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PREFACE

After the successful First International Symposium on Agricultural Engineering ISAE 2013, that was held in Belgrade from 4th to 6th of October, 2013, thanks to our colleagues we are organizing The Second International Symposium on Agricultural Engineering – ISAE 2015. Together with the University of Basilicata, School for Agricultural, Forestry, Food and Environmental, Sciences (Potenza, Italy), University of Sarajevo, Faculty of Agricultural and Food Sciences (Sarajevo, Bosnia and Herzegovina) and thanks to the Ministry of Education, Science and Technological Development, Republic of Serbia, support of the EurAgEng and the AMAPSEEC, and sponsor and donors, we have managed to organize the presentations of the 41 papers that were submitted to the Scientific Committee of the ISAE 2015 Symposium. We have arranged them in to eight sections and categorized them as Original scientific papers, Scientific review papers, Firs (short) communications, Case studies, Professional (Expert paper) and Popular papers. All papers within the Proceedings of the ISAE 2015 were reviewed by the members of the Scientific Committee and kind assistance of some members of other Conference bodies. However, the Scientific Committee of the ISAE 2015 agreed on issuing of group of papers whose authors either haven’t referred on reviewer’s comments or those which weren’t reviewed as submitted after the proposed deadline. However, it was decided to include them as well, considering the subjects and research approaches interesting.

Book of Proceedings of the ISAE 2015 International Symposium has 383 pages and it is organized in eight thematic sections. Section I – Crop, Fruit and Vegetable Production Systems (12 papers); Section II – Livestock Farming Systems and Equipment (2 papers); Section III – Power and Machinery; Diagnostics and Maintenance of the Agricultural Machinery (2 papers); Section IV – Post Harvest Technology, Processing and Logistics; measuring, Sensing and Data Acquisition in Agriculture (6 papers); Section V – Information Systems and Precision Farming; Modelling, Predicting and Optimal Control in Agricultural Engineering (8 papers); Section VI – Soil and Water Use and Environment (6 papers); Section VII – Energy, biomass and bio recourses in Agriculture (3 papers); Section VIII – Agricultural Policies, Sustainable Agriculture, ergonomics and Safety in Agricultural Machinery Exploitation (2 papers).

We wish to thank to all the authors for their contribution to the ISAE 2015 Symposium and to the all the Institutions, Associations, Universities, Sponsors and Donors for the contribution in ISAE 2015 Symposium organization.

CONTENTS

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First (Short) Comunication

ENERGY EFFICIENCY AND LABOUR PRODUCTIVITY OF NON-CONVENTIONAL SOIL TILLAGE SYSTEMS IN OILSEED RAPE AND WINTER BARLEY PRODUCTION

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Abstract. *Short-term study of non-conventional soil tillage systems was conducted at the experimental field near Štivica (45° 09' N, 17° 31' E) on hypogley-vertic type of soil and semi humid climate conditions. Oilseed rape (Brassica napus L.) and winter barley (Hordeum vulgare L.) were cultivated within four soil tillage systems: CT – mouldboard plough, disc harrow, seed-bed implement, drill, NcT1 – chisel plough, disc harrow, seed-bed implement, drill, NcT2 – chisel plough, rotary harrow integrated with seed drill, NcT3 – mouldboard plough, rotary harrow integrated with seed drill. As the efficiency indicators of different tillage systems the following parameters were observed: energy requirement, work rate and grain yield. Substitution of mouldboard plough with chisel in primary tillage (NcT1 and NcT2) provided substantially lower fuel consumption in those tillage systems than in CT, and in consequence, the specific energy efficiency were improved compared to conventional tillage. Labour requirement comparison also shows that those tillage systems were much more productive than conventional tillage. The average yields in non-conventional systems, with the exception of NcT3 in oilseed rape production, were not impaired by reduction of soil tillage and, therefore, proved that non-conventional tillage systems are not inferior to conventional tillage and could be an important tool to improve energy efficiency and labour productivity in oilseed rape and winter barley production.*

Key words: *soil tillage, specific energy, productivity.*

1. INTRODUCTION

Soil tillage predominates as the most energy and labour consuming field operation in arable crop production. More than half of direct energy (or fuel consumption) utilised from soil preparation to harvest was accounted to the soil tillage when conventional tillage system practised, in which case the primary tillage require up to 65% of total energy utilised before seeding [13]. The long term application of conventional tillage showed significant economic and environmental drawbacks. From an economic point of view disadvantages of conventional tillage systems are high energy and labour, large investment and maintenance costs of machinery, and ultimately higher costs of crop production. According to some European researches [18, 19] conventional tillage system requires 434 kWh ha^{-1} of energy and 4.1 h ha^{-1} human-machine work. In contrast, reduced tillage systems can bring about 30-40% savings of the energy and human-machine work, and direct sowing as much as 90%, compared with conventional tillage [10]. From an ecological point of view disadvantages of conventional tillage systems are increased soil compaction caused by excessive number of machinery passes, systematic reduction of soil organic matter (humus content) as a result of intensive and frequent tillage and the greater the susceptibility to soil erosion. A significant CO_2 emissions from the combustion of large amounts of fuel consumed in the intensive tillage is also an environmental issue [7].

The leaders in substitution of conventional tillage systems with different variants of reduced tillage and direct sowing in the world are the United States and Canada in North America and Brazil, Argentina, Uruguay, Paraguay in South American where conservation tillage and no-tilll system used on more than half of the total agricultural area [4]. The share of agricultural land in Europe under some system of reduced tillage has not been significantly increased until recent, and it is estimated that there are still less than 20% [5]. Despite knowledge of the possibilities of energy and labour savings by means of reducing the soil tillage, conventional tillage system is dominant in Croatia. In the main arable crop production regions in Croatia, Slavonia and Baranja, conventional tillage system is applied on the majority (over 90%) of arable land [20].

Previous studies suggest that reduced tillage is favourable for high density crops such as wheat, barley and canola, while much worse option for row crops such as corn and soybeans [7, 13, 16]. While some authors [2] have noticed a decrease of yield of some cereals with the degree of tillage reduction (14% lower average yields at a reduced tillage and 27% lower in direct drilling), others claim that there is no significant difference in yields between different tillage systems [12].

Reduced tillage systems, specific to sustainable agriculture, require productivity at least equal to that of conventional technology, optimized energy efficiency and, at the same time, diminished environmental impact. Taking into account these requirements, the main objective of this study was to determine the opportunities for energy efficiency and labour productivity improvements of soil tillage in arable crop production.

2. MATERIAL AND METHODS

The experiment was performed at agricultural company “PK Nova Gradiška” near village Štivica, located 150 km south-east from Zagreb (45° 09’ N, 17° 31’ E). Experimental field consisted of 12 plots with dimension length 185 m x width 54 m each, organized as randomized blocks with three replications.

The tillage with different systems was performed on the Hypogley-vertic type of soil [16] and its texture in ploughed layer belongs to the silty clay loam (Table 1). The climate in this area is semi-humid with a total annual precipitation of 776 mm and an average annual temperature of 11.0 °C (source: Meteorological and hydrological institute of Croatia).

Table 1 Soil particle size distribution.

Depth, cm	Particle size, %				Texture[1]
	0.2-2 µm	0.05-0.2 µm	0.002-0.05 µm	<0.002 µm	
0-30	16.0	28.0	22.0	34.0	SiCL
30-60	13.0	32.0	26.0	29.0	SiCL-SiL
60-90	13.0	31.0	28.0	28.0	SiCL

[1] SiCL = Silty clay loam, SiL = Silty loam

Implements, which were included in different tillage systems, are as follows:
Conventional tillage – mouldboard plough, disc harrow, seedbed implement, drill (CT);
Non-conventional tillage 1 – chisel plough, disc harrow, seedbed implement, drill (NcT1);
Non-conventional tillage 2 – chisel plough, rotary harrow with integrated drill (NcT2);
Non-conventional tillage 3 – mouldboard plough, rotary harrow with integrated drill (NcT3).

In this experiment a 4WD tractor with engine power of 136 kW was used for all tillage operations. The working width of the tillage implements (Table 2) was chosen according to the pulling capacity of the tractor.

Table 2 Soil particle size distribution

Field operation	Tractor	Implement	Working width (m)
Ploughing	JD 7820	Kuhn Multimaster 151	1.40
Chiselling	JD 7820	Agram GeoDec SVD-306	3.20
Discharrowing	JD 7820	Kuhn Discover XM 44/660	5.50
Seedbed preparation	JD 7820	Lemken Korund 750L	7.50
Sowing	JD 3650	Tive 901	6.00
Harrowing+Sowing	JD 7820	Kuhn Integra 3000	3.00

Energy requirement of each tillage system was determined based on the tractor's fuel consumption. Energy equivalent of 38.7 MJ L^{-1} was presumed [1]. The amount of fuel consumed was measured for each implement during tillage and sowing on each plot. On plots where chisel was used the primary tillage were done to the same depth as with mouldboard plough (approx. 30 cm). Due to the fact that in NcT2 and NcT3 systems the sowing was done along secondary tillage in single pass, the energy consumption for sowing was also added to CT and NcT1 systems.

The labour requirement was determined by measuring the time for finishing single tillage operation at each plot of the known area. The yields were determined by weighing grain mass of each harvested plot, and recalculated according to storage grain moisture content. Schedule of the field operations (tillage, fertilizing, sowing, crop protection, harvesting) and soil moisture content at the moment of tillage are shown in Table 3. On the experimental field previous crop was winter wheat. Fertilization and crop protection was uniform in all systems, determined by crop specific nutrient requirements and pest occurrence.

Table 3 Date of field operations and application rates

Description	**Oilseed rape**	**Winter barley**
Tillage & Sowing		
Primary tillage	July 7th 2013	October 14th 2014
Soil water content (%) at 5; 15; 30 cm depth	32.3; 34.9; 43,3	39.2; 51.6; 49.8
Secondary tillage	September 3rd 2013	November 15th 2014
Soil water content (%) at 5; 15; 30 cm depth	20.2; 42.0; 41.7	37.7; 54.4; 54.4
Sowing date	September 3rd 2013	November 15th 2014
Crop-cultivar (kg ha^{-1})	Extrom (2.9)	Barun C1 (200)
Fertilizing		
Application date	August22nd 3013	October 13th 2014
Fertilizer (kg ha^{-1})	MAP 12:52 (200) KCl 60 % (100)	MAP 12:52 (200); KCl 60% (100); Urea 46% (50)
Application date	February 18th 2014	February 20th 20015
Fertilizer (kg ha^{-1})	CAN 27% (250)	CAN 27% (200)
Application date	March 15th 2014	April 4th 2015
Fertilizer (kg ha^{-1})	Urea 46% (300)	Urea 46% (150)
Crop protection		
Application date	September 3rd 2013	February 22nd 2015
Chemical-rate (l ha^{-1})	metazaklor+klomazon (1.9+0.2)	triasulfuron (0.045)
Application date	October 20th 2013	April 14th 2015
Chemical-rate (l ha^{-1})	quizalifop p tefuril (1.0)	epoksikonazol+krezoksim-metil (0.8)
Application date	March 21st 2014	April 15th 2015
Chemical-rate (l ha^{-1})	klorpirifos+cipermetrin (0.9)	pinoksaden (0.7); tribenuron methyl (0.012)
Application date	April 7th 2014	May 4th 2015
Chemical-rate (l ha^{-1})	boskalida+dimoksistrobin (0.5)	azoksistrobin+klortalonil (2.5)
Harvest		
Harvesting date	July 1st 2014	June 26th 2015

The climate conditions during these field trials were favorable for growing rapeseed and barley. Mean monthly air temperatures matched the long-term averages, with a sufficient amount of precipitation during the growing season which is evident from Walter climate diagram (Figure 1).

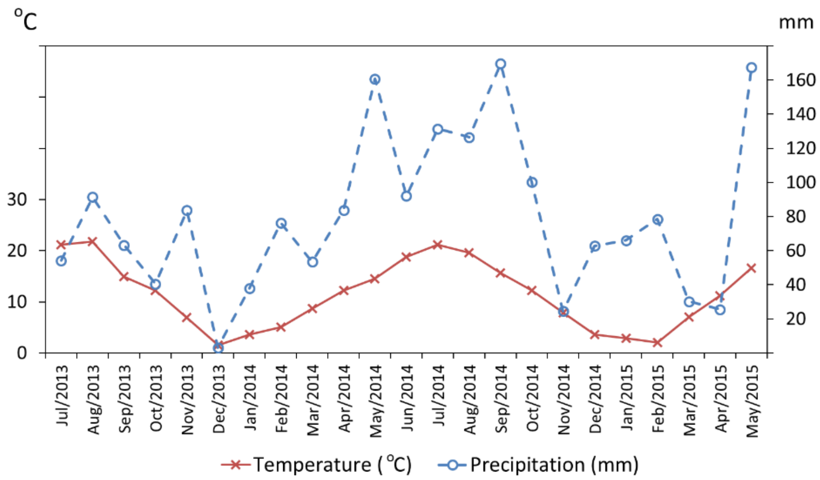

Fig. 1 Walter climate diagram for oilseed rape and barley cropping period.

Statistical analysis of data was done with computer program SAS [14] using analysis of variance (ANOVA). The significance of differences between the observed parameters were indicated by F-test at the level of probability p = 0.05.

3. Results and discussion

3.1. Yield

In oilseed rape production the greatest average yield of 3.87 t ha^{-1} was achieved by conventional soil tillage system (CT) followed by NcT2 with average yield of 3.61 t ha^{-1} and NcT1 with 3.53 t ha^{-1}. The lowest average yield was obtained with NcT3 system 3.36 t ha^{-1}, which is 13 % lower than CT. According to ANOVA, differences of average oilseed rape yields obtained by different soil tillage systems were statistically significant between CT and NcT3, at probability level of $p<0.05$, while NcT1 and NcT2 yields were not significantly different to other tillage systems. In the cultivation of winter barley there were no significant differences in yields achieved on different soil tillage systems. The highest average yield of 5.47 t ha^{-1} was obtained with NcT1 system, while the lowest average yield of winter barley was on NcT2 system 5.28 t ha^{-1}.

3.2. Energy efficiency and labour productivity

Soil tillage with mouldboard plough was expectedly the most energy and labour consuming task, and has largely contributed to high fuel consumption in tillage systems where was applied (Table 4). In oilseed rape production the greatest fuel consumption in soil tillage was recorded in CT system 42.7 L ha^{-1}. NcT3 system enabled 15.2 % saving and NcT1 16.8 % saving of fuel compared to conventional tillage. The greatest energy saving per hectare (24 %) in oilseed rape production was obtained by NcT2 system. Similar trends regarding energy consumption were noticed also in winter barley production where the share of fuel used for primary tillage ranged from 48 % for chiselling in NcT1 to 67 % for ploughing in NcT3 system, of total energy used for tillage and sowing.

Comparing these data to other researches, some variations could be expected due to different soil types, field conditions and machinery and equipment used. For example, Filipović et al. [6] reported 42.1 L ha^{-1} fuel consumption in conventional tillage system, 30.5 L ha^{-1} in tillage system similar to NcT1 and 36.9 L ha^{-1} in system similar to NcT2 in this research, while Košutić et al. [9] reported 46.9 L ha^{-1} in CT system and 29.3 L ha^{-1} in NcT1 resembling system. Both mentioned studies were conducted on silty-loam, therefore a somewhat lighter texture soil.

Specific energy requirements for different soil tillage systems varied due to wide range of yields obtained for crops cultivated, but a decrease of energy demands with reduction of soil tillage is clearly noticeable. In oilseed rape production the greatest specific energy consumption of 426.7 MJ t^{-1} was recorded in conventional tillage system as a consequence of highest fuel consumption, in spite of the highest average yields obtained. Tillage system NcT3 with 15.2 % lower fuel consumption provided only 2.3 % lower specific energy, due to significantly lower yields. In contrary, in tillage systems where average yields were on par with conventional system, considerable savings were achieved, 8.6 % less specific energy requirement in NcT1 and 18.4 % less in NcT2 compared to CT. Similar trends regarding specific energy consumption were noticed also in winter barley production where achieved savings varied from 7.4 % in NcT3 tillage system 43.3 % in NcT2 compared to highest specific energy (362.4 MJ t^{-1}) recorded in CT.

Productivity of different soil tillage systems have been calculated both considering the time required per hectare and in respect to obtained yields. Conventional tillage (CT) was the most time consuming system with 2.05 h ha^{-1} spent in oilseed rape production, while in winter barley the highest overall value was recorded in NcT3 system, 2.56 h ha^{-1} or 9.1 % more than for conventional tillage. The most efficient tillage systems were NcT1 and NcT2, in both growing seasons. Achieved saving of time required for soil tillage and sowing of oilseed rape were 37.8 % in NcT1 and 39.7 % in NcT2, while in winter barley production NcT1 system consumed 32.7 % less and NcT2 system 32.0 % less time per hectare compared to conventional tillage.

Similar relations are noticeable in productivity per ton of grain yield, where NcT3 required 0.56 h t^{-1}, or 6.0 % more than CT system in oilseed rape production, and 0.48 h t^{-1} in winter barley, or 9.3 % more than conventional tillage. Again the most efficient systems were NcT1 and NcT2, with 31.7 % (NcT1) and 35.3 % (NcT2) higher productivity than CT in oilseed rape, while in winter barley NcT1 system was 34.2 % and NcT2 31.1 % more productive compared to conventional tillage. Coicu [3] and Košutić et al. [11] also highlighted a significant increase in labour productivity with degree of soil tillage reduction, realised through adequate tillage systems where yields were not impaired.

Table 4 Energy and labour requirement of different soil tillage systems

Tillage system	Oilseed rape				Winter barley			
	Fuel L ha^{-1}	Energy MJ t^{-1}	Productivity h ha^{-1}	Productivity h t^{-1}	Fuel L ha^{-1}	Energy MJ t^{-1}	Productivity h ha^{-1}	Productivity h t^{-1}
CT	**Average yield = 3.87 t ha^{-1} a [(1)]**				**Average yield = 5.355 t ha^{-1} a**			
Plough	24.23	242.1	1.30	0.34	24.96	180.4	1.36	0.26
Disc harrow	9.76	97.5	0.33	0.09	12.82	92.6	0.33	0.06
Seed-bed implement	5.86	58.6	0.17	0.04	7.84	56.7	0.28	0.05
Drill	2.85	28.5	0.25	0.06	4.53	32.7	0.37	0.07
Total	**42.70**	**426.7**	**2.05**	**0.53**	**50.15**	**362.4**	**2.34**	**0.44**
NcT 1	**Average yield = 3.53 t ha^{-1} ab**				**Average yield = 5.474 t ha^{-1} a**			
Chisel	17.07	187.3	0.53	0.15	13.37	94.5	0.66	0.12
Disc harrow	9.76	107.1	0.33	0.09	9.35	66.1	0.27	0.05
Seed-bed implement	5.86	64.3	0.17	0.05	7.84	55.4	0.28	0.05
Drill	2.85	31.3	0.25	0.07	4.53	32.0	0.37	0.07
Total	**35.54**	**390.0**	**1.28**	**0.36**	**35.09**	**248.1**	**1.58**	**0.29**
NcT 2	**Average yield = 3.61 t ha^{-1} ab**				**Average yield = 5.279 t ha^{-1} a**			
Chisel	17.07	183.1	0.53	0.15	13.37	98.0	0.66	0.12
Rotary harrow + drill	15.38	165.0	0.71	0.20	14.64	107.3	0.93	0.18
Total	**32.45**	**348.1**	**1.27**	**0.35**	**28.01**	**205.3**	**1.59**	**0.30**
NcT 3	**Average yield = 3.36 t ha^{-1} b**				**Average yield = 5.348 t ha^{-1} a**			
Plough	24.23	279.0	1.30	0.39	24.96	180.6	1.37	0.26
Rotary harrow + drill	11.99	138.1	0.59	0.17	21.40	154.9	1.19	0.22
Total	**36.22**	**417.1**	**1.89**	**0.56**	**46.36**	**335.5**	**2.56**	**0.48**

[(1)] Different letters indicate significant ($p \leq 0.05$) differences

4. CONCLUSIONS

The results of this research reveal some important advantages of non-conventional tillage systems over the conventional tillage in arable crop production. Soil tillage systems greatly differ regarding energy requirement. Substitution of mouldboard plough with chisel in primary tillage (NcT1 and NcT2) provided substantially lower fuel consumption in those tillage systems than in CT, and in consequence, the specific energy efficiency was improved compared to conventional tillage. Labour requirement comparison also shows that those tillage systems were much more productive than conventional tillage with mouldboard plough.

Considering that the average yields in non-conventional soil tillage systems, with the exception of NcT3 system in oilseed rape production, were not impaired by reduction of soil tillage this short-term experiment showed that non-conventional tillage systems could be an important tool to improve energy efficiency and labour productivity in oilseed rape and winter barley production. In the selection of preferred soil tillage system, assuming uniform levels of yield, the advantage should be given to a system with lower level of tillage intensity in order to minimise energy and labour requirements.

In order to promote non-conventional tillage systems to a greater percent of acreage, further researches should be carried out to investigate the influence NcT systems in cultivation of spring crops like maize and soybean which are also represented in crop rotation on majority of arable land in Croatia.

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Case Study

OPTIMAL PROFILE OF ROTARY TILLER KNIFE FOR CONVENTIONAL ROTOR ROTATION DIRECTION

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Abstract. *Optimal profile of knife, in which all points of the profile enter the soil at the same place during tillage, was determined for the following design parameters of the rotary tiller: radius ($R = 0.25$ m) and angular velocity ($\omega = 16.038$ s^{-1}), and for soil tillage parameters: working depth ($a = 0.1$ m) and working speed ($v_m = 0.77$ m/s). The positions of the knife tip and every point of the knife were determined by parametric equations. First, the time interval in which knife tip reaches the critical point (soil surface) was determined. Also, the time intervals in which all points on the knife defined as X and Y with respect to the knife tip reach their critical point were determined. Equation which can describe optimal shape of knife profile can be obtained by equalizing the travelled distance in the x-axis direction of the knife tip with any other point on the knife profile. The curve, which represents the optimal shape of knife profile, was determined for the given parameters. If X is 30 mm, then Y is 7.164 mm, and if X is 60 mm then Y is 18.587 mm. The angle of inclination of the function Y(X) in the coordinate beginning (at the point of the knife tip) is 9.86^0.*

Key words: soil tillage, rotary tiller, knife profile (shape), parametric equation, nonlinear algebraic equation.

1. INTRODUCTION

The "L" type of knife of rotary tiller has three parts: the vertical part (frame), the curved part and horizontal cutting part (wing), [3]. The angle between rotor diameter and upper part of the knife (wing) is called the angle of knife position γ and its value is constant. When the angle of knife position γ is deducted from the angle between rotor diameter and tangent of the trochoide the cutting angle ε is obtained [4]. When the angle of knife position γ increases the cutting angle ε is reduced.

The cutting angle of the moldboard on ploughs, cultivator mattocks and other working bodies with rectilinear motion, ranges from 20 to 30° at minimal power [4]. The cutting angle ε of rotating working bodies constantly changes and its value is considerably higher which results in greater energy consumption when these bodies are employed. The risk of reducing the cutting angle ε and cutting resistance implies the possibility that the mattock can cut untilled part of the plot with its rear part.

Working speed of the implement, circumferential velocity of the rotor knife, working depth, number of rotor rotations, diameter and direction of rotation of rotary tiller rotor are the parameters which need to be used to define the angle of installation of knife wing γ [6, 7, 8].

A three dimensional simulation of motion of knife with different shapes and at different working regimes needs to be applied in order to resolve the problem of knife shape and position which would eliminate friction between the knife and uncut part of the sod [1, 2, 4, 10, 15].

Too much energy is used when the soil is tilled by rotary tiller, and there are also vibrations of the rotor as well as of the entire machinery if the rear part of knife batters, slips, or compact the soil [9]. In order to ensure proper operation of the rotary tiller and minimal use of energy during tillage, it is necessary to define the optimal profile of the rotary tiller knife for the given values of work parameters.

2. MATERIAL AND METHODS

The aim of this research was to determine optimal shape of rotary tiller knife for conventional rotor rotation direction. The starting values for the calculation were R = 25 cm, a = 10 cm, ω = 16.038 s^{-1} i v_m = 0.77 m/s [3]. Optimal profile of knife in the coordinate system $Y(X)$ was determined for an independent variable X within the range from 0 to 6 cm with the increment of 1cm. The angle of inclination α was also determined in the XY coordinate system. The trajectories of the tip of the knife (point A), point B of the knife profile where X = 3 cm, and point D of the knife profile where X = 6 cm are presented in xy coordinate system.

The equations were solved with "Scientific work place" program [11, 12, 13, 14]. The trajectories were drawn in SWP and CorelDraw programs.

3. RESULTS AND DISCUSSION

Optimal profile of knife, which would have every point of the profile entering the soil at the same place during tillage, was determined for the set design parameters of rotary tiller R and ω, and also for the soil tillage parameters a and v_m. It was earlier concluded that the critical point is on the soil surface [7, 8]. Optimal curvilinear knife profile can be defined by coordinates X and Y (Figures 1 and 2), that is, by the function $Y(X)$.

Parametric equations of the trajectory of knife tip of point A for the selected coordinate system (Figure 1) are as follows

$$x(t) = x_A(t) = v_m \cdot t + R \cdot \cos \omega t \, , \tag{1}$$

$$y(t) = y_A(t) = R - R \cdot \sin \omega t \, . \tag{2}$$

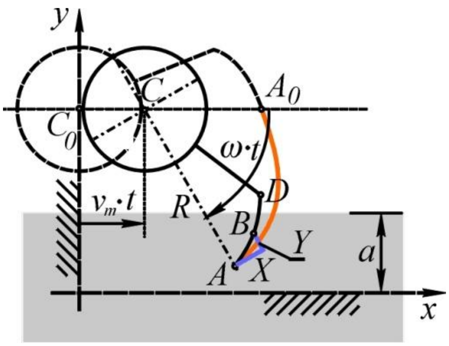

Fig. 1 Trajectory of knife tip A and position of arbitrary point B

Parametric equations of the trajectory of knife tip of arbitrary point B for the selected coordinate system (Figures 1and 2) are as follows

$$x_B(t) = x(t) - Y\cos\omega t + X\sin\omega t = v_m \cdot t + R\cdot\cos\omega t - Y\cos\omega t + X\sin\omega t\,, \tag{3}$$

$$y_B(t) = y(t) + Y\sin\omega t + X\cos\omega t = R - R\cdot\sin\omega t + Y\sin\omega t + X\cos\omega t\,. \tag{4}$$

The X and Y values show displacement of the point B with regard to the knife tip A

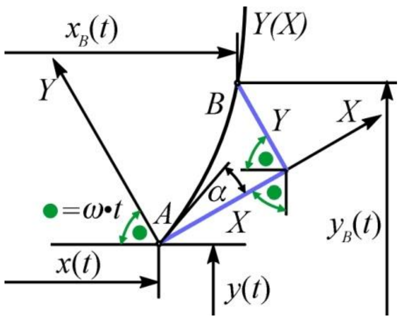

Fig. 2 Optimal profile in the coordinate system *XY*

The time point $t_p = t_{Ap}$, at which the tip of the knife A enters the soil, can be defined by the following expressions based on the condition $y(t_p) = a$ and equation (2):

$$R - R\sin\omega t_p = a \Rightarrow \sin\omega t_p = \frac{R-a}{R},\quad \cos\omega t_p = \frac{\sqrt{R^2-(R-a)^2}}{R},\quad t_p = \frac{1}{\omega}\arcsin\frac{R-a}{R}\,. \tag{5}$$

By inserting the (5) in (1) the following is obtained:

$$x(t_p) = \frac{v_m}{\omega}\arcsin\frac{R-a}{R} + \sqrt{R^2-(R-a)^2}\,. \tag{6}$$

The time point t_{Bp}, with its value near the t_p, when the arbitrary point B of knife profile reaches the soil level, is defined by nonlinear algebraic equation based on the condition $y(t_{Bp}) = a$ and equation (4):

$$R - R \cdot \sin \omega t_{Bp} + Y \sin \omega t_{Bp} + X \cos \omega t_{Bp} = a\ , \qquad (7)$$

which can be transformed to the following quadratic equation according to $z = \sin \omega t_{Bp}$:

$$\tilde{A} z^2 - \tilde{B} z + \tilde{C} = 0\ , \qquad (8)$$

where:

$$\tilde{A} = (R - Y)^2 + X^2, \quad \tilde{B} = 2(R - a)(R - Y), \quad \tilde{C} = (R - a)^2 - X^2\ . \qquad (9)$$

The right solution to the quadratic equation (8) is as follows

$$z = \sin \omega t_{Bp} = \frac{\tilde{B} + \sqrt{\tilde{B}^2 - 4\tilde{A}\tilde{C}}}{2\tilde{A}}\ , \qquad (10)$$

and, because of (9), it depends on *X* and *Y* values which specify the required knife profile, that is

$$z = z(X, Y)\ . \qquad (11)$$

When (10) and (11) are considered, the following stands:

$$\cos \omega t_{Bp} = \sqrt{1 - z(X, Y)^2}\ , \quad t_{Bp} = \frac{1}{\omega} \arcsin z(X, Y)\ . \qquad (12)$$

By inserting (10-12) into (3) the following is obtained

$$x_B(t_{Bp}) = \frac{v_m}{\omega} \arcsin z(X, Y) + (R - Y)\sqrt{1 - z(X, Y)^2} + Xz(X, Y)\ . \qquad (13)$$

The fundamental equation which defines the required knife profile can be obtained from the following condition

$$x_B(t_{Bp}) - x(t_p) = 0\ , \qquad (14)$$

and, when (6) and (13) are considered, it has the following form

$$f(X, Y) = \frac{v_m}{\omega}\left[\arcsin z(X, Y) - \arcsin \frac{R - a}{R}\right] + (R - Y)\sqrt{1 - z(X, Y)^2} + Xz(X, Y) - \sqrt{R^2 - (R - a)^2} = 0 \qquad (15)$$

The equation (15) represents an implicit function of the variables *X* and *Y*, i.e. the required equation for optimal knife profile for the set tillage parameters *R*, *a*, ω and v_m for conventional rotor rotation direction.

This implicit function $f(X, Y) = 0$ can be presented numerically, in a table, in the explicit form *Y*(*X*), figure 2, by setting the arbitrary values for variable *X* and, based on (15), by numerical determination of their corresponding values *Y*.

It is also possible to determine numerically the inclination angle α of the function *Y*(*X*) at the tip of the knife (the origin) since the tangency of this angle is equal to the first extraction of the function. Based on the above said, and considering that *Y* (0)=0, the following stands

$$\alpha \approx \arctan \frac{Y(X_0)}{X_0}\ , \qquad (16)$$

where X_0 is a randomly selected very small value of the *X* variable.

A table which presents the optimal profile *Y*(*X*) is to be made for the following values *R* = 25 cm, *a* = 10 cm, ω = 16.038 s^{-1} and v_m = 0.77 m/s for conventional rotor rotation direction, based on equation (15), where the values of independent variable *X* range from 0 to 6 cm with the increment of 1cm. Also, the inclination angle α needs to be determined, and in the same *x*,*y* coordinate system the trajectories of the knife tip (point

A), point *B* of knife profile where $X = 3$ cm, and point *D* of knife profile with $X = 6$ cm need to be presented.
The aforesaid table of optimal profile $Y(X)$ is presented in the table 1. The values from table 1 for *Y* are obtained by inserting the corresponding value for *X* in a nonlinear algebraic equation (15) and by calculating numerically the corresponding values of *Y*. Those calculations were completed by SWP (Scientific Work Place) program.

Table 1 Values of the Y coordinate calculated with respect to the X optimal profile

X, mm	Y, mm
0	0
10	1.948751511
20	4.331417331
30	7.164304526
40	10.46735819
50	14.26488505
60	18.58652563

Implicitly set function (15), for the given values, by SWP and CorelDraw programs, is presented in Figure 5.

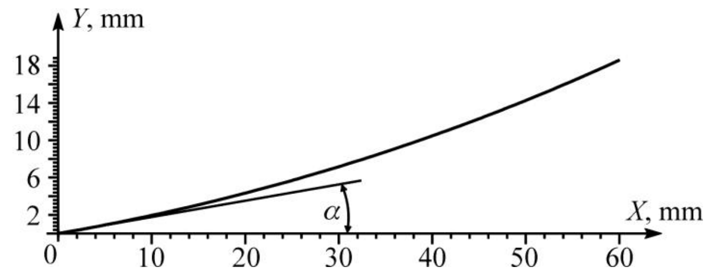

Fig. 4 Implicitly set optimal knife profile in the *xy* coordinate system

Figure 4 also shows the angle α which was determined by using the equation (16) for $X_0 = 0.0001$ m, and which value is 9.86^0.
Figure 4 shows the optimal shape of knife profile. By determining the bending of movable coordinate system XY, it is possible to determine the angle of knife position γ with respect to the working parameters.
Figure 5 shows the trajectory of knife tip *A* for the set values based on the parametric equations (1) and (2). The same figure also shows the trajectories of *B* and *D* points of knife profile based on the parametric equations (3) and (4) where $X = 30$ mm and $Y = 7.164304526$ mm for *B* point, and $X = 60$ mm and $Y = 18.58652563$ mm for *D* point.

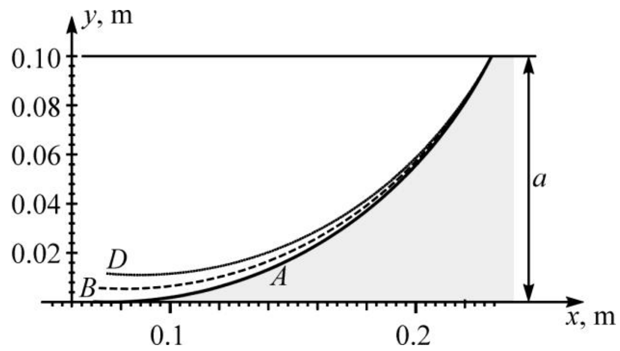

Fig. 5 Trajectory of the knife tip (A) and
two arbitrary points of the knife profile (B and D)

Figure 5 clearly shows that all three points for the given values, and obtained optimal knife profile enter the soil at the same place which ensures that the rear part of the knife has no contact with untilled soil and that it also penetrates the soil with least resistance.

4. CONCLUSIONS

A curve which represents optimal shape of knife profile was determined for the set design and work parameters. The value Y = 7.164 mm was obtained for $X = 30$ mm, and Y = 18.587 mm was obtained for $X = 60$ mm. The inclination angle of the function in the origin of the XY system was $\alpha = 9.86^0$.

Future research should focus on determining the function of knife profile in the coordinate system which is bent for the value of angle α with respect to the XY coordinate system, where the function of knife profile in that coordinate system would have the inclination angle equal to zero, as the parabola in the origin.

