickling cucumber is the most significant in Hungary the production area of which is roughly 3-6 thousand hectares.

The annual demand of the canning industry for 6-9 cm and 9-12 cm calibrated cucumber is generally 50-60.000 tons. Though the picking of smaller size-fractions (under 6 cm) reduces the quantity of crop the revenues can be increased notably due to the higher price of this fraction.

The most important link in the chain of production and distribution is the solid inland processing industrial background which is inevitable for the export of fresh produce as well.

The subject of the present study is the mechanized production of pickling cucumber developing rapidly in the last years.

The present essay presents the up-to-date, mechanized production and post harvest technology of pickling gherkins. Inquiries were made by Csengerker Kft. in Csenger and its co-producers and by HORKER Kft. in Koroncó and its vendors.

The aim of the evaluation and publishing of the experiences and the presentation of the plant and economic indexes of the machinery necessary for the production is to promote the spreading of a modern, market orientated cucumber production technology. (Fenyvesi 2004) [1]

Key words: *Foil Covered Field Vegetable Production, Mechanisation, Economic, Machine Investment- and Utilisation Cost*

THE MAJOR MACHINES OF THE PRODUCTION TECHNOLOGY

The studied technology is based on drop irrigation, soil-cover cultivation method for which ridge forming machine type HORTUS HPD-165 and foil and tube layer type AF1 is used. In order to further early ripening and crop safety plant covering foil tubes can be prepared by the machine type AFF-1000. For harvesting picking machines type STIEGER with picking belt are used by which crop can be harvested on the same territory 2-3-times a week without causing treading damages to the vegetation. At the local distributional settlements low capacity stringed grading machines type UBV are used, while in the canning factory grading is done by the also string-system high capacity grading machines type FLEISCHMANN. Grading before sale is necessary because the selling price is highly dependent from the size of the produce. During the canning procession different systems of washers, graders, bottle fillers, cap fasteners and sterilizers and palettizers are used.

PRESENTATION OF THE PRODUCTION TECHNOLOGY

The machine technology of production is presented on the basis of Table 1. and Table 3. The tables show the denomination of operation, the machine applied for the certain operation, and the type of the power machine connected to it together with the shift performance of the connected machines and the calculated shift performance of the working machine for the given economic year. Some of the economic data are also included: the selling price of the working machine and the power machine in the year 2004, the operational cost of the same per shift hour together with the operational cost of the connected machines.(Gockler-Hajdú 2004) [2]

Stubble ploughing by disc-harrow is unavoidable in order to work the stem remains of the forecrop into the soil and to prevent weeding. This is followed by deeper loosing. The subsequent delivery of nutrients is ensured through spreading of organic manure and fertilizers. These nutrients get into the soil by deep ploughing. The next operation is spring top fertilization which is worked into the soil by ploughing processing. The first step of forming a ground surface of appropriate quality is seed bed preparation followed by levelling of the surface and ridge bed preparation. The next operation is mulching and hauling in the hosepipe. Water and plantlet supply is connected to the operation of planting. Forming of the foil tunnel comes next. In the vegetation period of the cultivated plant dropping system irrigation is necessary in order to achieve a high quality final product and a better crop yield. Plant protection is applied about 12 times.

It is to be kept in mind by harvesting that the frequent picking of cucumber results in a higher proportion of the more valuable smaller size fractions affecting the success and thrift of the total production. In case of plain cultivation picking twice a week is advisable. When picking cucumbers not only the totally intact but also the drossy ones are to be picked as these oppress and weaken the plant. Another important point is to avoid damages caused to the plant during harvesting the spindles are not to be trodden, turned or torn.

The *belt cucumber picking carriage type STEIGER* (Figure 1) has been developed in order to satisfy the above demand and to facilitate the manual harvesting of the produce. The machine is – subject to framing – attended by 16-28 hand picking workers working in a lying position in order to avoid treading the vegetation. The collecting belt of the machine mounted on a tractor collects and forwards the cucumber into the trailer pulled by the power machine. Thanks to its shaping and mode of operation the machine fits in the domestic technological line.

Figure 1 Belt cucumber picking carriage type STEIGER

Besides a size proportion of 43 % of the cucumber falling into the standard size range of 5-9 cm the machine can be operated with a territorial performance of 0,20-0,22 ha/h, resp. with a specific mass performance of 63,4 kg/(h x person). For picking up the abandoned produce 2-4 foot-workers need to be employed. According to surveys the performance of the pickers measured in cucumber mass is increased by 20 % by harvesting by picking carriage in comparison to the traditional hand picking.

According to measurements the shaping of the machine creates an appropriate position for the picking workers and fulfils the tasks of transport within the field at the same time.

In the studied technology cucumbers are to be *graded* twice, once before commercial takeover and once before canning procession.

The purchase prices depend on the size of gherkins. The smaller size the produce is, the higher the value will be. There is a significant difference among the purchase prices of the individual size fractions it is, therefore, an elemental interest of both the producers and the dealers that the harvested quantity is graded. The hoarded produce gets into the processing factory afterwards where it will be sorted into more size fractions again so that the gherkins in the glasses will be homogeneous.

The grading machines applied by takeover and processing are generally operated on the same grading principle (stringed grading machines) but while the smaller capacity simple pregrading machines are appropriate for takeover the ones operating by the processing plants are more complicated with an expert design and extremely high capacity.

On the stringed grading machines there are plastic covered rolling chain pairs running beside one another with an increasing airspace. The produce to be graded proceeds on either chain pair until the slackening gap is the same size as the diameter of the cucumber. Then it falls down to the forwarding belt situated beneath the chain.

Table 1 The basic economical data of the operations of cucumber production

Denomination of operation	Type of machine applied in the technology		Shift	Price of		Direct cost of operation		
	working machine	power machine	Perfor-mance	working machine	power machine	working machine	power machine	total
			(ha/h)	(EUR)		(EUR/h)		
Stubble ploughing	Kühne 770-7,2 disc harrow	John Deere 8120	3	19164	141560	10	29	39
Medium deep loosing	RÁBA 10-14/5	John Deere 8120	1,2	3644	141560	3	29	32
Spreading organic manure	AGRO 65 TSZ tandem	John Deere 6220	0,7	7132	65492	4	16	19
Fertilizer transport	MBP 6,5 R	John Deere 6220	4	6016	65492	2	16	18
Spreading of fertilizer	Tornado 5	John Deere 6620	4	9604	72324	6	19	26
Deep ploughing	Kühne 720-7/6-16-M-TJ	John Deere 8120	1,5	8312	141560	6	29	36
Fertilizer transport	MBP 6,5 R	John Deere 6220	4	6016	65492	2	16	18
Spreading of fertilizer	Tornado 5	John Deere 6620	4	9604	72324	6	19	26
Ploughing processing	S-2 H/M	John Deere 8120	4,8	7452	141560	7	29	37
Seed bed preparation	Lemken Korund 600 K	John Deere 8120	4	14952	141560	9	29	39
Levelling the surface	Kühne KH - 5,6 S	John Deere 6220	3,8	5740	65492	4	16	19
Ridge bed preparation	Hortus HPD-165	John Deere 6620	0,4	10384	72324	12	19	31
Mulching, hauling in the hosepipe	AF 1	John Deere 6620	0,25	4336	72324	3	19	22
Water supply	DETK-115 tanker	John Deere 6220	0,9	6800	65492	4	16	20
Transport of plantlets	MBP - 6,5	John Deere 6220	4	6016	65492	2	16	18
Planting	Fedele Mario	John Deere 6620	0,1	3696	72324	4	19	24
Preparation of foil tunnel	AFF-1000	John Deere 6620	0,2	7480	72324	14	19	33
Irrigation	Nadir		0,25	8800	0	24	0	24
Spray mixture transport (12x)	DETK-115 tanker	John Deere 6620	4,8	6800	72324	4	19	23
Spraying (12x)	Gambetti GB Export 1500/16 v	John Deere 6220	4,8	16236	65492	9	16	25
Picking	Steiger	John Deere 6620	0,2	44000	72324	16	19	35
Transport	MBP - 6,5 – 2 pcs	John Deere 6220		12032	65492	4	16	20
Transport following pregrading	HL 92.02 road	IFA L 60 1218 DSK		7536	33720	3	20	22

Table 2 The economical indexes of the operations of cucumber production on 20 ha

Denomination of operation	Machine working hour	Direct operational cost of connected machines	Additional operational cost of connected machines	Total operational cost		Cost of operation
				working machine	power machine	
	(h)	(EUR)	(EUR)	(EUR)		(EUR)
Stubble ploughing	6	235	49	74	210	284
Medium deep loosing	16	515	101	54	562	616
Spreading organic manure	28	544	128	141	531	672
Fertilizer transport	5	87	19	12	94	106
Spreading of fertilizer	5	127	26	39	114	153
Deep ploughing	13	465	88	96	457	553
Fertilizer transport	5	87	19	12	94	106
Spreading of fertilizer	5	127	26	39	114	153
Ploughing processing	4	145	31	37	139	176
Seed bed preparation	5	194	40	59	175	234
Levelling the surface	5	96	22	24	94	118
Ridge bed preparation	50	1559	399	812	1146	1958
Mulching, hauling in the hosepipe	80	1743	377	286	1834	2120
Water supply	22	437	94	114	417	531
Transport of plantlets	5	87	19	12	94	106
Planting	200	4708	1065	1188	4585	5773
Preparation of foil tunnel	100	3330	840	1878	2292	4170
Irrigation	80	1920	468	2388		2388
Spray mixture transport (12x)	48	1127	224	251	1100	1351
Spraying (12x)	48	1182	321	591	912	1503
Picking	100	3524	917	2149	2292	4441
Transport	100	1967	440	507	1900	2407
Transport following pregrading	150	3365	479	433	3411	3844
Production technology - total	**1.080**	**27571**	**6192**	**11196**	**22567**	**33763**
Cost per hectare (EUR/ha)						**1688**

Table 3 The basic economical data of the operations of cucumber manipulation

Denomination of operation	Applied machine acc. to technology		Shift performance	Price of the machine	Cost of electricity	Direct cost of operation	Cost of energy
	type	engine-capacity					
		kW	(t/h)	(EUR)	(EUR/kWh)	(EUR/h)	(EUR/h)
Pregrading	UBV - II	1	0,5	4400	0,088	1,5	0,1
Grading	Fleischmann	8	7	79200	0,088	26,9	0,7

Table 4 The economical indexes of the operations of cucumber manipulation on 20 ha

Denomination of operation	Machine working hour	Direct operational cost of connected machines	Additional operational cost of connected machines	Total operational cost		Cost of operation
				working machine	power machine	
	(h)	(EUR)	(EUR)	(EUR)		(EUR)
Pregrading	480	718 + 42 (Cost of electricity)	218		978	978
Grading	34	915 + 24 (Cost of electricity)	321		1260	1260
Prod. tech. and Grading - total	**1.594**	**29270**	**6731**	**11196**	**24805**	**36001**
Cost per hectare (EUR/ha)						**1800**

Several different makes and types are used for *pregrading* in Hungary. The present study covers the stringed *grading machines type UBV-II-AG* and UBV-III-AG (Figure 2). The machines have been developed to satisfy the demands of small factories and commercial takeover sites. The rate of charging and the level of attendance of the machines operated under the above circumstances are varying.

Figure 2 Stringed grading machine type UBV-II-AG

The machines consist of conveyer belt, grading chains with grader, and the collecting forwarders. The difference between the two machines is only the number of chain pairs.

It can be stated on the basis of the surveys that the top capacity of the machines is roughly 1 t/h regarding the grading machine UBV-II-AG and 1,4 t/h regarding UBV-III-AG. Practically the utilization of the machines is only 40-80 % owing to the non-optimal attendance. By the application of the machines an exactness of grading by length of about 60 % can be achieved which can modify according to variety, adjustment and mode of operation.

The grading previous to commercial takeover does not meet the requirements of the canning industry. Therefore, grading for canning purposes is necessary. The specific mass is of vital importance hereby as it ensures the steady appearance of the canned product packed in glasses. In order to ensure this the graders applied here sort the raw material not only for the standard size fractions but much more the fraction limits of which overlap each other. The *grading line made by the company FLEISCHMANN* is appropriate for this purpose. The line consists of two grading machines with continually growing gap sizes. The workers emptying the containers attend the machines in a way which makes it possible to operate the machines independently as well.

Investigations prove that the performance of the machine in the productive period is 8,5 t/h. The shift performance is round 60-80 t. The size exactness of the machine regarding diameter and length is 40-50 %.

It can be stated on the basis of the surveys that the stringed grading machines type UBV-II-AG , UBV-III-AG and FLEISCHMANN fit well in the domestic technological line. The performance and the operational exactness of the machines are up to the present commercial requirements.

THE RESULTS OF THE ECONOMIC SURVEY

The results of the economic survey of cucumber production on a 20 hectare area are shown in Table 2. and Table 4. Apparently, the machine working time necessary for the cultivation of the 20 hectare growing area in case of connected machines has been stipulated related to the individual operations. On this basis the direct operational cost of the connected machines can easily be calculated by multiplying the *direct operational cost of the machine per shift hour* (Table 1. and Table 3.) with the effective working time. Furthermore, the additional cost of connected machines has also been stipulated which is affected by the capital return on fixed and current assets as well as by the general costs of farming. As a result the cost of the individual operations related to 20 hectare growing area has been defined the total of which equals the total production costs of cucumber production on 20 hectares and also the specific cost per hectare has been stipulated. The costs of field cucumber production, harvesting and grading are specified in the table.

It can be stated on the basis of the results that the operational cost of the working machines (11.196 EUR) is the half of that of the power machines (22.567 EUR). The total operational cost amounts to 33.763 EUR, 1688 EUR per hectare.

Taking the manipulation costs amounting to 2238 EUR into consideration the total cost of machine utilization is 36.001 EUR, 1800 EUR per hectare.

The investment cost of the machines applied in the production technology amounts to 593.996 EUR out of which the purchasing price of the working machines amounts to 197.300 EUR, which equals about 33 % of the total investment cost while the purchasing price of the power machines is 313.096 EUR, about 53 % of the total cost of machines. The purchase price of manipulating machines is 83.600 EUR, about 14 % of the total investment.

In case of power machines it can be stated that one power machine with an engine capacity of 140 kW is needed for the hard cultivation works, while the tasks of nutrients delivery, ridge-bed preparation, mulching, hauling the hosepipe, planting, foil tunnel preparation, plant protection, harvesting and tractor delivery are fulfilled by a 70 kW main and a 60 kW aid machine. For the road transport of the produce a low-cost trailer can be used. With the above method of applying power machines lower acquisition costs and a more effective utilization of power machines can be achieved.

Cucumber production on 20 ha demands 1080 shift hours of machine work, out of which the two lower capacity tractors represent a great proportion, about 800. In comparison to this the 44 shift hour performance of the high capacity power machine in the course of cultivation is negligible. Road transport with its 150 shift hour capacity demand is one of the most time-demanding operations.

The time demand of manipulation is over 500 shift hours, in which the working hours of the smaller capacity machine type UBV are dominant.