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Original Scientific Paper

THE IMPACT OF NPK FERTILIZERS ON THE YIELD AND ENERGY EFFICIENCY OF SUGAR BEET AND SOYBEAN PRODUCTION

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Abstract. *Agricultural production is of a great importance for the human population being the major source of food for the population of the planet, whose number is increasing daily. The objectives of this study are the evaluation of the energy embodied in the process of fertilizer application in the sugar beet and soybean production and identification of the energy input – output relation. Data from three production season were collected and analysed. In the case of both cultures results show that the highest share in total energy consumption has the energy input through the application of fertilizers. The nitrogen content in total energy consumption in sugar beet production was 51.89%, 38.44% and 31.83%; phosphorus was 1.77%, 3.66% and 4.18%; potassium was 3.09%, 5.24% and 2.87%. In soybean production the nitrogen content in the energy balance through the seasons was 37.86%, 39.55% and 39.38%; phosphorus was used in first and last season, with content of 4.69% and 3.46%; potassium was used in second agricultural year with the content of 2.30%.*
Based on the data obtained, it was concluded that the use of fertilizers is very important for the sustainability of agricultural production and that it must be balanced concerning the negative impact of excessive amounts on the both production economy and ecology.

Key words: *soybean, sugar beet, fertilizer, energy input, energy output, energy efficiency*

1. INTRODUCTION

Production of sufficient quantities of food and industrial raw materials, both for the existing population and for generations to come, is one of the most important tasks of the society [11]. Therefore, the development of agriculture, its sustainability and continuous improvement is crucial for humanity [7, 14, 27]. Modern agricultural production can not be imagined without the use of fertilizers, particularly in terms of better utilization of plant biological yield [7, 8, 9, 26, 28]. Otherwise, the yield of crops would be significantly reduced regardless the application of all other cultural practices carried such as tillage, crop protection and care.

In current agricultural practice nutritive value of fertilizers was evaluated on the basis of their impact on crop yield increase and possibility of yield quality improvement [16, 17]. However, with the advancement of all sectors, including agriculture, more and more analyzes are dedicated to the energy flow in fertilizer production and application analysing the processes such as transport, storage and handling of fertilizers. All these analysis show that the share of energy consumed in agriculture is very high ranging in some countries up to 5% of total energy consumption in the country. Energy inputs can be divided into the following groups [2, 18]: direct energy inputs (human power, diesel fuel, water and electricity), indirect energy inputs (chemicals, fertilizers, seeds and machinery); renewable energy inputs (human power, seeds and manure fertilizers) and non-renewable energy inputs (diesel fuel, electricity, chemicals, water, fertilizers and machinery).

In the total energy consumption, the share of the built-in fertilizers goes up to 50% [5]. This is one of the key reasons for devoting the additional research and to pursue its rationalization with the aim of not only economically viable [6], but also environmentally effective production [3, 20, 23, 24].

The aim of this paper is the analysis of energy consumption in the production of sugar beet and soybean since they are considered to be energy demanding crops. Special attention was given to the energy consumption via mineral fertilizers. Based on the final results it could be possible to achieve a sustainable agricultural production, with focus on the environmental sustainable crop production.

2. MATERIALS AND METHOD

Tests were conducted on the property of PKB Corporation "7 July" in Jakovo (Vojvodina region, Serbia). The aim was to determine the energy parameters of sugar-beet and soybean production in the conventional tillage production system. Data were collected for the 2009/10, 2010/11 and 2011/12 seasons.

In order to determine the energy efficiency of crop production energy input (direct, indirect) and energy output were identified.

The method used for energy efficiency analysis [19] is based on the energy input analysis (definition of direct and indirect energy inputs), calculation of the energy consumption for a given plant production and the energy efficiency. On the basis of sugar beet and soybean production output and the energy input, specific energy input, energy output-input ratio and energy productivity were estimated. The energy inputs were calculated by multiplying the material input with the referent energy equivalent [12, 15]. The quantities of material input were obtained directly from the farm managers.

3. RESULTS AND DISCUSSION

3.1 Energy consumption and energy output in sugar beet production

Energy inputs and output in sugar beet production are presented in Table 1 and Table 2. Data presented in Table 1 represent average values from the three years trials.

Table 1 Energy consumption for sugar beet production

Input	Quantity per unit area (unit ha^{-1})	Energy (MJha^{-1})	%
Direct			
Diesel fuel (l)	158.26	7564.86	27.10
Kerosene (l)	5.45	200.13	0.82
Total	163.71	7764.99	27.93
Indirect			
Labor (h)	9.84	19.29	0.07
Tractor (h)	9.10	833.91	3.11
Combine (h)	0.72	63.43	0.55
Transport (h)	3.78	112.63	0.38
Machinery (h)	6.07	380.54	1.53
Nitrogen (kg)	179.10	11845.28	40.72
Phosphorus (kg)	62.6	778.72	3.20
Potassium (kg)	89.44	997.24	3.73
Insecticides (kg)	6.82	690.01	2.80
Fungicides (kg)	0.99	212.35	0.59
Herbicides (kg)	13.99	3321.49	12.04
Water (m^3)	1.70	1.73	0.01
Seeds (kg)	16.70	835.15	3.52
Total indirect	400.52	20020.99	72.07
Total input		27785.99	

Table 2 Energy output for sugar beet production

	Season		
	09/10	10/11	11/12
Yield (kg/ha)	78323.43	56128.78	10020.00
Output (MJ/ha)	1315833.60	942963.50	168336.00

Table 1 shows specific energy consumption per ha and the share of the specific energy input in total energy consumption. Data showed that the highest amount of energy in the production is consumed thorough the fertilizers. Its share in total energy consumption was 47.56% in average, for the three years trial. Energy input through water is the water consumed in plant protection and therefore its share is proportionally lower. Irrigation was not performed. The second most intensive energy input was fuel and had 27.10% share in the total energy consumption.

Energy parameters from three production seasons are given in Table 3.

Table 3 Energy parameters for sugar beet production

Energy parameters	Season		
	2009/10	2010/11	2011/12
EI, MJ/kg	0.51	0.45	1.82
ER	33.11	37.20	9.21
EP, kg/MJ	1.97	2.21	0.55

Asgharipour et al. (2012) [4] carried an economic analysis of sugar beet production system in Iran, in Khorasan Razavi province. The total energy input was 42231.9 MJ/ha, and approximately 29% and 22% were from chemical fertilizers and irrigation water, respectively. Econometric assessment indicated that energy inputs of human labor, machinery, diesel fuel, total chemical fertilizers, farmyard manure, electricity, and irrigation water made significant contribution. Total energy output of sugar beet production was 563645.4 MJ/ha. The specific energy, energy productivity and net energy of the sugar beet production were 1.3 MJ/kg, 521413.7 MJ/ha and 0.8 kg/MJ, respectively. The energy input is approximately the same in this study and in season 2009/10. It is significantly higher here than in the seasons 2010/11 and 2011/12 in the Sava region in Serbia. Lower quantities of fertilizer were used in Iran, but irrigation was applied. Yields are higher in the Sava region in Serbia for the first two seasons, but not in the third, because of the reduced amount of fertilizer used.

Gulistan et al. (2007) [12] carried an economical analysis of sugar beet production in Tokat province of Turkey. The results revealed that total energy consumption in sugar beet production was 39685.51 MJ/ha, where fertilizer had a share of 49.33% and diesel fuel 24.16%. The output/input energy ratio was 25.75 and energy productivity was 1.53 MJ/ha. Compared with the results which are presented, it is obvious that the energy input is higher, but the output is lower, which shows the ratio of output / input. The percentage share of mineral fertilizer and diesel fuel is about the same.

Haciseferogullari et al. (2013) [13] calculated energy balance of the sugar beet production for middle Anatolia conditions (Konya region). According to the obtained results, the total energy input, energy output, output/input ratio and net energy ratio were found to be 19760.65 MJ/ha, 378491.2 MJ/ha, 19.15 and 18.15, respectively (for 6.9 t/ha yield). Compared with the results presented in previous section, lower input and output were obtained compared to 2009/10 and 2010/11 seasons. Even with the drought periods in these seasons, energy output in Serbia region was higher. The results indicate the higher benefit for sugar beet growing in the Vojvodina region near river Sava. This could also be concluded based on the higher yields. However, in the absence of rainfall and irrigation, there was an obvious reduction of yields in 2011/12 season.

Reineke et al. (2013) [22] calculated energy balance parameters for sugar beet cultivation in commercial farms in Germany. Authors collected data from 285 fields. Total energy input (median) was 17.3 GJ/ha, energy output 261.7 GJ/ha, energy gain (energy output less input) 244.6 GJ/ha, output/input ratio 15.4 and energy intensity (energy input versus natural yield measured in Grain Equivalents) was 87.4 MJ/GE. The energy input is lower than in all three seasons in the Vojvodina region, but the output is higher when compared with last season in Serbia. There was not enough rainfall in that season. Farmers in Germany have used lower quantities of nitrogen fertilizers. The increased use of organic fertilizers in these farms also reduced the energy inputs.

3.2 Energy consumption and energy output in soybean production

Energy inputs and output in soybean production are given in the Table 4 and Table 5. The values represent in the table 4 are the average values of three years trials.

Table 4 Energy consumption for soybean production

Input	Quantity per unit area (unit ha^{-1})	Energy (MJ/ha)	Share %
Direct			
Diesel fuel (l)	86.71	4144.99	36.72
Total	86.71	4144.99	36.72
Indirect			
Labor (h)	5.88	11.51	0.10
Tractor (h)	5.36	493.11	4.38
Combine (h)	0.48	31.61	0.29
Transport (h)	1.11	33.00	0.29
Machinery (h)	3.42	298.32	2.65
Nitrogen (kg)	66.32	4393.04	38.93
Phosphorus (kg)	37.60	467.69	4.08
Potassium (kg)	22.92	255.5	2.30
Insecticides (kg)	1.00	101.52	0.90
Herbicides (kg)	4.65	1105.76	9.74
Water (m^3)	1.13	1.16	0.01
Seeds (kg)	94.11	338.80	2.51
Total indirect	216.16	7204.82	63.28
Total input		11349.81	

The data show that the highest average share in the total energy consumption had fertilizer (45.31%) followed by fuel (36.72%) and herbicide usage (9.74%). Water was used only in the operation of plant protection. The soybean yield per hectare significantly decreased from season to season (Table 5).

Table 5 Energy output for soybean production

	Quantity per unit area (unit ha^{-1})			Share, %		
	09/10	10/11	11/12	09/10	10/11	11/12
Yield (kg/ha)	3300.00	2350.00	1351.26			
Output (MJ/ha)	82500.00	58750.00	33781.58	77.34	77.35	59.04
Straw (kg/ha)	1208.77	860.00	1172.00			
Output straw(MJ/ha)	24175.38	17200.00	23440.00	22.66	22.65	40.96
Total output	106675.38	75950.00	57221.58	100.00	100.00	100.00

Energy parameters from three production seasons are given in Table 6.

Table 6 Energy parameters for soybean production

Energy parameters	Season		
	2009/10	2010/11	2011/12
EI, MJ/kg	3.65	4.75	8.01
ER	8.85	6.80	5.29
EP, kg/MJ	0.27	0.21	0.12

Abbas and Majid (2012) [1] calculated energy input-output ratio and have carried an economic analysis of soybean production in the main agricultural production areas in Iran. The results revealed that soybean production consumed a total of 29895.49 MJ/ha, of which the share of diesel fuel and chemical fertilizer energy consumption were 67.47 and 9.5%, respectively. About 68.4% of the total energy inputs used in soybean production were direct (human labor, diesel) and the rest (31.6%) were indirect (seeds, fertilizers, manure, chemicals, machinery). Mean grain yield which was in rain-fed farming system was about 1850 kg/ha. In the current study, total energy output and net energy was estimated to be 54131 and 24235,5 MJ/ha, respectively. Also, energy productivity and energy use efficiency (EUE) were determined to be 0.06 kg/MJ and 1.81 respectively. When these results are compared with previously presented, it can be concluded that significantly less fertilizer was used but these lower quantities were compensated with the irrigation which had a positive effect on yield even with the lower quantities of fertilizer. However, the output is approximately equal to the output of the season with the lowest productivity in addition to Sava region in Serbia. Results show that optimal quantities of fertilizer should be used. Quantities higher that optimal will not provide higher yield and on the other side will lead to higher energy consumption and lower energy productivity.

Kordkheili et al. (2013) [15] calculated the energy input-output ratio and they have also carried an economic analysis for soybean production in Mazandaran province of Iran. The results indicated that total energy input for soybean was about 38756.32 MJ/ha. Among all energy inputs electricity (49.42%) and fertilizer (20.82%) had the highest energy values per hectare. The values of specific energy consumption for soybean cultivation were 12.12 MJ/kg. Total energy output was 79902.21 MJ/ha. Compared to here presented results, the energy output shown here is lower only in the first season. In the second and especially in the third is higher, although the percentage of the fertilizer is lower. This confirms the importance of irrigation, which is omitted in the region of Sava in Serbia. Soybean yield was higher in the Sava region in 2009/10 season. In the next season output is approximately equal, while in the dry season 2011/12 is lower in study. The reason has already been mentioned

Ramedani et al. (2011) [21] determined the energy consumption and evaluation of inputs sensitivity for soybean production in Kordkuy county of Iran. The results showed that the total input was 18026.50MJ/ha, total output 71228.86 MJ/ha, and approximately 66.67%, 14.32% and 6.18% were from diesel fuel, chemical fertilizers and irrigation, respectively. Inputs in the Vojvodina region in all three seasons were lower. There was no irrigation and significantly lower quantities of diesel fuel were used. However, the use of mineral fertilizers was higher in the Sava region. This led to higher output in the first two seasons, while in the third it was lower, due to drought and lack of irrigation.

3.3 Energy consumption and yield

The need to improve agricultural production is growing day by day. World population is growing and the demand for food is increasing. For this reason the main objective of modern agricultural production is to increase the crop yields. Based on the results it is evident that reducing the quantity of the used mineral fertilizers with the lack of irrigation decreases the overall crop production productivity [25].

To establish the nature of a relationship between two quantitative variables regression analysis was used [10]. An interesting fact is related to the positive correlation between yield and energy consumption in the production of sugar beet, presented with r = 0.93 in Figure 1.

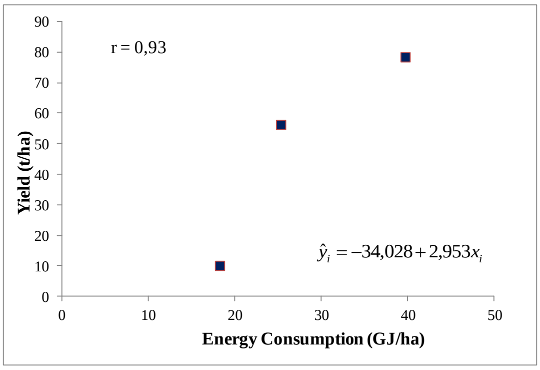

Fig. 1 Correlation between energy consumption (GJ/ha) and yield (t/ha) in sugar beet production

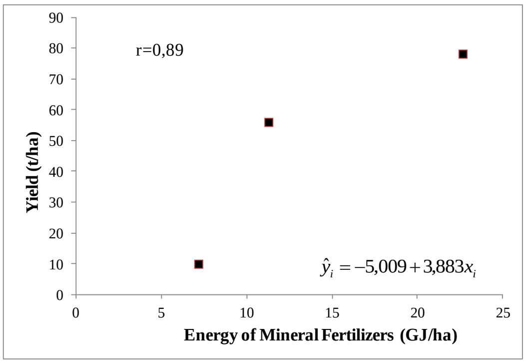

Fig. 2 Correlation between energy of mineral fertilizers (GJ/ha) and yield (t/ha) in sugar beet production

With the increase of energy input yields are increased and thus, the energy output. Major role in this certainly have mineral fertilizers, as shown in Figure 2, where r = 0.89. The correlation is in this case is positive and shows that the adequate use of mineral fertilizers is of great importance in obtaining higher yields. Application has to be well balanced in order to meet the requirements of rational energy use and economic feasibility, but also the impact on the environment.

Concerning the soybean production, Figure 3 shows a very significant correlation between the yield and the energy consumption (r = 0.99).

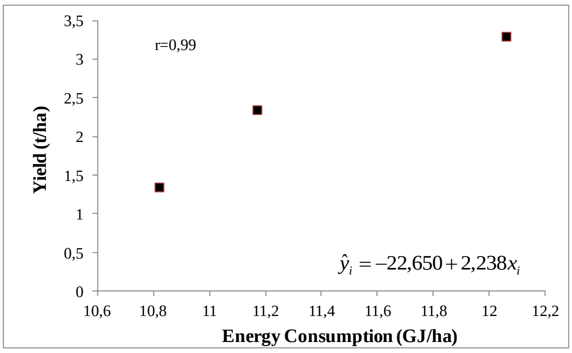

Fig. 3 Correlation between energy consumption (GJ/ha) and yield (t/ha) in soybean production

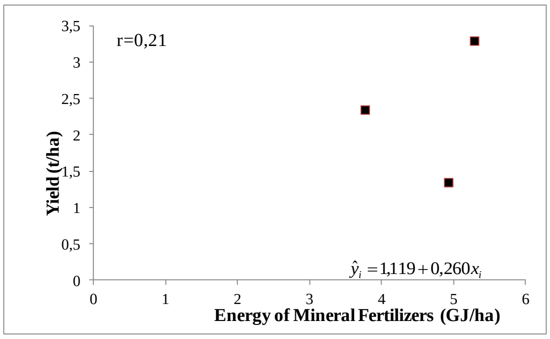

Fig. 4 Correlation between energy of mineral fertilizers (GJ/ha) and yield (t/ha) in soybean production

Comments are like those in the case of sugar beet, with special emphasis on the optimum amount of fertilizer and irrigation in the critical months (June, July and August), particular in the case of low precipitation. Based on the Figure 4, it is evident that the correlation between yield and energy input through mineral fertilizers is not significant (r = 0.21). There is a linear relationship between the two specified parameters, which gives room for continued research and monitoring of the impact of the use of mineral fertilizers on yields and their energy value in the coming seasons.

CONCLUSIONS

Task of agricultural production is not just to produce food. It must above all be a cost-effective, profitable and must meet certain environmental standards. On the basis of the above research results through three seasons of sugar beet and soybean, it can be concluded that with the reduction of mineral fertilizer use from year to year yield decreases. Lack of irrigation can also significantly affect the yield, which is best shown in the 2011/12 season, when in the summer months rainfall was minimal. This is also reflected on the decrease in output, especially in sugar beet. The fact that the intensive agricultural production can not be imagined without the use of fertilizers requires a balanced fertilization, with the optimum amount of fertilizer applied at the right place and the right time. This is not much to lose in production if smaller quantities of fertilizer are used. It will be cost-effective and will have a positive impact on energy efficiency of the productions systems in region and on environmental sustainability. The economical difference in having lower quantities of fertilizer can be used in investments in irrigation which can, as results have shown, lead to the higher yields, better energy utilisation, better energy efficiency and positive effect on the agro-ecological condition in the region.

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Case Study

ANALYSIS OF DIFFERENT COMBINE WHEAT HARVESTERS TECHNICAL-EXPLOITATION PARAMETERS

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Abstract: *Wheat is a plant that has the most important place in food production. Success in the wheat production highly depends on successful harvest. This paper aims to draw attention to the exploitation and energy parameters of modern wheat combine harvesters with different concepts in order to see the possibilities of increasing the labour productivity and reducing the fuel energy consumption per unit of product. The results of the exploitation combine testing indicate that combine A, depending on the speed, had a productivity of 1.75 to 2.83 ha / h with the fuel consumption of 15-25 L / ha, and time fuel consumption of about 43 L / h with the engine load of 70 to 80%. Combine B had 13.61 L / ha fuel consumption, ie 38.11 L / h with the productivity of 2.8 ha / h and average speed of 5.5 km / h. Combine C achieved an average performance of 4.34 ha / h with the fuel consumption of 14.40 L / ha, and time fuel consumption of 62.1 L / h with the 71 – 80% engine load. It can be seen that the development of combine harvesters goes in the direction of increasing bandwidth, and that these efforts are simultaneously developed in the combine different concepts and different technical solutions. Efficiency coefficient of the harvester is 0.7, but it can be significantly increased with better harmonization of working regime and working conditions.*

Key words: *wheat, energy, energy efficiency, losses, productivity.*

1. INTRODUCTION

The fact that the period when crop is in a good condition for harvesting lasts only five to ten days, imposes very short period available for the harvesting. So, harvesting itself must be very fast. This is especially noticeable in case of wheat and other cereals that are prone to the grain shedding losses and lodging. The other problem is that together with the lodging comes weeds growth that is intensifying five to ten days after the technological maturity of the seed [4].

Wheat combine harvesters, like the all other technical systems, have their potential capacity that should be used fully in order to have the lower costs of their usage. Concerning the fact that combine harvesters are very complex and sophisticated machines a good knowledge of the whole system is necessary if optimal functionality is needed [7]. According to Čuljat (1997) [6] there are two basic principles of harvesting, tangential, axial and the combination of these two. Conventional tangential system is using the beating principle and the axial type is based on the friction principle. The later principle is becoming more popular these days since their capacity of grain mass is higher than 12 kg/s [5]. Grain loss during the harvesting is the limiting factor for improving the harvester productivity. Comparative tests of these two harvesting systems showed that harvesters with the axial working principle have the lower grain losses and grain damage [9]. Higher drum speed causes more intensive flow mass through the thrashing unit, which causes higher free grain losses on the cleaning system. The efficiency of the thrashing unit rapidly decreases with the increase of the grain flow mass since there is a higher quantity of straw and grain mass and in this mass grain can easily lost themselves [2, 1]. Introduction of the contemporary combine harvesters has changed the overall harvesting organisation. Harvester productivity also depends on grain yield and this parameter can be a limiting one [8].

The aim of this paper is to establish and define optimal parameters of the different types of combine harvesters in condition of wheat harvest, in order to see the further possibilities of the optimisation of harvest in sense of organization, education and planning of harvesters' maintenance.

2. MATERIAL AND METHODS

Testing of combine harvesters was carried all days throughout the day, from the beginning of work till the end of day and the return from the field. The following parameters were tested:

- working speed, on the 30 m long track;
- Combine harvester productivity;
- Fuel consumption;
- Working width;
- Grain mass collected from harvester emptying auger (grain flow);
- Gran and straw mass collected from the harvester rear end (losses).

For the experiment a stopwatch, alignment rods, tape measure, fabric linen and precise weighing device were used.

Before the experiment, combine harvesters were prepared. On the rear side, fabric linen was placed in order to collect the straw and grain losses. On the emptying auger fabric linen was placed in order to collect the grain mass more easily [3].

The experiments were taken on the fields of Agricultural Corporation Belgrade plant during the wheat harvesting season (Tab. 1). Temperature during the day was 25 °C (in the morning) and up to 38 °C (during the day) with the 44-70% air humidity. These high temperatures during the day caused the low grain water content (below 13%) which was optimal for the grain storage.

Table 1 Data about the crops

Harvester type	Harvester A	Harvester B			Harvester C
Crop characteristics	Mercantile crop	Seed crop	Seed crop	Mercantile crop	Mercantile crop
Variety	PKB Talas	Evropa	Balkan	Evropa	NS 40 S
Crop height (cm)	85	79.50	84.70	68.70	88
Length of the grain head (cm)	-	8.50	6.10	7.88	around 8
Number of plants / (m^2)	680	730-750	640-680	620	745
Moisture content (%)	13	11	11	14	11.4
Mass (kg/hl)	78	84	83	82	78
Yield (t/ha)	6.80	6.20	5.80	6.10	7.50
Grin / straw head ratio	1: 0.57	1:0.60	1:0.80	1: 0.50	1: 0.57
Crop condition	Straight	Straight	Straight	Straight	around 20% of the surface was lodged
Weed presence	<1%	<1%	<1%	<1%	<1%

In the field where combine harvester A was working, the number of plants per m^2 was 680. Combine harvesters B and C worked in conditions of seed wheat and the number of plants per m^2 was 660 – 820 causing the oscillation in the grain yield from 6.8 to 8.3 t/ha.

2.1. Experimental set up

Three types of contemporary combine harvesters were tested. Harvester A had the six cylinder DEUTZ TCD 4V Tier 4i engine, with the 7.8 L and 267 kW. Harvester B had a six cylinder Caterpillar C9 Stage 3a engine, with the 9.3 L and 220 kW. Harvester C had a Case IH FPT Euro 3B (interim Tier 4A) engine, with 12.9 L and 420 kW (ECE R120).

The header elevators on the harvesters B and C had the possibility of reverse motion in order to protect the harvester from the jam.

The newest technology of thrashing was realized on Combine harvester C, enabling the axial mass flow along the drum that was 2,638 mm long and that had the diameter of 762 mm (Tab. 2). All three harvesters had the drum speed of 220 to 1,180 min^{-1}.

Table 2 Technical characteristics of harvesters A, B and C

Characteristics	Harvester A	Harvester B	Harvester C
Cutterbar width (mm)	6,300	6,000	9,200
Threshing unit			
pre-accelerator width (mm)	-	1700	-
threshing drum (length*)/diameter (mm)	1,521/600	1,650/600	(2,638*)/762
accelerating drum diameter (mm)	590	450	
Cleaning system	cascade	cascade	axial
Section number	6	6	1
Surface (m^2)	6.70	7.48	6.5
Bunker capacity (L)	8,500	8,600	12,330
Type of motor/(kW)	TCD 4V/267	C9/220	Case FPT/420
Harvester mass without the cutterbar (kg)	12,240	13,000	17,300

3. Results and discussion

Testing results showed that the capacity of the Combine harvester A depends on the working speed, straw quantity and yield that was, in average, 7.29 t/ha (Tab.3).

Table 3 Working parameters of the Harvester A

No.	Wheat variety	Yield (t/ha)	Grain / straw ratio	Working speed (km/h)	Grain flow (kg/s)	Cutterbar losses (%)	Threshing unit losses (%)	Total losses (%)
1.	PKB Talas	6.847	1:0.69	3.50	3.60	-	0.05	0.05
2.	″	6.850	1:0.65	4.54	5.49	-	0.19	0.19
3.	″	7.738	1:0.65	5.05	5.97	0.14	0.65	0.79
4.	″	7.740	1:0.66	5.95	7.97	0.46	1.15	1.61

In the given conditions A combine harvester had the working speed from 3.50 - 5.95 km/h. In this regime harvester was able to accept all the harvested mass without having any jam. The flow of the grain was 3.60 to 7.97 kg/s while the total mass flow was 6.09 to 13.23 kg/s. Total loss was between 0.05 to 0.19% for the working speed not higher than 4.50 km/h. When the speed was 5 km/h total loss was 0.79% and in conditions of 6 km/h the total loss was 1.61%. This was the limiting value. The sampling was not carried for the speed of 7 km/h since the estimation was that the losses will go above 2% which is unacceptable.

Analysing the grain from the hopper, it was concluded that the cleaning of the grain was good, there were no impurities and semi harvested grainheads. The percentage of the broken grain was very low, even unnoticeable.

Combine harvester A was with the tangential drum and section separation unit. Grain / straw ratio, after the separation unit, was 1/0.66 that, when it is compared with the natural sample that has the ratio of 1/1.1, leads to conclusion that the straw was in good condition for the collection. Hopper capacity of 8500 L was in accordance with the working regime as well as the unloading period of 100 s. Unloading auger had the capacity of 85 L/s. Other exploitation parameters of the Combine harvester A are given in table 4.

Table 4 Exploitation parameters of the Harvester A

No.	B(m)	v (km/h)	W_h(ha/h)	Q(L/h)	Q_{ha}(L/ha)
1.	6.26	3.49	1.75	43.42	24.81
2.	5.90	4.54	2.14	42.30	19.76
3.	6.05	5.05	2.44	43.40	17.78
4.	5.96	5.95	2.83	43.00	15.20
Avr.	6.04	-	-	-	-

Combine harvester A, had the productivity of 1.75 to 2.83 ha/h, depending on the working speed, and fuel consumption of 43 L/h with the 70 to 80% engine load. Working time efficiency coefficient was 0.7.

Combine harvester B had the working speed of 5-6 km/h. The speed was varied from 6 to 9 km/h (Tab. 5). In this regime harvester was able to accept all the harvested mass without having any jam. The capacity if harvested grain was 13 kg/s but in this regime the losses were high in the seed wheat so the capacity was declared to be 8 kg/s with the losses that were below 1%. In the conditions of mercantile wheat the capacity of harvested grain was declared to be 10 kg/s with the losses that are lower than 2%.

The main limiting factor for the combine harvester capacity was the straw / grain ratio. The ratio was 1.1 to 0.5 straw to grain. Seed wheat had more straw so it limited the combine harvester capacity. It even lowered the nominal capacity for 30%. In case of mercantile wheat the problem was not so intensive.

With the working speed of 7.5 km/h (Tab. 5) losses were significantly higher (higher than 2%). In this regime 10 to 15% of total losses came from broken and semi harvested grainheads. Changing of the drum and ventilator speed didn't make any changes. Generally, the optimal working regime for the Combine harvester B in mercantile wheat is with losses up to 2% and in seeding wheat with the losses up to 1%. Header losses are also given in Table 5 but the values are very low. It is evident that these losses are growing with the higher working speeds but are still negligible.

Table 5 Working speed, grain flow and total losses of Harvester B

No.	Wheat variety	Yield (t/ha)	Grain / straw ratio	Working speed (km/h)	Grain flow (kg/s)	Cutterbar losses (%)	Threshing unit losses (%)	Total losses %
1.	Evropa (s)	5.62	1 : 0.60	5.02	7.04	0.00	0.30	0.30
2.	Evropa (s)	3.73	1 : 0.66	7.39	7.65	0.00	0.74	0.74
3.	Balkan (s)	4.94	1 : 0.66	7.72	10.57	0.09	3.15	3.24
4.	Balkan (s)	4.99	1 : 1.11	7.47	13.15	0.10	4.22	4.32
5.	Balkan (s)	5.00	1 : 0.67	8.87	12.33	0.15	2.22	2.37
6.	Evropa(m)	6.95	1 : 0.44	7.28	12.11	0.08	0.56	0.64
7.	Evropa(m)	6.64	1 : 0.50	8.38	13.94	0.13	0.60	0.73
8.	Evropa(m)	4.73	1 : 0.84	8.85	12.88	0.13	0.83	0.96
9.	Evropa(m)	4.73	1 : 0.82	9.41	13.54	0.13	0.82	0.95

From Table 6 it can be seen that Combine harvester B had the average productivity of 2.8 ha/h with the average fuel consumption of 13.61 L/ha.

Threshing system of the Combine harvester B has the APS system aimed at speeding of straw mass through the threshing system. In this sense, the straw, after leaving the harvester is of a poor quality if compared with the Combine harvester A. Working time coefficient of the Combine harvester B was 0.7 i.e. at the same level as in the case of Combine harvester A.

Combine harvester C had the optimal working conditions concerning the grain water content. The drum speed was 860 min^{-1}, ventilator speed was 1,000 min^{-1} and of straw chopper 3,020 min^{-1}. Working speed was 5.14 to 6.17 km/h. In this regime harvester was able to accept all the harvested mass without having any jam. Grain mass flow was 9 – 10.36 kg/s and total mass flow 13.84 – 16.57 kg/s. Total losses in this regime was low, 0.36%. In the regime of higher speeds the losses were higher. In the regime of 6 km/h the losses were 0.44% which it acceptable. Maximal working speed was 7.20 km/h and the achieved mass flow was18.98 kg/s. This mass flow is acceptable concerning the fact that the number of the grainheads was 800 / m^2, yield on the location 8.24 t/ha and the specific terrain with the micro depressions. Still, in these conditions, losses of 0.72% were tolerable (Tab. 7).

Table 6 Productivity and fuel consumption of the Harvester B

Date	Starting time	End time	Working time	Surface	Fuel	Average			
			(h)	(ha)	(L)	(ha/h)	(t/h)	(t/ha)	(L/ha)
2.07.	08.02.17	15.47.21	5.82	15.10	212.00	2.60	16.99	6.54	14.04
2.07.	15.50.53	20.47.03	4.00	11.75	159.00	2.94	20.02	6.82	13.53
3.07.	07.36.23	12.37.47	2.75	8.38	114.00	3.05	19.36	6.35	13.61
3.07.	12.41.06	20.59.14	6.38	18.91	247.00	2.96	17.62	5.95	13.06
4.07.	07.43.21	10.04.59	1.88	4.95	67.00	2.63	15.68	5.96	13.53
5.07.	18.16.47	20.38.07	2.10	5.49	72.00	2.62	16.85	6.44	13.11
6.07.	08.32.33	17.47.55	6.03	18.45	237.00	3.06	19.75	6.46	12.84
6.07.	17.48.19	20.37.38	2.35	5.95	85.00	2.53	14.76	5.83	14.29
7.07.	08.16.25	19.12.19	8.02	21.49	302.00	2.68	16.72	6.24	14.05
10.07.	11.21.41	20.22.15	6.43	18.94	265.00	2.94	17.37	5.90	13.99
Total			45.76	129.42	1860.00	2.80	17.51	6.25	13.61

Table 7 Working parameters of the Harvester C

No.	Wheat variety	Yield (t/ha)	Gran / straw ratio	Working speed (km/h)	Grain flow (kg/s)	Cutterbar losses (%) (%)	Threshing unit losses (%)	Total losses (%)
1.	NS 40 S	8.24	1:0.60	6.17	10.36	0.19	0.25	0.44
2.	″	6.85	1:0.54	5.70	8.99	0.13	0.16	0.29
Avr.	-	7.54	1:0.57	5.93	9.67	0.16	0.20	0.36

Header losses were not negligible when compared with the total losses. It is evident that the losses are growing with the speed increase but still they are in the acceptable range. The reason can be intensive lodging of the crop. More than 20% of the surface was lodged. The other problem was coming from the bad synchronisation of harvester cutter bar and crop condition. Analysing the grain from the hopper, it was concluded that the cleaning of the grain was good, there were no impurities and semi harvested grainheads. The percentage of the broken grain was very low, even unnoticeable.

Combine harvester C had the straw chopper, on the rear end. Grain / straw ratio, after the separation unit, was 1/0.57 that, when it is compared with the natural sample that has the ratio of 1/1.05, leads to conclusion that the straw was in good condition for the collection even though it was of the poor quality. The hopper capacity of 12.3 t was in accordance with the working regime as well as the unloading period of 80 s. Unloading auger had the capacity of 159 L/s. Exploitation parameters of the Combine harvester C with the header width of 9.2 m, are given in Table 8.

Table 8 Exploitation parameters for the Harvester C

No.	B (m)	v (km/h)	W_h (ha/h)	Q (L/h)	Q_{ha} (L/ha)
1.	8.68	7.20	5.00	61.40	12.28
2.	8.36	6.17	4.12	62.10	15.07
3.	8.58	5.70	3.91	62.00	15.85
Avr.	8.54	6.35	4.34	61.83	14.40

Combine harvester C had the productivity of 4.34 ha/h, average fuel consumption of 14.40 L/ha and hourly fuel consumption of 62.1 L/h at the 71 to 80 % of the engine load. Time chronography for a shift, showed that combine has finished 24 ha with the average productivity of 4 ha/h and time efficiency coefficient of 0.75.

4. CONCLUSIONS

Based on the exploitation testing and analysis, the following conclusions can be made:

- capacity of the Combine harvester C is the highest if compared to the other harvester. In this regime the losses of 1% were acceptable. Compared to Combine harvester A the capacity of the Combine harvester C was even 102% higher.
- productivity of the Combine harvester C was 55% and 78% higher when compared to Combine harvester B and Harvester A.
- working speed had a significant influence on productivity.
- as for the fuel consumption, the lowest value was found for the Combine harvester B, that is 5.6% lower when compared to Combine harvester C and 30% lower if compared with the Combine harvester A. However, if the yields are taken into account, the situation is slightly different and the combine harvester C has the lowest fuel consumption 1.91 L/t, followed by Harvester B with 2.58 L/t and harvester A with 2.64 L/t.
- productivity of the harvested grain is in correlation with the surface of the separation unit and with the angle of lap of the thresher unit. This correlation is stronger with the growing of these parameters. With the axial separation system these surfaces are equal or slightly larger than in tangential system but the angel of lap is significantly higher (up to 180^0) and this fact brings all the advantages to this system.
- if the time efficiency coefficient and working width efficiency coefficient are higher it is possible to additionally lower the fuel consumption and increase the productivity of all three types of harvesters. This can be achieved with the better organization of the harvesting process and with the introduction of guiding systems.

Generally, the overall conclusion is the technical solution of these complex machines significantly influence the on the working quality of the harvesters as well as on the exploitation parameters.

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Popular paper

THE CULTIVATION AND PROCESSING OF MEDICINAL PLANTS IN SLOVAKIA

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Abstract. *Slovak Republic is placed in the Central Europe. It lies in the climatically favorable mild zone of Northern Hemisphere. Nowadays 150 and about 200 medicinal plants are used in the official therapy and in popular doctoring, respectively. A wide range of herbs are now produced in Slovakia and can be divided into three broad categories: − those collected from the wild (either individually or on commercial scale), −contracted supplies from small-scale growers and − large-scale production on agricultural farms. The large-scale cultivation of medicinal plants belongs to the special agricultural production. It is an only way of supply the contracted volume and quality of these crops. The important elements for optimal technology of medicinal plants cultivation are: selection of biological material, soil cultivation, seeding and planting, nutrition and fertilization, control of harmful factors, harvest, processing and conservation.*

Key words: *Cultivation fields, Herbs, Production, Raw material, Technology*

1. INTRODUCTION

The most often sources in Slovakia and possibilities of medicinal, aromatic and spice plants obtaining [3]:

a) Harvested from nature (conditions ex situ) – from different localities (meadows, forests, groves etc.): mistletoe (*Viscum album* L.), lungworts (*Pulmonaria officinalis* L.), coltsfoot (*Tussilago farfara* L.), field horsetail (*Equisetum arvense* L.), sweet flag (*Acorus calamus* L.) etc. . . .

b) Harvested from cultivated areas – cultural agro-ecological conditions (arable land – fields, gardens etc.): eastern purple coneflower (*Echinacea purpurea* /L./ Moench); milk thistle (*Silybum marianum* /L./ Gaertn.), lemon balm (*Melissa officinalis* L.), pot marigold (*Calendula officinalis* L.), common sage (*Salvia officinalis* L.) etc. .

c) Harvested from nature and cultivated areas – combined way used by the species, which is possible to be harvested from natural localities as well as from cultivated lands: goat rue (*Galega officinalis* L.); St John's wort (*Hypericum perforatum* L.); oregano (*Origanum vulgare* L.); common agrimony (*Agrimonia eupatoria* L.); German Chamomile (*Matricaria recutita* L.) etc. .

d) Harvested from artificially managed conditions (*in situ* conditions) – temperate rooms, greenhouses, cultivated in hydroponics etc.: common sundew (*Drosera rotundifolia* L.); sweet leaf (*Stevia rebaudiana* Bertoni /L. / Hemsl.) etc.

e) Import – allochthone species (foreign for Slovak flora): roselle (*Hibiscus sabdariffa* L.), Quinine Bark (*Cinchona officinalis* L.), Cat's whisker (*Orthosiphon stamineus* Benth.), Flat-plane Leaved Vanilla (*Vanilla planifolia* Andr.), cherry laurel (*Laurocerasus officinalis* Roem.) etc...

The very interesting and profitable area is the isolation of pure natural (herbal) substances by pharmaceutical, cosmetics and food companies. The mentioned natural products use as pharmaceutical preparations for antitumor, sedative, UV-protection treatments. Of course, many natural substances have been replaced by synthetic materials in contemporary chemical technologies. Our long tradition in the Slovak pharmaceutical industry is the isolation and manufacture of pure morphine from poppy (*Papaver somniferum* L.), sylimarine from milk thistle (*Sylibum marianum* L.), β-naphthoquinone from henna (*Lawsonia inermis* L.), β-escine from horse chestnut (*Aesculus hippocastanum* L.), β-ecdysterone from leuzea (*Rhaponticum carthamoides* /Willd./Iljin) etc. [5]. Recent developments of technology enabled introduction of advanced digital image techniques related to the plant tissues analysis, simulation and modeling up to the smallest cell scales [1]. Cell walls are the major components of plant tissue. They provide the most significant difference between plant cells and other eukaryotic cells. The most abundant cell type in all plant parts is the parenchyma. Geometrical dimensions of parenchyma cells are very small and the cell wall structure analysis requires using of different microscope techniques that allow observation at a nano-scale.

An alternative in studying mechanical cell wall properties is setting up a model of an artificial cell wall consisting of polysaccharides which imitate properties of the natural cell wall [4]. An artificial cell wall is composed of artificial parts and is an emerging technology. Polysaccharides as polymeric carbohydrate structures are formed of repeating units of mono- or disaccharides joined together by glycoside bonds. The polysaccharides structures are often linear, but may contain various degrees of branching. They can be often quite heterogeneous, containing slight modifications of the repeating unit. These macromolecules can have distinct properties in the structure from their monosaccharide building blocks. Polysaccharides can be amorphous or even insoluble in water. Polysaccharides network, based on bacterial cellulose supplemented with xyloglucan and pectin, can be used as the model cell wall [4].

2. Agricultural aspects of medicinal plant cultivation

The production of herbs is important for Slovakia´s agricultural industry and would seem the best way of ensuring the required quality and quantity of particular plants in future. Commercial cropping of herbs is both important for the economy and employment and also allows land which is not ideal for food production to be used to grow plants which thrive in poor, mountainous soils [8].

Cultivation of medicinal plants depends on sufficient amount of good quality biological material during establishment of stands. Success of cultivation depends on selection of good quality seeds or planting material, especially varieties that fulfill a yield requirement together with qualitative demands on an active ingredient [6]. .

Advantages of medicinal plants cultivation in comparison to harvest of wildly growing medicinal plant species: − higher concentration (number) of plants per area, − regular agro-biological control of stand, − higher and more stable yields, − possibility of mechanization using, − better harvest access, conservation and processing of raw material [4].

The important parameter of cultivated medicinal plant species is yield of main product, which can be reached only in optimal conditions. Production ability of stands is influenced by many external agro-ecological conditions, e.g. climate, soil, terrain.

However, since the 1970 production of medicinal plants has increased quite markedly in Slovakia. The main reason is that under the previous regime, farming tended to be grouped into large specialist co-operatives focusing on cereals, root crops, animal feeds etc. Specialist small-scale production of medicinal plants was not encouraged. This began to change in the late 1980 and Slovakia now regards large-scale herb cultivation as important. They tend, however, to be treated much like any others crop: chamomile and ergot are grown as cereals. Others like sage, levanter, mint, angelica, elecampane and hyssop are cultivated like rot crops while foxglove, plantain and agrimony go through the system like feedstuffs [8].

Although production is improving there is still considerable potential: the small-scale producers treating their plots like market gardens manage yields of 150 − 200 $kg.ha^{-1}$, which is considerably higher than the volume suppliers. Using standards agricultural techniques may thus not be the best way of cultivating medicinal plants. It is also a fairly unpredictable business with problems of yields, variable demand for particular plants, chemical protection, inadequate drying and storage facilities and labor-intensive production systems. Many of the growers also know little about the herbs they are cultivating or their end uses [8].

Today, Slovakia´s herb production is still unable to meet its growing demands for herbal medicines. At the same time the country is going through a period of rapid political and economic change and is also having to rapidly health service and systems.

The large-scale cultivation of medicinal and aromatic plants belongs to the special agricultural production. It is an only way of supply the contracted volume and quality of these crops.

This special crop production is of great importance from several points of view in the specialized agricultural farms: * rational (offering appropriate occasion for unemployed people), * production (better exploitation of problematic land resources e.g. /salty soil, lower quality soils in sub-mountainous or mountainous areas/) and * economic (from the viewpoint of market value the medicinal plants belong to the most effective agricultural crops) [8]. Table 1 presents an actual situation in medicinal and aromatic plant cultivation in Slovakia in 2014 [2].

Table 1 Species of medicinal and aromatic plants and their produce volume in 2014.

Cultivate area [ha]	Volume of production [t]	Plant species
2,191.07	7,189.70	chamomile (*Matricaria recutita* L), St. John's Worth (*Hypericum perforatum* L.), marigold (*Calendula officinalis* L.), lemon balm (*Melissa officinalis* L.), mint (*Mentha spicata* L.), agrimony (*Agrimonia eupatoria* L.), sage (*Salvia officinalis* L.), dill (*Anethum graveolens* L.), plantain (*Plantago major* L.), hyssop (*Hyssopus officinalis* L.), marjoram (*Origanum majorana* L.), yarrow (*Achillea millefolium* L.), coriander (*Coriandrum sativum* L.), angelica (*Angelica sylvestris* L.), basil (*Ocimum basilicum* L.), lavender (*Lavandula spica* L.), marshmallow (*Althaea officinalis* L.), etc.

3. ISOLATION OF NATURAL PREPARATIONS FROM THE MEDICINAL PLANTS

Extracts are preparations of liquid (liquid extracts and tinctures) and solid (dry extracts) consistency, obtained from herbal drugs, which are usually in a dry state.

Liquid extracts (*extracta fluida*) are liquid preparations of which, in general, 1 part by mass or volume is equivalent to 1 part by mass of the dried herbal and animal matter. These preparations are adjusted, if necessary, so that they satisfy the requirements for content of solvent, and, where applicable, for constituents. Liquid extracts are prepared by using ethanol of a suitable concentration or water to extract the herbal drug or by dissolving a soft or dry extract (which has been produced using the same strength of extraction solvent as is used in preparing the liquid extract by direct extraction) or the herbal drug in either ethanol of a suitable concentration or water. Liquid extract may be filtered, if necessary. Slight sediment may form on standing, which is acceptable as long as the composition of the liquid extract is not changed significantly. Dry extracts are solid preparations obtained by evaporation of the solvent used for their production. Dry extracts usually have a loss on drying or a water content of not greater than 5 % m/m.

Any rate, the production process of each herbal preparation needs to be well documented following every step and wherever necessary. The results of each step should be defined and tested accordingly. These in-process controls, in addition to the documentation of all used materials, machinery and condition, define the production process and the resulting preparation and represent the basis for the good manufacturing practices (GMP). Figure 1 gives an idea of possible influences on the extract and the resulting quality [1].

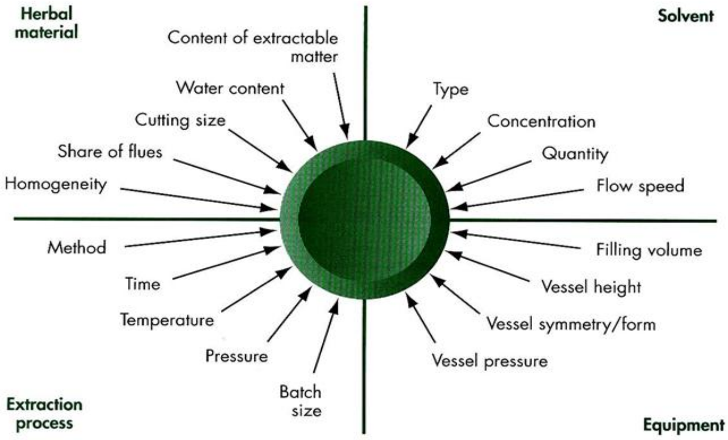

Fig. 1 Influences caused by extraction and quality parameters on the quantity and composition of the native drug extract ration [1].

Many points defining the quality of the finished natural preparations need to be taken into consideration throughout. Many characteristics of herbal product evolve from the definition of the herbal raw material and its preparation. These include proper definition and description as well as identification techniques (TLC, GC, HPLC, and fingerprints), purity and assay [1].

4. CONCLUSION

Medicinal plant quality can be as plant material and plant extracts suitable for human consumption or application and effective in treating the intended ailment. Ideally, such a definition would bring chemically consistent products, free or adulteration or contamination, to markets. The diversity within and among plant populations and the interactions of the plants with growth environment along with both pre- and post-harvest crop management, however, can lead to significant alterations in the bioactivity of plants and plant extracts. The meet quality and safety requirements for medicinal plants, various groups have developed procedures, such as Good Agriculture Practice (GAP), Good Collection Practice (GCP) and Good Manufacturing Processes (GMP), to guide those responsible for producing, processing and dispensing medicinal plants to the consumer [7]. An important aspect of these quality control measures is the identification and documentation of the plant material from field to final distribution.

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First (Short) Comunication

RESEARCH ON ASSESSING THE PURITY OF PLANT PRODUCT OBTAINED FROM THE MECHANIZED HARVESTING OF CHAMOMILE INFLORESCENCES

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Abstract. *In recent years, worldwide sales of medicinal plants and products based on them had a steady growth. This is due to the side effects of synthetic drugs, but also on the consumers desire to return to traditions, realizing the importance that phytotherapy has on health. For these reasons, the quality of the plant product obtained from harvesting medicinal plants is extremely important. The paper represents a continuation of experimental research conducted within INMA, related to the mechanized harvesting of chamomile inflorescences, using different sizes for the active parts. It presents the assessment of purity, one of the quality indexes for the plant material, by processing the experimental data using multivariable functions. The conclusions issued after interpreting the results constitute an important premise for the optimization of the process of mechanized harvesting on chamomile inflorescences, in order to build efficient equipment and to promote a sustainable agriculture*.

Key words: *quality indexes, experimental data, multivariable functions.*

1. INTRODUCTION

The chamomile (*Matricaria recutita L.*), known since antiquity, is one of the oldest, most popular and used herbs. It has been playing such an important role in the traditional medicine because it contains a very large number of active substances that are beneficial for the human body. Even today, the effects of the chamomile are subject to further to ample clinical studies and of laboratory. It is cultivated mainly for the therapeutic importance of its flowers presenting a high content (0.5-1.5%) of volatile oil, rich in azulene, flavonoids, coumarins and other valuable compounds. Volatile oil content (in blue colour) of inflorescences varies from one country to another. [1],[2]

Generally the therapeutic action of the medicinal plants is influenced by the quality of the harvested material. For the reasons enunciated previously and in the case of the chamomile, the material purity is particularly important. This refers to the content of inflorescences with the stalk shorter than 2 cm, from the entire quantity of vegetal material mechanized harvested. As in the case of other medicinal plants, the large scale production of the chamomile can be achieved only through the mechanization of the harvesting process.[3]

This work is a continuation of the experimental research, where were manufactured and tested several typo dimensions of scraper combs for the harvesting of chamomile inflorescences (comb with straight teeth or comb with curved teeth).

This paper aims to analyze one of the quality indexes of product obtained during mechanized harvesting of chamomile, namely the purity of harvested matter. For two of the dimensional variants of comb (one with straight teeth and one with curved teeth), it was performed a compared assessment of the material purity of the harvesting process, by means of processing experimental data, using multivariate regression functions.

2. MATERIAL AND METHODS

Characteristics of chamomile crop where tests were performed are shown in table 2.

Table 1 Characteristics of chamomile culture

Variety	Pearl
Average number of chamomile plants [pcs m^{-2}]	326
Average number of weeds [pcs m^{-2}]	12
Average number of mature flowers [pcs m^{-2}]	1986
Average number of buds which have not blossomed [pcs m^{-2}]	46
Average production of fresh inflorescences [kg/ha]	3204
Average mass of 100 inflorescences [g]	13.2
Average diameter of inflorescences [mm]	19.4
Minimum and maximum height between which the flowers grow [mm]	298...583

It was used for testing a trailed machine for harvesting chamomile, with conveyer type picker and scrapers combs. This type of harvesting device is suitable for chamomile harvester with lower working capacity, compared to some of new advanced solutions of high productivity, in the field [4],[5]. The combs act only on the floral floors which are harvested, corresponding to the working height. Chamomile inflorescences collected during harvesting are taken over by a conveyor, to be split into the machine bunker.

There were executed and tested several types of scrapers combs with straight teeth (Fig. 1 a) and curved teeth (Fig. 1 b). In both types of teeth the gap between teeth is shaped like a rounded "U". [6] Notations used in Figure 1 have the following meaning: p

- tooth pitch; L - length of the teeth; d - distance between two consecutive teeth; b - width of the teeth; R - the radius of curvature of the combs with curved teeth, R=L, $m = \sqrt{2}L$

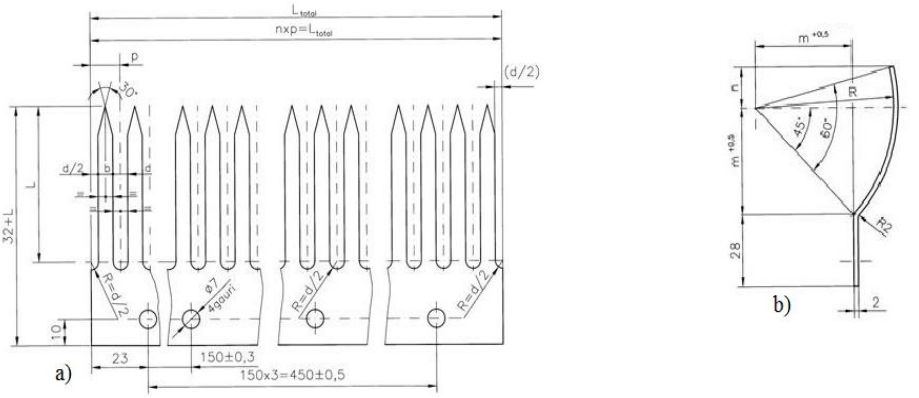

Fig.1 The shape of combs: a) with straight teeth; b) with curved teeth

Dimensional characteristics of scraper combs variants chosen to be analyzed, are: V1 (with straight teeth): d=4mm; p=14 mm; L=100 mm; b=10 mm and T2 (with curved teeth):d=4mm; p=12 mm; L=80 mm; b=8 mm; R_{T2}=80 mm. There have been chosen the variants for which were registered the highest harvesting values, for each type of teeth. The harvesting degree is the main indicator that characterizes any harvesting process.

The purity of the product obtained at harvesting was expressed as a percentage being the participation of the faction of flowers without peduncle or with the peduncle ≤ 30mm at the analyzed sample of material from bunker. More samples out of harvested material (5 samples) have been analyzed for determining the purity, both for V1 and T2, for each combination from all possible ones related to work conditions (namely, the values of working speed, harvesting height and comb peripheral height).

After carrying out the experiments it was found that the values determined for the purity of harvested material are dependent on certain conditions which are expressed with some values that we impose to the working speed, to the working height and to the peripheral speed of the combs. So, the purity is a variable that depends on several independent variables simultaneously. This dependence can be expressed by means of analytical expressions, whose general shape must be determined, as a function of the type:

$$y = f(x_i, a_0, a_i, a_{ii}, a_{ij}) \tag{1}$$

Due to the complexity dealing with this issue the crossing of some stages is necessary: drafting a suitable program of organizing experiences, determining the values of constants, testing the variables significance, testing the accuracy form of the equation [9].

The multivariable functions may be of the polynomial regression function type or function of polytropic regression.[7],[8],[9]

*Function of regression of polynomial form***,** with three independent variables, which has the form [9]:

$$y = a_o + \sum_{i=1}^{3} a_i \cdot x_i + \sum_{i=1}^{3} a_{ii} \cdot x_i^2 + a_{12}x_1x_2 + a_{13}x_1x_3 + a_{23}x_2x_3 \tag{2}$$

where: x_1 , x_2 , x_3 are independent variables, y is a dependent variable and a_0, a_i, a_{ii}, a_{12}, a_{13} si a_{23} are the constants whose value has to be determined.

Polytropic regression function, with three independent variables, which has the form [9]:

$$y = a_o \cdot x_1^{a_1} \cdot x_2^{a_2} \cdot x_3^{a_3} \tag{3}$$

The structure of the experimental research software used to determine the function y is given by: The number $n_* = 14$ of experiments made for different values of the independent variables, necessary to determine the coefficients; The number $n_o = 4$ of experiments made for identical values of the independent variables, necessary to determine the experimental error; The total number of experiments:

$$n = n_* + n_0 = 14 \tag{4}$$

The main characteristics of the experimental program, defined in relation with the requirements for the determination of some functions appropriate to the investigated processes are: *the compatibility,* (defined in relation to the achievement of a unique solution of the coefficients), *the orthogonality* (defined according to some estimations of the coefficients, uncorrelated), *the adequac*y (defined in relation to the achievement of some conclusive values of the indicators of testing of the significance of coefficients and the adequacy of the function form).[9]

For the multivariable regression functions (polynomial and the polytropic) are carried out:

a) The coefficients calculation - The determination of these constants is made with the least square method, expressing the sum of the squares of deviations of the measured values to those calculated with the modeling program. The constants from the expression of the multivariable function is determined after solving a system of linear equations, which are obtained putting the condition that the sum to be minimal. [7],[8],[9]

b) Testing the significance of coefficients - is done using the Fisher test, calculating the sum of the experimental error squares and the sums due to the coefficients. Is calculated:

$$S_e = \sum_{i=n_*+1}^{n} \left(y_i - \sum_{i=n_*+1}^{n} \frac{y_i}{n_o} \right)^2 \tag{5}$$

$$S_0 = nb_0^2,\ S_j = a_j^2 \sum_{i=1}^{n} X_{ij}^2 \qquad j = 1, 2, 3, ..., m_1 \tag{6}$$

Calculated the ratios: $$F_o = \frac{S_o(n_o - 1)}{S_e},\ F_j = \frac{S_j(n_o - 1)}{S_e},\ j = 1, 2, 3,….m_1 \tag{7}$$

If $F_0 \geq F(1-\alpha, 1, n_o - 1)$, $F_j \geq F(1-\alpha, 1, n_o - 1)$, $F_{jj} \geq F(1-\alpha, 1, n_o - 1)$, $F_{1j} \geq F(1-\alpha, 1, n_o - 1)$ and $F_{23} \geq F(1-\alpha, 1, n_o - 1)$ the coefficients a_0, a_j, a_{jj}, a_{1i} and respectively a_{23} are significant. If the condition is not met for one or more factors, they are equal to zero. The critical values F ($P = 1 - \alpha$, $k_1 = 1$, $k_2 = n_o - 1$) are given for the level of significance $\alpha = 0.95$ [7],[8],[9]

c) Testing of the adequacy of the function form - was studied using the Fisher test:

$$F = \frac{(S - S_e)(n_o - 1)}{S_e(n - n_o - m_1)} < F(1 - \alpha, n_* - m_1, n_0 - 1) \tag{8}$$

where m_1 represents the number of function coefficients (without a_0). If this condition is met, than the function form is adequate. [7],[8],[9]

In order to express the purity of harvested material by means of multivariable regression functions, independent variables which influence this dependent variable, as well as their variation range, were chosen. These independent variables are: *Working speed:* $v_l = 0.5 – 1.22\ Kmh^{-1}$; *Harvesting height:* $H=0.3 – 0.45\ m$; *Combs peripheral speed:* $v_p = 0.52 – 1.08\ ms^{-1}$. The calculation algorithm shown above was used to create a program in the programming language Turbo Pascal 7.

The experimental program of tests for the determination of the multivariable functions for calculating the purity of the harvested material for the variants V1 and T2 of scraper combs, is shown in the Table 2.

Table 2 **-**Experimental program of purity testing , using V1 and T2

No. experiment	v_l **[km h^{-1}]**	***H*** **[m]**	v_p **[m s^{-1}]**	**Purity V1 [%]**	**Purity T2 [%]**
1	0.5	0.30	0.52	68.6	69,4
2	1.22	0.30	0.52	41.3	45,3
3	0.5	0.45	0.52	82.3	83,2
4	1.22	0.45	0.52	58.7	57,3
5	0.5	0.30	1.08	61.5	70.5
6	1.22	0.30	1.08	41.8	47.8
7	0.5	0.45	1.08	83.5	88.3
8	1.22	0.45	1.08	60.6	66.8
9	0.5	0.30	0.76	60.5	66.8
10	1.22	0.30	0.76	40.7	49.8
11	0.76	0.45	0.76	66.6	81.5
12	0.76	0.30	0.76	48.4	64.8
13	0.76	0.30	1.08	47.5	64.4
14	0.76	0.30	0.52	43.8	61.4
15	0.76	0.30	0.76	48.4	64.8
16	0.76	0.30	0.76	44	68
17	0.76	0.30	0.76	52	60
18	0.76	0.30	0.76	49	65

3. RESULTS AND DISCUSSION

3.1. Determination of the multivariable functions for calculating the purity of the harvested material for the variant V1 and T2 of combs

Using the calculation program, the regression coefficients and testing coefficients of coefficient signification for polynomial function suitable to harvested material purity for variant V1, as well as T2 variant, were calculated. Function form has not been suitable for any case. Then, the regression coefficients and the coefficients of testing of the coefficients significance for the function of the polytropic form corresponding to the purity of the harvested material, for the variant V1 were calculated:

a_1 = 124.733573780 F_1 = 62152.229762 > F=8.25 results: *a_1 is significant;*
a_2 = - 0.432344679 F_2 = 77.724003312 > F=8.25 results: *a_2 is significant;*

$a_3 =$ 0.865760493 $F_3 =$ 64.397591996 > F=8.25 results: *a_3 is significant;*
$a_4 =$ 0.006808698 $F_4 =$ 0.012941849 < F=8.25 results: *a_4 is not significant.*

The coefficients are recalculated: a_1 =124.7335738, a_2 = - 0.4323447, a_3 = 0.8657605, a_4 = 0
Coefficient of testing of the adequacy of the function form is F=1.415 < F_{tab} = 9.4, so the form of the function is adequate [9]. The polytropic function that allows the calculation of the harvested material purity for the variant V1 of the combs is:

$$P = 124.7335738 \cdot v_l^{-0.4323447} \cdot H^{0.8657605} \cdot v_p^0 . \tag{12}$$

Then, the regression coefficients and the coefficients of testing of the coefficients significance for the function of the polytropic form corresponding to the purity of the harvested material, for the variant T2 were calculated:
a_1 = 109.50611276 F_1 = 118617.229762 > F=8.25 results: *a_1 is significant;*
a_2 = - 0.425454853 F_2 = 133.50203672 > F=8.25 results: *a_2 is significant;*
a_3 = 0.566835415 F_3 = 48.96368052 > F=8.25 results: *a_3 is significant;*
a_4 = 0.061648780 F_4 = 1.881928766 < F=8.25 results: *a_4 is not significant.*
The coefficients recalculated are: a_1 =109.5061128, a_2 = - 0.4254549, a_3 = 0.5668354, a_4 = 0
The coefficient of testing of the adequacy of the function form is F=1.962 < F_{tab} = 9.4, so the form of the function is adequate [9]. The polytropic function that allows the calculation of the harvested material purity for the variant T2 of the combs is:

$$P = 109.5061128 \cdot v_l^{-0.4254549} \cdot H^{0.5668354} \cdot v_p^0 \tag{13}$$

In figures 2 and 3, are shown the experimental values of harvested material purity in comparison with theoretical values, calculated based on polytropic functions, previously obtained, for variant V1 of combs, respectively for variant T2.

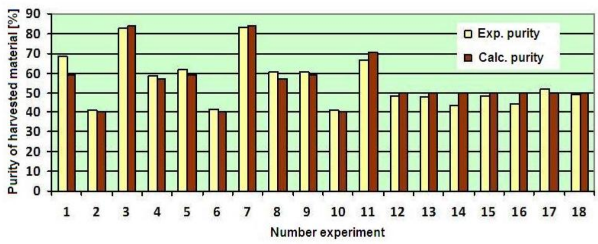

Fig. 2 Purity of the harvested material for the variant V1 of combs.
LEGEND: experimental purity, calculated purity

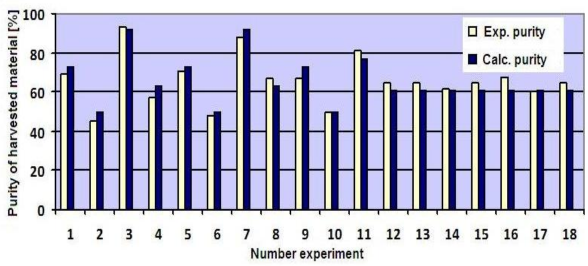

Fig. 3 Purity of the harvested material for the variant T2 of combs.
LEGEND: □ experimental purity, ■ calculated purity.

Usually in a process of harvesting, the working height (of harvesting) H is established and is maintained constant. In this case the purity of the harvested material can be determined using functions of two variables, dependent on working speed ($v_l=x_1$) and of the peripheral speed of the combs ($v_p=x_2$), having the form:

$$f(x_1,x_2) = a_0 + a_1x_1 + a_2x_2 + a_3x_1^2 + a_4x_1x_2 + a_5x_2^2 \tag{14}$$

Using the values from table 3 and program MathCad, the constants of two-variable function of form (14) can be determined, through which the variant of harvested material purity can be studied at working height of H=0.3m, for combs variants V1 and T2. [10].

Table 3 Experimental values of the harvested material purity for the V1 and T2 at the working height H=0.3m

No. experiment.	v_l [km h^{-1}]	v_p [m s^{-1}]	Purity V1 [%]	Purity T2 [%]
1	0.5	0.52	68.6	69.4
2	0.5	0.76	60.5	66.8
3	0.5	1.08	61.5	70.5
4	0.76	0.52	43.8	61.4
5	0.76	0.76	48.4	64.8
6	0.76	1.08	47.5	64.4
7	1.04	0.52	42.3	53,0
8	1.04	0.76	50.7	55,6
9	1.04	1.08	47.2	55,6
10	1.22	0.52	41.3	45.3
11	1.22	0.76	40.7	49.8
12	1.22	1.08	41.8	47.8

For the purity of the material properly harvested of V1 at H=0.3 m, for a coefficient of correlation R=0.916, the function (14) has the form:

$$P(v_l,v_p) = 111.305 - 126.135v_l + 3.156v_p + 49.37v_l^2 + 17.805v_lv_p - 11.207v_p^2 \tag{15}$$

For the purity of the material properly harvested of T2 at H=0.300m, for a coefficient of correlation R=0.99, the function (14) has the form:

$$P(v_l,v_p) = 62.431 + 1.832v_l + 23.309v_p - 18.999v_l^2 + 1.6v_lv_p - 12.88v_p^2 \tag{16}$$

In Figures 4 and 5 the variation of the harvested material purity depending on the working speed ($v_l = x_1$) and of the combs peripheral speed ($v_p = x_2$) is presented, at a working height H=0.3 m, for the variants V1 and T2 of the combs, using the functions given by the relations (15) and (16).

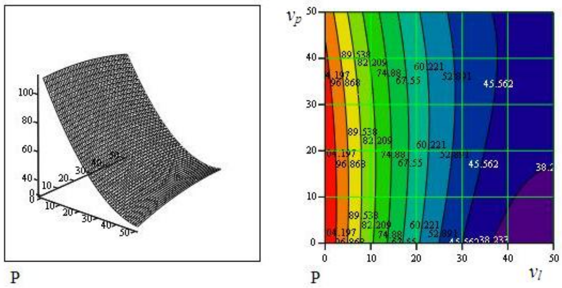

Fig.4 Variation of purity of the harvested material (P) for the variant V1 of the combs depending on v_l and v_p, at a working height H=0.3 m

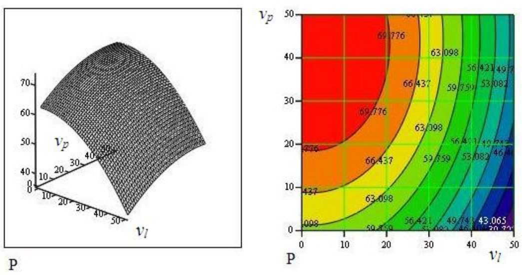

Fig. 5 Variation of purity of the harvested material (P) for the variant T2 of combs depending on v_l and v_p, at a working height H=0.3 m

In figures 6 and 7 the variation of the harvested material purity at a working height H=0.3m is represented, depending on the working speed, for each peripheral speed of the combs, corresponding to each of constructive variants studied (V1 and T2).

Figure 6 shows that the purity of the harvested material for the variant V1 decreases depending on the working speed, being less influenced by the peripheral speed of working parts, the values being close. In this case it is more advantageous to use the lowest peripheral speed (v_{p1}=0.52 ms^{-1}).

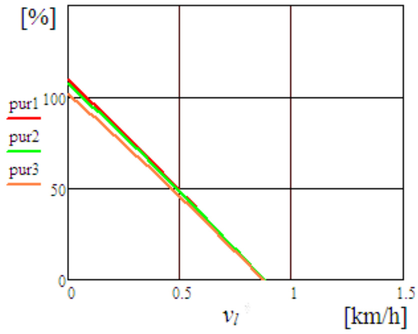

Fig. 6 Variation of the harvested material purity for V1, depending on v_l, at H=0.300m.
LEGEND: the purity for the combs peripheral speed v_{p1}=0.52 ms^{-1},
the purity for the combs peripheral speed v_{p2}=0.76 ms^{-1},
the purity for the combs peripheral speed v_{p3}=1.08ms^{-1}.

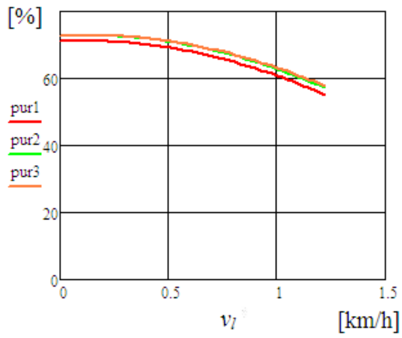

Fig. 7 Variation of the harvested material purity for T2, depending on v_l, at H=0.300m.
LEGEND: the purity for the combs peripheral speed v_{p1}=0.52 ms^{-1},
the purity for the combs peripheral speed v_{p2}=0.76 ms^{-1},
the purity for the combs peripheral speed v_{p3}=1.08ms^{-1}.