CONCLUSIONS AND PROPOSALS

The surveys conducted have proved that the machine work costs of field foil covered cucumber production compared to the production costs of other field vegetable varieties are high. (Figure 3)

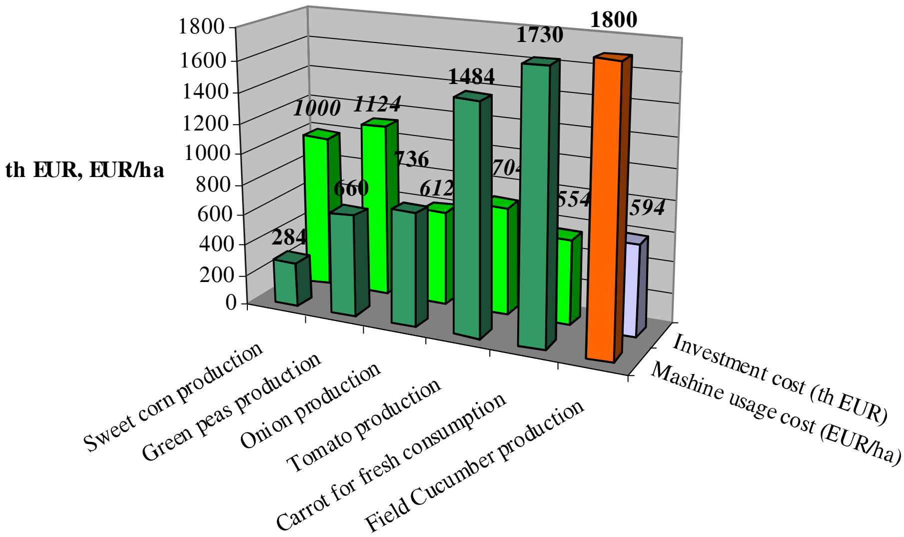

Figure 3 The production costs and investment of the examined field vegetables

The significant hand labour demand is characteristic of this product by planting as well as by the preparation of the foil tunnel but first of all by harvesting when the expert and quality work of 28 persons might as well be needed.

A high quality final product can be ensured through hand picking. But it comes at a price. The picking personnel of 16-28 persons represents a remarkable loan cost but knowing the domestic wage levels this cost is not so very remarkable and the competitiveness of production can be ensured.

The present study focuses on the costs of machine operations only the production cost is, therefore, 15 Euro Cent/kg besides a calculated average yield of about 12 t/ha. The cost of hand labour applied during production and the costs of material and other inputs necessary for production were not defined. All these demand further substantial expenditure adding further to the production cost and the cost of the final product.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Review paper

THE ROLE AND IMPORTANCE OF ASSET SUPPLY IN HUNGARIAN AGRICULTURE

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SUMMARY

During the changing of the agricultural production in the past years, the agricultural devices and tools that give the technological and technical background of the production were not be able to renew, develop and increase along with the fast and considerable increasing amount of the production units. The available device file is significantly both qualitative and quantitative underdeveloped even in the present days.

The results of the research can be used for the rationalisation of the mechanization developing activities of the farmers, for the correction of the operation of machine using and farming assisting co-operation forms that are based on the service of the small businesses and for the greater spreading of the individual organization constructions.

***Key words**: asset supply, cost-saving machinery-using cooperations, machine investments and usage cost*

INTRODUCTION

The competitive position of the farms and their products are basically affected during a longer term by the technical and technological level of the agricultural production, by the plant and production structure, by the workmanship of the farmers, those is shortly the modernity of the farming. Nowadays the market accepts high quality products, those only can be produced with modern technology. However the continuous technical renewal means great load to the farmers who use the machines and devices, because the prices are always increasing. Therefore the number of the farmers, who are not able to buy modern machinery is increasing because the lack of the sufficient resources. For the problem one solution could be the different forms of agricultural co-operations that in some cases exist and function well for decades in Western Europe, while during their operation these organizations proved that they can help to use the available technical resources more rationally and with this, decreasing the disadvantages of the shortage of capacity and over-mechanization (Nagy - Magó 2006). [6]

In the beginning of the 1990s in Hungary – besides the several well-tried forms – the machine and farm supporting circle was also appeared. Since then, during the past decade these co-operations did not reach the efficiency of the western organizations that have a great past, but proved that this form can be suitable for better organizing the technical suppliance (Takács – Baranyai – Nagy 2005). [7]

Our goal was to prove that there is a need for such co-operations, while farmers have problems according to the shortage of capacity and surplus, those they can not solve efficiently by themselves.

MATERIAL AND METHOD

For defining the realistic productional conditions, the machine usage and the readyness for co-operation, a survey with questionnaires were done in two counties among the small and medium sized farmers.

The groups of the questions on the questionnaires were the followings:

- the shape of the farm, the range of activities
- the sizes of the own and the leased fields
- the age and capacity of the devices used on the farm
- the formation of investments
- the presence of the shortage of capacity and surplus, their handling method and
- the willingness for co-operation

We have sent our questionnaires to farmers who live and work in Békés and Bács-Kiskun counties. Finally 92 questionnaires were valuable out of the 99 that were sent back to us.

RESULTS

The general characteristics of the farms

Most of the farmers who were chosen into the sample group (60,9%) work as a cropper, 21,7% in a family farm and the rest does the production as individual contractor.

More than the half of the farms (56,5%) do more than one agricultural activities. The determinant group of activities is the simple seed growing agriculture that can be found at 82,6% of the farmers. The animal husbandry and livestock keeping is also significant with 41,3%. The ratio of the vegetable and fruit producing is smaller: 21,7% and 17,4%. And

9,8% of the farmers marked „other agricultural activities" that is most of the times lending the machines to others.

The average size of the examined fields was 26,5 hectares. The smallest farm had 1 hectare, the largest had 213 hectares of private owned fields. The farmers are aware of the fact that if they want to improve their efficiency, they have to increase the size of their fields, but according to the low profitability that is typical in agriculture, generally they can not buy more land. The half of the chosen sample farms tries to solve this problem with field leasing. This results the average size of the cultivated areas become 38,1 hectares and the size of the largest farm size is 298 hectares. For the poorest farmers, not even the land leasing can be workable, so the size of the smallest cultivated area stays 1 hectare.

The structure of device coverage

Based on the given answers to the questionnaires we have analysed the device coverage of the farms. We have summarized the results of the device coverage, the age of the machines and buildings and their capacity in Charts 1 and 2. Of course the capacity data reflect the subjective opinions of the farmers and it is not sure that they are close to the truth. From the results it can be seen that in case of the machines a significant plus capacities arise that leads to slow return of the capital that is charged in the devices, to the increasing of the specific costs and in the end to the decreasing of the competitive position.

The significant accumulated residues at the farms is slightly reduced by the lack of the fail-safe operation of the machines, caused by their higher ages that means more disadvantageous working order. But according to these the operational costs (maintenance and repair) increase remarkably, that also influences negatively the efficiency of the farming.

Chart 1 Average age and capacity of devices

Name	Average age (years)	Average capacity (%)
Tractors	12,9	51,3
Combines	17,0	46,8
Implements	11,7	36,1
Animal husbandry buildings	17,2	49,3
Storage (crop, machine)	14,4	76,2

Chart 2 Most important device coverage markers for power-machines

Marker	Results
Number of tractors/combines (pcs)	146/20
Average tractor output (kW)	62,60
Tractor density marker (pcs/100 hectares)	4,17
Output per area (kW/hectare)	2,61
Number of tractors per farm (pcs)	1,59

Analysing the tractor distribution by their age (Figure 1) the following can be established according to the machine investment subsidization. In the different economy groups, the higher ratio of the machines 1-4 years old and 10-12 years old marks the year when a machine purchasing was supported. From 1993 the applications of the so called ÁFI (National Development Institute) let several farmers to have new machines. The supporting system that was applied in those years did not have conceptions and they did not consider the real capacity of the farms. Most of the applicants were the farmers with 20-40 hectares who mostly applied for machines around 60 kW and they did buy these kind of machines. These machines are now 10-12 years old and we find a great number of them in the chart. The second and from the point of view of the judgements a more strict wave of machine investment subsidization after the turn of the millennium was the 25% subsidization for machines and later the SAPARD and AVOP applications. These subsidies give the higher ratio of most of the 1-4 years old machines.

According to Figure 1, it can be stated that there is a tight connection between the actual subsidy applications and the willingness of farmers for buying new machines. One of the negative effects of the subsidization is that it is able to take farmers away from reality and determine them to buy bigger and more expensive machines. This causes extremely high extra costs at social, provincial and venturing levels.

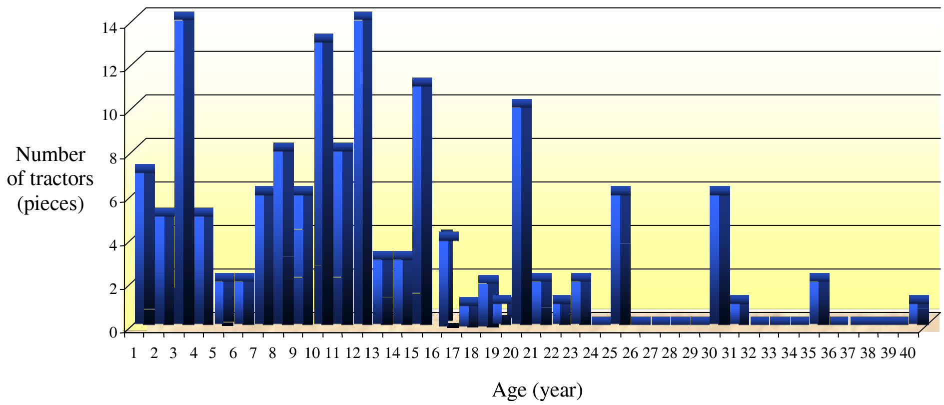

Figure 1 Tractor distribution by age

The structure of machine investments

Examining from 2002, the 44,6 % of the sample farms invested in machines. The total amount of the investments was 1.330.000 EUR since then, and the average investing amount was 14.500 EUR. The source structure determined according to the total amount of investments can be seen in the Figure 2.

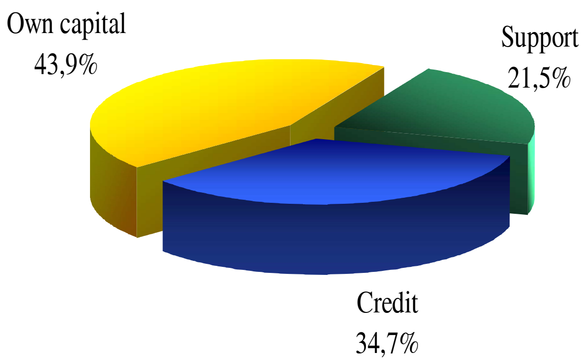

Figure 2 Structure of machine investments since 2002

The willingness of farmers for co-operation

In connection with the device coverage we have mentioned the unnecessary capacities that occur at farms, but from the point of view of our survey it is important to talk about the lack of capacity too.

According to the given answers to the questionnaires in case of the individual operations:

- 65,2% of the farmers have surplus of capacity
- 79,3% of the farmers are lack of capacity and
- another 79,3% uses wage-work during production.

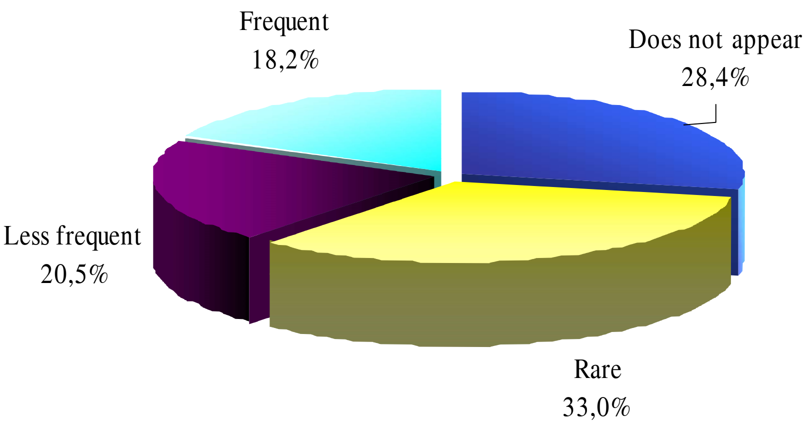

Figure 3 The frequency of machine work for each other, based on mutuality, according to the given answers of the farmers

According to the results maybe it seems that all of the shortage is filled with wage-work, but it is not really true after considering the received answers in connection with the willingness for co-operation (**Figure 3**). 18,2% of the farmers stated that they often help each other at critical operations. Only 28,4% of the asked aversed from co-operation, so it can be assumed that the rest (more than 70%) could co-operate effectively within organized frames.

EVALUATION OF THE RESULTS, SUGGESTIONS

The results of the examination show that according to the needs and possibilities of the farmers there is a reason for the existence of the different forms of co-operations between them. By applying the cost effective shared machine using forms, the loads of the farmers can be reduced significantly both in the field of investments and operation. Furthermore there could be other advantages too. Besides the easing of the solution for the problems according to the mechanization they can also assist other factors, conditions of the production to become more advantageous (farming aid).

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad
Expert paper

ESSENTIALS AND SPECIAL FEATURES OF FRUIT PLANTATION DESIGN IN BULGARIA

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SUMMARY

Taken into consideration are several basic stages in the design of the fruit plantations with perennial plants including: information service – preliminary, current, computer; practical preparation and enrolling workers – fulltime and part-time courses, practical training, applicants' knowledge and skills evaluation; selecting the place for planting – reading the macro- and micro-relief, requirement about underground water level, soil, locating the area necessary; technology selection – planting schemes, cultivation methods, methods for fruit initial treatment; specifying the life-time assets demanded – species and varieties selection of perennial plants, determination of nursery plants needed, required machinery and constructions, consumer material required – compost by kind and amount, chemicals, wrapping by kind and amount; financial insurance – business plan, prices and realization, credit.

Applying of such design approach for perennial plants creates favourable conditions for achieving high output of the machines and labour resources and the most favourable premises for full-value utilization of the plants.

***Key words**: fruit plantation, growing conditions, design*

INTRODUCTION

Outstandingly favourable soil-climate conditions in Bulgaria with a diverse relief and microclimate are the reason because the country traditionally develops agriculture as a basic branch in its economy. Minding these favourable preconditions, thus the growing plantations of perennial plants (orchards and vineyards) is one of the important priorities facing the country before our incorporating the European Union.

Despite the unfavourable nature settings during the last 15 years it is to be noticed the areas for growing perennial plants decreasing considerably, together with the production yielded from them.

According to the data [2], the main orchard species in the country are: apples, pears, plums, cherries, morello, apricots, peaches, raspberries and walnuts. The young perennial plants (from 0–5 years) occupy 3-4 %, but the waste - over 20 % from the area of the harvested orchards.

During 2004 year the harvested areas with orchard perennial plants are 38 454 ha – by 3,3 % less in comparison to these from 2003 year. From 2000 year to 2005 year the harvested areas with vine perennial plants are reduced by 153 200 ha to 94 724 ha. [2]. The basic reason for this lessening is the uprooting of the waste orchard and vineyard plants, the legislative changes made for the consolidation of the land property, lack of sector financing, lack of coordination between the producers and the manufactures, the complicated registration in the agricultural farms, weak points in the science and the educational system in the sector has resulted in the absence of highly-qualified cadres.

Despite the hardships facing the agricultural producers then during the last 2006 year has been seen a significant interest to the planting of new and modernization of existing orchard and vineyards. The favorable influence is show on priority grants, which will be aided as the country incorporates in the EU.

Taking these changes in mind, many farmers are staying unprepared for the new production conditions. The basic question, which is asked, is: What is necessary to have, in order to dare to plant a fruit plantation, and how to modernize the one we already have?

The database used up to now and the methodics for design of fields with perennial plants in Bulgaria do not allow to be taken under consideration the objective alterations taken place in the agriculture. Many authors take regard to the incoming changes [1], [5]; partially give suggestions for technologies for growing perennial plants. Others give decisions for the separate orchard cultivars [10], [12], [13], [14].