Figure 7 shows that the purity of the harvested material for the variant T2 decreases depending on the working speed, being less influenced by the peripheral speed of working bodies, the values being close. In this case it is more advantageous to use the highest peripheral speed (v_{p3}=1.08 ms^{-1}).
Comparing the two graphs it has found that for same working height, the same working speed and even for the same peripheral speed, the purity of the harvested material is higher when using the version with curved teeth of the active bodies - T2.

4. Conclusions

The analysis of results of experimental data processing relating to the purity of the material obtained at the mechanized harvesting of chamomile inflorescences highlights the following aspects: the purity of the harvested material can be expressed only through a regression polytropic function, both for V1 and for T2; the expressions of the analytical functions of several variables for purity do not depend on the peripheral speed of the combs for the interval considered for this, for the both variants of the combs (V1 with straight teeth and T2 with curved teeth); regardless of the version of active part used, the purity is decreasing depending on the working speed, at the working height H=0.3m; for variant T2, the purity takes higher values than for the variant V1, for the same working conditions. So, theoretically it has pointed out that to obtain a high purity material at a working height H=0.3m it is advisable to use working bodies with curved teeth, having a high peripheral speed, at the working speed as low as possible. The theoretical results obtained from this analysis is an important prerequisite for improving the working performances of the equipment for harvesting of chamomile inflorescences to promote them, as well as an argument in the favor of re-launching the cultivation of this species in Romania, in accordance with the development of sustainable agriculture.

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Case Study

COST OF TRANSPORTATION IN FOIL COVERED FIELD CUCUMBER PRODUCTION TECHNOLOGY

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Abstract. *In the paper we present the up-to-date mechanized production technology of cucumber production from ridge bed preparation till harvesting including transporting as well. By the presentation of the performance and economic data of machines necessary for production, we are emphasizing the significant volume of transport tasks in the production technology of pickled cucumber. In the present production technology the costs of machine operations and cost of material handling is about 14 Euro Cent/kg concerning the production cost of cucumber. It can be stated on the basis of the results that the total operational cost of the machines amounts 1688 EUR per hectare, which include the cost of transport and material handling in value of 390 EUR/ha. Special attention is to be paid to the machine operations like foil tunnel preparation, picking and planting which the most* ***costly*** *ones are representing about 12, 13 and 17 % of the total machine operation costs. It is worth mentioning that cost of transport and material handling takes the highest value, about 23 % of the total cost of mechanisation.*

Key words: *Foil covered filed, Logistic, Mechanisation, Economic, Machine Cost, Material handling*

1. INTRODUCTION

The subject of the present study is the mechanized production of pickling cucumber developing rapidly in the last years [2], [7].

The cucumber is one of the most important vegetable crops in Hungary. The home consumption and the exported quantity is also remarkable. Regarding the production area and the quantity produced, pickled cucumber is the most significant in Hungary. The production area is roughly 3-4 thousand hectares. The most important link in the chain of production and distribution is the solid inland processing industrial background which is essential for the export of fresh products as well [3].

By the presentation of the performance and economic data of machines necessary for production, we are emphasizing the significant volume of transport tasks in the production technology of pickling gherkins [1], [4].

2. MATERIAL AND METHODS

2.1. Presentation of the Production Technology

The machine technology of production is presented on the basis of Table 1. The table shows the operations, the machine applied for the certain operation, and the power category of the power machine attached to it. The Table 2 shows the shift performance of the attached machines. Some of the economic data are also included: the price of the working machine and the power machine in the year 2013, the operational cost of the same per shift hour together with the operational cost of the attached machines [5].

Table 1 The machine technology of production of foil covered field cucumber production

Operations	**Type of machine applied in the technology**	
	working machine	**power machine**
Stubble ploughing	Kühne 770-7,2 disc harrow	140 kW tractor
Medium deep loosing	RÁBA 10-14/5	140 kW tractor
Spreading organic manure	AGRO 65 TSZ tandem	60 kW tractor
Fertilizer transport	MBP 6,5 R	60 kW tractor
Spreading of fertilizer	Tornado 5	70 kW tractor
Deep ploughing	Kühne 720-7/6-16-M-TJ	140 kW tractor
Fertilizer transport	MBP 6,5 R	60 kW tractor
Spreading of fertilizer	Tornado 5	70 kW tractor
Ploughing processing	S-2 H/M	140 kW tractor
Seed bed preparation	Lemken Korund 600 K	140 kW tractor
Levelling the surface	Kühne KH - 5,6 S	60 kW tractor
Ridge bed preparation	Hortus HPD-165	70 kW tractor
Mulching, hauling in the hosepipe	AF 1	70 kW tractor
Water supply	DETK-115 tanker	60 kW tractor
Transport of plantlets	MBP - 6,5	60 kW tractor
Planting	Fedele Mario	70 kW tractor
Preparation of foil tunnel	AFF-1000	70 kW tractor
Irrigation	Nadir	
Spray mixture transport (12x)	DETK-115 tanker	70 kW tractor
Spraying (12x)	Gambetti GB E. 1500/16 v	60 kW tractor
Picking	Steiger	70 kW tractor
Transport	MBP - 6,5 – 2 pcs	60 kW tractor
Transport following pre-grading	HL 92.02 road	Trailer

Table 2 The basic economic data of the operations of cucumber production

Operations:	Shift performance (ha / hour)	Price of (th EUR)		Direct cost of operation (EUR/hour)		
		working machine	power machine	working machine	power machine	total
Stubble ploughing	3	19	141	10	29	39
Medium deep loosing	1,2	3,6	141	3	29	32
Spreading organic manure	0,7	7,1	65	4	16	19
Fertilizer transport	4	6	65	2	16	18
Spreading of fertilizer	4	9,6	72	6	19	26
Deep ploughing	1,5	8,3	141	6	29	36
Fertilizer transport	4	6	65	2	16	18
Spreading of fertilizer	4	9,6	72	6	19	26
Ploughing processing	4,8	7,4	141	7	29	37
Seed bed preparation	4	14	141	9	29	39
Levelling the surface	3,8	5,7	65	4	16	19
Ridge bed preparation	0,4	10	72	12	19	31
Mulching, hauling in the hosepipe	0,25	4,3	72	3	19	22
Water supply	0,9	6,8	65	4	16	20
Transport of plantlets	4	6	65	2	16	18
Planting	0,1	3,6	72	4	19	24
Preparation of foil tunnel	0,2	7,4	72	14	19	33
Irrigation	0,25	8,8	0	24	0	24
Spray mixture transport (12x)	4,8	6,8	72	4	19	23
Spraying (12x)	4,8	16	65	9	16	25
Picking	0,2	44	72	16	19	35
Transport		12	65	4	16	20
Transport following pre-grading		7,5	33	3	20	22

2.2. The Major Machines of the Production Technology

The technology is based on drip 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 (Fig. 1 and Fig. 2) are used by which crop can be harvested on the same territory 2-3-times a week without causing treading damage to the vegetation. 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. According to measurements, the structure of the machine creates an appropriate position for the picking workers and fulfils the tasks of transport within the field at the same time [6].

Fig. 1 The mass transport on the belt conveyor and the position of picking personnel on the machine

Fig. 2 Belt cucumber picking carriage type STEIGER

3. RESULTS AND DISCUSSION

The results of the economic survey of cucumber production on a 20 hectare area are shown in Table 3. Apparently, the machine working time necessary for the cultivation of the 20 hectare growing area in case of attached machines has been stipulated related to the individual operations. Based on this, the direct operational cost of the connected machines can be easily calculated by multiplying the *direct operational cost of the machine per shift hour* (Table 2) with the effective working time. As a result, the cost of the individual operations related to 20 hectare growing area has been defined the total production costs of cucumber production on 20 hectares and also the specific cost per hectare has been determinate. The costs of field cucumber production and harvesting are specified in the Table 3.

Table 3 The economical indices of the operations of foil covered field cucumber production on 20 ha

Operations:	Machine working hours (h)	Cost of operation (EUR)
Stubble ploughing	6	284
Medium deep loosing	16	616
Spreading organic manure	28	672
Fertilizer transport	***5***	***106***
Spreading of fertilizer	5	153
Deep ploughing	13	553
Fertilizer transport	***5***	***106***
Spreading of fertilizer	5	153
Ploughing processing	4	176
Seed bed preparation	5	234
Levelling the surface	5	118
Ridge bed preparation	50	1958
Mulching, hauling in the hosepipe	80	2120
Water supply	***22***	***531***
Transport of plantlets	***5***	***106***
Planting	200	5773
Preparation of foil tunnel	100	4170
Irrigation	80	2388
Spray mixture transport (12x)	***48***	***1351***
Spraying (12x)	48	1503
Picking	100	4441
Transport	***100***	***2407***
Transport following pre-grading	***150***	***3844***
Canning industry technology - total	**1.080**	**33763**
Cost per hectare (EUR/ha)		**1688**

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 the power machines (22.567 EUR). The total operational cost amounts to 33.763 EUR, 1688 EUR per hectare.

The investment cost of the machines applied in the production technology is 510.396 EUR out of which the purchasing price of the working machines amounts to 197.300 EUR, which equals about 39 % of the total investment cost. The purchasing price of the power machines is 313.096 EUR, about 61 % of the total cost of machines.

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. 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. A low-cost trailer can be used for the road transportation of the product. With this selection of 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 [9, 10].

4. CONCLUSIONS

The machine work costs of field foil covered cucumber production compared to the production costs of other field vegetable varieties are high [8].

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. In the present production technology the costs of machine operations and cost of material handling is 14 Euro Cent/kg besides a calculated average yield of about 12 t/ha.

It can be stated that special attention is to be paid to the machine operations like foil tunnel preparation, picking and planting which the most costly ones are representing about 12, 13 and 17 % of the total machine operation costs. It is worth mentioning that cost of ***transport and material handling*** takes the highest value, about 23 % of the total cost of mechanisation.

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Case Study

TILLAGE FOR PERENNIAL PLANTATIONS BY USING ROTATING MACHINERY

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Abstract. *Intensive fruit production involves large investment in the creation of modern fruit plantations, which require the full-intensity implementation of agro-technical measures, during their exploitation. One of the basic measures is the tillage or maintenance of the inter-row space in the plantation, because that measure has a crucial influence on the growth and productivity of cultivated fruit trees. Good results in fruit production can only be achieved in conditions of proper and timely tillage. Intensive tillage in fruit plantations is a highly energy-demanding agricultural measure.*

This paper explores the operational parameters of the rotational inter-row tiller brand "Termometal", models PTF-125 and PTF-145. In the past years, the tested types of machinery are increasingly used in fruit growing in our country.

The analysis of the results shall acquaint current and potential customers with the exploitation of energetic parameters of those machines. In that way, they are given the chance to select the equipment correctly, in accordance with the production conditions of the plantation.

Key words: *perennial crops, mechanized tillage, movable rotational tiller, tractor unit.*

1. Introduction

Modern technology for the cultivation of perennial plants implies the use of the grassing procedure in the tillage of the inter-row surface, while the row surface, i.e. the protected area should be mechanically tilled. Such tillage methods require a sufficient amount of moisture during the vegetation of the crops, which is mainly ensured by using technical irrigation systems. Investments in irrigation systems and other protection and care equipment elevate the costs for growing and maintaining modern plantations. Such investments are made in agriculturally developed countries, while in our conditions, perennial plants are cultivated without irrigation and there is often a deficit of moisture in the soil.

In order to manage soil moisture more rationally in domestic orchards, the land surface is intensively tilled [2]. Such tillage must meet all quality standards for soil tillage, including the fulfillment of all environmental standard. Inadequate tillage can result in the destruction of the equipment and the loss of organic matter [6]. The highly intensive production of fruits is directly defined not only by the biological characteristics of the different sorts, but also and first of all, by the correct and timely tillage of the soil [1,3]. In the case of perennial plantations, soil tillage is technologically conditioned by a higher number of parameters, determined by the characteristics of the perennial plants, e.g. growing shape, soil properties and terrain conditions.

The mechanical tillage of the soil in the immediate vicinity of plant rows represents a highly complex technical problem, given that the land surface is under the crown and next to the stem of the plant [8, 10]. The access to this area is limited for standard machinery and tools, which are symmetrically aggregated in relation to the tractor as driving machine. Due to the lack of adequate machinery in domestic fruit and wine growing, herbicides are usually used in order to destroy weeds growing in the row space [9, 11]. The fact is that the application of pesticides pollutes the environment and destroys only the weed vegetation, without tilling the soil and improving its properties.

The use of modern machinery for row tillage requires large investments, given that such machinery is imported into our country [7]. So far, all the attempts of the domestic industry to develop and produce this kind machines were unsuccessful. Therefore, they have had a limited use in our country, where an insufficient number of machines has been imported. The main problem is that these machines are expensive in terms of the purchasing power of local fruit growers. In our country, the soil is additionally tilled by using domestic rotational tillers that can be laterally moved. That is why; there has been enabled the passage of tractors under the crown of the plants, in plantations with extensive planting and high crowns, obtaining thus a narrow strip of untilled surface in the row of plants. Figure 2.

2. MATERIALS AND METHOD

In accordance with the aims of the research, there was performed an experiment with two types of domestic inter-row rotating tillers, manufactured by the company "Termometal", models PTF-125 i PTF-145, which differ by their working width. The rotational tiller, in combination with tractors IMT-539 and R-65 (as shown in picture 1) was tested in a plantation of plums, in cultivation form, with an enhanced pyramidal crown, in the period July 3-5, 2015.

During the experiments, there carried out measurements in field conditions of fruit production, within the following parameters:

- Bulk density of the soil (Kopecký cylinders);
- speed of movement (obtained as a quotient of the traversed path on a 50 m track and the time, in which the tractor traversed that path);
- pulling force in the stabilizer (measured with the help of Amsler's dynamograph);
- hourly fuel consumption (obtained by volumetric methods - scale length);

- specific fuel consumption (calculation method);
- fuel consumption per unit area (obtained as the quotient of time consumption and the productivity of the unit);
- torque on the PTO shaft of the tractor, determined by the measuring system with transducer 2 *nKm* and transducer TD2. The control measurement of transducer TD2 was carried out with the help of the oscilloscope Tektronix 2230.

a b

Fig. 1 Rotational tiller PTF-125: a) in combination with tractor R-65; b) in combination with tractor IMT-539

The plants were planted in a cambisol soil, with an inter-row and row spacing of 4 x 3.5m. The construction of the machinery makes possible a lateral movement of 10-45 cm in relation to the outer edge of the right wheel of the tractor. With the help of such set-up, the machine can approach, to a great extent, the stems of the plants, so that there will remain, after tillage, only a very small untilled surface in the rows, as shown in figure 2.

Fig. 2 Untilled land surface within the rows

Table 1 Technical characteristics of the tested means

Technical characteristics of tractor	IMT 539	IMR 65	Technical parameter	PTF -125	PTF -145
Power engine [kW]	28	47	Agregate type	Mounted	Mounted
Speed engine at max. power [min^{-1}] [min^{-1}]	2000	2300	Working clutch [cm]	116	137
$M_{max.}/n_{Mmax}$ [Nm/min]	149/ 1400	185/ 1200	lateral shift [cm]	28	35
specific expenditure within the engine fuel [g/kWh]	225	282	Dillage depth [cm]	do 18	do 18
Energy supply in reference at konst. mass [kW/t]	19.44	20.33	Number of blades	20	24
Specific mass without ballast [kg/kW]	51.42	49.16	The number of rotations of the rotor [min^{-1}]	260	260
Specific mass with ballast [kg/kW]	-	75.00	Weight [kg]	227	264
Mass without ballast [kg] with ballast [kg]	1440 -	2360 3600	Tractor power [kW]	25-35	35-45

List of symbols

Eha – specific energy	[kWh/ha]	Q – fuel consumption hourly	[l/h]
Fv – drawbar pul	[kN]	Qha – specific energy	[l/ha]
k_t – specific soil resistens	[N/cm^2]	v – driving speed	[km/h]
M_{max} – max. torque	[Nm]	Wh – poductivity	[ha/h]
n_{Mmax} – speed engine at M_{max}	[min^{-1}]	φ – adherence	[-]
Pv – power pull	[kW]	λ – slip of wheels	[%]
q – specific eff. fuel cons.	[g/kWh]	η – coeff. advantag.	[-]

3. RESULTS AND DISCUSSION

3. 1. Test conditions

The soil of the 7-year-old plum plantation belongs to the ambisol type. According to the data contained in Table 2, it is possible to establish that the testing conditions were worsened by the fact that the surface layer was relatively small and that, based on its bulk density, the soil belongs to the category of heavier ambisol varieties.

Table 2 Soil moisture and bulk density

No	Measuring spot	% hymidity	Vol. mass (g/cm^3)
1.	Surfice	21.77	1.364
2.	Depth 5 cm	22.96	1.489
3.	Depth 10 cm	22.69	1.420

3. 2. Technical characteristics of the tractor

In this study there were used tractors IMT-539, which have potential characteristics on a concrete substratum, without ballast, according to the Test Report and O.E.C [5], as shown in Table 3.

Table 3 Potential pulling characteristics of tractors IMT 539

Degree transmission	**v** (km/h)	Pv (kW)	Fv (kN)	n (min^{-1})	λ (%)	q (g/kWh)
I	1.88	5.85	11.62	2100	16.20	485.0
II	2.80	8.86	11.72	2095	16.40	390.0
III	5.15	16.04	11.57	2080	14.70	275.0
IV	7.52	21.19	10.10	2065	10.60	250.0
V	11.60	22.67	6.87	2040	5.20	240.0
VI	22.75	22.30	3.48	2010	2.00	255.0

Pulling characteristics of tractor R-65 on stubble with ballast -Table 4.

Table 4 Potential pulling characteristics of tractor R-65 with ballast [4]

Degree transmission	Pv (kW)	Fv (kN)	**v** (km/h)	λ (%)	Qh (l/h)	q (g/kWh)	ή (-)
I	9.90	15.69	1.75	27.7	7.68	643.0	0.207
II	15.40	15.07	2.83	27.1	9.88	532.0	0.322
III	26.69	14.21	5.21	21.9	13.92	433.0	0.558
IV	32.29	11.35	7.90	11.8	15.28	392.0	0.675

Taking into consideration the technical possibilities of tractor IMT-539 and the energy requirements of the rotational tiller PTF-145, which requires a pulling force of 35-45 kW, that combination was not tested in the experiments. The tractor IMT-539 was tested in the experiment in combination with the rotational tiller PTF-125, because energy requirements are within the exploitation possibilities, i.e. it requires a pulling force of 25-35 kW for tillage at a depth of 18 cm, while the tractor has a pulling force of 28 kW. However, experience shows that tractors IMT-539 are much more practical in plantations, due to their size and thei mostly unprotected cabin. This unit was used in the experiment because it has a tilling depth up to 10 cm.

3. 2. Energy parameters of the Tractor-Implement Unit

By monitoring the Tractor-Implement Unit consisting of Tractor IMT-539 and Rotational Inter-Row Tiller PTF-125, there were measured the main parameters, which are shown in table 5. Test results show that the work depth of the rotational tiller, in combination with different tractors, was about 7.9 cm, when working with tractor IMT-539, and 9.2 cm when tractor R-65 was used in combination with both tillers.

Table 5 Energy parameters of the unit consisting of Tractor IMT-539 and Rotational tiller PTF-125

Number of measurement	M (Nm)	n_{PTO} (o/min)	P_v (kW)	v (km/h)	Fv (kN)	Q_h (l/h)	Q_{ha} (l/ha)	W_h (ha/h)	E_{ha} (kWh/ha)
1.	180	500	10.70	2.47	1.90	5.60	14.81	0.42	25.47
2.	190	510	11.60	2.34	2.44	5.65	13.98	0.40	29.00
3.	286	515	17.78	2.79	3.15	5.49	13.04	0.49	36.28
4.	188	490	11.20	1.95	2.30	5.53	14.90	0.36	31.11
5.	183	475	10.45	2.18	2.36	5.57	26.46	0.38	27.50

By analyzing table 5, we can see that fuel consumption, when working in such a combination, reached at best 13.05 l/ha, with an efficiency of 0.49 ha/h and an energy consumption of 36.28 kWh/ha. Energy consumption, when using this combination, oscillated between 25.47 kWh/ha and 36.28 kWh/ha, while efficiency oscillated between 0.36 and 0.49 ha/h.

The results of the tested Tractor-Implement Unit, consisting of Tractor R-65 and Rotational Tiller PTF-125 (Table 6) show that the technological speed of this unit is lower in average (2.19 km/h) compared to the average movement speed of the first unit (2.34 km/h), which can be explained by the fact that the first unit can cross the plantation more easily, without any disturbance, like in the case of the second unit. The lowest consumption for this unit is achieved in variant 2, where fuel consumption is 15.2 l/ha, efficiency 0.43 ha/h and energy consumption 42.28 kWh/ha.

Table 6 Energy parameters of the unit consisting of Tractor R-65 and Rotational Tiller PTF-125

Number of measurement	M (Nm)	n_{PTO} (o/min)	P_v (kW)	v (km/h)	Fv (kN)	Q_h (l/h)	Q_{ha} (l/ha)	W_h (ha/h)	E_{ha} (kWh/ha)
1.	210	475	12.47	2.21	2.20	6.52	17.26	0.38	29.68
2.	334	490	20.72	2.45	3.67	6.39	15.20	0.43	42.28
3.	222	480	13.52	2.30	2.84	6.58	16.29	0.39	33.78
4.	219	465	13.05	2.17	2.68	6.44	17.36	0.40	36.26
5.	215	458	12.18	1.82	2.75	6.49	28.51	0.32	32.05

The energy parameters of the third Tractor-Implement Unit (Table 7), consisting of Tractor R-65 and Rotational tiller PTF-145, with a working width of 137 cm, showed the lowest fuel consumption in variant 4, amounting to 17.97 l/ha, with an efficiency of 0.42 h/ha. The analysis of the results shows that, in spite of its larger working width, the average efficiency of this unit is not significantly better than the one of previous units.

Table 7 Energy parameters of the unit consisting of Tractor RTf-65 and Rotational Tiller PTF-145

Number of measure ement	M (Nm)	n_{PTO} (o/min)	P_v (kW)	v (km/h)	Fv (kN)	Q_h (l/h)	Q_{ha} (l/ha)	W_h (ha/h)	E_{ha} (kWh/ha)
1.	248	480	14.73	2.20	2.60	7.71	20.40	0.39	37.77
2.	262	500	15.98	2.31	3.35	7.77	19.25	0.38	42.05
3.	258	480	15.42	2.19	3.17	7.61	20.84	0.41	37.61
4.	395	505	24.49	2.44	4.33	7.55	17.97	0.42	58.31
5.	254	490	14.40	1.91	3.25	7.67	33.67	0.33	43.64

This is explained by the fact that, in the case of all the three units, it was necessary to pass three times, in order to till the inter-row distance of the tested culture. In addition to that, smaller-sized units can be more easily driven through the plantation, reducing thus the overlap of each pass and improving performance.

CONCLUSIONS

In spite of the good quality of tillage in terms of soil fragmentation, the classic way to additionally till the soil by means of rotational machinery represents an energy-demanding operation. Besides the energy consumption arising from the tillage of the inter-row surface, we should take into account the energy and work necessary for the remaining untilled surface within the row, which implies an increase of approximately 35%, according to the researches of some authors.

Further research should determine the economic parameters of the soil tillage process by using modern machines with bending angle, which simultaneously till the row and the inter-row surfaces. Their use should significantly save energy, so that larger investments in their acquisition would be covered in an acceptable time period. The results of the research in this area should be presented to potential customers, who grow fruits in our country, in such a way that they might obtain the necessary education and understanding of contemporary tendencies in the application of the most modern technical solutions.

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Case Study

MECHANIZED PLANTING TREES ROSEHIP (ROSA CANINA) AND BLACKBERRY (EUBATUS FOCKE)

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Abstract. *Rosehip and blackberry occupy an important place in the diet because of their beneficial effects on the entire human organism. They are very widespread in nature. The growth in range shrubs, in addition to roads, the borders of fields, along forest glades, meadows. Lately crops have been raised for controlled production.This paper presents the results of hand-planting (classical planting) and mechanized planting with hydrobohrer trees rosehip (*ROSA, cultivar *Rosa canina) and blackberry (*EUBATUS FOCKE cultivar *Thorn-free). The best results in the receipt of the trees were variants of planting with hydrobo*hrer at rosehip 95.0*8 % and blackberry 44.00 %.*

Key words: *Rrosehip, Blackberry, Hand planting, Hydrobohrer.*

1. INTRODUCTION

An important part of fruit production is to produce quality seedling production and vegetative rootstock seedlings. It is a prerequisite to achieve the basic tasks of fruit production: obtaining high yields of quality fruit, low cost with minimal input from human labor. The first step is to choose from growth rootstock surface quality, such rootstock planted in the ground and inoculate, and appropriate technology works get quality plants. Unfortunately, over trees planted vegetative rootstock is highly dependent on precipitation (rain, irrigation). In a year during the planting time there is not enough rainfall (drought conditions) lacking satisfactory reception, and finally good quality seedlings.

The use of hydrobohrer in planting seedlings and vines is intensifying in the world. It consists of head hydrobohrer where they perforate four opening diameter of 3 mm, body hydrobohrer with two pipes in the T-shaped slippers hydrobohrer pushing into the ground and control the depth of planting and hydrobohrer hose that connects to the pressure pipe atomizer. The diameter of tube hydrobohrer, head hydrobohrer and the number and diameter of the openings of the head depends on the root system of vegetative rootstocks or fruit trees or vines that are planted. Hydrobohrer head is made so that it can be screwed to the body hydrobohrer.

Rosehip and blackberry beneficial effect on the entire human body, are excellent in the treatment of many diseases and prevention are indispensable.

Rosehip is very rich in antioxidants, about 1600 mg% of vitamin C, vitamin P, vitamin B12, about 0.02 mg% of B2, B1, vitamin K, about 12 - 18 mg% of vitamin A and carotene that stimulate natural defenses and immunity and protect against many diseases. It also contains sodium, tannin, flavonoid, 3% citric acid and malic acid, fatty oil and essential oil, 15% sugar, 10% pectin, vanilla, dextrin. Rosehip has a beneficial effect on the digestive tract and it is excellent in the treatment of many diseases, and prevention is indispensable.

Blackberry cultivar Thorn free is created in the United States. It ripens late. It is harvested in August and September and often in. October. Inbred and highly yielding cultivar. The yields can not be higher than 25 t/ha. The fruit is medium-large to large (about 5 g), spherical to obtusely conical shape, sturdy, glossy black colour, sour taste with a medium intense aroma, good quality. The fruit is transportable, suitable for freezing and processing of all types [5]. Unlike other species of blackberry fruit, blackberry trees Torn free have no spines.

Noble varieties of blackberries are now in our country is grown in a relatively small area of about 1200 hectares. The average production of blackberries is about 16.000 t [2], with the average yield of 15-25 t/ha [3, 6]. The blackberry fruit has extremely high biological value. It is considered a rich source of iron, potassium and vitamin C. Fresh fruits and juice blackberries are excellent laxative, mineral substances and organic acids which regulate blood pH, improve blood work and have influence on blood pressure. Vitamins strengthen immunity, pectins contribute to the protection from arteriosclerosis and heart attack while cellulose improves the digestion. Blackberry fruit has advantages over other food ingredients and by the fact that the energy value [5].

The aim of this research was to examine the advantages and disadvantages of introducing hydrobohrer to planting other crops compared to conventional manual planting. The paper presents results of planting trees rosehip (ROSA, cultivar *Rosa canina*) and blackberry (EUBATUS FOCK, cultivar *Thorn free*) using manual planting (classical planting) and mechanized planting with hydrobohrer.

2. MATERIAL AND METHODS

Examination of planting trees was carried out on the Reva property (44^0 51' 20" N, 20^0 32' 29" E). Planting of trees was carried out in early April 2012, and the results were recorded in the second decade of June in 2012.

Planting trees of rosehip varieties Rosa canina was performed in two variants: hand planting (planting classical) and planting hydrobohrer in 3 replicates per 95 plants. The planting distance was 3x1 m. Planting trees of blackberries Thorn free was performed in two variants: hand planting (classical planting) and planting hydrobohrer in 5 repetitions per 100 trees. The planting distance was 2x1 m.

Hand planting was carried out with 5 workers: two workers with planting hand, one worker puts the trees into holes and two workers are covering seedlings.

Planting hydroboher has also performed with 5 workers: one worker on the tractor Belorus MTZ 82, one worker with hydrobohrer, one worker was puting the trees into holes and two workers were covering the roots. Hydrobohrer consists of head hydrobohrer where they perforate four opening diameter of 3 mm, body hydrobohrer with two pipes in the T-shaped slippers hydrobohrer pushing into the ground and control the depth of planting and hydrobohrer hose that connects to the pressure pipe atomizer.

During the planting chronography was done and the parameters of the labor exploitation.

3. RESULTS AND DISCUSSION

Based on the results of planting vegetative rootstock during the dry season, Komnenić et al. (2014) [4] concluded that planting with the hydrobohrer guarantees a significantly higher percentage of rooted plants relative to manual planting. The best results are achieved in the variant hydrobohrer+water+ earthworm 94% and where possible, the recommendation is to perform hydrobohrer planting. Exploitation parameters of hydrobohrer in the planting rootstock are: the average time on the rootstock amounted 2.04 s, earthworm that added to the average in the amount of 11 g, the spent rootstock by 0.06 ml of fuel and that the underlying land entered 0.64 l water.

Table 1 provides exploitation parameters of hydrobohrer obtained during the planting process. The table shows that the average time spent per tree was 4.30 s, fuel consumption per tree was 2.68 ml and gross operating time per tree was 6.02 s.

Table 1 Exploitation performance indicators

Parameter	Unit	Size
Time on the tree	s	4.30
Fuel used of the trees	ml/tree	2.68
Gross operating time for the tree	s	6.02

Table 2 presents the results of the rooted trees of rosehip Rosa canina depending on the variant of the experiment. With the planting with hydrobohrer+water the percent of the rooted plants was 95.08 % and for hand planting it was 88.77 %. The results show a high level of rooted plants of rosehip seedling when planted with the hidrobohrer compared to hand planting. When planting with hidrobohrer percentage of rooted plants was 6.31% higher compared to manual planting.

Table 2 Results of the rosehip (*Rosa canina)* rooting

Variants	Hydrobohrer + water			Hand planting		
	Planted trees (pieces)	Rooted plants (pieces)	Rooted plants (%)	Planted trees (pieces)	Rooted plants (pieces)	Rooted plants (%)
1	95	93	97.89	95	82	86.32
2	95	85	89.47	95	88	92.63
3	95	93	97.89	95	83	87.37
Average	95	90.33	95.08	95	84.33	88.77

Table 3 presents the results of the blackberry rooting depending on the variant of the experiment. With planting with the hydrobohrer+water the rooting was 44.00 % and for hand planting it was 33.40 %.

Table 3 Results of the blackberry (*Thorn free)* rooting

Variants	Hydrobohrer + water			Hand planting		
	Planted trees (pieces)	Rooted plants (pieces)	Rooted plants (%)	Planted trees (pieces)	Rooted plants (pieces)	Rooted plants (%)
1	100	52	52.00	100	36	36.00
2	100	39	39.00	100	51	51.00
3	100	34	34.00	100	45	45.00
4	100	50	50.00	100	11	11.00
5	100	45	45.00	100	24	24.00
Average	100	44.00	44.00	100	33.40	33.40

Results of blackberry rooting after two months show very low level both in planting using hidrobohrer and in the manually planting. Planting with the hidrobohrer percentage of rooting was 10.60 % higher when compared to manual seeding.

4. CONCLUSIONS

Based on the results of rosahip and blackberry planting the following can be concluded:

- Planting with hydrobohrer guarantees a significantly higher percentage of rooted trees compared to manual planting;
- The best result was achieved rosehip rooting Rosa canina when planted with hydroborer had 95.08% of rooting, while the case of blackberry hand planting gave only 33.40 % of rooted plants.
- Planting hidrobohrer gives better results in rooting of seedlings compared to manual planting in both cases of rosehip and blackberry.
- Where it is possible, it is recommendation to use hydrobohrer for trees planting.

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Case Study

USING THE CONTROL CARDS FOR THE STATISTICAL QUALITY CONTROL OF THE PESTICIDE USE

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Abstract. *Controlling the pesticide application during the production of food commodities ensures good quality products and healthy products that have an affordable price on the market. The basic concept of the statistically controlled application refers to the comparing of real-time-situation data in pesticide application with the calculated ones. This concept can provide a valid conclusion about the pesticide application process. Using statistical methods in controlling the quality of agricultural products means using the serial procedures and methods of data collecting, data processing and data analysing.*
ISO 9000 Standard gives the standards for the plant protection quality control as well as for the agricultural product control. Control charts represent the main tool for controlling the plant protection procedures and the quality of obtained products. Proper use of the statistical charts enables the more precise application having as a consequence the lowering of the production costs. Statistical control of the agricultural products is based on the defining the toleration boundaries for the product safety or defining the possible deviations in the area of the given measures and standards. Statistical control of the products improves the overall production process by decreasing the variations in the samples themselves. The results obtained with the control charts can serve for the improvement of the application process, decreasing the number of variations influencing the process, lowering the application costs and, with all this, achieving the overall income.

Key words: *pesticide sprayers, sprinkler capacity, static control, control chart.*

1. INTRODUCTION

The use of pesticides presents risk to both, humans and the environment. Therefore, our goal is to reduce that risk to a minimum, in order to obtain safe food from the point of view of pesticide usage. The proper use of pesticides, among other things, includes an appropriate application process, which must be regularly controlled in terms of standards and uniform distribution of the plant surface.

De Jong et al. (2000b) [3] found that horizontal vibrations and a higher operating width have an impact on the regular depositing of substances. Lerch (1986) [6] and Živković et al. (2006) [10] analyzed the technical solutions for the use of pesticides and concluded that the quality of pesticide distribution depends on numerous factors. Novak (1990) [8] and Bugarin et al. (2005) [2] found that resource scarcity and coverage are not strictly proportionate. The coverage of the target surface does not increase proportionally to the increase the quantity of dispersed liquid, but it can rather decline. Bugarin et al. (2003) [1] and Urošević et al. (2006) [9] found that there are no universal sprinklers for all arable crops and weather conditions, but the choice of the nozzles should be carried out according to the specific conditions for pesticide usage.

This paper presents the results of tests regarding the disposition of protective fluids across the jet width of sprinkle nozzles. The statistical control of distribution is carried out by using control charts. From the standpoint of statistical quality control, there are two types of variations of disposition of protective fluids across the jet width of sprinkle nozzles: random and systematic [8]. Random variations occur as the result of numerous factors, which appear in a random and irregular way, in various directions and with different intensities. This type of variation is almost inevitable, but it is generally minimal and therefore it is allowable. Systematic variations are those variations that occur as a result of the effects of a certain factor and do not occur by chance [9]. They may be too large and cannot be tolerated. When they appear, they can lead to changes in Gauss's distribution. The role of statistical quality control is that, in such cases, it is possible to detect on time the effect of additional factors that create systematic variations, measuring their strength and enabling their timely remedy. In the presence of these variations, the features of the product are unpredictable. That is why; if quality variations in the product are the exclusive effect of random factors, then the observed production process is **″under control″**, i.e. **within the boundaries of statistic control.**

It is very important not only to elaborate the control charts accurately, but also to interpret them properly. When interpreting control charts, there a series of terms is used for the description of a particular condition in the control chart, which shows that a process is "under control" (Juran, 1999) [5].

Control charts are used in order to identify and isolate systematic from random variations in the production process. The purpose of the control charts is to detect the presence of additional factors based on significant variations in the observed characteristics. That is why the purpose of this paper is to apply control charts in order to show the uniform distribution of jets in a spray with 16 nozzles.

2. MATERIALS AND METHOD

Statistical theory has developed principles in order to carry out the continuous observation of processes, on the basis of control charts. The control chart is used as an indicator that detects variations in the production process and shows the moment when it is necessary to carry out an intervention, in order to maintain the process in a state of optimum cost-effectiveness.

The main problem, when creating control charts, is the concept of control limits. The limits established in the control chart are the limits of the confidence interval, in which it is expected that, within a certain probability, the observed parameter will deviate from the sample. When these values exceed the established limits, it means that a certain systematic factor is acting, that the process is out of control and that it is necessary to stop it to examine and correct the cause of the disruption.

There are several types of control charts, but out of them, the mean-value control chart is the primary means of quality control most frequently used during the production process, while control charts for variation interval and standard deviation are the auxiliary means for the control of variability around the arithmetical mean-value.

First of all, there should be defined the elements (the central line and the control limits according to both, American and British systems) of the mean-value control chart ($\bar{X} - chart$) and, after that, the same elements of the accompanying control chart, in which flow variability is measured by jet segments, are expressed by the absolute measure of variability, i.e. by the variation interval (I-chart).

With the help of the control chart for the arithmetic mean-value, we showed the disposition of the arithmetic mean-values of the observed flow jet by segments in 36 nozzles.

The central line of the control chart for the mean value is defined by the expression:

$$\bar{\bar{X}} = \frac{\bar{X}_1 + \bar{X}_2 + \ldots + \bar{X}_k}{k} = \frac{\sum_{i=1}^{k} \bar{X}_i}{k} \tag{1}$$

Control limits:

- According to the American system

$$A_{g1,2} = \bar{X} \pm A_1 \cdot \bar{I} \tag{2}$$

- According to the British system

externally $B_{g1,2}E = \bar{X} \pm A'_1 \cdot \bar{I}$ (3)

internally $B_{g1,2}I = \bar{X} \pm A''_1 \cdot \bar{I}$ (4)

The central line of the control chart for the variation interval is calculated as follows:

$$\bar{I} = \frac{I_1 + I_2 + \cdots + I_k}{k} = \frac{\sum_{i=1}^{k} I_i}{k} \tag{5}$$

Control limits:

- According to the American system

$$Ag_1 = \bar{I} \cdot B_1 \quad end \quad Ag_2 = \bar{I} \cdot B_2 \tag{6}$$

- According to the British system

externally $Bg_1E = \bar{I} \cdot B'_1$ *end* $Bg_2E = \bar{I} \cdot B'_2$ (7)

$$\text{internally} \quad Bg_1I = \bar{I} \cdot B_1'' \quad end \quad Bg_2I = \bar{I} \cdot B_2'' \tag{8}$$

The quality of pesticide usage is assessed on the basis of the uniformity criterion, i.e. the homogenous distribution of the protective fluid over the treated area. In order to ensure the uniform distribution of the protective fluid in the sprayers, the nozzles are of utmost importance. Accordingly, a sprayer can be considered good or bad depending on whether it is equipped with good or bad nozzles. High-quality nozzles ensure the uniform distribution of liquids across the working width and, therefore, of the protective substance on the entire surface to be treated. When using sprayers, we should pay great attention to their proper setting and control.

The flow of crop sprinkler nozzles was experimentally measured. There was obtained data regarding the flow and distribution of liquid at all nozzles, as shown in table 1. During the experiment, the distribution system was placed at a height of 0.6m, in order to obtain a working width of 1m, taking into account that the tested nozzles have a jet angle of 80°. The quantity of liquid released over the jet width (which represents the distribution of liquid), separately through each nozzle, was measured at each 20cm, so that there would be 4 measuring points per meter of jet width and for every nozzle.

3. RESULTS AND DISCUSSION

Based on the control chart that tracks the movement of the average flow in 16 nozzles, we can say that the average flow in all the nozzles was within the permitted limits and that the examined sprinklers have a steady jet flow (Fig. 1).

Table 1 Results of flow measurement over the entire jet width, in the case of sprayers with 16 nozzles

Number of nozzles	Flow per jet segment (l/min)					Σ
	I 20 cm	II 20 cm	III 20 cm	IV 20 cm	V	
1.	0.32	0.34	0.35	0.32	0.33	1.68
2.	0.32	0.32	0.38	0.36	0.34	1.72
3.	0.35	0.30	0.37	0.36	0.36	1.74
4.	0.32	0.32	0.36	0.36	0.35	1.70
5.	0.31	0.32	0.38	0.34	0.33	1.68
6.	0.33	0.33	0.35	0.32	0.31	1.64
7.	0.31	0.35	0.37	0.33	0.34	1.70
8.	0.36	0.34	0.36	0.34	0.32	1.72
9.	0.35	0.35	0.37	0.33	0.31	1.71
10.	0.34	0.33	0.36	0.33	0.32	1.68
11.	0.34	0.35	0.35	0.31	0.33	1.68
12.	0.32	0.33	0.36	0.33	0.32	1.66
13.	0.32	0.32	0.37	0.32	0.33	1.66
14.	0.35	0.35	0.37	0.32	0.31	1.70
15.	0.33	0.32	0.35	0.33	0.32	1.65
16.	0.32	0.32	0.34	0.33	0.33	1.64

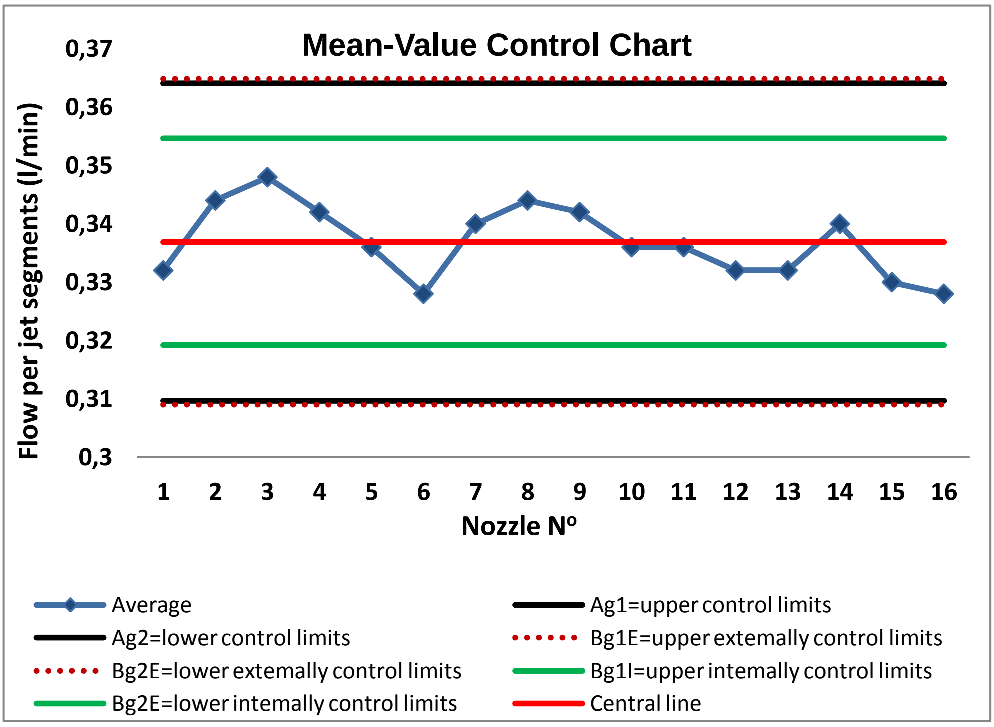

Fig. 1 Control chart of the average nozzle flow

There is no doubt that the arithmetic mean is the first indicator that should be defined in the control process of the nozzle flow. But that is not enough to fully characterize the quality of protective liquid distribution in a certain nozzle. It may happen that the mean-value control chart shows a uniform flow, but the dispersion value per jet segment is not satisfactory. Dispersion increase may occur independently of the changes in the value of the arithmetic mean. Therefore, besides the mean values and the structure of the μ-chart, it is compulsory to monitor the movement of the dispersion index across the jet width. If the segmental dispersion of the jet is expressed by the variation interval, there will be used and built an I-chart, i.e. a control chart for the variation interval. It monitors the dispersion of the variation interval of individual segments compared to the mean-value of all intervals and control limits. The results are illustrated in graphic n°. 2. It is clear that nozzles number 15 and 16 have an average distribution exceeding American control limits. It indicates that these two sprinklers do not perform a uniform segmental distribution of the liquid jet and therefore they should be replaced.

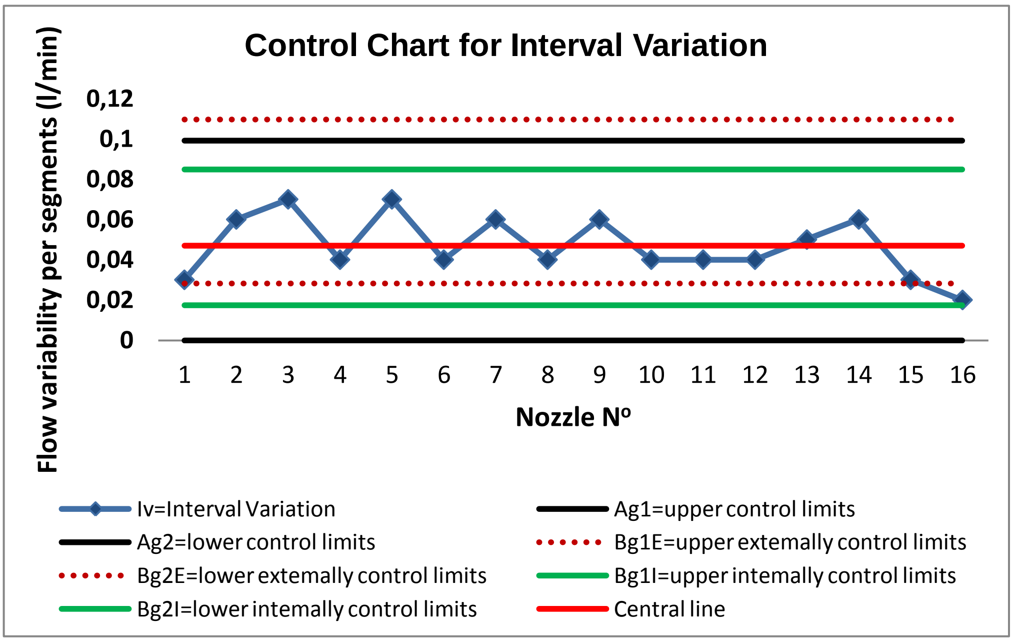

Fig. 2 Control chart for sprinkling variability, expressed through the variation interval

4. CONCLUSIONS

The quality of pesticide usage in terms of the uniform distribution of the protective liquid may be improved with the help of statistical quality control, which applies statistic analysis in order to monitor, control and continuously improve the process. Control charts are used as the basic tool of statistical analysis. They are used to compare data with the calculated statistical control limits marked as boundary lines on the chart.

Approaching the European Union and adopting international standards imposes a set of criteria, i.e. quality standards, regarding the use of pesticides, especially from the point of view of food safety and environmental protection. Statistical quality control, especially with the help of control charts, may greatly contribute to the fulfillment of the prescribed norms.

The flow test of the nozzles in terms of uniform distribution of the jet in a sprinkler with 16 nozzles and its statistical analysis showed a non-uniform flow of liquid through the nozzles, as well as deviations in relation to the control limits. That shows that sprinkler users should apply the aforementioned statistical methods, in order to improve the quality of pesticide usage and replace the nozzles that significantly deviate from the expected distribution of fluid.

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Case Study

IMPACT OF TECHNICAL SPRAYING FACTORS ON LEAF AREA COVERAGE IN A VINEYARD WITH HARDI ZATURN AXIAL FAN SPRAYER

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Abstract. *Research is conducted in a vineyard with a Hardi Zaturn axial fan sprayer. The influence of major technical spraying factors (type of nozzle, working speed and spray volume) were observed on coverage of the treated area. The working speed of sprayer was set at 6 and 8 kmh^{-1}, and spray volume on 250, 300 and 350 lha^{-1}. In research, Lechler blue (TR 8003C), yellow (TR 8002C) and green (TR 80015C) nozzles are used. The research was set as three - factorial field experiment with 18 treatments in 4 repetitions. Sixty water sensitive papers (WSP) were used for the treatment, which was processed with digital image analysis (DIA) and ImageJ software. The major technical spraying factors have a high significant statistical impact (**) on the main property of the research. By decreasing the ISO number of nozzles and by increasing the working speed and spray volume, we found the increasement of area coverage. The best adjustment of technical spraying factors (area coverage of 51.45%) was achieved with a green nozzle (TR80015C), working speed of 8 kmh^{-1}, spray volume of 350 lha^{-1}, and working pressure of 19.53 bar. The lowest area coverage was achieved with a blue nozzle (TR 8003), working speed of 6 kmh^{-1}, spray volume of 250 lha^{-1}, and working pressure of 19.53 bar 3.57.*

Key words: *axial sprayer, working speed, nozzle, spraying norm, area coverage, water sensitive paper*

1. INTRODUCTION

Agriculture is an inseparable part of the overall global ecological system, where humans, animals, plants, climate factors and agricultural engineering are in interaction. Therefore, aim is to improve, enhance or develop new technical solutions for agricultural machinery to introduce measures and procedures that would result in minimal interventions in the ecosystem [10]. With the technical correctness of the working machine in plant protection, it is particularly important to adjust the technical parameters of spraying – working speed of sprayer, working pressure, air flow and velocity, spraying norm, type of nozzle, etc. Only synergy of properly configured technical parameters and technical accuracy of the machine provide adequate results. The most commonly used method, to test the settings of technical parameters in field conditions on the area coverage, is with water sensitive papers and with digital (computerized) image analysis [5, 9, 3, 6]. One of the main technical factors is droplet diameter, which is decreasing by increasing the working pressure [13]. Also, by increasing the working pressure, the number of droplets in spray is increasing [12]. This implies that by reducing the droplet diameter and by increasing the working pressure, coverage of treated area is increasing [3]. Coverage of treated area is the main thing of whole plant protection, and the main task of technical spraying factors is to increase this property. This research is a part of the modern world trends where the application of agricultural engineering in plant protection aspires to achieve the highest possible coverage of the treated area with the least losses of liquid in the form of drift [7]. Also, it is particularly important to further investigate the technical spraying factors of the plant protection, because in Croatia the new law is in the force (*NN 14/14*), linked to sustainable use of pesticides and mandatory inspection of all technical systems in plant protection (*European Directive: 2009/128/EC and 2006/42/EC)* [1].

The objective of this research is to determine the influence of major technical spraying factors (type of nozzle, working speed and spray norm) on average area coverage. This will be examined through the exploitation of axial fan sprayer with different settings of the major technical factors of spraying.

2. MATERIJAL AND METHODS

In this study mounted vineyard axial fan sprayer is used with the plane rectangular air flow (Fig. 1) Sprayer is tested according *EN 13790* standard [1] through European directive *2009/128/EC* and *2006/42/EC.*

Fig. 1 *Hardi Zaturn*

The study used three types of nozzles as a technical spraying factor A in statistical analysis: *Lechler TR 80015C*, *TR 8002C* and *TR 8003C*. All selected nozzles are marked according *ISO 10625* standard, where *TR* denotes the type of spray (hollow cone); *80* is spray angle; *015*, *02* and *03* are nozzle flows in U.S. gallons at 2.75 bar and *C* is the material of which they are made (polyoxymethylene with a ceramic insert). Adjustment of air flow and nozzles are shown in Table 1.

Table 1 Air flows and velocity with nozzle adjustment

Statistical parameters	Air velocity, ms^{-1}		Nozzle orientation	
	Left side	Right side	Position	Angle, °
$\overline{X}$	19.38	15.58	1.	Off
σ	5.17	4.24	2.	+15
C.V., %	26.68	27.20	3.	+10
	Air flow, m^3h^{-1}		4.	+5
	6 km/h	8 km/h	5.	0
Q_r	14 154.75		6.	-5
Q_t (f=1.5)	13 980.00	18 400.00	7.	Off
Q_s, m^3km^{-1}	84.92	113.23	8.	Off

F – Foliation factor

Second technical spraying factor of this research is a working speed of sprayers (factor B) which is set to the two speeds - 6 and 8 kmh^{-1}. Working speed of the sprayer is followed by tractor board computer and is checked by the stopwatch at the exact distance in the vineyard. The third technical spraying factor in the study is spraying norm - factor C. The study used three spraying norms: 250, 300 and 350 lha^{-1}. After determination of vineyard volume and spraying norm, the next step of sprayer calibration is to calculate required nozzle flow and pressure (Doruchowski et al., 2012). In Table 2 overall calibration of sprayers is shown.

Table 2 Calibration parameters for both of the sprayers

Nozzle	N_r, l/ha	v_r, km/h	Q_m, l/min	p, bar	Nozzle	N_r, l/ha	v_r, km/h	Q_m, l/min	p, bar
TR 8003C	250	6	0.87	1.51	TR 8002C	250	8	1.16	5.78
TR 8003C	325	6	1.13	2.56	TR 8002C	325	8	1.51	9.78
TR 8003C	400	6	1.40	3.88	TR 8002C	400	8	1.86	14.81
TR 8003C	250	8	1.16	2.69	TR 80015C	250	6	0.87	5.60
TR 8003C	325	8	1.51	4.56	TR 80015C	325	6	1.13	9.47
TR 8003C	400	8	1.86	6.90	TR 80015C	400	6	1.40	14.35
TR 8002C	250	6	0.87	3.25	TR 80015C	250	8	1.16	9.96
TR 8002C	325	6	1.13	5.50	TR 80015C	325	8	1.51	16.84
TR 8002C	400	6	1.40	8.33	TR 80015C	400	8	1.86	25.52

Velocity of an air current is measured with a mobile meteorological station, *Kestrel, Weather and Environmental meters – model 4500* (wireless data transmission). Three air flows are calculated: real air flow - Q_r, theoretical air flow - Q_t [4], and specific air flow - Q_s [9], Table 1.

For determination of spray pattern WSP are used (water sensitive papers - yellow rectangular strips). On surface they have a thin layer of bromophenol, which in contact with water turns blue. Therefore, the droplets that fall on a WSP are used for determination of average area coverage. The study used WSP from the Swiss manufacturer *Syngenta*. Papers are placed on 3 levels of canopy: peak, the middle and lower levels. On each level 5 papers is set on both side of the leaves, with the use of 4 vines in repetition. So, for each vine we used 15, and for each treatment 60 WSP 36 treatments in total = 2160 WSP. WSP are also used for the evaluation of drift intensity. Drift is measured in 2 untreated side rows in 4 repetitions for each treatment. In each repetition we used 6 WSP (3 vertical and 3 horizontally). WSP with droplets is shown in Fig. 2.

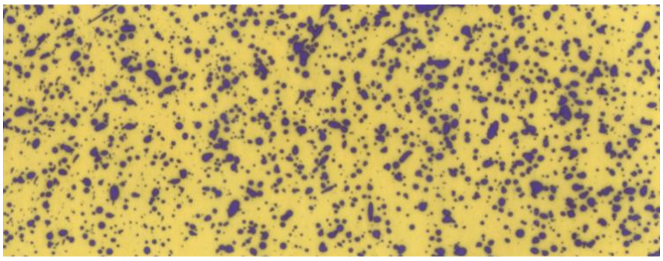

Fig. 2 Water sensitive paper

After field research, the WSP samples were collected and each one was analyzed by using the DIA - digital image analysis and by using *ImageJ* software [11].

3. RESULTS AND DISCUSSION

In Table 3. are shown average weather condition during the research, and average *LAI* and *LAD* for vines in research, where is: E_e is solar radiation; T_z is air temperature in the vineyard; ω_z is relative air humidity in the vineyard; v_v is wind speed; $\uparrow$ is wind direction; *LAI is* leaf area index and *LAD* is leaf area density.

Table 3 Weather conditions and leaf factors

Statistical parameters	Weather conditions during the experiment					Leaf area	
	E_e, Wm^{-2}	T_z, °C	ω_z, %	v_v, ms^{-1}	$\uparrow$, °	*LAI*, m^2m^{-2}	*LAD* m^2m^{-3}
$\overline{X}$	376.14	19.07	53.29	0.83	203.57	1.76	4.59
σ	186.86	2.20	6.76	0.29	42.75	0.20	0.52
C.V., %	49.34	11.24	13.63	50.69	19.97	11.62	11.25

In Table 4 is shown the main properties and results of the research with an axial fan sprayer – Hardi Zaturn, where are: $\bar{A}_p$ - average area coverage; A - type of nozzle (A_1 – *TR 8003*; A_2 – *TR 8002*; A_3 – *TR 80015*), B – working speed (B_1 – 6 kmh^{-1}; B_2 – 8 kmh^{-1}), C – spraying norm (C_1 – 250 lha^{-1}; C_2 – 300 lha^{-1}; C_3 – 350 lha^{-1}).

Table 4 Analysis of variance for the main properties of the research

ANOVA		$\bar{A}_p$, %			
		$\overline{X}$	$LSD_{0,05}$	$LSD_{0,01}$	*F- test*
A	A_1	34.07	3.17	4.30	34.76**
	A_2	39.39			
	A_3	43.38			
B	B_1	35.22	0.87	1.14	66.31**
	B_2	42.67			
C	C_1	32.75	2.37	3.22	72.48**
	C_2	37.96			
	C_3	46.13			
AB			1.67	2.35	6.76**
AC			4.60	6.70	1.46 n.s.
BC			3.55	4.98	3.26*
ABC			7.84	13.00	2.39 n.s.

Table 4 show that the main technical spraying factors (nozzle type, working speed and spraying norm) have a statistically significant impact (**) on the main property of the research - average area coverage. With decreasing of *ISO* nozzle number (from *TR 8003C* to *TR 80015C*) and with increasing of working speed (from 6 to 8 kmh^{-1}) and spraying norm (from 250 to 350 lha^{-1}), the average area coverage is statistically increasing. With the same nozzle and spraying norm but with higher working speed, higher working pressure was required for spraying default norm (ex. with TR 80015C nozzle, spraying norm of 250 l/ha and with working speed of 6 km/h required working pressure was 5.60

bar; with the same nozzle and spraying norm but with working speed of 8 km/h required working pressure was 9.96 bar, Tab. 2), so with pressure increasment, the average area coverage is also increasing.

5. Conclusion

According to the measurements of weather conditions during the study, the application is carried out according to the rules of plant protection in almost ideal conditions (wind speed less than 3 m/s, air temperature less than 22 °C and air humidity higher than 50 %). Used spraying norms are suitable for the form and volume of the orchard, and they follow global trends of spray norm reduction. Also, the working speeds of the orchard sprayers are located within the optimal agritechnical operational speeds. Used nozzles and working pressures are suitable to the row width and they are ensuring required spraying norms. The major technical spraying factors have a high significant impact (**) on the main properties of the research. By decreasing the *ISO* number of nozzles and by increasing the working speed and spray volume, we found increasement of area coverage. During the settings of the technical spraying parameters, the main object must be the largest area coverage with the minimal liquid drift. This is possible only with technical correctness of the orchard sprayer and with spraying in good weather conditions. The results and scientifically based conclusions can serve all agricultural producers, because so far in Croatia there is no scientifically based research related to this issue. Also, it is particularly important to further investigate the technical spraying factors of the plant protection, due to the bigger reduction of production costs with the same biological effect.

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Professional (Expert) paper

BERRY HARVESTING BY PULSED AIR FLOW

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Abstract. *This paper presents a unique technical solution of berry fruit harvesting by accurately controlled pulsations of air flow. A special harvester, which induces strong turbulent fluctuations of atmospheric air from both sides of the plants, has been designed and tested in the past fifteen years. It is towed behind a tractor, but also equipped by own diesel engine that drive all hydraulic components and, indirectly, the fan, pulsating air flow control units, machine leveling system and fruit conveyer. The study is focused to operational parameters of the harvester, technical specification and design.*

Key words: *Berry fruit, air harvester, turbulent pulsations, fan, hydraulics.*

1. INTRODUCTION

Contemporary berry fruit production suffers from the high costs of manual harvesting, because of increasingly expensive fruit pickers and their luck. Globalization of world market and economy in general has resulted in appearance of new demands related to increased competition, and introduction of new highly rigorous standards of food quality and security [5]. It is widely accepted that costs of manual berry fruit harvest reach 70-75 % of total production cost [11]. Therefore, in order to decrease the total production costs, general trends of berry harvesting worldwide move towards mechanized harvesting - mechanical berry harvesters have been designed and introduced in operation [10]. They operate on the simple mechanical principle: fruit is detached from the plant by vibrating elements, so called shakers possessing elastic “fingers”, through direct mutual contact [7]. In order to achieve most of possible benefits of mechanized harvesting, application of berry pickers of this kind demands careful analysis, including careful defining shaking amplitude and frequency (see, [8], for example).

The paper presents a unique technical solution of berry harvesting by induced pulsed air flow, including the analysis of its technical and operational properties in comparison to existing mechanical shaking harvesters and manual pickers. According to [5], “there have been attempts to develop technology of air harvesting in the world, where American and Argentine companies have gone the furthest. However, nobody has managed to “pack up” technology into a commercial product available to a wider market at an affordable price”.

2. TECHNICAL SPECIFICATION AND OPERATION

According to the authors knowledge, KOKAN 500s is the unique operational berry harvester that utilizes pulsating turbulent air jets to in mechanized picking the berry fruits. The air stream velocity and pulsating frequency can be accurately controlled, in order to shake canes of berry plant in appropriate way and, consequently, detach the fruits from plant bush [3]. The air jets have an additional important role: the induced turbulent air flow aerodynamically decelerates free fall of picked fruits (delaying fruits receive on catching system) and remove dry leaves/twigs by intensive air stream.

Table 1 Basic technical specification of the combine [1]

Max. length (harvest configuration - fully extended drawbar)	4700 mm
Min. length (transport configuration - drawbar retracted)	4000 mm
Max. width (harvest configuration - opened flank collection platforms)	3340 mm
Min. width (transport configuration - closed flank collection platforms)	2500 mm
Height (the lowest harvester position)	2500 mm
Weight (without workers and collected crop)	2500 kg
Operational (harvest regime) speed	2 km/h
Harvesting capacity	5 ha/day
Maximum lifting height of the harvester	500 mm
Storage capacity of collected fruit	1000 kg
Storage capacity number of crates	50 pcs
Number of persons serving the harvester (minimum)	2 persons
Minimum height of air tunnel	2000 mm
Maximum height of air tunnel	2500 mm
Maximum entrance width of harvester air tunnel	1450 mm
Maximum exit width of harvester air tunnel	850 mm
Internal diesel engine power	55 kW

Basic technical data are given in table 1. All parameters are carefully chosen in order to achieve optimal working parameters, especially machine efficiency and reliability. In addition, general configuration of combine is presented in the figure 1. The following components of the harvester are presented this figure:

(1) main fan;

(2) oil cooler with auxiliary fan;
(3) control board;
(4) sealed hydraulic oil reservoir;
(5) gear-type hydraulic motor, which drives transport system of picked fruits;
(6) main hydraulic pump;
(7) internal combustion (diesel) engine and
(8) towing beam.

Fig. 1 Air berry harvester KOKAN 500s.

In addition, figure 3 shows components of picking, receiving and transport system of the harvester KOKAN 500s:
(1) main fan;
(9) main air duct;
(10) gear-type hydraulic motor, which drives pulsed air controller;
(11) main fan hydraulic motor;
(12) air jets nozzles with deflectors and
(13) transporter of picked fruits.

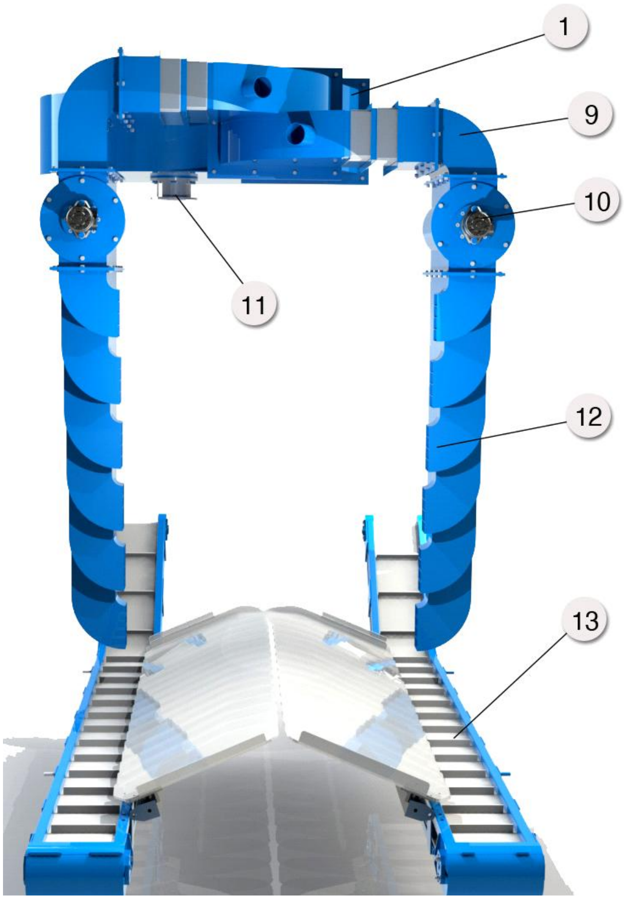

Fig. 2 Picking, receiving and transport system of the harvester KOKAN 500s.

Power transmission from the internal diesel engine toward harvester working systems and their components is performed by appropriately designed hydraulic system sketched in figure 3.

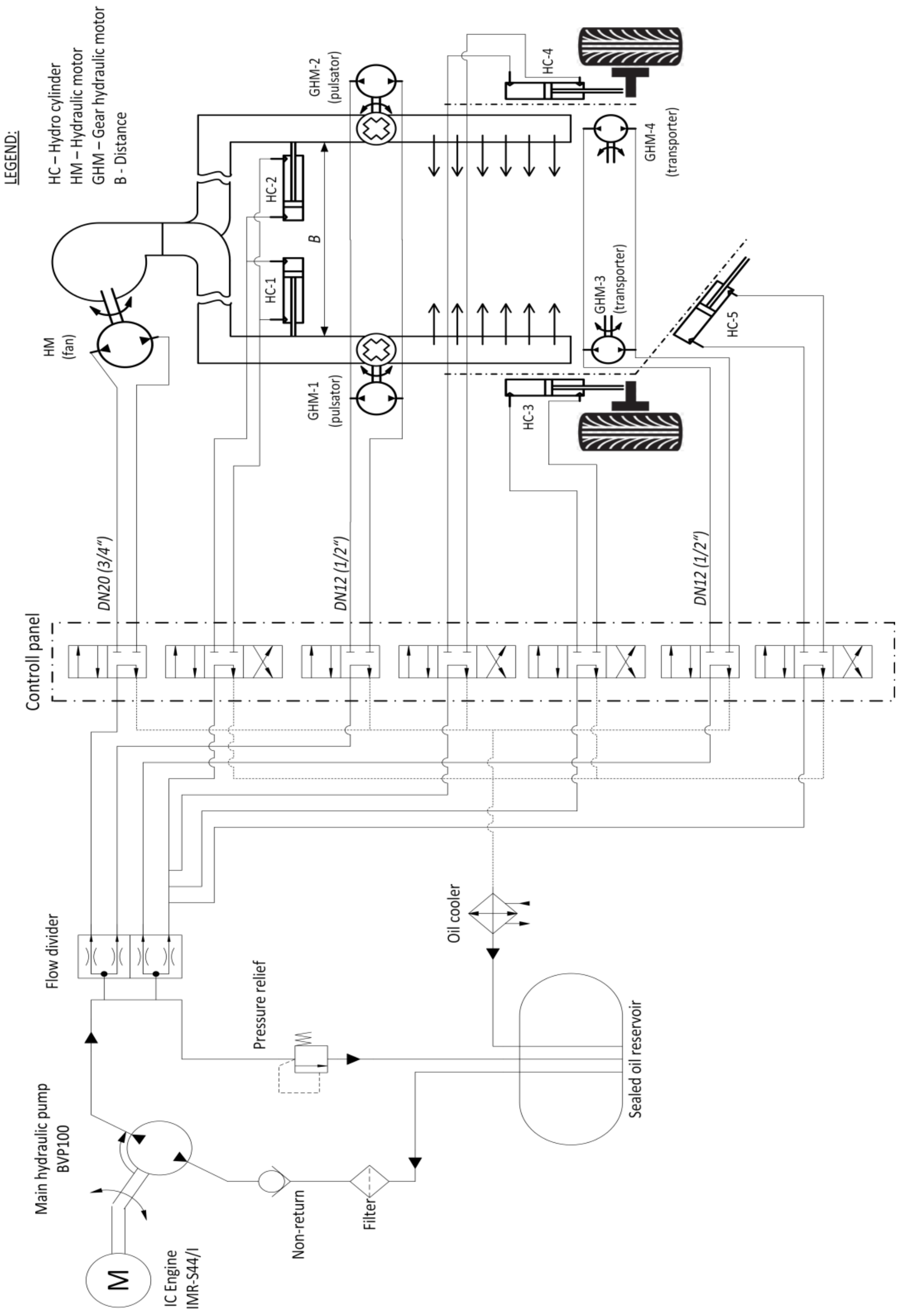

Fig. 3 Hydraulic scheme of the combine KOKAN 500s.

The air berry harvester is powered by one IMR S44/I diesel engine (pos. 7 in fig. 1), with continuous rated power of 46.5 kW at 2000 rpm, and the torque is 245 Nm at 1300 rpm. Power is transmitted from the engine and used to drive the main hydraulic pump BVP 100 (pos. 6 in fig. 1). The hydraulic power generated by main pump is further distributed via control panel (fig. 3) to other hydraulic energy consumers:

- hydraulic motor that drives harvester main fan (pos.1 in figs. 1 and 2);
- two gear-type hydraulic motors driving the flow pulsators (pos.10 in fig.2);
- two gear-type hydraulic motors, for powering two transporters of picked fruits (pos.5 in fig.1), and
- five hydro-cylinders for different harvester adjustments (HC-1 to HC-5 in fig.3).