Some, such as [15], [16] give offers for different designs schemes of orchard and vineyards perennial plants reporting the specific particularities of the region, but they are inapplicable in the conditions in Bulgaria. To have account on the soil-climate conditions, prevailing sort weeds, labour resource, prices and others, so the effective production needs special designs schemes laying out in every region, applied program products and etc.

The requirements for efficiency in the production can be fulfilled only in the overall problems solving. This is means certainly to be state grounds for the basic stages of making designs of perennial plants including: information insurance, practical preparation and workers enrolling, selecting planting place, technologies choosing options, defining the needed long-time assets, specifying the wanted consumatives, finances insurance.

SOME SPECIAL FEATURES OF FRUIT PLANTATION DESIGN

What do we need to have, in order to dare to begin a fruit plantation, and to modernize the one we already have?

The fruit plantations plan building and every species of perennial plants demands a preliminary project creation. The goal is to the most favourable conditions for reaching high machine performance and the labour resources and the most favourable premises for profiting from the plant.

The reaching of the standing aim it is required to follow the stages shown n Fig.1.

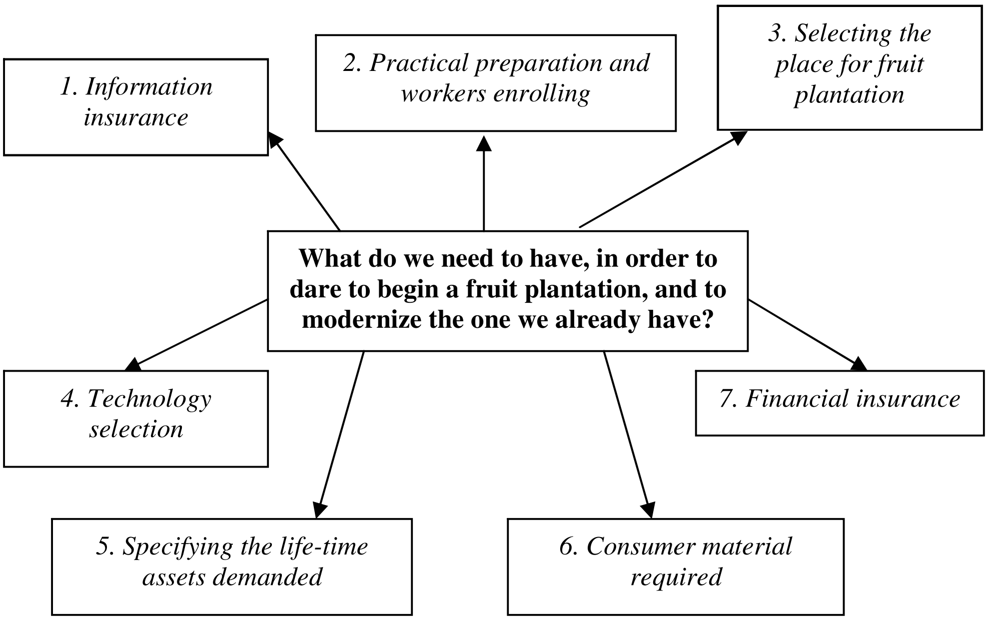

Fig.1 Graphical scheme for fruit plantation design

Information insurance

The information service assures using different sources on all levels for the project development and fulfilment.

The information service can be preliminary (literature for general purpose by list), from the current and reference literature, on Internet.

1. Preliminary – literature for general purpose by list

Being included science and professional literature.

2. Currently running, referenced by list

The main current sources used for the information service of a developed project for fruit plantations are: official data from National Statistic Institute (NSI); information of the national institutions – agency for employment, agrostatistics by the Ministry of Agriculture and Forests; information from regional resources; information from local sources – community administration, community office of agriculture and forests; data from scientific papers and conferences, thesis, similar successful elaborated projects, information collects on a specified subject - quest investigations and etc.

3. From Internet links

Practical preparation and workers enrolling

For successful perennial plants growing in the project preparation there must be kept in view the possibility for recruiting specialized cadres. In many regions such cadres are not to be found or short and for that reason arises the necessity to add instruction to the workers using organised specialized theoretic and practice courses of education.

1. Fulltime and part-time courses

The courses can be run in scientific institutes, universities, colleges and others profiled scientific unions disposed with the necessary number specialists and equipment.

2. Practical training

After the certain course studies ending up, the applicants' are recommended passing the practical training of the knowledge mastered.

3. Applicants' knowledge and skills evaluation

The knowledge evaluation of the applicants' revises their theoretic and practical learning. Well as it will be if the applicants' have marks in all practical exercises on a rotary principle.

4. The estimate labour resources (regular, seasonal)

Selecting the place for fruit plantation

To make new perennial plants is such a responsible process involved with many factors of ecological, biological and economical essence. Making mistakes at the beginning of its creation, there will be discovered on a later point and many times are not corrected which is the cause for major financial losses, this meaning a prior investment for its first step.

1. Reading the macro-and micro-relief

One of the most important tasks of the project with perennial plants is the regard to the influence of the macro-and micro-relief. The relief and the terrain place create variety in the temperature and water regime in the soil.

The slopes with a southerly exposure are greatly warmer, in comparison the northerly, as the difference becomes bigger, as the slope becomes bigger. From another point of view in equal other conditions the northerly slopes have much more favourable water regime and so on. In this sense, changing the intensiveness of the climate factors, the relief creates a specific microclimate, which is of a peculiar meaning for growing perennial plants successfully.

Not to mention on a last place, there must be beared in view, that applying successfully mechanized cultivation in the gardens with perennial plants it is good if the slope does not exceed 10-12 ^{0} on purpose not to cause difficulties in the mechanised production processes.

2. Requirement about underground water level

The designs with perennial plants must consider that the high level of the subsoil waters influence unfavourably the viability of the roots. The level of the subsoil waters must exceed 1,5 m above the surface.

3. Requirement about soil

Appropriate soils are counted those, which have a good water and air regime and good natural fertility. The good aeration of the soil in the zone of developing the root system, together with the humidity and enough nutritive substances present, it is an important condition for the normal growth and the fruit bearing.

It thought essentially the influence of the mechanical composition of the soil on the mechanised treatments in a given plant. The soils with a heavier mechanical composition and with a high humidity easily pack when some mechanised operations take place in between the inter rows. Respecting these peculiarities in the making projects with perennial plants the designer must provide for opportunities for irrigation and mechanization of the processes.

The soil reaction has influence on the assimilability of the nutritive elements in the soil. At pH lower than 5,5 the assimilability of the nitrogen lessens, the phosphor and the potassium, while at pH over than 7,5 the assimilability of the iron becomes difficult.

The choice of soils for perennial plants in the project drawing must be looked close that the sort and species composition of the plants, the natural soil fertility, the soil structure, the soil reaction, the contents of the active carbonates, the moisture retentive ability and etc. The best indicator showing the soil adaptability for growing a certain crops is the development, fruit bearing and the long life of the existing plants of a given orchard kind or the sorts of vineyards massives in the planned region where the young plant is projected.

4. Locating the area necessary

The allocation of the area to be needed depends on the volume of production and the available area, which we have at our free use. The scheme for organising the areas for growing perennial plants are so exploited that optimal organisational-economic conditions are thus set for introducing modern progressive technologies for growing perennial plants of an intensive kind, having maximal mechanisation of the labour-intensive processes.

Besides the above-listed requirements, last but not least when allocating the area for planting perennial crops it must be made an issue of the close distance to populated places and the potential chances for the production realization.

From the fields' positions distributed among the populated areas are judjed to a large degree the transportation expenses and from here on the cost price of the generated production.

Technology selection

1. Planting schemes

The correctly chosen scheme gives the most rational utilization of the fields, optimal light and nourishing plants schedule, insures favourable conditions for effective working of the run machines and labour hands, results in optimal high yield and production quality.

The planting of perennial plants sets an important emphasis on the calculation of the planting distance. For its correct estimation it is good to know the type of the used paddings and the cultivars and what canopy will turn into after the fully plants' growth.

2. Cultivation methods

In order to rate the efficiency of every crop, we must choose an appropriate growing technology. The final result from the designing reflects on the expenses for the chosen technology and the expected yields. When there are being used as well the data taken from the market survey on the coming market prices of the production, the potential profits can be calculated. Then the difference between incomes and expenses gives a presentation of the effectiveness of the named culture.

The chosen technology must assure for using the field effectively, the technical means and the labour resources in the farm, for obtaining sufficient in quantity and quality production, reasonable incomes the production sale.

3. Methods for fruit initial treatment

The right choice of suitable technology for preservation must be made regarding the physiological processes in the fruits (breathing, transpiration and so on), the ecological and the agrotechnical factors (soil properties, sea-level altitude, light regime, trimming, fruits massiveness, time of maturity).

The practicable ways for fruit preservation can be done in casual fruitstores, refrigerator fruit stores, and refrigerator fruit stores with a controlled atmosphere, store-keeping in the polythene packings.

The refrigerator store keeping is applied broadly in practice [7].

There are usually other ways of fruit store keeping, such as preparing raisins out of some sorts of grapes and dried fruits only of some orchard sorts [8].

Specifying the life-time assets demanded

1. Species and cultivar selection of perennial plants

The right choice of appropriate species and cultivars of perennial plants predetermines the success of their creation.

The choice of species and cultivars is done attending to the ecological conditions in the region where the planting will be started, their successful development under these conditions, the stable yields and high-quality production obtained. An important point in the design of young plantations is thought to be the profitability of the production realization. The successful realization depends on both the quantity and quality of production as well as on the market demand. Considering these features it is a rule to make prior estimation if possible and a market survey on the needs in that region.

When the production will be offered on the home market for fresh consummation it is well to be thought about various sorts which ripe in different stretches of time and to bear fruits during a long period of time.

When the fruits will be distributed and given in manufacturing companies (canning factories, wine-works) it is advisable to be made preliminary contracts and itemizations with the manufactures for the planting of sorts for easy processing.

In case that the production is separated for export expedition there must be looked for possible variants of transportation without damage and so on.

All that calls for the choice of brands and sorts to be agreed with specialists in perennial plants, as well as economists in the sphere of production realisation abiding the dynamic changes in the market.

2. Determination of nursery plants needed

The required planting material for establishing plantation must be contracted a year before the enrooting. The producers of such material must possess accordingly the certificates for quality, authenticity and the healthful state of the planting material.

The defining of the necessary amount of planting material for 1 ha is done complying with the recommended interrow and between row distances for the separate species and cultivars, and also by adopted planting scheme.

After settling down more precisely the necessary amount of planting material for 1 ha it is calculated for the whole area and it is made a corresponding order.

3. Required machinery

Building orchard gardens, vineyards and others is bound to additional expenses for specialized techniques. Depending on the scales of production and the financial capacities of the farm in the project there are described the options for employing the techniques at hand and buying new or second-hand specialized techniques or renting such.

4. Required construction [9].

Consumer material required

1. Compost by kind and amount [6]
2. Chemicals [6]
3. Wrapping by kind and amount

All expenses made cultivating the perennial plants, the biggest of which are those starting with the harvesting and wrapping of the production.

The kind used for wrapping depends on the type of the collected production. The most widely spread are the harvesting containers with a sliding bottom such as the polythene and the wooden cassettes. The wrapping commonly used must be of one kind to make easier the mechanized processes running the loading–unloading services and the transportation.

Financial insurance

1. Business plan

The business plan is absolutely needed step in the work on projects for fruit plantation creating. The business plan is a document, which must be accompanying the documentation of the financing proposal – too often – the main document. The business plan should give an answer to several questions, which one financing organization or bank usually brings: 1.What is the scale dimension of the searched financing? 2. How will be the funds spent? 3. How will be the funds used to the best?

2. Credit, prices and realization

The crediting sources can be different governmental and international programs like "Sapart" National fond agriculture and etc.

3. Normative regulations – list of documents

Every single financing organization grants a list of the necessary documents [4].

CONCLUSIONS

Applying of such design approach for fruit plants creates favourable conditions for achieving high output of the machines and labour resources and the most favourable premises for full-value utilization of the plants.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Prethodno priopćenje
Preliminary communication

PERFORMANCE OF THREE MECHANICAL HARVESTING SYSTEMS FOR OLIVES IN PORTUGAL

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ABSTRACT

Three mechanical harvesting systems for olives have been tested in field trials in the two main Portuguese regions of olive production: Trás-os-Montes and Alentejo. These tests took place in traditional olive orchards with 100 to 150 trees per hectare.

In the three systems, olives were harvested with the same trunk shaker and were collected manually (system I); with a tractor mounted rolling canvas (system II); with an inverted umbrella (system III).

Results are revealed in terms of working rates. The main factors that influence the systems performance are discussed.

***Key words**: olives, mechanical harvesting, performance*

INTRODUCTION

Olive production assumes in Portugal and in the Southern European countries in general high economic value that justifies studies to solve the production difficulties. One of those difficulties is the high cost of traditional manual harvesting system, because labour is becoming more difficult to find and it is expensive.

Mechanized harvesting is one answer for this problem. Tree shakers are now widely accepted among growers, in spite of being unable to detach 100% of the production.

MATERIAL AND METHODS

Field trials carried out in Portugal in eleven traditional olive orchards (sites) over three years. Traditional olive orchards vary from 100 to 150 trees per hectare. Six of the olive orchards are in Trás-os-Montes region and five are in Alentejo region. A total of 2535 trees were used in the field trials.

In Trás-os-Montes there are three main cultivars: Cobrançosa, Verdeal and Madural, whereas in Alentejo, Galega is the main cultivar.

The mechanical harvesting systems studied are based on a trunk shaker mounted on the front loader of a 60kW four wheel drive tractor. Three different systems were used to collect olives detached:

In system I (Fig 1) the olives detached are collected on a 10m × 10m canvas placed under the canopy projection, and moved by four labourers. In a parallel row, a second group was placing another canvas under the next tree to be shacked. A second tractor and trailer was standing by to collect the olives when canvas became too heavy, as well as to provide transport to the processing unit.

Figure 1 System I

In system II (Fig 2) the olives detached are collected on a rolling canvas catching frame mounted on a second tractor. Two labourers are necessary to support the canvas movement. The canvases are made by two 4m × 8m separate parts, laid down on either side of the tree.

In system III (Fig 3) the olives detached are collected by a 9m diameter inverted umbrella linked to the tractor front-end-loader under the trunk shaker frame. The inverted umbrella can store temporarily 200/250 kg of olives in a collecting tray. Under the collecting tray a lead may be hydraulically open to allow discharge of the olives.

Figure2 - System II

The experimental design was a randomized complete block with three treatments (system I, II and III) and three replications.

Figure 3 - System III

Measurements

The following time in seconds, were taken:

Tvt - medium value of time per tree for trunk shaking (in systems I, II and III);

TDV - medium value of time to move the tractor/shaker unit, from one tree to next (in systems I, II and III);

TDeP - medium value of time to unroll the canvas and lay it under each tree (in system II);

TEP - medium value of time to roll up the canvas (in system II);

TPAt - medium value of time during which the canvas is under each tree (in system II);

Tdaz - medium value of discharging time of the inverted umbrella (in system III).

Na -Number of trees between discharges (in system III).

The mass of the olives harvested by the shaker was measured. The mass of olives remaining on the trees was evaluated by manual picking from a sample of trees selected by randomization.

Work rates (WR) were computed from the following expressions:

$$\text{System I} \rightarrow \ WR = \frac{3600}{TVt + TDV} \quad \text{System II} \rightarrow \ WR = \frac{3600}{TDeP + TPAt + TEP + TDE}$$

$$\text{System III} \rightarrow \ WR = \frac{3600}{TVt + TDV + \frac{Tdaz}{Na}}$$

RESULTS

Table 1 show the work rates results, per system and site

Table 1 Work rates by system, in trees per hour.