The highest percentage of hydraulic power is consumed for driving the main fan, which transfers it further to air stream. The air supply to nozzles (pos. 12 in fig. 2) is provided via complex ducts system (pos. 9 in fig. 2) by using alternate air flow pulsation. Pulsations are generated by two pulsators (pos. 10 in fig.2), each powered with its own gear-type hydraulic motor ZMB.F19.

The berry fruits, detached from the bush plants with a pulsating air stream, fall to the left or right transporter (pos. 13 in fig.2). Each of these two transporters are powered with own gear-type hydraulic motor ZMB.F8 (pos. 5 in fig.1).

It should be noted that main fan and pulsed flow control units are designed specifically for KOKAN 500s. In order to achieve high enough pressure of air, the fan is designed following radial geometry of turbo-machines (see [2], [6], [9], etc.).

3. PROPERTIES

Performed field tests indicate that KOKAN 500s can be applied in various berry fruits harvesting: Raspberries, Blueberries, Blackberries and Black Currants. In contrast to mechanical (plant shaking) combines, KOKAN 500s agitates the fruit plants without direct contact. Consequently, fruit bruise, bush damage rate and expected rate diseases spreading are much smaller in the latter case.

Decelerated free fall of detached berry fruits is additional important design superiority of KOKAN 500s, which results in further reduction of harvested fruit bruising.

The harvester is very flexible in operation. Most of the machine working parameters, such as air jet velocity and pulsations frequency, machine leveling, etc., can be easily and independently adjusted. Consequently, it can be applied on various terrain slopes and for harvesting of different berry varieties. The application of air flow also enables purification of the collected fruit – separation of dust and plant leaves.

Besides all these advantages, the application of air berry harvester may also provide the following benefits:

- harvest is selective, i.e. highly focused to mature fruits;
- almost without birth or plant defects;
- almost without breaking the gender branches (what can reduce the yield), etc.

4. CONCLUSIONS

Presented air berry harvester is interesting and unique technical solution that indicates future potential for berry fruit harvesting. Although the machine is still in full operation, further optimizations and design advances are also anticipated by the manufacturer.

At the moment, we propose introduction of a common pulsator, placed just before main duct branching. This way, the one gear-type hydraulic motor would be enough for its powering, instead of two.

Potential markets for BSK's "Air Berry Harvester" "KOKAN 500S" is the Balkan region, the countries of Europe and North America. Potential buyers are large individual farmers (producers who have more than 5 hectares of fruit plantations), fruit associations and fruit processors (colds) with its own plantations [5].

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Original Scientific Paper

EFFECT OF THE MICROCLIMATE FACTORS ON EVAPOTRANSPIRATION RATE IN NURSERY PRODUCTION

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Abstract. *A lysimeter study was conducted to determine evapotranspiration (ET) rate of Red Maple (Acer Rubrum) under field conditions. The average daily measured ET for the plant was 998.75 g. Simple linear regression analysis showed that a solar radiation or a VPD based stochastic ET model could be successfully used to predict ET in terms of R^2 values of 0.875 and 0.684 respectively. Multivariable, first and second order regression models with an R^2 of 0.883 and 0.899 respectively showed that the first order multiple linear regression model was adequate to demonstrate effects of climate factors on measured ET. Statistical analysis showed that using a first order linear regression model was more practical than using a second order model since the more complex second order model did not significantly improve the R^2 of the ET model. Even though Stanghellini and Fynn ET models were developed under greenhouse conditions, they predicted ET under field conditions better than Penman.*

Key words: *Evapotranspiration, Deterministic ET models, Stochastic ET models.*

1. INTRODUCTION

Intensive agricultural crop production requires a detailed understanding of environment, water, nutrient needs, and interactions among them throughout each growth stage. Correct estimation of irrigation needs during each plant growth stage is especially important in maintaining high agricultural productivity [1]. The rate and amount of ET tend to be the core data required to design irrigation projects, and are also essential for managing environmental pollution. Application of excess water with nutrients to plants creates drainage, salinity and other environmental problems by leaching. Precise application of water to the plants not only prevents nutrient loss and conserves water, but also reduces cost and protects the environment [2].

Since ET is a very important process for intensive crop production, environmental quality, cost, as well as water and nutrient conservation, many researchers have conducted studies to quantify ET. As a result, many complex methods have been developed to compute transpiration based on lots of climatological parameters such as temperature, solar radiation, wind speed and relative humidity and also plant characteristics such as leaf area index, and stomatal resistance. However, all these models are criticized for being computationally difficult and data intensive allowing many opportunities for errors. So, it is desirable to develop reliable, simple, inexpensive and practical methods for the estimation of ET in proportion to one or two input parameters such as vapor pressure deficit (VPD) or solar radiation [3].

Weighing lysimeters are one of the most accurate devices for directly measuring ET and calibrating ET equations, especially for container grown plants. They measure the mass fluctuations of soil media moisture at precise time intervals while accounting for amount of water added to soil via rainfall or irrigation, or the amount of water lost through ET [4, 5]. However, measurement of ET has been used almost entirely for research applications due to the required equipment complexity and cost. Therefore, the prediction of ET from one or two meteorological data is potentially more useful since the measurement of weather parameters is much easier than the measurement of ET. Furthermore, recent advances in sensor and datalogger technology permit accurate and easy measurement of on-site weather data. In order to achieve this goal in intensive crop production, computer-controlled systems in agricultural production are required [5].

Red Maple (*Acer Rubrum*) is one of the most common plants grown for landscapes and nurseries. The main objective of this study was to compare measured value of ET obtained by lysimeters with relevant meteorological parameters such as solar radiation, VPD, air temperature and also to develop simple model for ET prediction of Red Maple.

2. MATERIAL AND METHODS

This study was conducted at the Ohio Agricultural Research Development Center (OARDC), Wooster, Ohio (41° 48 N' latitude), USA in August and September. The nursery plant used was *Acer Rubrum* (Red Maple) acquired as 1.25 m tall “whips” and potted in 26.5 L containers. The plants were located on a 1.8 × 1.8 m spacing in the gravel surfaced experiment area. The height and diameter of the container were 30 cm and 35 cm respectively and the medium depth of soil mix in the container was 20 cm. The potting medium used in the experiment, Metro Mix 510 (The Scotts Company, Marysville, OH), was common to the nursery industry and recommended for its good physical and chemical characteristics. The general ingredients of the growing medium were composted pine bark (20-45%), horticultural vermiculite (15-30%), Canadian sphagnum peat moss (25-35%), and processed bark ash (5-25%). The dry bulk density of the medium was estimated by the manufacturers to be 0.24 – 0.32 g/cm^3. A slow release fertilizer called Osmocotewas used to fertilize the plants and the N-P-K ratio of the

Osmocote was 18-6-12. No soil or water salinity was present. The salinity level of the medium was normal based on its pH (pH=7.2) and electrical conductivity (EC=3.0 dS/m). The water source for irrigation was local city water with a pH and soluble salts (electrical conductivity) of 7.2 and 0.53 dS/m respectively. Meteorological data (air temperature, wind speed, wind direction, relative humidity, barometric pressure, rainfall and radiation) were obtained from an automatic recording weather station located adjacent to the nursery growing area.

A Q-COM Inc., Irvine, CA computer controlled micro-irrigation system with GEM3V2 software was used to sense the medium tension. In the experiment, potting media tension was allowed to go up to 21 kPa. Irrigation was done manually by considering the tension levels and observing cumulative water loss with the weighing lysimeter. Sampling intervalwas 15 minutes. In order to measure ET, A SATORIUS F330S automatic weighing scale with an accuracy of ±1 g was placed beneath one of the plant containers. In order to determine leaf area index (LAI), a total of 10 leaves were removed from different parts of the plant and then measured as a basis for determining the average leaf area. An electronic area-meter was used to measure each sample leaf. The horizontally projected area of the plant was calculated assuming a rectangular shape, resulting in a LAI of 1.58.

2.1. Deterministic Transpiration Calculation Methods

Penman, Fynn and Stanghellini ET calculation methods were used. Penman (1948) first derived the combination equation for computing the ET by considering the aerodynamic and energy budget equations that are required for evaporation and removing the vapor. The Penman combination equation is as follow:

$$\lambda E = \frac{\Delta}{\Delta+\gamma}\left(R_n - G\right) + \frac{\gamma}{\Delta+\gamma} 6.43(1.0 + 0.53U_2)(e^o{}_z - e_z) \tag{1}$$

where; λE = Latent heat flux density (MJ. m^{-2}. d^{-1}), Δ = Slope of the saturation vapor pressure curve versus air temperature (kPa/^{o}C), R_n = Net radiation (MJ .m^{-2}.d^{-1}), G = Soil heat flux (MJ. m^{-2}.d^{-1}), γ = Psychometric constant (kPa/^{o}C), U_2 = Wind velocity at 2 meter (m/s), e_z^o = Saturation vapor pressure at mean air temperature (kPa), e_z = Vapor pressure of the air (kPa).

Fynn and Stanghellini both modified the combination equation to calculate transpiration under the greenhouse conditions [1, 6]. The Fynn model was defined as:

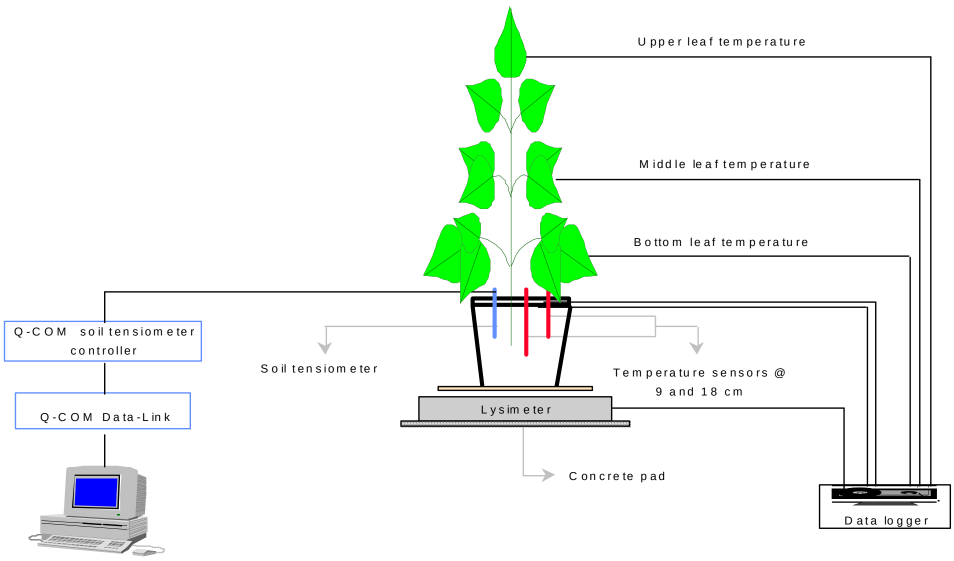

Fig. 1 Schematic drawing of instrumental setup for Red Maple.

$$ET = \frac{2LAI.\rho.C_p\left[e_s(T_a) - e(T_a)\right]/r_w + \delta(Q_{RAD} - Q_G)}{L_v \gamma r_c} \tag{2}$$

where; ET = ET rate ($Kg.m^{-2}.s^{-1}$), L_v = Latent heat of vaporization of water ($J.kg^{-1}$), Q_G = Rate that energy is stored in the canopy ($J/m^2.s$), Q_{RAD} = Irradiance absorption rate by the canopy ($J/m^2.s$), ρ = Air density (kg/m^3), C_p = Specific heat of air at constant pressure ($J/kg.\ ^oC$), $e(T_a)$ = Vapor pressure at air temperature (Pa), r_w = Air resistance for water vapor transfer (s/m), $e_s(T_a)$ = Saturation vapor pressure at air temperature (Pa), LAI = Leaf area index, γ = Psychometric constant ($Pa/^oC$), r_c = Crop resistance for water vapor transfer (s/m), δ = Slope of saturated vapor pressure curve with temperature ($Pa/^oC$).

The Stanghellini model was defined as:

$$LE = \frac{2.LAI.\rho_a.c_p}{1 + \frac{\delta}{\gamma} + \frac{r_i}{r_e}}\left[0.07\frac{\delta}{\gamma}\frac{I_s}{\rho_a c_p} + 0.16\frac{\delta}{\lambda}\frac{T_h - T_o}{r_R} + \frac{1}{r_e}\frac{e_a^* - e_a}{\gamma}\right] \tag{3}$$

where; LE = Latent heat flux ($W.m^{-2}$), C_p = Air specific heat at constant pressure ($J.Kg^{-1}.C^{-1}$), ρ_a = Air density ($Kg.m^{-3}$), δ = Slope of saturated vapor pressure curve with temperature ($Pa.^oC^{-1}$), γ = Thermodynamic psychometric constant ($Pa.^oC^{-1}$), r_e = Transfer resistance of external heat ($s.m^{-1}$), r_R = Radiation heat transfer resistance ($s.m^{-1}$), r_I = Transfer resistance of internal heat($s.m^{-1}$), I_s = Shortwave irradiance ($W.m^{-2}$), T_h = Ambient temperature (^oC), T_o = Temperature at the external surface (^oC), = Saturation air vapor pressure (Pa), e_a = Air vapor pressure(Pa), LAI = Leaf area index ($m^2.m^{-2}$).

Hourly ET was determined as the lysimeter mass losses while considering irrigation and precipitation mass gains, though based on water balance method. In this research we checked whether the ET models developed under greenhouse conditions are suitable for outdoor conditions. In order to evaluate individual and combined effects of climate factors on the measured ET, linear multiple regression analyses were done with Minitab (Release 12.1, by Minitab Inc.) at the 90% confidence level.

3. RESULTS AND DISCUSSION

Leaf and air temperature, wind speed, solar radiation, VPD, and measured transpiration were plotted for 24 hour periods (Fig. 2). The plants were subjected to the highest transpiration stress during the mid-day when air and leaf temperature, and radiation were all at the maximum levels and relative humidity was low. The daily transpiration rate of Red Maple was found to range from a minimum of 850 g $tree^{-1}$ day^{-1} to a maximum of 1789 g $tree^{-1}$ day^{-1} for sunny days. Even for cloudy days, transpiration was significant, ranged from a minimum of 450 g $tree^{-1}$ day^{-1} to a maximum of 855 g $tree^{-1}$ day^{-1}. The equations between measured ET vs. solar radiation and measured ET vs. VPD were measured ET = 0.1961*Rad.+19.419 with R^2=0.758 and measured ET = 0.066*VPD+44.411 with R^2=0.647, respectively. Using the R^2 coefficient from a simple linear regression analysis over two months of continuous data (excluding all night time data), it was evident that solar radiation with a coefficient of 0.758 was slightly better correlated to ET than VPD with a coefficient of 0.647. Consistent with other evapotranspiration studies given in Fynn et al., Yang et al., and Stanghellini [1,4,6], it was found that there was a good correlation between VPD vs. transpiration rate and solar radiation vs. transpiration rate. In the very early morning, VPD, solar radiation, and transpiration were all very low. As the solar radiation increased, transpiration was more responsive to solar radiation than VPD. In the late afternoons, when solar radiation was decreasing, the driving force for transpiration depended more on VPD. The correlation between calculated and measured hourly ET rates of Red Maple excluding all night time data for Fynn, Stanghellini and Penman ET models were 0.645, 0.644, 0.582 respectively. It was observed that the R^2 value of the VPD and solar radiation based ET model was better than the R^2 value of the Fynn, Stanghellini and Penman ET models. Although the Penman model was developed mainly for outside conditions and had a wind factor in the formula, its R^2 value was the lowest one since there was no resistance term in it. Average measured ET and calculated ET for Fynn, Stanghellini and Penman were 840.1, 703.0, 674.3, and 1100.5 g/day respectively when excluding all night time data.

This indicates that Fynn and Stanghellini ET models underestimated the measured ET 16.32% and 19.74% respectively. On the other hand, Penman ET model overestimated the measured ET 30.99% (Table1).

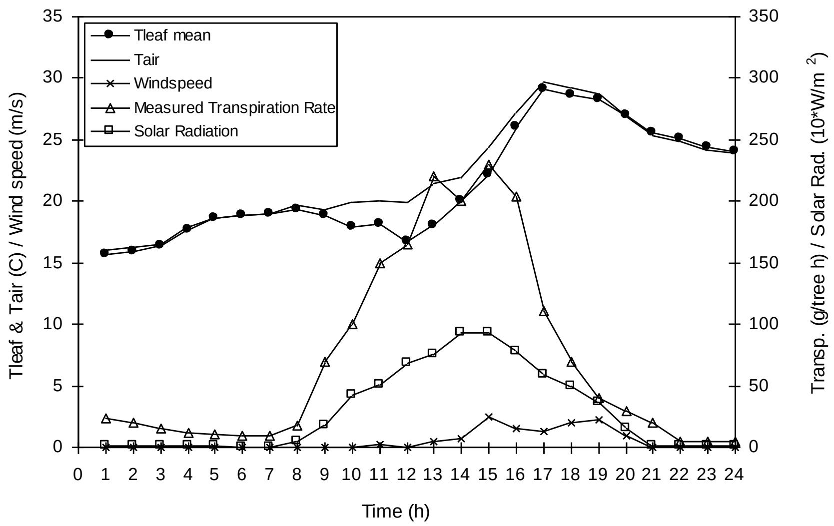

Fig. 2 Air temperature, wind speed, measured transpiration and solar radiation, and vapor pressure deficit for Red Maple on a sunny day (August, 14th).

Although there were seven input parameters (solar radiation, average leaf temperature, relative humidity, wind speed, average medium temperature, tension, and air temperature) in the regression analysis, nonsignificant terms were eliminated one by one from the model using backward elimination technique. The result of the backward elimination procedure for the second ordered model resulted with R^2 = 89.9%. By comparing the R^2 values of the first and second order regression models, it was concluded that the effects of interactions to the model did not make the model better.

Table1 Differences between measured ET and calculated ET for two months of data (including all night time data).

ET calculation methods	Average Calculated ET (g/day)	Average Measured ET (g/day)	R^2	Error (%)
Stanghellini	1100.21	998.75	0.81	10.16
Fynn	1068.10	998.75	0.78	7.0
Penman	1255.43	998.75	0.88	25.70

Therefore, it was assumed to be better to use a simple first order regression model requiring less input variables. Statistical analysis also shows that there were significant correlations among VPD, radiation and measured ET making a VPD and radiation model a very practical solution for ET estimates. For this purpose, equation (4) was obtained with an R^2 = 87.8% by performing a multiple regression analysis where:

$$\text{Measured ET} = 2.16 + 0.185\ (rad.) + 0.0125\ (VPD) \quad (4)$$

CONCLUSIONS

Results of the linear regression analysis showed that there was high correlation between solar radiation, VPD and measured ET. A solar radiation or a VPD based ET model could be successfully used to predict ET rate of the plant. Comparing R^2 values of these two ET models, it was concluded that a solar radiation based ET model predicted ET better than the VPD based ET model. The Stanghellini and Fynn ET models were similar to each other in terms of R^2 values and error in the prediction of ET. Even though Stanghellini and Fynn ET models were developed under greenhouse conditions, they predicted ET under field conditions better than Penman. Transpiration tended to be more proportional to VPD for cloudy days and more proportional to solar radiation for sunny days. The driving force for transpiration in late afternoon as the solar radiation was decreasing was VPD. Statistical analysis showed that using a first order linear regression model was more practical than using a second order model since the more complex second order model did not significantly improve the R^2 of the ET model.

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First (Short) Comunication

FUEL CONSUMPTION AND PRODUCTIVE EFFECTIVNESS OF THE ALFALFA MOWING BY THE OSCILLATORY AND ROTARY MOWERS

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Abstract. *This study summarizes results of three-year study performed on an oscillatory mower IMT 627.667 and a rotary mower with two drums PÖTTINGER CAT 185, with the special attention on fuel consumption and production effectiveness. The aim of the research was to obtain optimal values of parameters for the tested mowers by conducting comparative analyses of various technical characteristics of the mowers from the aspect of the exploitation parameters, working quality, fuel consumption, etc. Over three-year study period, at the average working speed of 5.97 km h^{-1}, the average fuel consumption of the oscillatory mower IMT 627.667 was 2.22 l h^{-1}. Average specific fuel consumption was 2.59 l h^{-1}, with average pure effectiveness of 0.88 ha h^{-1}. The average fuel consumption over three-year study period of the rotary mower PÖTTINGER CAT 185 was 3.37 l h^{-1}, at the average working speed of 9.67 km h^{-1}. Average specific fuel consumption was 2.77 l h^{-1}, with average pure effectiveness of 1.47 ha h^{-1}. During the test of the oscillatory mower IMT 627.667, the average three-year study production effectiveness was 0.77 ha h^{-1}, at the average working speed of 5.97 km h^{-1}, while mowing by the rotary mower PÖTTINGER CAT 185, the average production effectiveness was 1.43 ha h^{-1}, at the average working speed of 9.67 km h^{-1}*.

Key words: *fuel consumption, productive effectiveness, plant mowing*

1. INTRODUCTION

Mowers are basic machines for cutting plant species in animal husbandry. They meet strict demands with regards to: universal utilization, qualitative stem incision with as little losses as possible, high productive effectiveness, economic performance, exploitation reliability and simple maintaining. Alfalfa is one of the most important fodder crops in Serbia. In 2010, it was grown on surface of 187.079 *ha*, yielding 5.8 $t\ ha^{-1}$ [10]. Period of alfalfa exploitation, yield and quality fodder feed mainly depend upon number of mowing during vegetation period [3, 6, 11]. Radivojevic (2000) [9] says that in order to have an even cut, it is necessary to harmonize the relative aggregate moving speed with speed of mower's cutting device oscillation speed. Mower's moving speed ranges from 2/3 of cutting device oscillation speed. In the case of slower moving speed (V = 5 $km\ h^{-1}$), double cutting of the already cut off plants happens due to uncoordinated relation with oscillation speed. In the case of mower's speed increase (V = 8 $km\ h^{-1}$), that is significantly decreased. Ó Dogherty and Gale (1986) [7], give results of the laboratory research of plant reaction at the moment of cutting by rotary elements at speed of 45 $m\ s^{-1}$. Mowing process for given variants indicates critical speeds in interval from 15 to 30 $m\ s^{-1}$, under which the cutting effect significantly decreases. Slower speeds cutting elements below said values causing lodging of plants and their wrapping around them. It has resulted in greater energy consumption and higher incision cut. Barac et al (2007) [1], state that the moving speed of the oscillatory mowers is limited 5 to 7 $km\ h^{-1}$, whereas the rotary mowers work without jamming and at greater speeds of 12 $km\ h^{-1}$, so that they have greater working effectiveness. It is stated [5] that oscillatory mowers with two movable knives at the average moving speed of 4.4 $km\ h^{-1}$ made technical production of 0.4 $ha\ h^{-1}$, and fuel consumption of 7.5 $l\ h^{-1}$. Rotary mower with drums, at the average speed of 7.9 $km\ h^{-1}$, made technical production of 0.68 $ha\ h^{-1}$. The rotary mower with drums RK 135 was tested [4] on the alfalfa yield of 3.22 $t\ ha^{-1}$, and the working speed ranged between 6.55 to 9.40 $km\ h^{-1}$ with production effectiveness of 0.60 do 0.78 $ha\ h^{-1}$. Over three-year long testing period, the mower had the average specific fuel consumption of 4.17 $l\ h^{-1}$. It was stated [2] that mowers belong to the group of the agricultural machines which consume lots of energy. Therefore, the appropriate attention has to be paid to adjustment of the given parameters. It was stated [12] that the production effectiveness of the tested mowing machines per tests ranged from 0.49 to 1.06 $ha\ h^{-1}$ at the working speed of 3.73 to 8.82 $km\ h^{-1}$ for the oscillatory, and 1.20 to 2.10 $ha\ h^{-}$ at working speeds of 8.57 to 15.25 $km\ h^{-1}$ for rotary mowing devices. After testing the exploitation characteristics of the oscillatory and rotary mowers, [8], stated that the rotary mowing apparatus had maximal working effectiveness of 3.17 $ha\ h^{-1}$, whereas the oscillatory had 1.06 $ha\ h^{-1}$.

2. MATERIAL AND METHODS

This three-year study summarizes results of oscillatory mower IMT 627.667 and rotary mower PÖTTINGER CAT 185 fuel consumption and productive effectiveness during alfalfa mowing and its hay preparation. The researches were performed on the private estate of Aleksandar Mršić in Mačkovac (43^0 33' 33''N; 21^0 12' 53''E) in immediate vicinity of the Institute for Fodder plants Kruševac, in the alfalfa age of five and six. Researches were made in three-year mowing system under dry farming conditions (without irrigation), in stage of full blooming. The average yield of alfalfa during the three-year study was 4.5 $t\ ha^{-1}$, 4.3 $t\ ha^{-1}$ and 4.6 $t\ ha^{-1}$, respectively. The green mass yield was determined by alfalfa mass measurements, taken from a length meter with swath width and calculated per hectare. The exploitation parameters for each mower were measured simultaneously (moving speed, fuel consumption). Mowers' moving speed was determined by the chronometer method, based on the path driven per time unit. The fuel consumption was measured by the volume method for each test. The attained parameters were used for determination of average values for each test. The measurements of fuel consumption for tested mowers were done exclusively for mowing, and they didn't included fuel consumption for other operations, such as flipping, halts, etc. The productive effectiveness was defined applying the chronometric method, i.e. measuring working time of the tested mowers at certain moving speeds.

3. RESULTS AND DISCUSSION

According to the given results, table 1, it is obvious that the lowest (Pg) fuel consumption per hour for the oscillatory mower IMT 627.667 was made during the second year of research (2012) at the first test and it was 1.85 $l\ h^{-1}$ (working speed 3.95 $km\ h^{-1}$), whereas the greatest fuel consumption was also during the second year (2012) at the third test, 2.85 $l\ h^{-1}$, at the working speed regime of 8.28 $km\ h^{-1}$. At the specific fuel consumption (Psg) of the tested type of the cutting device, it was obvious that the least fuel was consumed during the second year of research (2012), at the second probe, 2.32 $l\ h^{-1}$, whereas the greatest fuel consumption was during the third year (2013) at the first test, 3.10 $l\ h^{-1}$. Pure effectiveness (Wh) ranged from minimal 0.60 $ha\ h^{-1}$ at the first test during the third year of research (2013), to maximum 1.22 $ha\ h^{-1}$ during the second year of research (2012) at the third test.

Table 1 Fuel consumption of oscillatory mower IMT 627.667

Research year	Parameter		Test 1	Test 2	Test 3	Average
2011	Fuel consumption - (Pg)	$(l\ h^{-1})$	1.88	1.99	2.82	2.23
	Pure effect - (Wh)	$(ha\ h^{-1})$	0.61	0.84	1.20	0.88
	Specific fuel consumption - (Psg)	$(l\ ha^{-1})$	3.08	2.37	2.35	2.60
	Moving speed - (V)	$(km\ h^{-1})$	3.92	5.44	8.25	5.87
2012	Fuel consumption - (Pg)	$(l\ h^{-1})$	1.85	1.97	2.85	2.22
	Pure effect - (Wh)	$(ha\ h^{-1})$	0.61	0.85	1.22	0.89
	Specific fuel consumption - (Psg)	$(l\ ha^{-1})$	3.03	2.32	2.34	2.56
	Moving speed - (V)	$(km\ h^{-1})$	3.95	5.52	8.28	5.92
2013	Fuel consumption - (Pg)	$(l\ h^{-1})$	1.86	1.95	2.78	2.20
	Pure effect - (W)	$(ha\ h^{-1})$	0.60	0.81	1.18	0.86
	Specific fuel consumption - (Psg)	$(l\ ha^{-1})$	3.10	2.40	2.36	2.62
	Moving speed - (V)	$(km\ h^{-1})$	4.10	5.75	8.48	6.11

The data on fuel consumption made during the alfalfa mowing by the rotary mower PÖTTINGER CAT 185 are given in the table 2. The presented results indicate that during research of this type of cutting device, the lowest (Pg) fuel consumption per hour was made during the second year of research (2012). At the first test it was 2.82 $l\ h^{-1}$ (working speed 8.45 $km\ h^{-1}$). The greatest fuel consumption per hour was during the first year (2011) at the third test, 3.68 $l\ h^{-1}$, at the working speed regime of 10.75 $km\ h^{-1}$. Analyzing the specific fuel consumption values (Psg), it was obvious that the least fuel was consumed during the second year of research (2012), at the third test, 2.58 *l h*$^{-1}$, whereas the maximum specific fuel consumption was during the first year (2011) at the first test, 2.93 *l h*$^{-1}$. Pure effectiveness (Wh) for the rotary cutting apparatus ranged from minimal 0.98 *ha h*$^{-1}$ at the first test, during the first (2011) and the third year of research (2013). The maximum value of 1.42 *ha h*$^{-1}$ was noted during the second year of research (2012) at the third test.

Table 2 Fuel consumption of rotary mower PÖTTINGER CAT 185

Research year	Parameter		Test 1	Test 2	Test 3	Average
2011	Fuel consumption - (Pg)	*(l h*$^{-1}$*)*	2.87	3.53	3.68	3.36
	Pure effect - (Wh)	*(ha h*$^{-1}$*)*	0.98	1.25	1.39	1.21
	Specific fuel consumption - (Psg)	*(l ha*$^{-1}$*)*	2.93	2.82	2.65	2.78
	Moving speed - (V)	*(km h*$^{-1}$*)*	8.55	9.78	10.75	9.69
2012	Fuel consumption - (Pg)	*(l h*$^{-1}$*)*	2.82	3.61	3.67	3.37
	Pure effect - (Wh)	*(ha h*$^{-1}$*)*	0.99	1.28	1.42	1.23
	Specific fuel consumption - (Psg)	*(l ha*$^{-1}$*)*	2.85	2.82	2.58	2.74
	Moving speed - (V)	*(km h*$^{-1}$*)*	8.45	9.70	10.85	9.67
2013	Fuel consumption - (Pg)	*(l h*$^{-1}$*)*	2.85	3.58	3.67	3.37
	Pure effect - (W)	*(ha h*$^{-1}$*)*	0.98	1.26	1.40	1.97
	Specific fuel consumption - (Psg)	*(l ha*$^{-1}$*)*	2.91	2.84	2.62	2.79
	Moving speed - (V)	*(km h*$^{-1}$*)*	8.50	9.65	10.80	9.65

The average fuel consumption values for the tested mowers per years of research are given in the table 3. According to the three-year research results, for the oscillatory mower IMT 627.667, it is obvious that the average fuel consumption value per hour (Pg) was 2.22 *l h*$^{-1}$ at the average working speed of 5.97 *km h*$^{-1}$. The average specific fuel consumption (Psg) was 2.59 *km h*$^{-1}$. The average working effectiveness (Wh) was 0.88 *ha h*$^{-1}$.

The average three-year fuel consumption per hour (Pg) measured during the test of the rotary mower PÖTTINGER CAT 185 was 3.37 *l h*$^{-1}$ at the average working speed of 9.67 *km h*$^{-1}$. The average specific fuel consumption (Psg) for this type of cutting device was 2.77 *l h*$^{-1}$. The average working effectiveness (Wh) was 1.47 *ha h*$^{-1}$.

Table 3 Average fuel consumption for tested mowers

Type of mower	Parameter		Research year 2011	2012	2013	Average
Oscillatory mower	Fuel consumption - (Pg)	*(l h*$^{-1}$*)*	2.23	2.22	2.20	2.22
	Pure effect - (Wh)	*(ha h*$^{-1}$*)*	0.88	0.89	0.86	0.88
	Specific fuel consumption - (Psg)	*(l ha*$^{-1}$*)*	2.60	2.56	2.62	2.59
	Moving speed - (V)	*(km h*$^{-1}$*)*	5.87	5.92	6.11	5.97
Rotary mower	Fuel consumption - (Pg)	*(l h*$^{-1}$*)*	3.36	3.37	3.37	3.37
	Pure effect - (Wh)	*(ha h*$^{-1}$*)*	1.21	1.23	1.97	1.47
	Specific fuel consumption - (Psg)	*(l ha*$^{-1}$*)*	2.78	2.74	2.79	2.77
	Moving speed - (V)	*(km h*$^{-1}$*)*	9.69	9.67	9.65	9.67

The production effectiveness is influenced by the working swath, green mass yields, weather conditions, technical condition and cutting device exploitation reliability and experience of the mower driver. The shorter time period for green mass mowing is the greater production effectiveness of the tested mowers.

Table 4 Productive effectiveness of oscillatory mower ИМТ 627.667

Research year	Parameter	Unit	Test 1	Test 2	Test 3	Average
2011	Moving speed - (V)	*(km h^{-1})*	3.92	5.44	8.25	5.87
	Swath speed - (Br)	*(m)*	1.54	1.50	1.48	1.51
	η_{pr}	/		0.85		
	Productive effectiveness - (Wpr)	*(ha h^{-1})*	0.51	0.69	1.04	0.75
2012	Moving speed - (V)	*(km h^{-1})*	3.95	5.52	8.28	5.92
	Swath speed - (Br)	*(m)*	1.54	1.52	1.51	1.52
	η_{pr}	/		0.85		
	Productive effectiveness - (Wpr)	*(ha h^{-1})*	0.52	0.71	1.06	0.76
2013	Moving speed - (V)	*(km h^{-1})*	4.10	5.75	8.48	6.11
	Swath speed - (Br)	*(m)*	1.55	1.54	1.52	1.54
	η_{pr}	/		0.85		
	Productive effectiveness - (Wpr)	*(ha h^{-1})*	0.53	0.75	1.12	0.80

η_{pr} = Coefficient of the used productive working time;

The lowest work effectiveness, i.e. work result, of the oscillatory mower IMT 627.667 was made during 2011 at the first exploitation test, 0.51 *ha h^{-1}*, at the mower moving speed of 3.92 *km h^{-1}*. The greatest work effectiveness was made during the third year of research (2013) at the third test, 1.12 *ha h^{-1}*, at the moving speed regime of 8.48 *km h^{-1}*, table 4. The data on obtained productive effectiveness for the alfalfa mowing by the rotary mower with two drums PÖTTINGER CAT 185 are given in the table 5. During the work of this cutting device, the lowest production result was during the third year of research (2013) at the first test, 1.27 *ha h^{-1}* at the working speed of 8.50 *km h^{-1}*, whereas the greatest value of 1.58 *ha h^{-1}* was during the second year of research (2012) at the third test, at the working speed of 10.85 *km h^{-1}*.