	System I		System II		System III	
	Mean value	Standard deviation	**Mean value**	Standard deviation	**Mean value**	Standard deviation
Site 1	**57**	3,6	**43,5**	1,3	**36**	1,8
Site 2	**90,1**	16,6	**50,8**	5,3	**47**	3,6
Site 3	**58,3**	6,7	**44,5**	3,3	**52**	4,5
Site 4	**41**		**36,5**	13,4	**41,3**	10,6
Site 5	**37,5**	3,5	**27**	5,6	**22**	
Site 6	**82,5**	13,4			**73,5**	10,6
Site 7	**36**	5,6	**35,5**	3,5	**33,5**	3,5
Site 8	**39**	4,6	**47,3**	4,6	**34**	4
Site 9	**80,3**	9,3	**63,7**	5	**42,3**	8,6
Site 10			**38**	7,1	**26**	5,7
Site 11	**46,5**	7,8	**42,5**	0,7	**36**	2,8

Comparison of work rates of the different systems in the same olive orchard

Considering that when growers decide to mechanize olives harvesting, they adopt system I as starting point, progressing then to system II or system III, the work rates of these two systems were computed in percentage of the work rate of system I. Results are shown in Table 2.

Table 2 Comparing systems – mean values

	Work rate of system II in % of work rate of system I	**Work rate of system III in % of work rate of system I**
Mean value	**0,84**	**0,75**
Standard deviation	0,17	0,14

Shaker efficiency

Shaker efficiency was measured by the ratio of mass of olives detached by the shaker and the mass of olives produced in the olive orchard. Results are presented in Table 3. Sites 5 and 6 do not include data, due to severe weather conditions. Results of sites 1, 2 and 3 were measured in trees used in the three systems.

Table 3 Shaker detachment capacity.

	System I	**System II**	**System III**
Site 1	67%	67%	67%
Site 2	87%	87%	87%
Site 3	71%	71%	71%
Site 4	73%	70%	41%
Site 5	92%		
Site 6	92%		
Site 7	84%	73%	77%
Site 8	79%	72%	72%
Site 9	80%	80%	74%
Site 10		77%	67%
Site 11	96%	90%	89%

DISCUSSION AND CONCLUSIONS

Work rates have a great interval between the minimum and maximum values. Some factors are responsible for that: the heterogeneity in the traditional olive orchards, the different soil conditions that interfere with the equipment evolution and the labour quality.

System I has a better performance, followed by system II, being System III the slowest. However system I has a great dependence on labour and its quality. With inefficient labour, this advantage may be strongly diminished. An efficient labour, moving the canvas can improve the work rate. Systems II and III have lower performance and are more affected by the soil conditions. For these two systems, it is important that soil conditions allow a good capacity to sustain traffic of heavy equipment.

The shaker efficiency results are between 70% and 80% of olive production detached, what is in accordance with Giametta (1986), Tombesi (1990), Martin (1994), Ferguson *et al.* (1994) e Sierra (1996). In system III, site 4 the result is much lower 41%, because the tree crown conditions turn necessary to shake secondary branches, not possible with the inverted umbrella. In this site, was necessary to shake trunk and secondary branches, to get results of 73% for system I and 70% for system III.

ACKNOWLEDGEMENTS

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Prethodno priopćenje
Preliminary communication

THE EFFICIENCY OF A GREENHOUSE FOG COOLING SYSTEM

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SUMMARY

Fog cooling has been proved to be one of the most efficient cooling methods in greenhouses in summer. The desired environment parameters such as temperature and relative humidity can be maintained by a control system. Greenhouse conditions vary in a non-linear pattern, thus adding long time constants to the system response. According to the thermodynamic properties of air, the mass and energy conservation equation was analyzed, and then a mathematical model of the fog cooling system was developed. In order to verify the fog cooling system efficiency, a simulation was performed. The aim was to achieve the desired optimal conditions for crop growth. With this model, growers can easily control greenhouses and save lots of energy.

Key words: *greenhouse, environmental control, fog cooling, simulation*

INTRODUCTION

Cooling systems are very important and urgent in greenhouses during hot seasons. Several cooling systems with various types of technical equipment have been used in many countries. These systems can efficiently maintain greenhouse temperature and humidity at acceptable levels during warm periods, such as roof shading, natural ventilation, forced ventilation, air-conditioning cooling, wet-pad and fan cooling,, and fog and fan cooling.

Roof shading is the most common technique (Kittas et al., 2003). Shading screens mounted externally or internally can reduce radiation inside the greenhouse; however, the temperature reduction may not meet the requirements of plants. Willits and Peet (1993) showed that the cooling efficiency of the black polyethylene films was less than 50%, while the white shading cloths were only slightly more effective. Onmura et al. (2001) revealed that in closed spaces with the planted roofs, the air temperature beneath the plants was lower than that of the air above, by nearly 4–5°C.

Natural ventilation or forced ventilation will reduce greenhouse overheating, but it may enhance the risk of water stress because it often increases plant transpiration (Seginer, 1984). If the temperature outside is extremely hot, it is impossible to only use ventilation to carry away the thermal energy from a greenhouse. Kittas et al. (2001) reported that high ventilation rates were not the best solution for mitigating crop stress in greenhouses in summer.

Air conditioning is considered an expensive method (Chen et al., 2001) since it has some disadvantages, such as high initial cost, expensive equipment installation and maintenance, more power consumption, and exhaust emission. Hence air-conditioning systems are rarely used in real greenhouse production.

The wet-pad and fan cooling system and fog and fan cooling system convert sensible heat into latent heat of evaporated water. These systems can provide the appropriate conditions for plant growth, such as desired relative humidity and temperature, in the greenhouse during the hot season. Evaporation can substantially improve the greenhouse climate. It can be conducted by spraying water droplets or forcing ambient air through wet pads in the greenhouse.

Wet-pad and fan cooling systems are very popular in China and some other countries (Zhang et al.,1999). The system forces outside air into the greenhouse through a wet pad. After humidifying and cooling, the air inside is removed by the fans at the opposite end. It can make the temperature to a low level quickly with high efficiency. The other advantage of this method lies on its simplicity of operation and control and does not entail any risk of wetting the plants. However the best condition is only at the entrance where the wet pad is situated. Significant temperature and humidity gradients (Kittas et al., 2003) in the airflow direction along the greenhouse are created because of the absorption of solar energy in the greenhouse. However, since the air must be forced through the pad, the speed of the air slows down.

A fog cooling system comprises some nozzles at the air entry along the airflow direction. It sprays the water as small droplets in order to increase the water surface contacting with the air, so as to enhance the heat and mass exchange between the water and the air. These small droplets should be in the fog range, approximately 2-60 μm in diameter (ASHRAE, 1972). The free-fall velocity of the droplets is slow (Frenkel, 1986), up to the order of 0-1 ms^{-1} in still air and the droplets are easily carried by the air streams inside the greenhouse. These facts result in a high efficiency of water evaporation and also keep the plants dry. However, pretreatment of the water should be required in order to prevent clogging, since the diameter of the orifice of each nozzle is 0.1-0.3 mm. In addition, incorrect operation of the system may cause plant wetting, disease bursting, and leaf scalding. Chunyu et al. (2002) and Arbel et al. (2003) worked on the operational characterization of a fog cooling system in combination with forced ventilation. Their results revealed that inside the greenhouse air temperature and relative humidity can maintain at 28°C and 80% during the hot seasons. A cooling method was designed for measuring dry-bulb temperatures during the operation of a fog system in greenhouses (Toida et al., 2006). Ning et al. (2005)

designed a new spray desuperheater for cooling. A new definition of fog cooling efficiency was developed and applied by Abdel-Ghany (2006).

The objective of this paper was to establish a mathematical model and characterize the fogging system based on the mass and energy conservation of the first law of thermodynamics. With this method, the water needed by the cooling control system can be exactly calculated, and the ratio of the supply time to the interval time can be designed to control the system. As a result, the cooling system can achieve a high efficiency by saving energy and water supply, and keep the plants in a desired environment.

MATERIALS AND METHODS

Properties of Moist Air

The "real" air is almost regarded as a composition of two components: standard dry air and water vapor. When water vapor is added into dry air, two processes may take place according to the temperature of the water, sensitive exchange and latent exchange processes. Transmitting, convecting or radiating occurs between the air and water caused by the difference in temperature, which is defined as the sensitive exchange process. This process has only heat change. On the other hand, if there is some mass changed through emitting (or absorbing) heat by water vapor coagulation (or evaporation) at the same time, then we call it latent exchange. According to the thermodynamic property, when the latent exchange occurs, the amount of moisture that the air can absorb will vary from zero (dry air) to maximum (saturation). The actual amount of water that can be absorbed by the air depends on the actual temperature and pressure of the air.

Energy and Mass Balance of the Greenhouse Air

The energy and mass balance of the air is essential when discussing the dynamic model of the greenhouse environment. The first law of thermodynamics indicates that mass and energy are conserved throughout a process. This process can be a mixing, heating, cooling, humidifying, or drying process. And the mass conservation equation can be expressed as

$$\sum m_{a,in} = \sum m_{a,out} \tag{1}$$

$$\sum m_{w,in} = \sum m_{w,out} \tag{2}$$

In a similar way, the energy conservation equation can be expressed as

$$\sum Q_{in} = \sum Q_{out} \tag{3}$$

Eqs. (1) to (3) are the equations used to calculate any conditions in a typical process involving moist air. With these basic equations, a cooling simulation model can be available.

SIMULATION AND RESULTS

Physical Model of the Fog Cooling System

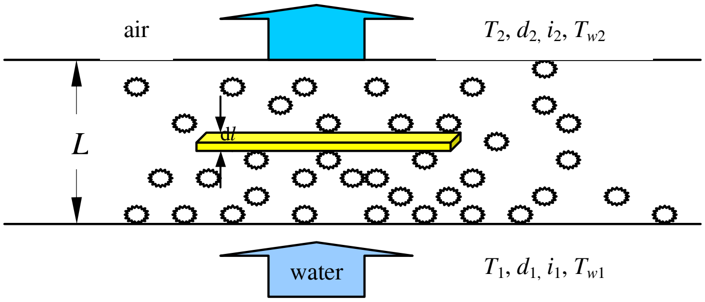

Figure 1 Energy and mass exchange processing

If the cross-sectional area is denoted as A_{cn}, the width of the exchange surface as L (Figure 1), and the area of heat and mass transmitting per volume (m^2m^{-3}) as a_H and a_M, respectively, the total area of heat and mass transmitting A_H and A_M can be described by Eq. (4)

$$A_H = a_H A_{cn} L$$
$$A_M = a_M A_{cn} L \tag{4}$$

Mathematics Model of the Fog Cooling System

1) The mass exchange process by the differential ratio humidity of saturation air can be expressed as Eq. (5)

$$-\mathrm{d}G_w = G_a \mathrm{d}d = \lambda_{md} a_M (d_b - d)\mathrm{d}l \tag{5}$$

where G_w——water flow ratio on the surface, (kg m^{-2} s^{-1})

G_a——air flow ratio on the surface, (kg m^{-2} s^{-1})

λ_{md}——mass change coefficient, (kg m^{-2} s^{-1})

d——air humidity ratio, (kg kg^{-1})

d_b——saturation air humidity ratio, (kg kg^{-1})

2) Sensible heat transferred through saturation air to the flow air is described by Eq. (6)

$$G_a c_p \mathrm{d}T = \lambda_a a_H (T_b - T)\mathrm{d}l \tag{6}$$

where c_p——moist air specific heat, (J kg^{-1} °C^{-1})

λ_a——air heat change coefficient, (W m^{-2} °C^{-1})

T——air temperature, (°C)

T_b ——air temperature on the air-water change surface, (°C)

3) Total energy of the air by the transfer Process is

$$G_a\left(c_p \mathrm{d}T + r\mathrm{d}d\right) = \left[\lambda_{md} a_M \left(d_b - d\right) r + \lambda_a a_H \left(T_b - T\right)\right]\mathrm{d}l \tag{7}$$

where r ——latent heat generated by water and air mixing streams J kg^{-1} .Supposing that a_H=a_M, neglecting the differential of the latent heat, then

$$G_a \mathrm{d}i = \lambda_t a_M \left(i_b - i\right)\mathrm{d}l \tag{8}$$

where λ_t——total heat change coefficient, (W m^{-2} $°C^{-1}$)

i ——enthalpy of the moist air, (J kg^{-1})

i_b ——enthalpy of the saturation air, (J/kg)

4) Energy balance is shown by Eq. (9)

$$G_a \mathrm{d}i = \pm \frac{1}{K} c_w G_w \mathrm{d}T_w \tag{9}$$

where

$$K = 1 - \frac{T_w \mathrm{d}G_w c_w}{G_a \mathrm{d}i}$$

5) Heat carried by water is

$$\pm G_w c_w \mathrm{d}T_w = \lambda_w a_H \left(T_w - T_b\right)\mathrm{d}l \tag{10}$$

Greenhouse Model of the Fog Cooling System

A schematic description of the fog cooling system is presented in Figure 2.

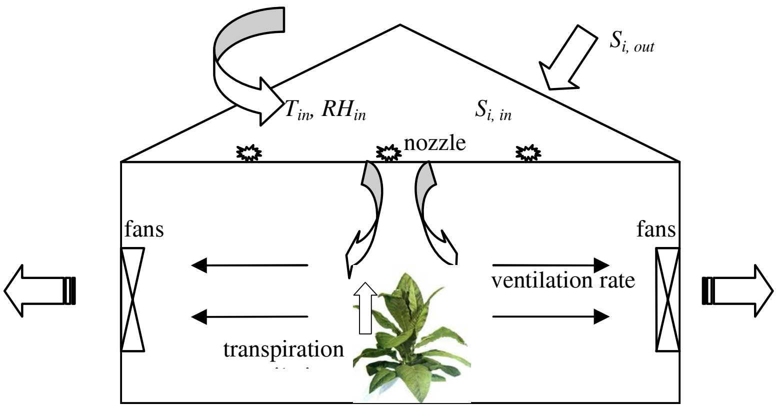

Figure 2 Model of a greenhouse cooling system

A simple greenhouse cooling ventilating model can be obtained by considering the differential equations (Pasgianos et al. 2003), which govern sensible and latent heat, as well as water balances on the interior volume. Eqs. (11) and (12) describe the total heat exchange process and mass transmitting in the greenhouse.

$$\frac{\mathrm{d}T_{in}(t)}{\mathrm{d}t}=\frac{1}{\rho C_p V}\left[S_i(t)-\lambda q_{fog}(t)\right]-\frac{V_R(t)}{V}\left[T_{in}(t)-T_{out}(t)\right]-\frac{UA}{\rho C_p V}\left[T_{in}(t)-T_{out}(t)\right] \tag{11}$$

$$\frac{\mathrm{d}w_{in}(t)}{\mathrm{d}t}=\frac{1}{\rho V}q_{fog}(t)+\frac{1}{\rho V}E(S_i(t),w_{in}(t))-\frac{\dot{V}(t)}{\rho V}\left[w_{in}(t)-w_{out}(t)\right] \tag{12}$$

where T_{in} the indoor air temperature (°C), T_{out} the outdoor temperature (°C), UA the heat transfer coefficient (W K^{-1}), ρ the air density (kg m^{-3}), C_p the specific heat of air (J kg^{-1} K^{-1}), S_i the intercepted solar radiant energy (W), q_{fog} the water capacity of the fog system (g $_{H2O}$ s^{-1}), λ the latent heat of vaporization (J g^{-1}), V_R the ventilation rate (m^3 s^{-1}), w_{in} and w_{out} the interior and exterior humidity ratios (g_{H2O} $kg^{-1}{}_{air}$), and $E(S_i,\ w_{in})$ the evapotranspiration rate of the plants (g_{H2O} s^{-1}).

Parameters of the Model

For simulation purposes, the area of the greenhouse was considered to be 1000 m^2 and the height to be 4 m. Accumulated experience shows that in order to obtain uniform conditions, the entry velocity of the air into the greenhouse should not exceed about 0.5 ms^{-1}. With this limitation, the length of the common greenhouse was limited to within 35 m. Shading screen was assumed to be equipped in the greenhouse, which can reduce the transmitted solar radiant energy by 50%. For simulation, it was determined that the initial temperature outside greenhouse was 40°C, the relative humidity of the air was 20%, and the solar radiation outside the greenhouse was 1,200 W/m^2. Three fans were assumed to be working. Other parameters required for the simulation system were also determined, including ventilation mass flow rate (30,000 m^3/h), the air density ρ (1.2 kg m^{-3}), the specific heat of air C_p (1006 J kg^{-1} K^{-1}), the solar radiant energy outside the greenhouse (1,200 W), the solar radiation inside the greenhouse (600W m^{-2} or 600 J $sec^{-1}m^{-2}$) and the latent heat of vaporization λ (2257 J g^{-1}). Substituting these values into Eqs. (11) and (12), the simulation was performed using computer program.

Results and Discussion

The simulation results by using this mathematical model are displayed in Figures 3 and 4.

Comparison between Figure 3 and Figure 4 shows that using the fog cooling system, the temperature inside can keep a low level although the temperature outside is very high. In summary, the fog cooling system has lots of advantages. Firstly, low temperature and high humidity will be obtained, instead of high temperature and low humidity in summer, which have adverse effects on plant growth. Secondly, using the simulation and experiment testing, some parameters can be calculated accurately. Thirdly, total water for cooling and the spraying time and interval time for system climate control can be calculated. Finally, the number of the fans can be calculated, if the water supply per minutes is fixed. For example, by running this fog cooling system, the final temperature inside will be kept at 27°C, and relative humidity inside 65%, compared with the initial temperature 41°C, and relative humidity inside 20%. Meanwhile the amount of water supplied can be gained, which is 504 kg/hour.

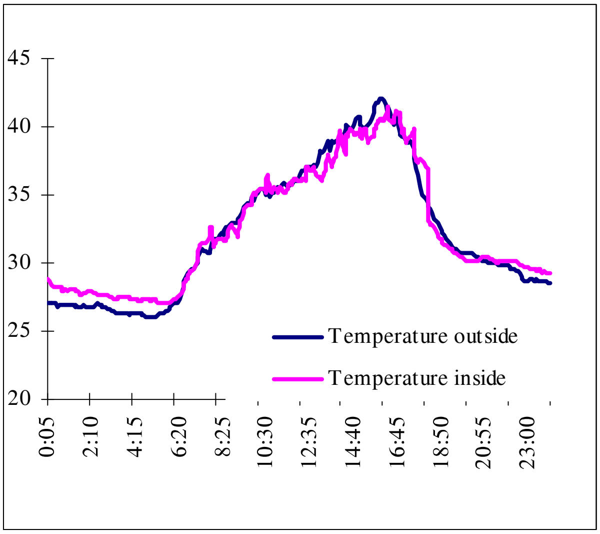

Figure 3 Temperature outside and inside without a cooling system

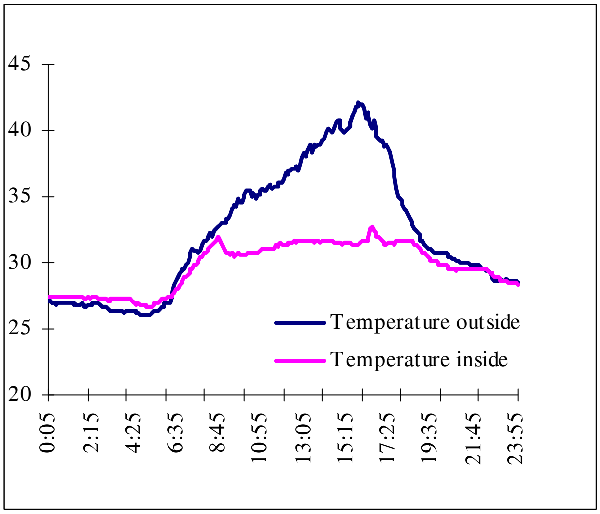

Figure 4 Temperature outside and inside with a fog cooling system

Comparison between Figure 3 and Figure 4 shows that using the fog cooling system, the temperature inside can keep a low level although the temperature outside is very high. In summary, the fog cooling system has lots of advantages. Firstly, low temperature and high humidity will be obtained, instead of high temperature and low humidity in summer, which have adverse effects on plant growth. Secondly, using the simulation and experiment testing, some parameters can be calculated accurately. Thirdly, total water for cooling and the spraying time and interval time for system climate control can be calculated. Finally, the number of the fans can be calculated, if the water supply per minutes is fixed. For example, by running this fog cooling system, the final temperature inside will be kept at 27°C, and relative humidity inside 65%, compared with the initial temperature 41°C, and relative humidity inside 20%. Meanwhile the amount of water supplied can be gained, which is 504 kg/hour.

However, it also shows that such a design presents difficulties both in the installation of the water distribution system and in its operation and control, which are subject to the varying environmental conditions. Many factors restrict the development of the fog cooling system. As it is known that, a fogging system includes: fine filters for the incoming water; a water storage reservoir; a high pressure pump with a pressure adjusting valve; electrically operated solenoid valves to facilitate rapid pressure release; and nozzles fitted to appropriate pipe work and distributed uniformly within the greenhouse. To improve the efficiency of the fog cooling system, several parameters should be taken into account. They are ventilation rate of the flow air, evaporation flow rate, plants transpiration, quantity and quality of water supply, water pressure outlet of the nozzles, nozzles diameter and distribution, solar radiation transmission into the greenhouse, etc.

1) The fog droplets should be very small for easy evaporation. This system uses high pressure spray nozzles with the highest possible uniformity of distribution, which sprays water into small droplets. The size of the droplets will be 2~60 μm in diameter.
2) The quantity of water supply is a very important factor to the cooling efficiency. And also the spraying time and interval time can affect the cooling efficiency.
3) High quality and pure water will be good for spraying and keep the nozzles from clogging.
4) The effective evaporative cooling systems must be combined with efficient ventilation. Many fans will be installed on one side or both sides of the wall in the greenhouse.
5) Each fan has the ability to make the mass flow rate between 0.2~ 1.0 kg/s, which makes the air flow in a desired speed and enhances the heat and mass exchange.
6) The strong solar radiation outside can not be ignored, which can increase the internal air enthalpy and the temperature in the greenhouse.

CONCLUSIONS

The current trend in greenhouse cultivation is to extend the growing and crop production season, in order to maximize the use of the equipment, extend the export season, and increase the annual yield per unit area and profitability. Fog and fan cooling systems are considered efficient cooling systems compared to wet-pad and fan systems, air-conditioners and other cooling systems. Fog and fan systems can maintain the desired temperature and relative humidity in hot seasons in greenhouses so that the crops can grow in optimal conditions to maximize the yield.

The model was established in this study to calculate the total water supply for evaporation. Almost uniform climatic conditions were achieved by using the fog cooling system in the greenhouse.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.344.5:631.544.45
Izvorni znanstveni rad
Original scientific paper

INVESTIGATION OF INSTANTANEOUS HEATING EFFICIENCIES AND STEADY THERMAL LOSSES OF A CONVENTIONAL AND AN INFRARED-RADIATION HEATED GREENHOUSE

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SUMMARY

In the present work, a parametric study is performed in order to quantify the contribution of each greenhouse component to the required energy consumption during heating. The investigation is based on a typical greenhouse in Western Greece, but the conclusions are expected to be valid for other locations with comparable climatic conditions. The magnitude of various thermal losses is accessed under steady-state conditions, and losses from the cover are singled out as the most significant. A conservative estimate of the instantaneous efficiency is defined (based on steady-state performance) and is used to investigate the effect of covers material on consumed energy. Direct plant heating by infrared radiation is considered as a potentially efficient option. Preliminary estimates based on steady-state performance indicate that IR heating reduces very significantly the thermal losses to the surroundings, and correspondingly increases the greenhouse's thermal efficiency.

***Key words**: Greenhouse, Energy balance, Infrared Radiation, Thermal Efficiency*

INTRODUCTION

Energy consumption for heating and cooling is the primary cost component in greenhouse operation and hence represents one of the most serious concerns for greenhouse operators throughout the world.

Conventionally, heating in a greenhouse is accomplished either by means of a piping system or by air heaters (e.g. Van de Braak 1988, Teitel et al, 1999). Thus, the interior of the greenhouse is heated to the same or even slightly higher temperature than the value targeted for the plants. To reduce energy consumption, some straightforward measures can be applied. They include, improvement in insulation by means of double glazing (e.g. Gupta and Chandra 2002), thermal screens (e.g. Silva et al 1991), the use of improved ventilation systems, (e.g. Wang and Boulard, 2000), etc. Although the above efforts resulted in energy savings, they did not question the basic premise of first heating the greenhouse environment and then letting the plants gain energy from it.

Starting back from the 90's and in parallel with energy-saving measures, efforts have been undertaken to intensify use of renewable energy sources, with the dual aim of reducing dependency on oil and also better protecting the environment. (e.g. Bailey 1988, Rozakis et al, 1997). Although the above energy sources are clean and inexhaustible, and thus represent attractive substitutes for conventional fuels, they are associated with high installation costs and are not available on demand. Furthermore, the conventional concept of first heating the air in a glassy greenhouse and then heating the plants through the warm air of the greenhouse remains unchanged.

A breakthrough alternative for reducing energy consumption in greenhouse heating could emerge by the use of Infrared Radiation (IR). By activating an IR source, plants and soil may receive heat directly. In this way, the air and cover temperatures may remain relatively low and heat losses are significantly reduced. The use of infrared radiation for greenhouse heating has been so far scarcely considered. Few works published in the early 80's (e.g. Blom and Ingratta 1981, Itagi and Takahashi M 1978), investigate the suitability of low intensity IR for greenhouse heating. For example, in Blom (1981), energy savings of 33-41% are reported by using an IR system, as compared to the conventional heating method. As a result of the above lack of information, infrared radiation is presently exploited to a very limited extent, mainly in the US. Thus, there is a pending need to investigate the potential of IR heating for greenhouse applications, and to identify favorable designs and optimum operating conditions. It is worth noting that far infrared radiation has recently come to be considered as a welcome substitute for conventional heating in certain food processing applications (e.g. Sakai and Hanzawa, 1994; Tanaka et al, 2006), because of its superiority in terms of reduced costs and increased product quality.

In the present work, a parametric study is performed in order to quantify the contribution of each greenhouse component to the required energy consumption during heating. The investigation is based on a typical greenhouse in Western Greece, but the conclusions are expected to be valid for other locations with comparable climatic conditions.

An assessment of the various thermal losses is made for steady state conditions and a conservative estimate of the instantaneous efficiency of the heating system is defined. Instantaneous efficiency is used to investigate the effect of cover materials on the consumed energy during conventional heating. Then, IR heating is considered and the basic energy balances dictating the steady-state temperature of each greenhouse component are formulated and solved. Finally, conventional and IR heating are compared in terms of steady losses and instantaneous efficiency.

METHODS TO COMPUTE GREENHOUSE ENERGY NEEDS

The greenhouse considered for the investigation is placed in the Technological Educational Institute (TEI) of Messologi in Western Creece. The shape characteristics of this gable greenhouse are the following:

Structure: metallic framework, glass cover

Dimensions: width 20m, length 25m, width of each structural unit 6.5m, height of side poles 2.60m, height up to the top of the greenhouse 4.30m, inclination of the roof 30^o, which is almost the latitude of the location. The total area of the soil A_s = 500 m^2, the area of the cover A_c = 815 m^2 and the volume of the greenhouse is $V =$ 1700 m^3.

Number of air changes: n = 1.5 h^{-1} (new greenhouse construction with good maintenance)

Total heat transfer coefficient through the cover: $K_c = 5.8W/m^2\ {}^0C$ (Papadakis et al, 2000)

Planting density: The cultivation consists of plants of lettuce and the greenhouse's soil has been assumed to be completely covered by plants. 25 plants per square meter (25/m^2). Mean weight of a plant is 150 gr

The greenhouse is equipped with a central conventional heating system, which consists of a central boiler and a hot water pipe system. Small funs capable of inducing horizontal air motion are placed over the plants in order to establish uniform distribution of the heating air. The efficiency coefficient of heating system was taken equal to n = 0.85.

To calculate and compare energy consumption for heating the greenhouse by use of conventional and infrared heating respectively the following assumptions were made:

1. The desirable temperature for the growth of the considered cultivation is $T_p = 14^o C$. Hence, this is also the desired temperature T_i of the greenhouse internal surroundings when using the conventional heating system.
2. The temperature T_{out} of the environment outside the greenhouse, is taken from the statistically most unfavorable weather conditions for the geographical area of the greenhouse, and is equal to 7 ^{0}C. This choice is made on the basis of systematic temperature measurements performed at the location of the greenhouse for a time period of 3 years (Kavga 2005). Hence, the initial temperature of both, greenhouse air and plants before the onset of heating has been set equal to 7 ^{0}C. These initial conditions represent a worst case scenario.
3. For comparison purposes, the time lag from the above initial conditions to the establishment of steady state, when heating either with a conventional or with an infrared system, is taken arbitrarily equal to 1 h.

For the greenhouse described above, a parametric study is made to quantify the contribution of each component of the greenhouse to the required energy. Then, by assuming the technological capability of direct heating of the plants by means of infrared radiation, estimates of the thermal losses to the surroundings for the case of infrared heating have been performed as well. To facilitate assessment of the efficiency of each heating system and permit direct comparison between the two, the following thermal efficiency coefficient is introduced:

$$n = \frac{Q_{p,t}}{Q_{total}} \tag{1}$$

In eq. (1), Qp,t stands for the amount of energy absorbed by the plants in order to reach the desired temperature (in the present study this temperature is 14 ^{0}C) and Qtotal is the total amount of energy provided by the heating system during the time needed for the plants to reach the steady temperature.

According to the above, thermal efficiency is relevant to the transient period of operation of the greenhouse, when the temperature of air and plants is gradually raised from the initial value to the desired final state. In addition to n, the steady-state heat losses provide a complementary assessment criterion, as they are representative of energy needs beyond the initial heating period.

Estimation of the energy needs using a conventional heating system

For the case of conventional heating, the total energy Qtotal required by the system is specified by the need to heat the greenhouse air and plants up to the desired temperature and also compensate all thermal losses of the greenhouse. Thermal losses vary with time during the above transient conditions, and as a result the system is rigorously described by a set of ordinary differential equations. However, computations are facilitated by a conservative estimate of Qtotal, provided by approximating thermal losses by their maximum value (which is attained under steady-state conditions). The total energy released during transient heating, Qtotal, may then be calculated from the energy balance equation inside the greenhouse as:

$$Q_{total} = (Q_1 + Q_2 + Q_3 + Q_4)\,\Delta t + Q_{a,t} + Q_{p,t} \tag{2}$$

In eqn (2), Q1 to Q4 are the steady values of the various thermal losses and Qa,t, Qp,t the energy needed to heat the inside air and plants (all defined in Notation). Finally, Δt stands for the time required to increase the greenhouse temperature to the desired value, which in this study is arbitrarily taken to be 1h and exploits experience gained to heat the greenhouse under consideration.