Table 5 Productive effectiveness of rotary mower PÖTTINGER CAT 185

Research year	Parameter	Unit	Test 1	Test 2	Test 3	Average
2011	Moving speed - (V)	*(km h^{-1})*	8.55	9.78	10.75	9.69
	Swath speed - (Br)	*(m)*	1.79	1.76	1.70	1.75
	η_{pr}	/		0.85		
	Productive effectiveness - (Wpr)	*(ha h^{-1})*	1.30	1.46	1.55	1.44
2012	Moving speed - (V)	*(km h^{-1})*	8.45	9.70	10.85	9.67
	Swath speed - (Br)	*(m)*	1.78	1.75	1.70	1.74
	η_{pr}	/		0.85		
	Productive effectiveness - (Wpr)	*(ha h^{-1})*	1.29	1.44	1.58	1.44
2013	Moving speed - (V)	*(km h^{-1})*	8.50	9.65	10.80	9.65
	Swath speed - (Br)	*(m)*	1.78	1.74	1.68	1.73
	η_{pr}	/		0.85		
	Productive effectiveness - (Wpr)	*(ha h^{-1})*	1.27	1.43	1.56	1.42

η_{pr} = Coefficient of the used production working time

The average values of productive effectiveness for the tested mowers per years of research are shown in the table 6. According to the obtained results, it may be concluded that the average productive effectiveness was 0.77 *ha* h^{-1} over three-year period of research for the oscillatory mower IMT 627.667, at the average working speed of 5.97 *km* h^{-1}. During the test of the rotary mower PÖTTINGER CAT 185, the average productive effectiveness value was 1.43 *ha* h^{-1}, with average working speed of 9.67 *km* h^{-1}.

Presented results are in conformity with the results given by other authors (12, 8, 1).

Table 6 Average productive effectiveness of the tested mowers

Type of mower	Parameter	Unit	Research year 2011	2012	2013	Average
Oscillatory mower	Moving speed - (V)	*(km* h^{-1}*)*	5.87	5.92	6.11	5.97
	Swath speed - (Br)	*(m)*	1.51	1.52	1.54	1.52
	η_{pr}	/		0.85		
	Productive effectiveness - (Wpr)	*(ha* h^{-1}*)*	0.75	0.76	0.80	0.77
Rotary mower	Moving speed - (V)	*(km* h^{-1}*)*	9.69	9.67	9.65	9.67
	Swath speed - (Br)	*(m)*	1.75	1.75	1.74	1.75
	η_{pr}	/		0.85		
	Productive effectiveness - (Wpr)	*(ha* h^{-1}*)*	1.44	1.44	1.42	1.43

η_{pr} = Coefficient of the used productive working time;

4. CONCLUSIONS

According to the results obtained over three-year research of the oscillatory mower IMT 627.667 and rotary mower PÖTTINGER CAT 185, it may be concluded that there is a significant difference in hour and specific fuel consumption. Rotary mower had greater average fuel consumption of 3.37 *l* h^{-1}. Therefore, it was significantly greater than the average fuel consumption of the oscillatory mower, 2.22 *l* h^{-1}. The average specific fuel consumption of the oscillatory mower was 2.59 *l* h^{-1} in comparison to the rotary mower, 2.77 *l* h^{-1}, respectively. The difference in favor of the rotary mower was also noticed during the research in regard to the productive effectiveness. The significant impact on the productive effectiveness was made by the moving speed, as well as the working swaths. The average productive effectiveness for the rotary mower was 1.43 *ha* h^{-1} with the average working speed of 9.67 *km* h^{-1}, and it is significantly greater in comparison to the average productive effectiveness of the oscillatory mower of 0.77 *ha* h^{-1} with the average working speed of 5.97 *km* h^{-1}. According to the results obtained during the research of the alfalfa mowing process, the advantage is given to the rotary mowers under defined conditions.

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Case Study

TURKISH LIVESTOCK HOUSINGS – GENERAL CONDITIONS, PROBLEMS AND POSSIBLE SOLUTIONS

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Abstract. *Housings in livestock facilities of Turkey are most of the time not designed and constructed based on scientific parameters and principles and housing systems thus are far away from meeting the environmental and health conditions of animals. Improper housing systems are among the most significant problems of livestock industry of the country and the number of facilities with modern buildings and housing systems are highly limited. Housings are constructed without taking local climate conditions into consideration and mostly the similar ones of the neighboring buildings are constructed. Although economic and strength parameters are considered in design, environmental control and internal installations are not sufficiently considered. Livestock industry is a significant industry in Turkey with regard to both capital use and supports provided to country economy. However, yield levels per animal are highly lower than the levels of developed countries. Housing systems are the critical components of the industry and they should be improved and developed to increase the current yield levels. Increasing yield levels will only be possible by providing proper environmental conditions to high-yield* races. *In the present study, current constructional and environmental conditions of the livestock housings of Turkey were assessed, existing problems were identified and possible solutions for these problems were discussed*

Key words: *Livestock housing, Environmental conditions, Structural members, Turkey.*

1. INTRODUCTION

Sufficient and balanced nutrition is an unchanged problem of mankind within ever changing and developing world. Animal products constitute the greatest component of human nutrition and with their biological properties they are indispensable and cannot be replaced by the other food stuff. Livestock industries have relative high shares in country economies and production-consumption levels of animal products are a significant indicator of development level of the countries. Livestock industry is the locomotive of agricultural economy. It is fully industrialized in developed countries and has become an indispensable component of the economy. It is a highly significant industry to meet the food demands of population, to get the highest return from a unit investment, to have several advantages in foreign trade and to create low-cost employment opportunities. Thus, livestock industry is a strategic industry to be developed at national level. It provides the raw material demands of various other industries through meat, milk, egg, textile, wool and skin-like products, provides support in founding feed, medication and equipment-like sub-industries.

Turkey has a great significance with regard to livestock industry. The industry of the country is in an ever-developing trend since the facilities have highly available transportation conditions; they are close to feed production centers and markets. Together with increasing population intensities, number of facilities around large cities is remarkably increasing. Especially during the recent years, migrations to large cities because of socio-economic reasons let the new settlements to be created toward the agricultural fields [1].

In Turkey, animal products are commonly obtained from cow, sheep, goat, buffalo, camel, poultry, turkey, duck, fish and some other marine species. With regard to meat production, poultry had the first place and it is followed by cow, sheep, goat, buffalo, turkey, and fresh-sea water species. Turkey has 14 415 257 cows, 29 289 247 sheep and 9 225 548 goats. Annual red meat production of the country is 996 125 tons, milk production is 18 223 712 tons, poultry production is 1 758 363 tons, fowl production is 3 359 tons and egg production is 1.3 million [2].

Although the country is at the similar development levels in livestock industry with developed countries, even better than some, the share of livestock production in national income is at relatively low levels. Such a case requires improving the yields per animal. Beside care and breeding practices, improved yield levels will only be possible by providing proper environmental conditions to high-yield races.

Researches have mostly focused on breeding and feeding of animals. However, sufficient research is not available on proper environmental conditions and proper housing systems. In Turkey, proper environmental conditions have not been provided in most of the facilities and proper design principles have not been obeyed during the construction of such facilities. Therefore, improper design and conditions of these facilities are the most significant barriers in front of country livestock industry. The number of facilities with modern technologies is highly limited and most of them are insufficient in ventilation, heating, lighting and hygiene conditions.

Nutritional demands of Turkish people, either living in rural or urban sections of the country, are met by agricultural enterprises. These enterprises are combined units for production of both plant and animal products. Livestock facilities constitute a part of such enterprises. Sufficient, quality and economic livestock production mostly depend on technical characteristics of buildings and housing systems of the facility.

The basic target in livestock production is to maximize enterprise profits through getting economic yield levels. Livestock industry of Turkey is ever-developing but desired yield levels have not been reached yet. Thus, as it was in throughout the world, researches have been carried out in Turkey to improve the yield levels and consequently the income levels of the producers. In the present study, current constructional and environmental conditions of the livestock housings of Turkey were assessed, existing problems were identified and possible solutions for these problems were discussed.

2. DESIGN AND PLACEMENT CONDITIONS OF LIVESTOCK BUILDINGS

In Turkey, most of the livestock barns are constructed as fully closed facilities because of traditional growing styles, lack of sufficient land source, animals easy control, safety and cold weather concerns. In places with available climate conditions, they are constructed either in semi-open or fully open styles and free-stall systems are applied in most of them [1]. Low temperatures are less concerned for livestock in mild climates. In countries with developed livestock industries, cold-barns are preferred providing almost identical indoor parameters with the outdoor climate parameters. In properly designed and constructed cold-barns, animals are able to present their natural behaviors. Such barns are highly healthy and their construction costs are also relatively lower than conventional fully-closed ones. Since mechanization and technology-use are available in these barns, works are implemented easily, labor costs and correspondingly the production costs are reduced [3]. Therefore, in livestock raising, low-cost open barns should be selected instead of high-cost fully closed ones. It was observed that Turkey had highly available conditions to implement free (open) and free-stall systems allowing natural behaviors of animals.

Sheep breeding is mostly implemented as pasture-dependent in Turkey. Sheep is housed in closed barns only during the hard winter months. In poultry industry, caged systems allowing more production per a unit area and they are preferred to meet the deficits in animal protein production and export demands of the country.

Most of the livestock facilities of agricultural enterprises of Turkey are not constructed according to a plan or project. Basically the similar ones of the neighboring facilities are constructed without taking local climate and environmental conditions into consideration. Primarily, the cost and strength of the building are emphasized. Similar buildings are sometimes constructed and constructional members are sized similarly in regions with totally different climate and environmental conditions. The issue is mostly disregarded just because of unawareness of the producers about the significance of buildings and housing systems in livestock breeding.

Nationwide researches on livestock facilities indicated that structural members and dimensions were not comply with the design principles. Facilities are far away from providing the functions expected from them. The part of facilities constructed with modern technologies is highly limited and most of them have various ventilation, heating, lighting and hygiene problems. Lack of emphasis in facility design and construction increased the constructional and technical problems and created improper living conditions for the animals. Old buildings also bring about various problems in livestock breeding activities.

Most of the enterprises build the livestock housing with their own potentials. The deficiency in facility construction is the lack of technical drawing or technical design of buildings. Producers usually prefer to construct the buildings without a project to reduce the initial investment costs. Only the state-supported buildings are constructed in accordance with pre-designed projects, while the rest is constructed on producer desires and similar facilities around. Since the facility owners arbitrarily alter the original projects during the construction of the buildings, optimum conditions are not able to be provided to animals. Most of the enterprises are traditional ones; therefore it is hard for them to adapt the new techniques in design and housing systems.

It is possible to have healthier systems and to minimize the environmental impacts through obligating the producer to construct the building with design projects. In this case, cost of such facilities should partially be met by the state incentives. There are several supports of the state provided for livestock production activities and construction or housing supports should then be included into such supports to allow the country to have modern housing systems equipped with relevant technical installations [4]. Technical knowledge and technology should be used for modern buildings with desired yield levels [5].

Facility owners spend most of their times for the care of animals and gain income from these facilities. Barns are most of the time close or adjacent to homes just for the safety concerns and to save from the labor spend over them. Decreasing young labor also affects the placement of barns. Such cases are not suitable for both human and environmental health. The way to eliminate such unhealthy conditions is to establish livestock cooperatives in villages to bring the animals together and remove them out of settlements and to take them close to pastures and provide a single-hand management for the entire herd.

General principles are not obeyed in placement of livestock facilities and various mistakes are made in positioning the barns within the enterprise yard. Producers usually disregard the future extension opportunities and construct the buildings where they think suitable. Livestock buildings are most of the time surrounded by the other facilities and owner’s home without allowing future extensions. Future extension plans should be made at initial design phase.

Small size of enterprises prevents the mechanization implementations. Such a case increases input costs and makes the quality production difficult. Producers usually experience marketing problems because of low quality products. On the other hand, majority of the livestock facilities operate under their full capacities. Since livestock breeding is usually implemented as small family business, yield levels are relatively low. Majority of enterprises are composed of low-yield local races. Small enterprises should get together under a cooperative and establish larger ones. In this case, producer knowledge about livestock breeding will increase and they will easily adapt agricultural renovations, then their marketing volumes and consequently the incomes will increase.

Producers have their livestock breeding knowledge from their families. Large facilities get technological knowledge from expert personnel and do a conscious production. Some large facilities have their own veterinarians. In small ones, labor demand is met by family members and sometimes they hire external labor based on their number of animals. 3. Construction materials and constructional members

The basic materials used in livestock housing construction are sand, cement, brick, stone, wood, concrete and tiles. Materials are usually tried to be supplied from close distances. Economic power of the enterprise, material supply and use, price, technical knowledge and common habits are effective in material selection.

Barn and facility construction constitute more than 50% of initial investment costs. Low-cost durable local materials with high insulation properties, less influenced by environmental conditions and playing positive roles over the control of environmental factors are commonly selected by the producers.

The stones used in foundation and building floors are supplied from stream beds or flood plains and commercial quarries. Rather than mechanical properties, most of the time easy supply and hauling are taken into consideration. Stone is the basic construction material used in building foundations since it is economic and strong. Bricks are preferred for wall construction in places where brick clay is abundantly available. As wood material, poplar and willow are widely used.

The bricks with low heat conductance are used in walls. Such bricks allow thinner wall thickness and thus provide wider available interior space. Therefore, it is also recommended that bricks should be used in wall construction of new barns and they should be laid with cement mortar. Livestock housing walls are mostly plastered. Plaster decrease heat conductance of the wall, prevent moisture diffusion into walls and decrease microorganism activities. Walls are plastered both from inside and outside.

In closed housings, windows are commonly placed over the opposite long side-walls. The total window spaces are usually lower than the recommended values.

Foundation depths are usually extended below the freezing depths. Cement mortar is used as the combining agent. Facilities are usually constructed over agricultural fields. Since the fields have low load bearing capacities, relevant measures should be taken while constructing the foundations. Foundation should lie over strong bases. Rock is the strongest base for foundations. Gravel and sand bases are also good foundation bases.

Floors are constructed as lean concrete over stone blockage. Producers prefer concrete floors for easy cleaning and better hygiene. Livestock housing floors should be rough to prevent sliding of animals. If the floors got slippery, roughness should be reestablished with various tolls and equipment.

Livestock housings in Turkey are usually constructed as load-bearing wall type, but recent large capacity buildings use wood, reinforced concrete or steel frame structures. It was observed that dimensions of load-bearing columns and beams are relatively high and they were placed in narrow spans. Irregular placement of column within the housing reduces the available space for animals, intervene the interior traffic and creates various problems in performance of daily works. Construction and member sizing significantly affect the building costs. The livestock housings are single-story buildings with low load levels over structural members. Therefore, new buildings should have simple construction, available local materials should be used and structural member sizes should be kept at minimum according to relevant design specifications. In this way, building costs should be kept at minimum.

French tile is usually used as the roof cover material of the buildings. Beside tiles, sheet metal and concrete covers are also used in some buildings. Eaves should be so constructed that they should prevent walls from precipitations and insulation material should also be used beneath the roof cover to prevent animals from disturbing noise to be created by precipitations [4].

A ceiling is not necessary in buildings constructed in mild climates. However, insulation is still recommended for roofs. Some producers don't use insulation materials just because of cost and labor concerns and they also don't know about benefits of insulation material (glass wool, synthetic foam, polystyrene).

Insulation levels of structural members should be improved especially in closed housings to provide proper heat conductance coefficients. Thus, the materials with high insulation values should be used rather than locally available materials. Sandwich panels should be used in roofs, pumice bricks or gas concrete blocks should be used in walls. Although the cost of recommended materials is higher than the local materials, they significantly reduce heat losses from the buildings especially during the winter months [6].

Since heat conduction coefficients of windows are higher than the other structural members, the area covered by the windows should be limited. However, window spaces in Turkish livestock housings are still below the recommended values. Windows should be openable to provide proper ventilation conditions during the winter months and to reduce the interior temperatures during the summer months.

4. AUXILIARY FACILITIES

Auxiliary facilities and other parts of buildings like hayloft, liquid and solid manure storages mostly exist, but space allocated to them are not sufficient in most of them. Therefore, necessity of auxiliary facilities should be explained to producers.

Some facilities are two-story ones, so the second story is hay storage. Also, half of the barn is sometimes used as feed storage. In this way, time and labor saved in feed and bedding transport and distribution. Hay storage also provides insulation for the building. In two-story buildings, a ceiling should properly be constructed. A reinforced concrete slab is suitable. Such a slab may increase the building cost but reduce the risk of fire [7].

Roughage storages are either directly attached to the buildings or connected with a pass-way to the building. Such a case provides time and labor savings. In buildings without a feed storage, feed is stored outside the buildings over the field. Feed storages are the most sensitive buildings against fire. Therefore, they should be placed at a certain distance from the other buildings. Feed storages should be so constructed that they should minimize labor needs, provide sufficient capacity and proper conditions. Open-sided sheds or cantilever sheds are mostly preferred roughage storages. They are easy to construct and low cost buildings. Large enterprises have specially-designed concentrate feed storages. They usually stored at a part of hay storage or between the barn and hay storage. Concentrate feed storages should be so designed that they should again minimize labor needs, provide sufficient storage volumes and proper storage conditions [4].

Since producers are not aware of the significance of ensiled feed, most of the enterprises don’t have silage basins. Silage may significantly reduce the feed costs and it is a well-balanced nutrient in dairy operations. High grain bins are not recommended for producers except for the large ones since they are expensive buildings and requires special design and operation. Thus, low horizontal silos are commonly preferred in Turkey.

Most of Turkish livestock facilities don’t have special partitions. Thus, buildings should be rearranged and special partitions should be provided.

Keeper rooms and administrative building are not also sufficiently emphasized in enterprises. Especially in high-capacity facilities, an administrative building should be constructed to keep records of animals and for well-operation of the facility. Within this building, an administrative office, keeper room, a bathroom and a toilet should also be provided.

Manure storage is the least emphasized issue in Turkish livestock facilities. Manure management is the basic problem of many facilities. Required attention is not paid on collection, storage and land application of manure. Facilities usually don't have manure storage basins and manure haphazardly stored just by the facility. Such a storage decreases the nutritional value of the manure and creates various environmental and health problems. Since there aren't manure storages in some and there are improper ones in some others, mechanization cannot be applied in manure collection. Such a case then increase the labor needs. All these negative issues create unhygienic conditions within the buildings and ultimately reduce the yield and facility productivity.

A small portion of solid manure is used over producer lands for their own needs and the rest is used as cowpat. In commercial enterprises, some of the manure is used in plant production activities and the rest is given to manure traders free of charge. Manure usually is not subjected to any physical, chemical and biological processes, except for drying [1].

Manure-induced indoor pollution may be eliminated through design of modern buildings. Environmental pollution and nuisance odor may be eliminated through proper manure storage and handling facilities. Biogas production may also be an alternative way of reducing odor and environmental pollution. The energy from the biogas facilities may be used to meet the energy demands of the farm [6].

According to Turkish laws and regulations, it is forbidden to build a livestock housing in places with a population over 20 000. Despite this law, there are a lot of them scattered around or within small towns. Social training and awareness may be a solution for such a problem.5. Indoor environmental conditions

Temperature and Relative Humidity: Temperature and relative humidity are the two most significant parameters in livestock housings. These parameters should be kept in between optimum limits and effects beyond these limits should be considered together. Ventilation systems are insufficient in many housing buildings since the producers are concerned about the health of their animal in cold weathers, especially in closed barns. They limit the ventilation to keep the indoor warm. Barns usually have higher temperatures than usual since the producers do not open the doors and windows during the winter months.

Relevant measures should be taken to keep the housing indoor temperatures between the limits and to provide keepers and animals a healthier ambient. Under cold conditions, ventilation speeds can be arranged to hold the temperature at optimum levels. Heat loss may also be reduced through selecting construction materials with high insulation capacities. Under hot conditions, indoor temperatures may be reduced by ventilation and shading implementations.

In most Turkish livestock housings, relative humidity levels are relatively high. Such high levels have various negative impacts on animal health and yields. Sufficient ventilation, heat and humidity insulations should be performed to prevent the possible negative impacts of high relative humidity over the animals and structural members. Poor indoor conditions are mostly because of high relative humidity levels rather than temperatures. Closing ventilation openings, doors and windows during the cold seasons to preserve the indoor temperature considerably increase indoor relative humidity levels. The wetness created through moisture condensation over the structural members increase mold and rust-like microorganism activities and result in corrosion and rotting over metal and wood members. Since appetite of animals decreases under high temperature and relative humidity conditions, their yields also decrease. Establishment of a well-ventilation system, temperature reductions through a cooling system when needed and a well-insulation of structural members may eliminate all these negative impacts of temperature and relative humidity over animals.

Temperature and Humidity Balance: Researches indicated that heat balance was not accomplished in most of the closed buildings of livestock housings of Turkey. Heat deficits of the buildings are mostly because of improper insulation, poor or improper material selection and under capacity operation of housings. Lower animal intensities increase the building surface area per animal and thus increase the heat loss. Higher heat conduction values also increase heat losses and decrease the indoor temperatures below the limits.

Extra heat sources may be used, animal density may be increased, indoor relative humidity may be allowed to reach a certain limit value, indoor temperature may be allowed to decrease until a limit value, door and window spaces may be reduced, heat losses through structural members may be reduced through various technical measures all to meet the heat deficit in housings without a heat balance. Animal intensity is a significant factor in heat balance. Lower temperature values makes the heat balancing difficult, while higher values makes it easier, but result in difficulties in ventilation. Thus, heat deficits can only be met through increasing number of animals [8, 9].

Instead of an extra heat source, increasing the insulation characteristics of structural members is the most common way to meet the heat deficit. Condensation may be observed while meeting the heat deficit in this way. Thus, structural members should have insulation values able to control moisture condensation over the internal surfaces of the members and able to prevent temperature variations within a housing because of day-night temperature differences [4].

Ventilation: Turkish producers are mostly not aware of the significance of ventilation in livestock housing. The number of ventilation chimneys and chimney cross sections are not sufficient. In general, windows are arranged as permanently closed fashion. In modern ones, air inlets are provided through windows and doors and air outlets through ventilation chimneys left over the roofs. In some barns, there are air outlets left over the roofs with certain intervals.

Additional chimneys should be provided or chimneys should be re-designed to bring the total chimney cross-sections into sufficient levels. Adjustable flaps or lids may be provided to adjust the ventilation capacities in cold or hot days. Transom windows should be used over the long side-walls as the air inlets.

Natural ventilation systems should be so designed that they should provide regular and sufficient ventilation. Such systems totally depend on proper design and placement of air inlets and outlets. Mechanical ventilation systems should also be installed since natural systems are depending on surrounding environmental conditions.

Lighting: Lighting is a serious problem with regard to environmental conditions in Turkish livestock housings. Sufficient lighting should be provided in design phase of the housings since it has significant impacts on animal health. Windows are the most basic structural members providing natural lighting to facilities. Thus, sufficient window spacings should be provided for both ventilation and lighting.

Since the window spaces are relatively low to keep indoor temperatures, lighting is most of the time insufficient in Turkish livestock housings. In such cases, feeding and cleaning works are difficult and there is always a risk of accidental incidents. Animals also are not receiving sufficient light in those buildings. Dirty and dusty windows also prevent sufficient light getting into the buildings.

6. CONCLUSIONS

In Turkey, livestock breeding activities have still been implemented traditionally, far away from scientific and technical principles. Climate parameters are most of the time disregarded and are not taken into consideration. The housing systems and buildings developed for a certain climate zone are similarly applied to another climate zones. Climate demands of animals are most of the time disregarded.

Livestock housings should be designed to be able provide proper environmental conditions. The ones without proper conditions should be improved or renovated. In this way, negative impacts of environmental factors on animals may be prevented, proper conditions may then be provided to animals and damaging impacts of such conditions on structural members may be prevented, too.

The basic objective of livestock housing construction is to prevent animals from improper environmental conditions and to provide healthy living and production spaces for them, to minimize labor needs through a rational feeding. Through controlling the environmental conditions in livestock housings is possible to provide optimum conditions to animals, to improve feeding efficiency, to provide better growth of animals, to have higher yield levels, to control diseases, to provide more comfortable working atmosphere to producers, to remove odor, dust, moisture and ammonia from the buildings and to reduce mortality rates. Therefore, climatic, structural and technical parameters should all be taken into consideration and a well-balance should be established among them in design of livestock housings in Turkey.

Climate conditions vary in Turkey from one region to another. There are even significant variations in climate factor within the same region. Therefore, buildings and housing systems should be designed in accordance with the special conditions of each climate zone. Already existing ones should be improved as to provide proper environmental conditions. Researches should be implemented to determine the best housing systems for various climates.

Temperature, relative humidity and wind are the most significant climate parameters to be considered in livestock housing design. These parameters are directly effective in selection of the housing system and type of material, sizing the structural members, orientation of the building. Besides, since local climate conditions are also effective in indoor climate conditions, they are also significant in ventilation and lighting calculations.

In Turkey, some measures should be taken to improve animal production which plays a great role both human nutrition and country economy. Animal production can be improved and levels of developed countries can be reached only through efficient livestock policies and every kind of yield-increasing research and development works. Research and development works should also be carried toward the productivity and sustainability in livestock raising enterprises, the housing systems, mechanization systems, animal breeding and health. Turkey with relatively higher labor potential and available climate conditions may create a significant competitive power in world markets through closely keeping up with technological developments in livestock industry.

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Case Study

VARIATIONS IN EXPLOITATION CHARACTERISTICS OF TRACTORS DEPENDING ON PRE-IGNITION ANGLE OF THE ENGINE

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Abstract. *Maintenance of tractors on small private farms in Bosnia and Herzegovina is not given sufficient and adequate attention. Consequences of such a trend reflect on exploitation characteristics of tractors, significantly increases fuel consumption and environmental pollution. The goals of the research focused on the part of the issue related to the influences of different pre-ignition angle of the engine on the available power at the PTO shaft and increase of the specific fuel consumption. The research was conducted in the laboratory and experimental facilities of the agricultural machinery testing station in 2015 at the Butmir range, Sarajevo. The obtained results indicate that the tractor power at PTO shaft varied from 21kW do 45kW, that is in a range from 46.6 - 100 %. Variation of the engine power caused changes in fuel consumption which in the plough mode varied from 4.01- 6.86kg/h of fuel (D-2). Cost-wise, this influenced variations from 2.25 to 4.72 €/h in the idle mode (stand gas) and from 5.57 to 8.81€/h in the plough mode. The obtained results confirmed the hypothesis that regular maintenance in accordance with manufacture's standards needs to be implemented; otherwise the costs of consequences will exceed the maintenance costs several times.*

Key words: *tractor, maintenance, engine power, fuel consumption.*

1. INTRODUCTION

In order to understand the importance of the pre-ignition for the process of combustion of fuel in diesel engines, one needs to be familiar with the overall process of supply, purification and combustion. It is understandable that manufacturers of engine continuously strive to improve the combustion system in other to better utilize the energy potential of the fuel. More recent generations of engines have computer controller combustion systems. However, in practice, hydro-mechanic systems of distribution of fuel are still dominant in agriculture tractors. The quantities are does through a high pressure pump which can be of rotary or linear type, but the deviations of the fuel quantity per cylinder should not exceed ±2%. In the case of such older types of engines, Kozarac et al. [3] the time for injection of fuel is limited to a period from 1/300 to 1/800 parts of second. Computer controlled engines („*Common Rail*“) have a much higher injection pressure (up to 2,000 Bar), and the injection velocity is measured in thousandths of a second.

Technical designs of engines continuously follow the perfecting of the quality of fuel Šilić et al. [6] which are expressed in respective cetane number, that is a ratio between the volume of fast burning cetane (n-hexane) and the volume of slow burning cetane (á-*Methylnaphthalene*). The process of combustion also depends on physical-chemical features of the diesel fuel such as, viscosity, chemical stability, percentage of sulphate, etc. Depending on the working conditions of the engine different additive are added to the fuel to enhance the combustion process, prevent solidification of paraffin, improve the chemical stability, prevent development of soot and tar pitch, which contaminate the environment and partly remain in the engines.

Bearing in mind the listed characteristics of engines and fuels, special attention needs to be given to regular maintenance which can significantly influence the performance. The pre-ignition angle of the engine can be one of the reasons for improper combustion of fuel. Therefore the goal of the research is to draw attention to the negative consequences of this factor and the requirement to do regular maintenance.

2. MATERIAL AND METHODS

The research was done in laboratories and experiment stations using a Zetor model 63.41 tractor assembly with double reversible plow. The part of the research done in the laboratories was related to different levels of adjustment of the pre-ignition angle and measuring of power with electric brake at PTO shaft and was conducted at the Testing station for agriculture machines of the Agriculture and Food Sciences Faculty in Sarajevo. The adjustments of the pre-ignition angle were done using the comparative and goniometric method for adjustment of angle. The goniometric method implied adjusting the pre-ignition angle with a comparator, and the comparative method implied a use of a template used also in the testing of exploitation characteristics of the tractor assembly. The following levels of adjustment of pre-ignition angle were applied:

A – Deviation of up to 10% (-17.8^0 early ignition /A´/; -16.2^0 late ignition /A˝/);
B - Deviation of up to 20% (-19.5^0 early ignition /B´/; -14.5^0 late ignition /B˝);
C - Deviation of up to 30% (-20.4^0 early ignition /C´/: -12.7^0 late ignition /C˝/);
K – Adjustments made according to manufacturer's regulations (Control).

Any deviation of the pre-ignition angle in comparison to the manufacturer's norm of 17^0 reflects on the power of the engine and other exploitation characteristics of the tractor. By calibrating the high pressure pump to inject fuel prior to 17^0 causes a change in the work of the engine, which is manifested in a way that the engine is noisier and has seemingly bigger power.

The experimental part of the research included measuring of fuel consumption during ploughing. The volumetric method of consumption expressed in liters was applied, specifically consumption per units surface area (L/ha) and specific consumption (g/kwh)

Lulo et al. [4]. The volumetric method was the basis for calculation of the other two forms of listed consumption. The volumetric consumption was translated into mass consumption through application of the following formula:

$$q=V[l]\cdot\delta\ [kg\ m^{-3}] \tag{1}$$

The results obtained from conducted measuring were processed with application of standard mathematical-statistic methods, presented in appropriate tabular breakdowns and graphs and discussed in relation to results obtained by other authors. In the work we applied the Spearman's *correlation coefficient*, which is often used for measuring of the relations among variables and when it is not possible to apply the *Pearson's correlation coefficient*.

3. Results and discussion

In case of a tractor engine with a properly adjusted high pressure pump the engine had an average engine power of 39.04 kW, and the average torque of 189.65Nm, and the average number of Rotation at the PTO shaft of 511.35 min^{-1}. Other statistic indicators are given in Table 1.

Table 1 Indicators of tractor performance at a pre-ignition angle of 17^0 (K control)

Pre-ignition angle 17^0 (K- control)	N_0	Min.	M ax.	Mean	Std. Deviation	Variance	Skewness
Rotation on PTO (min^{-1})	23	384	609	511.35	73.61	5418.78	-0.31
Torque (Nm)	23	97	230	189.65	37.81	1429.68	-0.99
Power on PTO shaft (kW)	23	24	45	39.04	5.07	25.77	-1.60

No – Number of measurements';
Skewness – measure of asymmetry data.

The simulation of movement of high pressure pump to an early ignition phase of up to 10% reflected on reduction of the average power of the engine to 38.33 kW, lower average torque of 174.78 Nm, as well as a lower average number of Rotation on the PTO shaft, which was at the level of 543.27 min^{-1}.

Table 2 Indicators of tractor performance at a 10% deviation of the pre-ignition angle

Deviation of 10% (A′ and A″)	Angle	N_o	Min.	M ax.	Mean	Std. Deviation	Variance	Skewness
Rotation on PTO (min^{-1})	17.8^0	30	368	615	543.27	74.34	5527.65	-1.13
	16.2^0	30	370	613	543.20	74.19	5504.50	-1.12
Torque (Nm)	17.8^0	30	96	226	174.78	5.23	1241.71	-0.44
	16.2^0	30	96	224	174.72	5.29	1245.82	-0.44
Power on PTO shaft (kW)	17.8^0	30	24	44	38.33	5.12	26.29	-1.16
	16.2^0	30	24	44	38.40	5.16	26.66	-1.17

When the high pressure pump was moved to the late ignition phase of up to 10% it caused a reduction in the average power of the engine to 38.40 kW and a smaller average torque at the level of 174.72 Nm. The average number of Rotation at the PTO shaft totaled 543.20 min^{-1}. When the high pressure pump was in the position of an early ignition phase (10-20%) it caused a reduction of average power of the engine to 36.30kW and a lower torque, which was at the level of 162.42Nm. In such a position of the pump the average number of Rotation at the PTO shaft totaled 552.10 min^{-1}.

Table 3 Indicators of tractor performance at a 10-20% deviation of the pre-ignition angle

Deviation of 10-20% (B–early; B-late)	Angle	N_0	Min.	M ax.	Mean	Std. Deviation	Variance	Skewness
Rotation of PTO (min^{-1})	19.5^0	30	424	615	552.10	60.95	3715.33	-0.73
	14.5^0	29	401	620	552.00	67.50	4556.38	-0.84
Torque (Nm)	19.5^0	30	93	208	162.42	32.58	1061.69	-0.50
	14.5^0	29	95	224	162.43	37.71	1422.59	-0.42
Power on PTO shaft (kW)	19.5^0	30	23	41	36.30	5.00	25.04	-1.22
	14.5^0	29	24	43	36.48	5.55	30.83	-1.27

Positioning of the high pressure pump to a late ignition phase (10-20%) influences a reduction of average power of the engine (36.48kW) and a lower average torque (162.43 Nm). In the respective position of the pump the average number of Rotation on the PTO shaft was 552.00 min^{-1}. After shifting the high pressure pump to the early ignition phase (20-30%) the average power of the engine was reduced to 34.48kW, torque to 149.43Nm, and the number of Rotation at the PTO shaft was je 539.03min^{-1}.

Table 4 Indicators of tractor performance at a 20-30% deviation of the pre-ignition angle

Deviation 20-30% (C–early; C-late)	Angle	N_0	Min.	M ax.	Mean	Std. Deviation	Variance	Skewness
Rotation on PTO (min^{-1})	20.40^0	30	411	602	539.03	60.95	3715.33	-0.73
	12.75^0	29	396	615	543.21	67.50	4556.38	-0.84
Torque (Nm)	20.40^0	30	80	194	149.43	32.58	1061.69	-0.50
	12.75^0	29	86	215	156.62	37.77	1426.67	-0.43
Power on PTO shaft (kW)	20.40^0	30	21	40	34.48	5.01	25.11	-1.24
	12.75^0	29	22	41	34.52	5.48	30.11	-1.30

Shifting of the high pressure pump to the late ignition phase (20-30%) reduced the average power of the engine to 34.52 kW and the average torque to 156.62 Nm. The average number of Rotation at the PTO shaft was 543.00 min^{-1}. After shifting the high pressure pump to late ignition mode (above 17^0) the tractor worked more quietly (seemingly nice sound of the engine) but its power declined. The power of the tractor engine in case of a deviation of the pre-ignition angle of up to 10% caused a reduction of the power at the PTO shaft by 0.85 kW, deviation of between 10 to 20 % cause a reduction of power by 2.7 kW and a deviation of the pre-ignition angle at the level from

20 to 30% caused a reduction of power by 4.66 kW. Asymmetrical data processed by skewness method was in the range -1.16 to -1.60.