Losses due to greenhouse air renewal (leakages - ventilation) are due to inevitable construction defects of the greenhouse as well as to the required ventilation through ventilation openings, and estimated by the equation:

$$Q_1 = 0.36 nV(T_i - T_O) \quad (W) \tag{3}$$

with:

n being the number of air exchanges (h-1)

V the volume of greenhouse (m^3) and

$(T_i - T_O)$ the temperature difference between incoming and outcoming air (^{0}C)

Convective losses from greenhouse cover occur through a system of resistances in series, provided by the inside air, the cover material and the outside air. They are given by the equation:

$$Q_2 = K_c A_c (T_1 - T_0) \text{ (W)} \tag{4}$$

where:

K_c is the total heat transfer coefficient through the cover (W/m^2 ^{0}C)

A_c is the area of cover (m^2) and

$T_i - T_O$ is the temperature difference between inside and outside air (^{0}C)

The energy losses by conduction from the greenhouse floor towards the earth are estimated by the equation:

$$Q_3 = K_2 A_2 (T_2 - T_1) \text{ (W)} \tag{5}$$

where:

K_s is the total heat transfer coefficient through the soil (W/m^2 ^{0}C)

A_s the area of greenhouse floor (m^2) and

$T_s - T_i$ the temperature difference between greenhouse floor and the earth, the latter taken equal to the outside air temperature $T_s = T_0$ (0°C). Also, the floor temperature is taken equal to the uniform interior temperature, Ti.

Heat losses by thermal radiation from the outer surface of the greenhouse can be evaluated by considering as control volume the whole greenhouse and applying the Stefan-Boltzmann law. Thus,

$$Q_4 = \sigma A_c \varepsilon_c (T_i^4 - T_{sky}^4) \ (W) \tag{6}$$

where:

σ is the Stefan- Boltzmann constant (W/m^2 K^4)

A_c is the area of cover (m^2)

ε_c = emissivity of cover

Definition of a sky temperature, T_{sky}, is a standard simplification for handling radial exchange with exterior surroundings. In the present study, the sky temperature is set equal to the outside air temperature, $T_{sky} = T_0$.

The energy stored in the greenhouse components during heating can be evaluated simply by considering the mass and specific heat of each component. The major contributions come from the plant canopy and the interior air, and are given by the expressions,

$$Q_{p,t} = \rho_m V_m C_{pm}(T_i - T_O) = m_p Cp_p (T_i - T_o) \tag{7}$$

$$Q_{\alpha,t} = \rho_\alpha V_\alpha C_{pa}(T_i - T_O) = m_a C_{p\alpha}(T_i - T_O) \tag{8}$$

with

m_α , m_p is the mass of inside air and plants (kg) and

$C_{p\alpha}$, Cp_p is the specific heat of air and of plants (J/kg ^{0}C)

When estimating the energy balance of the greenhouse, the contribution of the interior air is usually neglected because of its small heat capacity. However, in the present greenhouse, this contribution is not negligible and is thus retained.

By substituting eqn. (3) to (8) in equation (2), the total energy Q_{total} may be written as:

$$Q_{total} = (Q_1 + Q_2 + Q_3 + Q_4)\,\Delta t + Q_{a,t} + Q_{p,t}$$

It gives:

$$Q_{total} = 390.17 \;\; MJ$$

Using the above equations (3) to (8) the contribution of each greenhouse component to the required energy consumption during heating has been calculated. The results are displayed in figure 1. As expected, the contribution of convective losses through the cover is the most significant, followed at a short distance by the radiative losses of the cover.

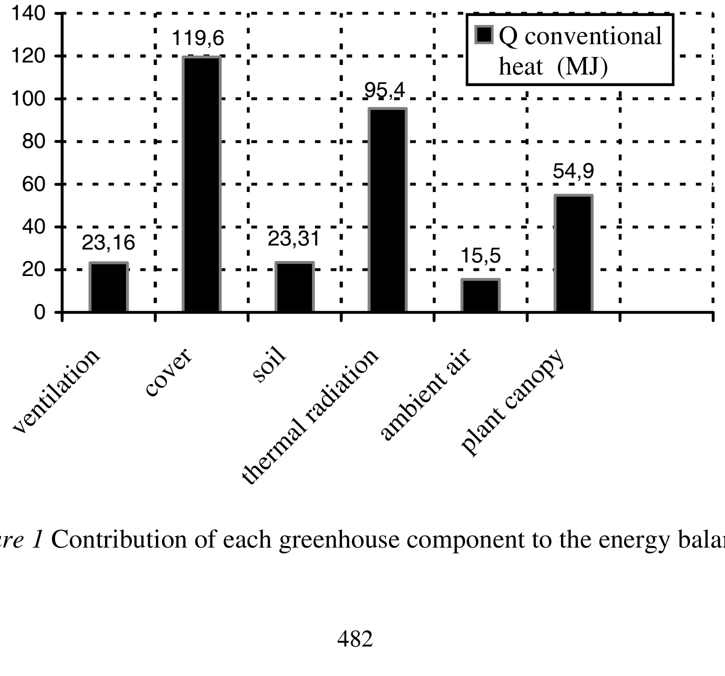

Figure 1 Contribution of each greenhouse component to the energy balance

By using eqn. (1) and the values of $Q_{p,t}$ and Q_{total} calculated above, the thermal efficiency coefficient $n = Q_{p,t} / Q_{total}$ is estimated as 0.1409 or 14.09 %. Although the selection of cover material affects energy losses, the potential for a significant reduction in the overall energy consumption through appropriate selection is limited. As shown in table 1 the coefficient of thermal efficiency calculated by using eqn. (1), ranges between 14 and 17.6 % for the various materials investigated.

Table 1 Total heat transfer coefficient and emissivity coefficient of several cover materials

Cover material	**n leakages/h**	K **W/m^2 ^{0}C**	ε_c	$Q_{p,t}$ **MJ**	Q_{total} **MJ**	**n (%) thermal efficiency**
Glass (4mm)	1.5	5.8	0.9	54.99	389.9	14
Double glass (3mm)	1.2	2.9	0.9	54.99	314.47	17.4
Simple sheet PE (8/100mm)	2.5	6.3	0.9	54.99	420.21	13
Double sheet PE (8/100mm)	1.2	2.9	0.9	54.99	314.47	17.4
Fiber Glass (fiber glass reinforced polyester sheets)	1.5	4.0	0.9	54.99	346.49	15.8
PVC	1.5	2.5	0.9	54.99	310.25	17.6

Estimation of the energy needs using an infrared radiation system

Next, the energy needs of the specific greenhouse when using an infrared radiation heating system are computed. The computation was based on the same assumptions as before, i.e. a desired plant temperature of $T_p = 14\,^0C$ and an outside environment temperature of $T_o = 7\,^0C$ derived from the specific climatic conditions of the most unfavorable month of the year. In order to compare the efficiency of transient heating by using an IR and a conventional heating system respectively, the previously defined efficiency coefficient will be involved and transient heating time will be initially set again equal to 1 h. It is noted however that much faster heating is feasible with high-power radiation sources, and thus additional benefits gained by a reduction in heating time will be assessed.

The key difference with infrared heating is that the plants receive thermal energy directly from the IR source and loose it by convection and thermal radiation to the inside air and the cover. Proceeding to a more rigorous formulation of the heat transfer problem under steady-state conditions, it is noted that the unknown temperatures of inside air and cover T_a and T_c respectively, may be calculated by considering two different control volumes and writing the corresponding balances. The first control volume consists of the internal greenhouse air, which exchanges heat by convection with the plant canopy, bare soil and inside cover surface and also looses heat by mass exchange with the exterior (air renewal by leakages and ventilation). The following equation represents a balance of these contributions at steady-state.

$$0 = A_b h_{ab}(T_b - T_\alpha) + A_p h_{ap}(T_p - T_\alpha) - A_c h_{ac}(T_\alpha - T_c) - nV0.36(T_\alpha - T_o) \qquad (9)$$

The second control volume consists of the greenhouse cover. The cover exchanges heat by convection with inside and outside air, but at the same time, it gains heat by radiation from the soil and plants, and emits thermal radiation towards the sky. A balance of these terms at steady-state leads to the following equation:

$$0 = \varepsilon_b A_b \sigma(T_b^4 - T_c^4) + \varepsilon_p A_p (T_p^4 - T_c^4) + A_c h_{ac}(T_\alpha - T_c) - \varepsilon_c A_c \sigma(T_c^4 - T_{sky}^4) - h_{co} A_c (T_c - T_o) \qquad (10)$$

where

ε_p, ε_c, ε_b is the emissivity of plants, cover and bare soil respectively

h_{ab}, h_{ac}, h_{ap}, h_{co} is the convective heat transfer coefficient between bare soil and inside air, between inside ambient air and cover, between plant canopy and inside air and between cover and outside air respectively (W/m^2 K) and

the others terms have been already mentioned above

Equations (9) and (10) are written with the implication that $T_\alpha > T_c$, which means that the cover is colder than the air. However, they are evidently valid in the opposite case as well. For the present application, it has been also assumed that the greenhouse floor is completely covered with plants and thus the contributions $A_b h_{ab}(T_b - T_a)$ and $\varepsilon_b A_b \sigma(T_b^4 - T_c^4)$ of bare soil are neglected.

Equations (9) and (10) may be solved analytically or numerically. By using the Mathematica software tool, the following temperatures of inside air and cover were calculated:

$T_\alpha = 283.377\,^0K = 10.2\,^0C$ and $T_c = 281.483\,^0K = 8.3\,^0C$

By using the above values and combining eqn. (9), (10) and (2), the total energy spent during transient heating is found equal to Q_{total} =221.44 MJ. With this value and the $Q_{p,t}$ value derived from eqn (8) ($Q_{p,t} = 54.99\ MJ$) the thermal efficiency coefficient is estimated as: $n = Q_{p,t} / Q_{total} = 0.2483 = 24.83\%$

A comparison of energy losses during conventional and infrared heating is shown schematically in Figure 3. With the exception of the energy required to heat the plants up to the desired temperature of 14 ^{0}C, which evidently remains unchanged, all other energy losses are appreciably reduced by using infrared heating. It is recalled that these losses correspond to steady-state operation of the greenhouse, and their very significant reduction is a result of the lower temperature gradient between cover and outside air. The lower cover temperature (8.2 ^{0}C for infrared heating compared to 14 ^{0}C for conventional heating) also results in an order-of-magnitude drop in the radiative losses to the environment. A comparison of Figs. 2 and 3 indicates that the economy achieved by IR heating by far outweights any benefits resulting from a change of cover material.

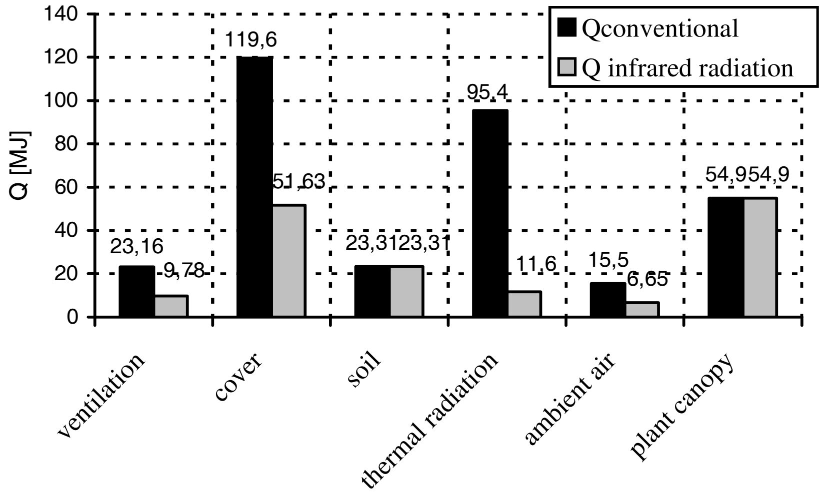

Figure 3 Comparison between conventional and infrared heating

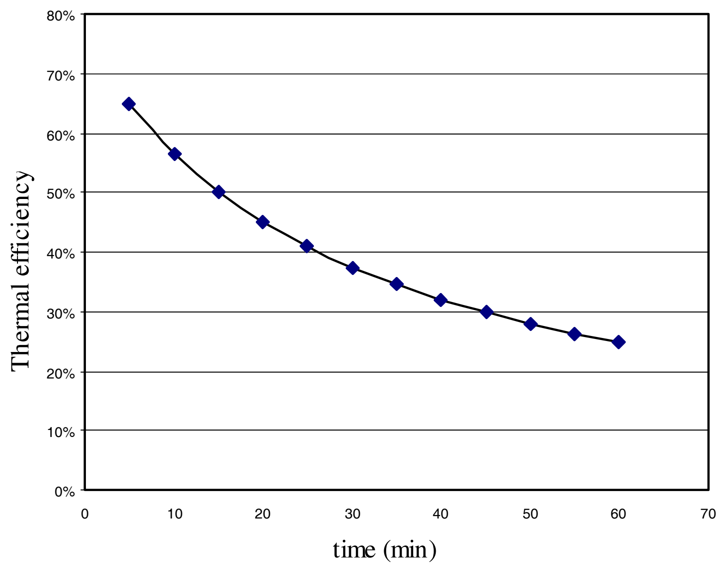

Figure 4 Relation between thermal efficiency coefficient and heating time

As already mentioned, comparisons in terms of the coefficient of thermal efficiency are based on a period of transient heating equal to 1 h. However, it is noted that a main benefit of IR heating is a dramatic reduction of the transient heating time. This reduction is achieved by increasing the intensity of radiation sources and is probably only limited by the receiving ability of the plants. At any rate, a tenfold decrease appears feasible. Thus, the present analysis concludes with an estimation of possible gains in efficiency stemming from the reduction of transient heating, and results are shown in Fig. 4 for times ranging from 5 min up to 60 min. Comparison of these results with the efficiency n=14.09 % achieved by conventional heating indicates improvements starting from 76 % and reaching up to 370 % for the shortest heating time assumed. This result motivates further investigation of possible exploitation of high power infrared radiation for greenhouse heating.

CONCLUSIONS

- A parametric study has been undertaken to quantify the contribution of each of the components of a greenhouse, located in Western Greece and heated by hot water pipes, to the energy consumption during heating. All estimates are made for steady state conditions, and results confirm the expected significant contribution of convective energy losses through the greenhouse cover (35 % of total losses). It is noteworthy that energy losses of the same order of magnitude (30 %) are caused by thermal radiation from the external surface of the greenhouse.
- A conservative estimate of the instantaneous efficiency of the heating system is formulated, on the base of steady-state conditions and transient heating lasting for 1 h. The relevant efficiency coefficient is used to assess the importance of cover material, and indicates that although thermal losses are somewhat affected by the material properties, the potential for a significant reduction of the overall energy consumption through a change of cover material is limited.
- The performance of a system based on direct heating of plants by infrared radiation has been considered. Detailed energy balances are formulated and significant differences are proven to exist among the temperatures of plantation, inside air and greenhouse cover. Calculations for the same case study show that IR heating results in 52 % reduction of steady heat losses. Also, the efficiency for transient heating is improved from 76 % up to 370 %, depending on the time assumed for achieving steady state.
- The next step to this study, already performed and submitted for publication, investigates and calculates the energy consumption to retain the desirable temperature in the greenhouse for the growth of plants over an entire thermal year. The calculation is based on the Degree-hours-heating (Dhh) method, and exploits meteorological data collected over a three year period. Heating of the greenhouse is assumed to occur by means of both a conventional and an alternative heating system involving direct infrared radiation (IR). Thus, the potential benefits of IR heating are examined over the entire thermal year. The main result is that the yearly energy consumption using IR heating system was rigorously calculated and a 50 % reduction over the conventional system was estimated.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Izvorni znanstveni rad
Original scientific paper

NUMERICAL SIMULATION OF FAN AND PAD EVAPORATIVE COOLING SYSTEM OF AN EXPERIMENTAL GREENHOUSE WITH TOMATO CROP

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SUMMARY

Aim of the study is to develop a methodology approach in order to simulate numerically (CFD) a greenhouse equipped with fan and pad evaporative cooling system. The main aspects of evaporative cooling systems in terms of heat and mass transfer are presented. The flow and boundary conditions are identified integrating both the external and internal climatic conditions. The crop (tomato) was simulated using the equivalent porous medium approach by the addition of a momentum source term, due to the drag effect of the crop, to the standard fluid flow equations. In addition, preliminary calculations were carried out in order the pressure drop, occurred in crop model due to air flow, to be determined as a function of leaf area and stage of crop growth. The water rate in pad, the temperature and humidity of incoming air and the operational characteristics of fans were specified to set up the CFD model. The numerical analysis was based on the Reynolds-averaged Navier-Stokes equations in conjunction with the realizable k-ε turbulence model. The finite-volume method (FVM) was used to solve the governing equations on the computational grid of a 3D full scale model. In computation, several differencing schemes of various orders are outlined and their accuracy is examined. Finally, the simulation approach was used mainly to identify the critical parameters of microclimate of greenhouse and the regions were these have to be measured during the upcoming experiments which will take place in Farm of Aristotle University of Thessaloniki. Results show the influence of the different airflow rates on greenhouse microclimate, indicating that the proper choice of ventilation rate is crucial factor in order to improve the efficiency of evaporative cooling systems. The numerical model is proved to be a *useful tool in order to study the performance of cooling pad systems for rational greenhouse design.*

***Key words**: CFD, evaporative cooling system, ventilation rate, greenhouse*

INTRODUCTION

The current trend in greenhouse cultivation is to extend the production season, in order to maximize the use of greenhouse equipment, extend the export season, increase the annual yield per unit area and increase the profitability. Nevertheless, in many Mediterranean greenhouses such a practice is limited because the cooling method used (mainly ventilation and shading) does not provide the desired conditions, especially during the hot summer months.

Natural ventilation and roof shading are the most common techniques. Ventilation reduces greenhouse overheating, but it may even enhance the risk of water stress because it often increases crop transpiration (Seginer, 1994). Kittas et al (2001) reported that high ventilation rates were not, a priori, the best solution for alleviating crop stress in greenhouses during summer conditions. Shading screens mounted externally or internally, may be used to reduce radiation inside the greenhouse but the effective temperature reduction is not really proportional to the shading rate. Willits and Peet (1993) showed that externally mounted black polyethylene films were less than 50% effective in reducing energy and temperature gains compared to their commercially given values, while white shading cloths were only slightly more effective.

If the greenhouse air temperature has to be kept near or below outside ambient temperatures, some form of cooling must be provided. Evaporative systems for cooling greenhouses have been developed to provide the desired growing conditions in the greenhouse during the hot period of the year. These systems are based on the conversion of sensible heat into latent heat. It can be done by spraying water droplets in a naturally ventilated building (by low or high pressure fog systems), or by forcing ambient air through wet pads. Both produce a temperature drop with an absolute humidity rise in the greenhouse, which contributes to decrease the vapour pressure deficit and moderate the transpiration demand (Katsoulas et al., 2001). Various works on evaporative cooling systems applied to horticulture, mainly fog systems, were already published, and, among others, those by Montero et al. (1981, 1990) and Giacomelli et al., (1985). Most of these works analyse the thermodynamic efficiency of the system and its climatic effects. Seginer (1994) found that evaporative cooling systems are mainly effective when crop transpiration is low, and Fuchs (1993) reported that a highly transpiring crop combined with a proper ventilation rate is the most effective mechanism to keep leaf temperatures moderate. A theoretical study was conducted by Arbel et al. (1999) to evaluate an evaporative cooling system for greenhouses by installing uniformly distributed fog generating nozzles in the space over the plants. Landsberg et al., (1979), proposed a theoretical model for the efficiency of evaporative cooling in different physical conditions and Bowen ratios. One limitation of this model is the a priori specification of the sensible heat to latent heat ratio rather than its deduction from actual crop behaviour. Moreover, this model was not tested against experimental data. More recently, Willits (2000) proposed a model to predict air and crop temperatures as a function of ventilation rate and external temperature and Kittas et al. (2003) present and validate a model to predict temperature gradients in an large evaporative cooled greenhouse.

The advantages of this method lie in its simplicity of operation and control and also in that it does not entail any risk of wetting the foliage. The main disadvantages are high cost and lack of uniformity of the climatic conditions which expressed with large temperature and humidity gradients along the greenhouse (from evaporative pads to extracting fans). The amplitude of such gradients is affected by many factors such as the geometry of the greenhouse, the outside climate conditions, the ventilation rate of the extracting fans and the flow rate of the water in the evaporative pads. In order to determine the influence of each parameter experimental investigations could be carried out, but these would be very expensive in time and money. Moreover it is very difficult to give fairly identical and stable boundary conditions in a field experiment, due to unstable and unpredictable weather conditions. Dynamic (Landsberg et al., 1979) or analytical models (Kittas et al., 2003, Willits 2003) can be used alternative for this purpose. Recent progress in flow modeling using computational fluid dynamics is also a good alternative. Computational fluids dynamics is an advanced technique for design in engineering; it is increasingly being used to analyze greenhouse microclimate with respect to structural specifications (Boulard and Wang, 2002; Bartzanas et al., 2004).

Aim of the present study was is to develop a methodology approach in order to simulate numerically (CFD) a greenhouse equipped with fan and pad evaporative cooling system in order to identify the critical parameters that affect the efficiency of fan and pad evaporative cooling systems in greenhouses. The next step will be the experimental verification of the proposed numerical model and the comparison of the numerical results with the results obtained by previous developed and experimentally tested analytical model (Kittas et al., 2003) which considered the greenhouse as a heat exchanger.

MATERIALS AND METHODS

The CFD technique numerically solved the Navier-Stokes equations and the mass and energy conservation equations. The three dimensional conservation equations describing the transport phenomena for steady flows in free convection are of the general form:

$$\frac{\partial(U\Phi)}{\partial x}+\frac{\partial(V\Phi)}{\partial y}+\frac{\partial(W\Phi)}{\partial z}=\Gamma\nabla^2+S_\Phi \tag{1}$$

In Eqn (1), Φ represents the concentration of the transport quantity in a dimensionless form, namely the three momentum conservation equations (the Navier-Stokes equations) and the scalars mass and energy conservation equations; U, V and W are the components of velocity vector; Γ is the diffusion coefficient; and SΦ is the source term. The governing equations are discretised following the procedure described by Patankar (1980). This consists of integrating the governing equations over a control volume.

The commercially available CFD code Fluent® (1998) was used for this study. Fluent® code uses a finite volume numerical scheme to solve the equations of conservation for the different transported quantities in the flow (mass, momentum, energy, water vapour concentration). The code first performs the coupled resolution of the pressure and velocity fields and then the others parameters, like temperature or water vapour concentration. Special items like the mechanical or climatic behaviour of the rows of tomato crop are determined using a customization, i.e a routine included in a used defined file (UDF) and built for the determination of the parameters exclusively relevant to the vegetation. The domain of interest was generated and then meshed using the integrated pre-processor of Fluent, Gambit.

The grid structure was an unstructured, quadrilateral mesh with a higher density in critical portions of the flow subject to strong gradients. The mesh consists of 53920 cells for the half of the greenhouse, as a geometrical symmetry of the model allows solving the model symmetrically. After several tries with different densities, the calculations were based on a 15 m (in x direction) by 8 m (in y direction) by 4.17 m (in z direction, ridge height of greenhouse) grid (Fig. 1). This results from an empirical compromise between a dense grid, associated with a long computational time, and a less dense one, associated with a marked deterioration of the simulated results. Moreover the grid quality was checked using as a criterion the EquiAngleSkew criterion (Fluent, 1998) and it was characterised as very good.

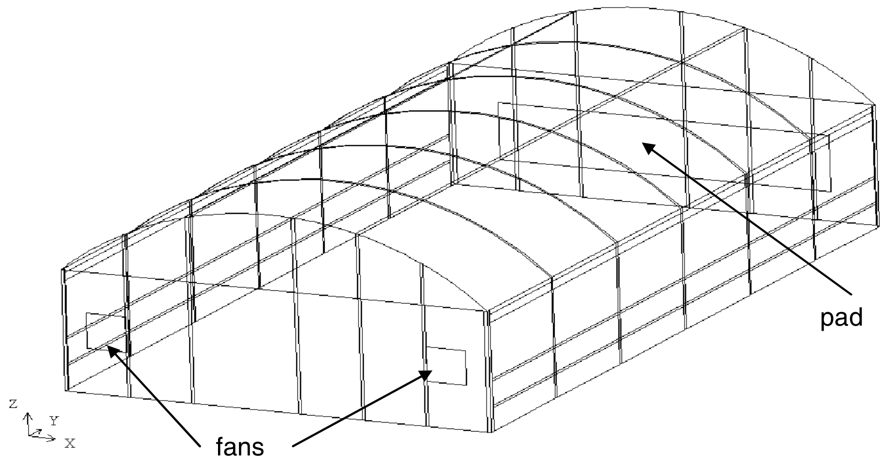

Figure 1 Wire-frame rendering of the greenhouse Computer Aided Design (CAD) model.

Wall type boundary conditions were imposed along the floor (39 °C), the roof (35 °C) and the side walls (35 °C). The classical no-slip boundary conditions are assumed for the walls. The standard *k*-ε model (Launder and Spalding, 1974) assuming isotropic turbulence was adopted in this study to describe turbulent transport. The species model was activated to account for the transport of air vapour inside the greenhouse. The crop was simulated using the equivalent porous medium approach (Boulard and Wang, 2002) by the addition of a momentum source term, due to the drag effect of the crop, to the standard fluid flow equations.

The simulation model was solved for three different ventilation rates corresponds to the air flow through the fans. The ventilation rates (m^3 h^{-1}) for the three tested cases were, 10600 (case 1), 7950 (case 2) and 5300 (case 3). The second cases correspond to the ventilation rate of the experimental greenhouse. For all the cases the external dry bulb temperature was 35 °C, the internal dry bulb temperature of the incoming air exactly after the pad was 27 °C, with mass fraction of water vapour of 0.0132 which leads to 59.80% air relative humidity. The imposed boundary conditions are the average daily values from measurements in the experimental greenhouse in a typical hot summer day.

RESULTS AND DISCUSSION

Numerical results show that the tested cooling system was able to keep the greenhouse temperature several degrees below outside air temperature for the three tested air flow rates of extracting fans. The highest the airflow rate the lower the air temperature increase the greenhouse. Mean air temperature inside the greenhouse was 30.5 °C for the lowest air flow rate and it was reduced to 29.6 °C and to 28.8 °C for the other two airflow rates. Although the length of the greenhouse it is no too long, important thermal gradients were observed in the direction for evaporative pads to extracting fans. Figure 2 shows the air temperatures along greenhouse length at the high of 1.0 m above the ground, in the middle of the greenhouse, for the three tested airflow rates: a gradual temperature rise, from the pads to the fans, reaches almost 6 °C when the lower airflow rate was used. A thermal gradient was also observed in the vertical direction, from greenhouse ground to greenhouse roof.

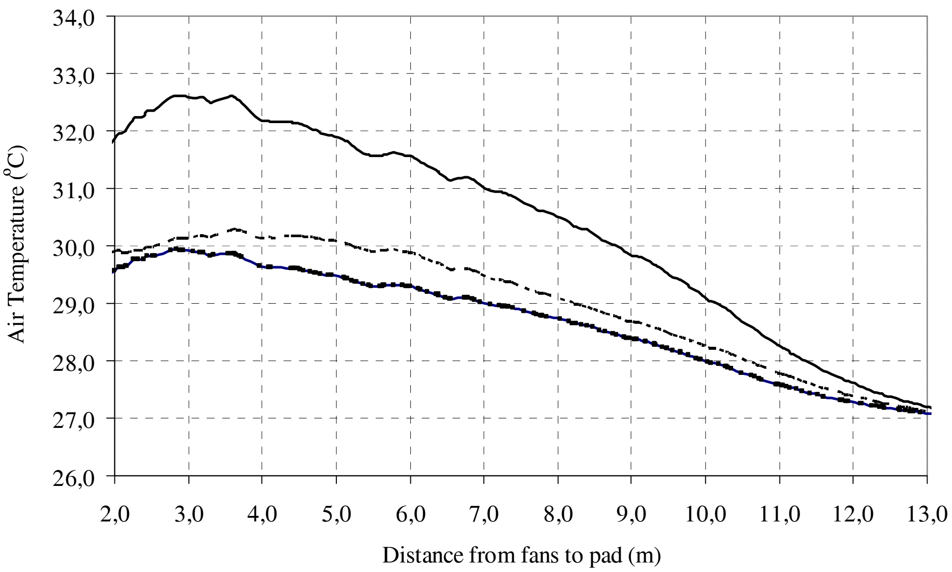

Figure 2 Air temperature distribution along greenhouse length at the middle of the greenhouse. —■—■— (case 1), - - - - - - (case 2) and —— (case 3).

However, the largest ventilation rates are not always the best solution to cool the greenhouse. The air velocity near the crop and the temperature difference that a given type can achieve must also be taken into account since these are important factors influencing the uniform growth of crop. Spatial heterogeneity of air velocity and climate inside greenhouse interfere with plants activity and influence largely crop behaviour through their effects on crop gas exchanges, particularly transpiration and photosynthesis. For instance increasing air velocity inside the greenhouse increases convective heat transfers and hence reduces the leaf – air temperature difference. Furthermore, air velocity might be expected to increase photosynthesis because of the reduced boundary layer resistance to the transport of carbon dioxide. Air velocity just after the evaporative pads was 0.8 m s^{-1} when the highest airflow rate was used and it was reduced to 0.6 and to 0.4 for m s^{-1} the other two airflow rates. Mean air velocity in the middle of the crop level was 0.52 with the highest ventilation rate and it was reduced to 0.35 and 0.18 with the other two used ventilation rates. Figure 3 presents the computed contours of air velocity when the highest ventilation rate was used.

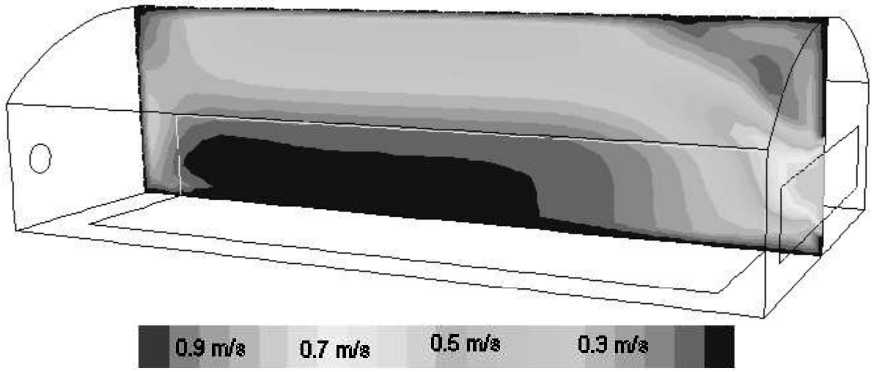

Figure 3 Computed contours of air velocity when the highest ventilation rate was used.

CONCLUSIONS

A CFD-based approach to numerically simulate a greenhouse equipped with fan and pad evaporative cooling system was presented in this paper. The influence of three different airflow rates of the extracting fans on air temperature and air velocity distribution inside the greenhouse was presented to demonstrate the capabilities of the numerical code to be used as a design tool in order to improve the efficiency of fan and pad evaporative cooling systems in greenhouses.

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35. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Expert paper

SURVEY OF THE PRESENT MECHANIZATION OF SMALL AND MEDIUM SIZE PLANT PRODUCTION FARMS

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SUMMARY

The participants of the Hungarian agriculture are faced by a great challenge in the coming years as they are to enter into competition with the producers of the European Community with their modern, substantially subsidized agriculture with significant capital adequacy in order to survive. The improvement of the production efficiency of the agricultural branch is, therefore, inevitable. Efficient mechanization is one of the means towards this aim.

The diversified property structure characteristic at present is not always coupled with efficient power and working machine system. In case of small size farming units the up-to-date, means and cost sparing solutions are rarely to be found and even the medium size farms do not necessarily own the efficient machine systems with all the technical-technological advantages of the present era furthering improvingly effective farming.

Considering the prevailing diversified property structure in the first phase of the research works the level of mechanization of the small and medium size farms acting in the different branches of crop production (arable farming, field vegetable growing, plantation) is to be estimated by means of questionnaires and personal interviews together with the characteristics of their machinery considering composition, function, modernity, working condition, utilization and value.

By the survey of small size farming units special emphasis is laid on the following points:

- *whether they have machinery of their own for carrying out the work operations of the production technology,*
- *which are the operations characteristically necessitating lease-work,*

- *and in case of over-mechanization which operations show a capacity surplus, i.e. a possibility for offering lease-work.*

The aim of the present research is to promote the cognition of the machine provision of small and medium size farms and their intention for improving mechanization and for investment on machines.

Key words: *Mechanisation of small and medium sized farms, optimal machine fleet, machine utilisation, machine investment and usage cost*

THE SURVEY METHOD

The first stage of the research work was gathering information on the form of farming (private entrepreneur, farmer, family enterprise, company, or farmer's co-operative), on the range of activity (arable farming, horticulture, fruit or vine growing, animal breeding), on the size of the cultivated area, on the production structure, on the buildings and storing sheds located in the farm, on the fleet of machinery and appliances, on the future intentions for improving the machine fleet as well as on the idle and narrow machine capacities by means of questionnaires.

Following the elaboration of the questionnaires personal visits have been paid to several farms covering a wide scale of different sizes and specific interviews made in order to obtain some personal knowledge of the level of the machine fleet applied to the given production structure, the possible ways of improving the machine fleet and the practice of machine use.

On the basis of the information gathered this way I am trying to introduce and systematize the prevailing practice of machine use. Besides improving effectivity and reducing the costs of machine use my aim is to develop a realistic machine use determined by the applied technology.

THE PRESENTATION OF THE PRACTICAL EXPERIENCES

It is characteristic of the past period that the possibility of *planned machine fleet improvement* was very limited due to the income circumstances of the farmers. In many cases they could not afford anything but the expansion of machine capacity bottleneck or the replacement of the most outworn machine. The gradual expansion of the rate of agricultural machine investment subsidisation offers the farmers an increasing possibility for the planned deliberate improvement of their machine system.

Thereinafter some farms active in different regions of the country where a larger scale development affecting mechanization has recently been realized will be presented. The chosen examples do not build a basis characterizing the whole branch but give a good demonstration of the present state.

The mechanization of the ***arable farms*** can well be demonstrated by the following examples.

- *In the small size category* a farm in ***Baranya county*** producing winter barley, winter wheat and soy on ***15 hectares*** has been surveyed where the main field cultivation works are done by a power machine type **LTZ 60AB** (*40 kW*).

Figure 1 The power machines applied in a 15 ha (left) and in a 70 ha (right) arable farming unit

The ***13,5 ha*** farming unit in the ***Jászság*** is dealing with grain and maize production and 30 % of the area is pasture. In this case the applied power machine is an elderly tractor type **MTZ-82** (*60 kW*) together with the most important connectable working machines and a trailer.

- As an example for *medium size farming units* a farm in the ***Kiskunság*** can be mentioned producing cereals and field vegetable on a territory of ***70 ha***. In addition to the old tractor type **MTZ-82** (*60 kW*) a newly purchased power machine type **MTZ-952** with a performance of *65 kW* together with the connecting working machines is also used for this activity as a result of planned improvement.

A ***Bácska*** farmer produces barley and wheat seed and sunflower on ***20 ha*** own and an additional ***20 ha*** hired land. At first a tractor type **MTZ-50** (40 kW) together with the necessary working machines had been used for all this but the increase of the hired area has made the purchase of an additional power machine, an **MTZ-82** with a performance of *60 kW* inevitable.

A farmer in ***Tolna county*** is active on ***50 ha*** arable land and about ***15 ha*** forest. In his production structure cereals, maize, sunflower and crucifer are to be found. His power machine fleet consists of 2 tractors type **MTZ-80** with a performance of *60 kW* and a self-propelled **Claas slaging machine**. As a new investment the machine fleet has been expanded by a grain harvester type **New Holland TC 56** in order to ensure that harvesting works are done in time and in acceptable quality.

Figure 2 Tractors type MTZ-50 and MTZ-82 with their working machines

- The ***Kiskunság*** farmer working on a ***281 ha*** area and cultivating an additional ca. ***50-60 ha*** for others in lease-work construction can be classified into the ***large-scale farm category***. This farmer has replaced his high-performance power machine type *RÁBA 250* used earlier by a power machine type **HTZ 17021** with a performance of *125 kW*, a sufficient capacity for the bulk of work to be done. Nevertheless, a power machine type **MTZ 80** with *60 kW* performance is also available for the crop cultivation works, but this capacity is not sufficient enough so he is planning to buy a new power machine with a performance of 80 kW in the near future. A **John Deere 2254** combine is available for the harvesting works. Loading and transporting tasks inside the farm are fulfilled by a telescopic loader type **John Deere 3200**.

An agricultural enterprise *in **North Hungary*** cultivating ***290 ha*** own area and an additional ca. ***30-40 ha*** in lease-work construction has chosen to apply a high capacity power machine type **Case IH Magnum 8930** with *160 kW* performance for carrying out the more energy demanding cultivation works due to the less advantageous relief conditions. Nevertheless, a **Fiatagri** tractor with a performance of *80 kW* and two power machines type **MTZ 80** are also available. After their rejection the latter two will be replaced by a newly purchased power machine type **MTZ 82 EU** representing the *60 kW* category. An "elderly" grain combine harvester type **Class Dominator 108** is also part of the system as a harvesting machine.

The agricultural entrepreneur in ***Pest county*** has one power machine type **Valtra/Valmet 8950** with a performance of *120 kW* and another one type **Valtra/Valmet 8400** with a performance of *100 kW* for carrying out the cultivation works on his ***298 ha*** farm with a classic sowing structure (cereals, maize, sunflower) and on the additional ***150-170 ha*** territory cultivated in lease-work construction. Furthermore, three power machines type **MTZ 80** are used for crop cultivation works. These are partly outworn so the rejection of part of them is timely. For grain harvesting one combine harvester type **Claas Mega 204** is available with a sufficient capacity for fulfilling the incurring tasks. Transport works are also done by the tractors. A storing hall is used for storing the produce. The low moisture content of the produce is ensured with the help of a recently created ***cleaning and drying plant***.

Figure 3 Modern machine fleet applied on a large-scale farm

The farmer visited in the ***Közép-Duna region*** has a ***151 ha*** area and offers substantial lease-work services additionally, cultivates totally about ***500-550 ha*** annually. For this activity he has a newly purchased power machine type **John Deere 8210 RT** with a performance of *160 kW* intended for fulfilling the tasks arising from the planned expansion of the lease-work services. Furthermore, one tractor type **MTZ 920** and two old **MTZ 82** type ones in poor technical conditions are available on the farm. These could reasonably be replaced by one new power machine of the 80 kW performance category. Harvesting capacity is ensured by a combine harvester type **John Deere 9640 WTS**. The major part of the transport is done by a lorry type **IFA W 50 L**.

The farmer in the ***Bácska*** cultivating about ***850 ha*** has a tractor fleet representing all performance categories: **New Holland 8870** (*160 kW*), **Fiatagri 180-90 DT** (*135 kW*), **Massey Ferguson 2680** (*90 kW)*, and two **MTZ 82-s** (*60 kW*) in poorer technical conditions. Harvesting works are done by two elderly **Claas Dominator 108** and two, already less foolproof lorries type **IFA W 50 L** are available for fulfilling the transport tasks.

The produced substantial quantity of produce is dehydrated with the help of a *grain drying and seed cleaning plant* established as a new investment, and further free drying capacity is offered to the farmers in the neighbourhood.

Figure 4 Up-to-date grain cleaning and drying plants

In order to demonstrate the versions of mechanization I would mention the following of the farms dealing in ***plantation and vine growing***:

A ***7 ha*** vine growing farm in the ***Homokhátság*** where cultivation works are done by an old power machine type **Zetor 50** (*35 kW*) with the connecting also outworn appliances.

The mechanization of the ***10 ha*** plantation consisting of vine, apricot, plum and sour cherry in ***Baranya county*** is excellent as there are modern working machines: a KT-2 disc, a SAE Turbomatic-1000 plantation sprayer, a Selvatici hole borer, an AP 801 trailer, and a hoeing machine type OMMAS connectable to the power machine **MTZ-82** (*60 kW*).

The farmer in the ***Bácska*** working on ***2 ha*** plantation and about ***7 ha*** arable land at present intends to extend the area of the plantation with and additional ***8 ha***. The technical conditions are given for this. There is a plantation tractor type **John Deere 5500 N** (*59 kW*) available on the farm and the connectable working machines: an offset rotary hoe type Calderoni FPS 90, a plantation sprayer type Hardi and an RZ-3 forage crusher are also up-to-date.

Another farmer also in ***Baranya county*** produces apricot, plum, elderberry and almond on ***12,8 ha***. The power machine applied is a newly purchased small tractor type TT-826 with a performance of *20 kW* well applicable on sloping area as well, equipped with all the connectable working machines and a trailer necessary for the technology.

Figure 5 The power- and working machine fleet of a farmer producing kernel fruits on 12 ha

The ***11 ha*** vine growing farm in the ***Kunság*** is also provided with modern machines. Their power machine is a plantation tractor type **Antonio Carraro TRF 8400 AC** (*50 kW*) and among the connectable appliances the trailer type AP 206, the Nobili Alfa plantation sprayer the TB 2.0 disc cultivator, the row bed rotary cultivator type Baiano and the fertilizer broadcaster Faza 300 are worth mentioning.

Figure 6 A 20 ha fruit growing farm with modern mechanization

The mechanization of the ***20 ha*** apple plantation in the ***Homokhátság*** is outstanding. The connected appliances of the up to date power machine type **John Deere 5500 N** (*59 kW*) are: PSZE-F-12,5 trailer, Calderoni TSC-150 rotary tiller, fork lift type Calderoni CHP-15 which can be fitted on a tractor, SAE Turbomatic 1000 plantation sprayer, etc. A ULO system colsdstore is available for fruit storage.

The mechanization and technical provision of the farming unit in ***Pest county*** producing apple and apricot on a ***76 ha*** plantation which may as well be called a large scale enterprise in case of a plantation is outstanding as besides the machines necessary for cultivation the means of produce manipulation and grading are also available and the storing capacity of the ULO system coldstore ensures the possibility of integration.

Figure 7 Old power machines already used for loading and transport works (loading bales) inside the farm only

Regarding the technical standard i.e. modernity or datedness of the applied machines a wide range of different varieties can be observed.

Some of the farming units subject to the survey have as a result of a new investment a modern machine fleet regarding both power- and working machines, but according to the experiences in many cases outworn sometimes even more than 30 years old power- or working machines are used (**Figure 7**). These power machines are already free of amortization costs their utilization costs are, therefore, very low. In a professional respect the use of them can be justified by the fact that they are good for fulfilling certain tasks inside the farm even in a less foolproof condition. But the real reason of their existence is the lack of capital.

OBSERVATIONS

A machine system optimally sized in view of cost or other parameter vitally important in respect of machine utilization is not or hardly to be found by the agricultural enterprises developed in the nineties. It can be explained by the imperative and *ad hoc* mechanization taking place in the nineties when the machines of the parting farmers' co-operatives were available at a very advantageous price. Accordingly, MTZ the former universal tractor of large scale farms and Rába 250 the high performance soil working machine have become the most frequently used tractor types of the certain farms. Broken into pieces the machine system of the former large scale enterprise was no longer adequate for the system approach mechanization of the numerous small and medium size agricultural enterprises. The power machine type Rába 250 has proved to be too big in relation to the capacity demand of the small and medium size farms. (A proof of this is the event in *Kiskunság*.) Mechanization can be realized in a cost sparing way if the gradually deteriorating MTZ power machines are replaced by power machines of appropriate technical standard and of a performance level determined by the size of enterprise a wide selection of which representing all performance categories are offered on the domestic market by several international producers. (A proper example for this is the farming unit *in North Hungary* where the two MTZ 80 tractors will be replaced by one MTZ 82 EU, or the one in *Közép-Duna region* where the two MTZ 82 power machines will be replaced by one tractor with a higher capacity.)

A more favourable tendency can be observed in the mechanization of the surveyed plantation farms. In many cases modern plantation tractors adequate for the task are available which power machines have many technical advantages in relation to the classical T-25 or MTZ-50 tractors used for fruit cultivation earlier. They are developed according to the demands of ergonomics and labour safety.

Regarding enterprise size categories it can be stated that in case of ***field crop growing*** one power machine is adequate for fulfilling the necessary tasks up to an area size of about *30 ha*. Within this category the tasks on a ***10-15 ha*** farm can be satisfactorily fulfilled by a lower performance (40 kW) tractor, though this performance category is not optimal for the harder soil works, while those cultivating nearby ***30 ha*** need a more powerful (60 kW) power machine. The farms working on ***40-50 ha*** generally have two power machines. These are most frequently the variations of the popular MTZ type tractors with a performance of about 60 kW.

Regarding the upper limit (***300 ha***) of medium size enterprises the power machine provision of the farms can be characterized by a higher capacity tractor with a performance of about 130-160 kW depending on soil structure and the nature of work. This is supplemented by an 80 kW and a 60 kW power machine. In this size category an own harvesting machine is also frequently available.

By the enterprises operating on a farm size of ***500 ha*** or more several different performance categories can be found. The chief machine with a performance of about 160 kW is also characteristic and it may be supplemented by a 80 or 100 kW tractor and the machine fleet also includes a further 2-3 generally MTZ type tractors depending on technical level. The more efficient fulfilment of transportation tasks is ensured by a lorry.

In case of a nearby ***1000 ha*** enterprise the performance categories are clearly differentiated. In order to ensure the workmanlike fulfilment of the different operations and the optimal division of labour on this size category 160, 130, 90, and 60 kW tractors are also available. The number of harvesting machines is also two at least depending on the capacity.

By all the ***plantation farms*** surveyed the size of which was between **10-20 ha** the machine fleet was based on one power machine. There were differences in the type and the structural set-up of the power machine determined by the financial possibilities and the relief- and cultivation conditions. Their performance varied between 20-60 kW.

CONSEQUENCES

It is clear also on the basis of the surveyed farms that the mechanization solutions of agriculture are in a transition period. The old dated solutions will gradually be replaced by new ones. The agricultural entrepreneurs are trying to favour the system approach low cost investments by their *improvements*. It must be kept in mind that economic optima can only be established or reached in case of a conscious improvement of mechanization.

The theoretically grounded results, consequences and the analysis of the present state emphasize the future tasks at the same time. The professional and financial conditions enabling the entrepreneurs to make their improvements more conscious must be made available for them.

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