In case of diesel engines, shifting of the angle caused tapping in the engine as well as a delay in ignition of fuel. In the late ignition phase the combustion of fuel was incomplete. Researches done by other authors noted the same occurrence. According to Šilić et al. [6] delays in combustion that exceed 0.002 seconds, result in a bigger quantity of fuel in the combustion area and causes rapid (peak) combustion which is accompanied with strong noise. Continuation of the analysis of the described occurrence shows (Fig. 1) that tapping (throbbing) in the engine causes an additional increase in pressure, but negatively reflects on the noise and vibrations.

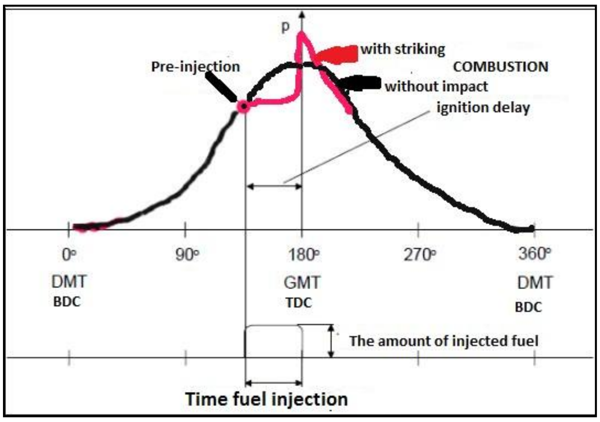

Fig. 1 Combustion process in a diesel engine (taken over)

Shifting of the high pressure pump from the optimum pre-ignition area reflects on exhaust gases. Specifically the engine exhausts gases of black or white color. The combustion process takes place in all diesel engines and is higher in the case of high-speed engines than in the case of low-speed engines. Eriksson [2] in his dissertation stipulates that early ignition time produces a pressure of so called “early development”, which results in a sudden increase of pressure which can be considered as an early expansion.

The usual period of combustion of fuel in engines Kozarac et al. [3] various from 0.0007 to 0.003 seconds. If the period of concealed combustion is too big (exceeds 0.002 sec), then a larger amount of fuel is accumulated in the combustion area, which will ultimately lead to the simultaneous combustion of fuel. The consequence is that the pressure and temperatures rapidly increase above the usual values. This occurrence is often called “peak combustion” or “rigid work” of the diesel engine. Peak combustion is not desirable because it burdens parts of the engine mechanism and can cause negative consequences.

The testing of the influence of the pre-ignition angle on the power of the engine and the torque were confirmed by the positive correlation factors. Correlations between the engine power and the size of the angle of the high pressure pump were at the level of 0.01 and 0.05. Correlations with the torque were at the level of 0.01.

3.2 Consumption of fuel depending on the pre-ignition angle

The analysis of fuel consumption revealed that deviation from manufacturer's norm (17^0) result in significant increase of fuel consumption. Results obtained are presented in Table 5.

Table 5 Fuel consumption in relation to pre-ignition angle

Pre-ignition	Fuel consumption (kg)		Increase in fuel consumption (%)	
	Stand gas 800 rotations/min^{-1}	Ploughing (1500 rotations /min^{-1})	*Stand gas* 800 rotations /min^{-1}	Ploughing (1500 rotations/min^{-1})
Manufacturer's norm (17^0)	1.75	4.01	0	0
10% Deviation (A-early)	1.95	4.38	11.11	9.20
10% Deviation (A-late)	2.02	4.53	15.10	12.94
20% Deviation (B-early)	2.80	5.78	59.54	44.10
20% Deviation (B-late)	3.07	5.66	74.93	41.11
30% Deviation (C-early)	3.51	6.58	99.72	64.05
30% Deviation (C-late)	3.67	6.86	109.12	71.03

Deviations of the pre-ignition angle in relation to the manufacturer’s norm (17^0) caused significant increase in fuel consumption. The biggest increase in fuel consumption was recorded in the „C-late” case and amounted to 1.91 kg/h that is by 109.12%. The presented indicators confirm that work with technically irregularly tuned tractor engine can exceed multiple times the costs of regular maintenance. As for the exploitation indicator of fuel consumption, other authors obtained similar results. In example, in their research Filipovic et al. [1] stipulated that the change of working speed in the ploughing mode from 5 km/h to 7 km/h increased consumption for 10.32%; Mileusnic et al. [5] stipulated that during ploughing at 30 cm the fuel consumption varied from 26-36 L/ha, or when calculated in percentages this means that consumption increased by 38.46%.

3.3 Effect of pre-ignition angle on fuel costs

The level of technical education of a large number of farmers is not at the level that would enable them to fully grasp the presented results of the research. If the obtained results are transformed and expressed as a loss of money then the farmers get a much clear picture of the importance of this issue. Definition of fuel consumption can be used to calculate the costs that are directly correlated. The fuel costs are calculated on the basis of the price of diesel fuel in BiH, which currently is at the level of 2.10 KM/l (1.07 €). Breakdown of fuel costs in relation to the pre-ignition angle is given in Table 6.

Table 6 Fuel costs in relation to pre-ignition angle

Pre-ignition angle	Fuel consumption (€/h)	
	Stand gas 800 min^{-1}	Plough 1500 min^{-1}
Manufacturer's norm (17^0)	2.25	5.16
10% Deviation (early)	2.50	5.63
10% Deviation (late)	2.59	5.82
Up to 20% Deviation (early)	3.59	7.43
Up to 20% Deviation (late)	3.94	7.27
Up to 30% Deviation (early)	4.50	8.46
Up to 30% Deviation (late)	4.72	8.82

In case of fine-tuned pre-ignition angle, fuel costs totaled 2.25 €/h on stand gas (idle mode) and 5.16 €/h in plough mode. After shifting the angle (deviation, A-early, up to 10%) the fuel costs totaled 2.50 €/h, that is 5.63 €/h in the plough mode. Fuel costs increased with the simulated deviation from the prescribed pre-ignition angle. In the plough mode in case of a 20.4^0 pre-ignition angle the difference in fuel consumption in relation to manufacturer's norm (17^0) was at the level of 3.67 €/h.

In case of early pre-ignition with a deviation of 19.5^0 before the upper dead center, in comparison to the normally tuned ignition, fuel costs totaled 3.59 €/h at 800min^{-1} in the plough mode, and at 1500 min^{-1} the value was doubled and totaled 7.43 €/h.

4. CONCLUSIONS

On the basis of conducted research which encompassed laboratory work, field work, research of literature and processing of data we draw the following conclusions:

- The average power of tested tractor engine with a fine-tuned pre-ignition angle totaled. 39.04kW. After simulated shifting of the pre-ignition angle the engine power significantly decrease and reached the following values:
  - In case of an early and late pre-ignition with an up to 10% deviation the average power totaled 38.33 kW;
  - In case of early pre-ignition (20% deviation) the average power totaled 36.30 kW, while in the case of late pre-ignition (20% deviation) the average power totaled 36.48 kW:
  - In case of early pre-ignition (30% deviation) the average power totaled 34.48 kW, while in the case of late pre-ignition (30% deviation) the average power totaled 34.52 kW.
- The effect of the pre-ignition angle on fuel consumption was tested in the stand gas (idle mode) (800 o/min^{-1}) and the plough mode (1 500 o/min^{-1}). In case of a normally tuned pre-ignition angle the consumption at 800min^{-1} was 1.75 kg/h, and at 1500 min^{-1} it totaled 4.01 kg/h. After simulated shifting of the pre-ignition angle the fuel consumption significantly increased. The following values were recorded:

- 10% deviation (A-early), consumption at 800min^{-1} was 1.95 kg/h, and in the plough mode at 1500min^{-1} 4.38 kg/h;
- 10% deviation (A-late), consumption at 800min^{-1} was 2.02 kg/h, and in the plough mode at 1500min^{-1} 4.53 kg/h;
- 20% deviation (B-early), consumption at 800min^{-1} was 2.80 kg/h, and in the plough mode at 1500min^{-1} it was 5.87 kg/h;
- 20% deviation (B-late), consumption at 800min^{-1} was 3.07kg/h, and in the plough mode at 1500min^{-1} 5.66 kg/h;
- 30% deviation (C-early), consumption at 800min^{-1} was 3.51 kg/h, and in the plough mode at 1500min^{-1} 6.58 kg/h;
- 30% deviation (C-late), consumption at 800min^{-1} was 3.67 kg/h, and in the plough mode at 1500min^{-1} 6.86 kg/h;

• Financial indicators of fuel consumption varied from 2.25 to 4.72 €/h with no load on stand gas and from 5.57 to 8.81 €/h in plough mode with a double furrow plough.

The obtained results confirmed the hypothesis that servicing of agriculture tractors should be done regularly and in accordance with manufacturer's norms as otherwise the consequences will exceed several times the costs of regular maintenance.

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Case Study

INFLUENCE OF LOAD, VELOCITY AND TRAJECTORY CURVATURE ON THE COMBINE'S STABILITY

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Abstract. *The paper is focused to analytical estimation of the combine ZMAJ 142 stability range under various working conditions, which include different speeds (0, 5, 10 and 15 km/h), radiuses of trajectory curvature (10 m, 15m, 20 m ,∞) and longitudinal and lateral slope of terrain in the range of up to 60 deg. Stability range is evaluated analytically for combine with empty bunker and bunker fulfilled with wheat grain. Applied simulation algorithm comprehends the mechanical stability criterion, supported with 3D analytical geometry tools and total-search optimization method.*

Key words: *Combine, slope, turning radius, speed, dynamics, stable movement*.

1. INTRODUCTION

Contemporary agricultural technique is frequently used over the sloped parcels, what may result in critical working conditions that impose additional technical requirements for safe and efficient operation. Within these specific working regimes and conditions, stability of tractors, their aggregates, harvesters and other mobile machines may be additionally violated by the negative influences of two forces. The first is the centrifugal force, generated during curvilinear motion of the mobile machine. The second possible problem that arises at sloped terrains is related to gravity force inclination from the normal axis of mobile machine pedestal, which is defined by its wheels.

Improper application of mechanization may cause serious damages, injuries and even death consequences [8], [13]. Even nowadays, application of modern tractors designed under severe safety standards are still exposed to high risks of accidents, including rollover [7], [3], [6]). To prevent such kind of problems, specific tractor designs and appropriate control systems have been reported in the past (see [10] among many others).

In order to improve the operational safety of agricultural technique, many reports propose application of analytical modeling in estimating the stability range of mobile agricultural machinery (see [9] and [5], for example). Analytical algorithm for evaluation of tractor dynamic stability is presented in [1]. Special experimental procedure for evaluation of components of tractor inertial tensor, which is of crucial importance for its dynamic stability, has been developed by [14].

However, beside agricultural tractors, crop harvesters also suffer from the problems related to static and dynamic stability when applied at sloped terrains. In order to clear-up the situation, analytical modeling has been applied by [11] for estimation of stability range of universal combines applied in wheat harvesting. They adapted the algorithm primarily formulated by [4] for evaluation of the tractor aggregates stability ranges. This study is direct continuation of their work, among others.

2. Material and methods

This paper presents an analytical approach in analyzing the static and dynamic stability ranges of universal combine, applied in wheat harvesting over sloped parcel. The model used has been developed through appropriate adaptation of algorithm of [2], founded on the principles of theoretical mechanics, 3D analytical geometry and following hypothesis:

- harvester is a non-deformable solid body;
- intensity of harvester velocity constant;
- flat parcel having constant slope;
- trajectory is circular, having constant radius R = const.;
- orthogonal Descartes coordinate system is defined with respect to fig. 1;
- resulting theoretical data should be converted to "real situations" following corrections proposed by [12].

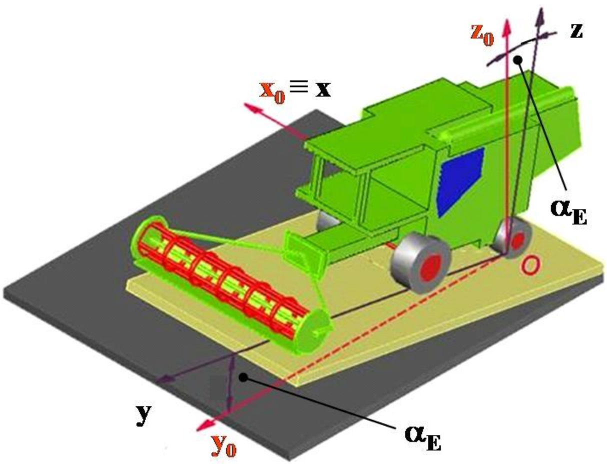


Fig. 1 A sketch showing the local reference coordinate systems $Ox_0y_0z_0$ and Oxyz of a universal harvester moving over the sloped plain terrain.

Theoretical stability ranges of the harvester under different operational conditions are defined using two inclination angles of the sloped terrain: longitudinal (elevation) angle α_E and lateral (roll) angle α_R. Appropriate definitions of these angles are illustrated in figs. 2 and 3.

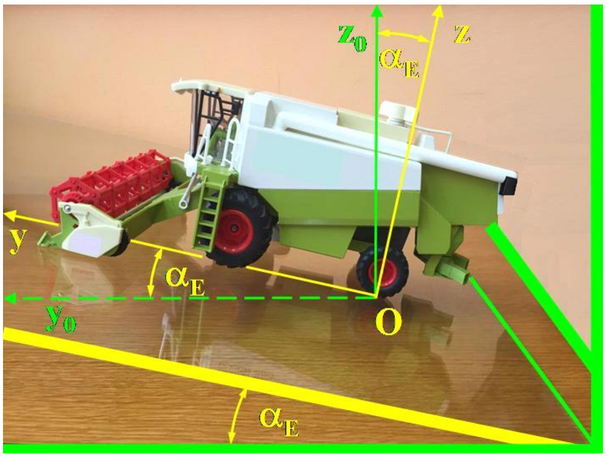


Fig. 2 Combine at longitudinal slope

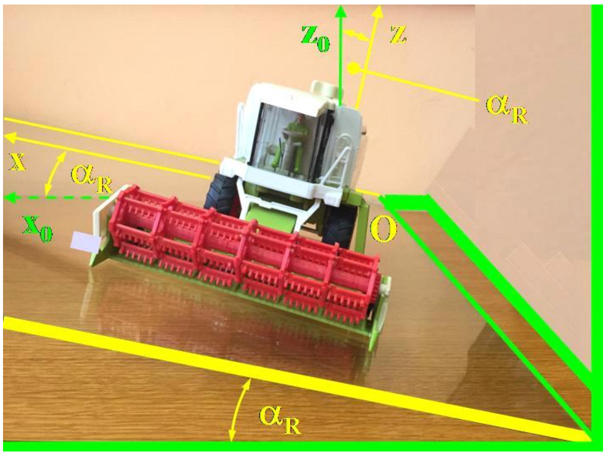
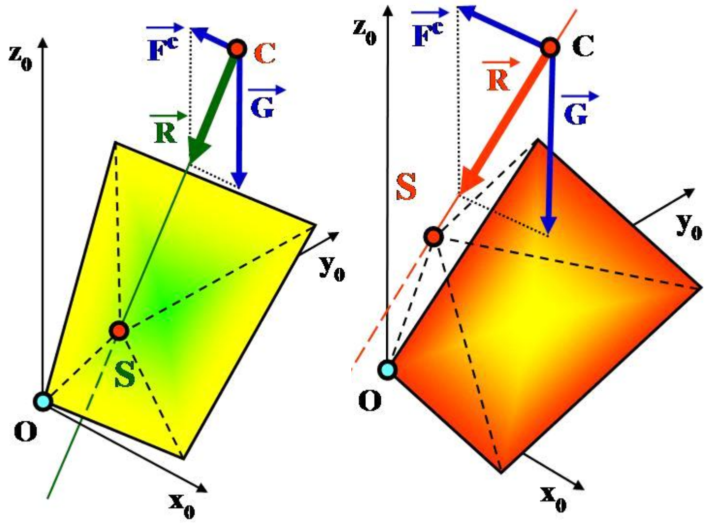


Fig. 3 Harvester at lateral slope

Besides previously listed hypothesis, the numeric algorithm used also assumes that harvester is supported at four points lying at the same planar surface. Each of these points represents the geometrical center of a contact surface between wheel pneumatic and flat terrain. These four ”points” define pedestal trapezoid of the harvester, presented in fig. 4. Consequently, combine’s stability can be checked according to basic principles of theoretical mechanics. Literally, the action line of resulting force (gravity force + centrifugal force), acting to the model harvester, must intersect the inner area of pedestal trapezoid (fig. 4). In opposite, model harvester does not operate in stable conditions: overturn hazard, machine damage or driver injury may occur.



(a) (b)

Fig. 4 Interpretation sketch of dynamic stability criterion of the model harvester moving at constant velocity over the sloped flat parcel and curvilinear trajectory: (a) stable operation and (b) non-stable working regime.

This well-known geometrical criterion of theoretical mechanics, related to stability of solid body, is further converted to numerical algorithm and computer code using the methods of 3D analytical geometry. In general, we followed [11] and [2], where detailed information on the algorithm is available.

Input data assumes the universal harvester ZMAJ 142 applied in wheat harvesting at flat parcel under following characteristic parameters:

- harvester mass 6250 kg;
- bunker volume 27 m^3;
- coordinates of gravity center x_C = 726 mm, y_C = 2817 mm, z_C = 1750 mm;
- bunker volume center x_B = 880 mm, y_B = 2750 mm, z_B = 2430 mm;
- wheat grain bulk density 840 kg/ m^3;
- test velocities 0 km/h, 5 km/h, 10 km/h, 15 km/h;
- test radiuses of curvature 10 m, 15 m, 20 m, ∞ (linear inertial movement).

3. RESULTS AND DISCUSSION

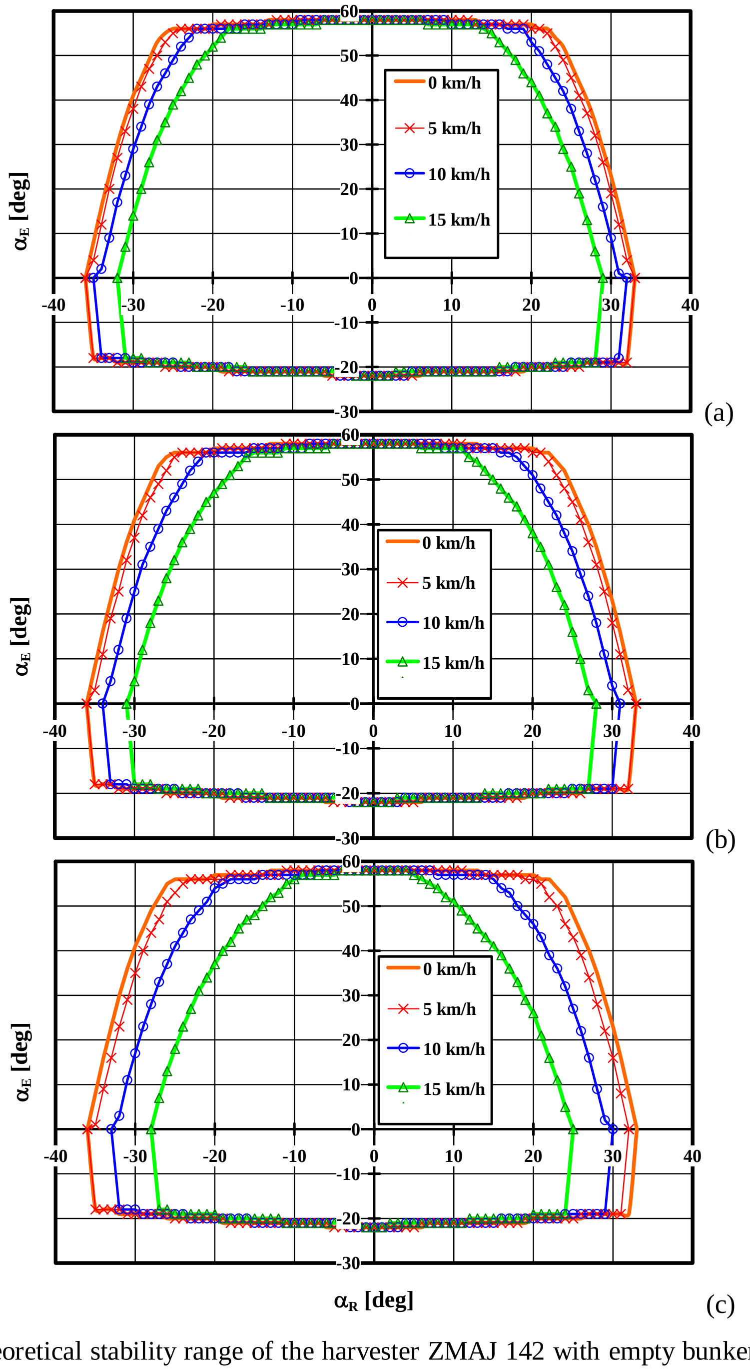


Fig. 5 Theoretical stability range of the harvester ZMAJ 142 with empty bunker, turning over sloped terrain at constant curvature radius R: (a) 20 m; (b) 15 m; (c) 10 m.

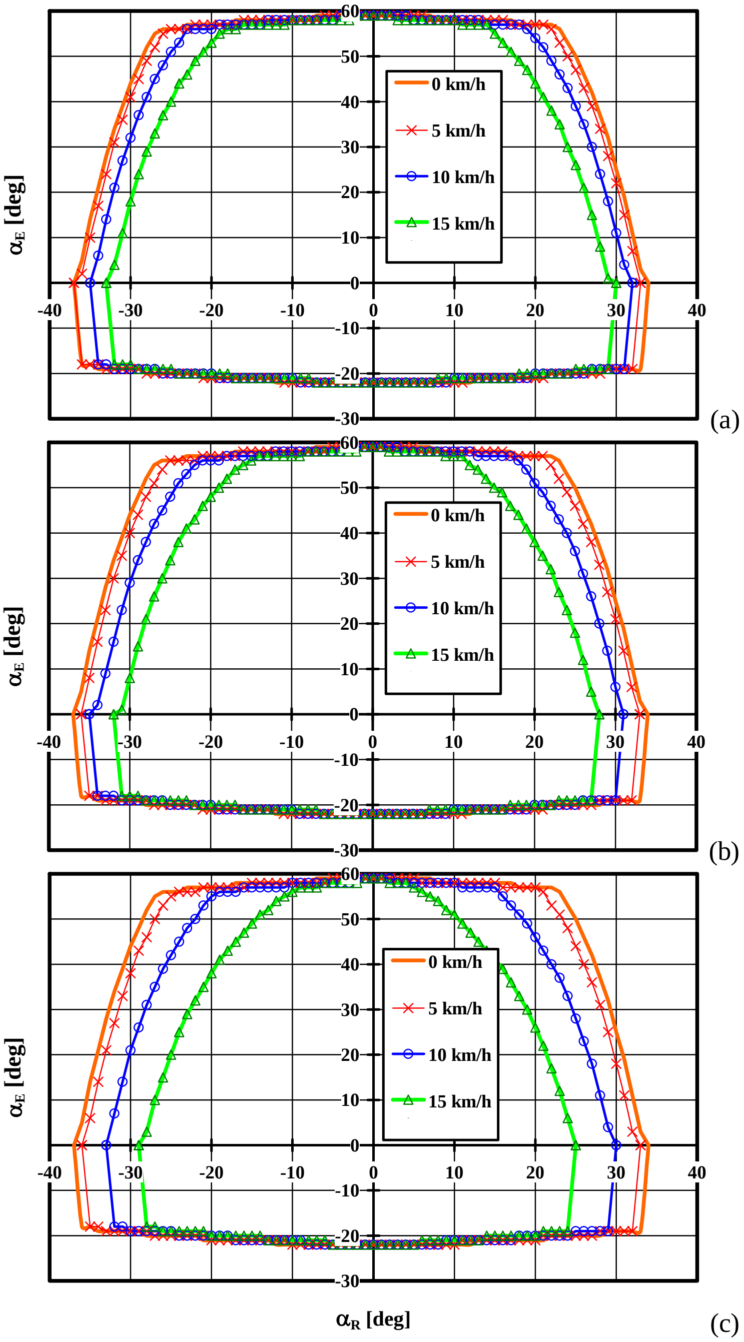


Fig. 6 Theoretical angular stability range of universal harvester ZMAJ 142 with full bunker of wheat seed, moving over sloped flat terrains at constant velocity and radius of trajectory curvature: (a) R = 20 m; (b) R = 15 m; (c) R = 10 m.

Fig. 5 presents the theoretical angular range of dynamic stability of the universal harvester ZMAJ 142 with empty bunker, moving over sloped flat terrain at constant velocities of 5 km/h, 10 km/h, 15 km/h and constant radius of circular trajectory curvature: 5 m, 10 m, 20 m and ∞ (linear trajectory). In analogue, fig. 6 illustrates the same stability range, but for the harvester having bunker full of wheat grain.

These figures verify the well known and expected negative influence of moving speed on the machine stability – increase of speed decreases the area of combine stability. In opposite, increasing the turning radius results in increasing the stability range. Finally, the mass of wheat grain in the bunker has also negative influence on the stability.

However, all this influences do not crucially decrease the dynamic stability range of the harvester tested. In all analyzed cases, the critical situation arises at negative longitudinal slope of the terrain, characterized with negative elevation angles α_E being around 20 degs. This is caused by inappropriate distribution of harvester mass, what is a typical characteristic of most of harvesters. Similar finding has been reported by [11], who proposed introduction of ballast on the rear side of the harvester.

Finally, it should be noted that this critical value of longitudinal slope (elevation angle) defines the whole angular stability range of the universal combine to be within 20 degs approximately. Even more, only negligible difference exists between the static and dynamic stability ranges. It follows that, under accepted assumptions in this study, it is enough to check only the static stability of the universal harvester, what is simpler in comparison to stability analysis of the harvester having curvilinear trajectory.

Presented data represents only a theoretical approximation of real situations. In the practice, these data should be corrected following [12].

4. CONCLUSIONS

The mass center position of tested harvester is high and too close to the front bridge, causing the high-level longitudinal asymmetry of the stability range. Therefore, the critical slope angle of the terrain which still guarantees the combines stability is strongly decreased. Such evidence indicates the need of introducing ballast on the rear side of the tested combine ZMAJ 142, in order to enlarge the stability domain.

Presented results of stability simulation indicate general decreasing the range of allowed terrain slope angles with decreasing radius of curvature of combine trajectory and with increasing the harvester speed. However, the critical conditions are evidenced at negative elevation angles of about -20 degs. Therefore, theoretically, harvesters of this kind can be used at sloped parcels up to elevation angles of 20 degs. However, for practical purposes, this value should be decreased following [12].

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Original Scientific Paper

INSTRUMENTAL AND SENSORY METHODS FOR EVALUATION OF DRIED FRUITS QUALITY

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Abstract. *Results of instrumental and sensory analysis of qualitative characteristics of dried quince are presented in the paper. Combined drying which applied in experiment, consisted of osmotic and convective. The osmotic drying was performed in a sucrose and water solution. The temperatures of osmotic solution were 40^{o}C and 60^{o}C, and the initial concentrations were 50^{o}Bx and 65^{o}Bx. Higher values of ΔE^*ab were recorded following the treatment of quince samples with the osmotic solution concentration of 65^{o}Bx. Lower values of the total colour change were recorded in the same samples after convective drying. Minor differences in colour after convective drying are caused by a greater amount of solute retained on the surface of the fruit and make barriers between fruit tissue and surrounding air. Temperature of osmotic solution 60^{o}C caused softening of quince tissue. Thermal softening has a positive influence on naturally hard quince tissue. The results of experiment point at positively affects of osmotic drying on physical properties and quality of dried quinces.*

Key words: *instrumental, sensory analysis, dried fruit*

1. INTRODUCTION

Quality cannot be represented by a single parameter as a feature. This term encompasses a multitude of features or characteristics of the product. Physical, chemical and other properties of dried fruit, which define its quality, can be evaluated by measuring instrument and sensor. Instruments can be designed to mimic human testing methods and can statistically be associated with human understanding and reasoning quality categories. However, there is still only humans can evaluate the quality, but the instruments used to measure properties that defines the quality have vital importance for research and control [1] (Abbot et al, 1997). Instrumental measurements have the advantage compared to the sensory evaluation, for both research and commercial purposes, as instruments reduce variations that may be caused by the human factor. The instruments are objective and precise, and can provide a common means of communication between researchers, companies, regulatory agencies and consumers [2] (Voisey, 1971).

The osmotic drying process involves the partial removal of water from a given food using a hypertonic solution consisting of one or more solutes [3]. The difference in osmotic pressure obtained from the system leads to a flow of water from the food to the solution and an opposite flow of solutes from the syrup to the product, although in smaller proportions. During that process physical and chemical properties of material change.

Colour is one of the most important properties of food products. The first quality assessment of a product is based on its colour. It is the first thing a consumer notices and it can determine the acceptability of a product. Exposing fruits to high temperatures during drying can have detrimental effects on the quality [4, 5, 6, 7]. Significant changes in colour often occur during convective drying [8]. Some authors claim that osmotic drying reduces the colour changes caused by enzymatic activities. However, osmotic drying is not efficient enough to prevent the tissue browning of certain fruit species.

Mechanical properties of products change during drying. Krokida et al., [9] studied mechanical properties of osmo-convective dried banana and apple. Thay found that osmo-convective dried samples presented more resistance to rupture that convective dried. That behaviour of osmo-convective samples authors explained due to more plastic structure caused by the sugar uptake during osmotic treatment. Mechanical properties of fruit are determined by the characteristics of the cells [1]. Exposing fruits to high-temperature fluids causes the chemical changes which affect the structure of fruit tissue. Water loss decreases the pressure in the cell thus decreasing the firmness of fruit tissues. Pressure in the cell (turgor) and cellular composition determines the viscoelastic properties of biomaterials [10].

The purpose of this paper was to study the effects of osmotic drying on physical properties and quality of quinces. The changes in colour, mechanical, sensory and of quinces were examined. The paper also provides a platform for launching a new quince product.

2. MATERIAL AND METHODS

The native quince variety "Leskovačka" was used in the experiment. Fruits of this variety are apple-shaped and characterised by intense aroma. Fruit was combined dried. Combine drying was combination of osmotic and convective drying. The osmotic drying was performed in a saccharose and water solution in an experimental osmotic dryer. Drier provides mixing solutions. Velosity of sucrose solution was 0.00913 m/s. Mass ratio material : solution was higher than 1:10. The temperatures of osmotic solution were 40^{o}C and 60^{o}C, and the initial concentrations were 50^{o}Bx and 65^{o}Bx. The first, second, third and fourth treatment had the parameter combinations of 50^{o}Bx-40^{o}C, 50 ^{o}Bx-60^{o}C, 65^{o}Bx-40^{o}C, 65^{o}Bx-60^{o}C, respectively. The osmotic drying lasted for 180 minutes and it was used as a pre-treatment. Kinetics of osmotic drying was evaluated on samples of quince dimensions 15x15x15 mm. The convective drying of quince sixths lasted for 23 hours at the temperature of 50^{o}C and the air velocity of 1 m s^{-1}. The moisture content of fruits was determined using the standard hot air oven method keeping the fruit in the oven for 24 h at 105^{o}C. The Initial moisture content of fresh quince was 83.44 %.

2.1. Instrumental analysis

2.1.1. Mechanical properties

The mechanical properties were examined by the compression and texture profile analysis test (TPA). The compression test was done on the cubes with the dimension of 10x10x10 mm every 20 minutes during osmotic drying. Cubes were cut from the quince sixths. Five cubes were used for one measurement. The TMS-PRO Texture Analyzer (Food Technology Corporation, Sterling, Virginia, USA) was used in the measurement of mechanical properties. Cylindrical plate with the diameter of 40 mm was used for compression. The speed of deformation was 30 mm min^{-1}. The rupture force represents the first peak on the force-deformation curve. Since the texture of fruits is anisotropic, the results of each treatment are expressed by the force ratio in order to minimize the biological variability.

The force ratio is formulated as follows:

$$f = \frac{F_o - F_i}{F_o} \tag{1}$$

where F_o is the rupture force of fresh fruit samples, F_i is the rupture force at a certain moment of drying. It indicates the intensity of fruit tissue softening.

Modulus of elasticity in the field of elastic deformations defined Young by the following equation [10]:

$$E = \frac{\sigma}{\varepsilon} \tag{2}$$

where E – modulus of elasticity, σ – stress, ε – extensional strain

Based on the calculated values of stress and strain diagrams were formed for each measurement. For the initial part of the stress – strain curve was found a linear relationship with a high coefficient of determination. It was therefore decided that the modulus of elasticity identify with constant of linear function [11].

The TPA test of double compression was done after osmo-convective drying [12]. The samples were cut from the osmo-convective dried quince sixths. The cut samples were in the form of cubes with the dimension of 10x10x10 mm. The samples were deformed up to 70 % of their initial height. The test speed was 30 mm min^{-1}. A cylindrical plate with the diameter of 40 mm was used. The TPA test can be performed on final products because this process simulates food mastication.

2.1.2. Colour

The colour was measured at the beginning and after every 20 minutes of osmotic drying, and after combined drying. The samples were in the form of cubes with the initial dimension of 15x15x15 mm. The same surface of a sample was always measured. The colorimeter CR-400 (Konica Minolta, Tokyo, Japan) was used for the measurements. The colour of the same samples was also measured after convective drying. The measured values of quince colour during osmotic drying were shown in the CIEL*a*b* colour system. Within this system, L* indicates lightness, the parameters –a* and a* are green and red colour, and the parameter –b* and b* are yellow and blue colour. The total colour change ΔE*ab was used for the assessment of sample colour change. The total colour change is [13]:

$$\Delta E^* ab = \sqrt{\left(L_o{}^* - L^*\right)^2 + \left(a_o{}^* - a^*\right)^2 + \left(b_o{}^* - b^*\right)^2} \tag{3}$$

where $L_o{}^*$, $a_o{}^*$ and $b_o{}^*$ designate the initial values of fresh fruit samples, and L*, a* and b* the values after osmotic drying.

2.2. Sensory analysis

Sensory properties of four dried quince samples were evaluated by a panel of eight trained assessors (trained in accordance with ISO 8586:2012) from the Institute of Food Technology, University of Novi Sad (Novi Sad, Serbia). The sensory analysis was performed using a quantitative descriptive analysis and the assessors evaluated only the sensory properties that were the most relevant for fresh quinces according to Szychowski et al. [14]. The assessors evaluated the intensities of sweetness, bitterness, sourness, astringency, off-taste and quince flavour by linear numerical scale, where 0 represents no intensity while 10 represents extremely strong intensity of evaluated sensory properties.

The evaluation of quince samples was carried out in individual booths with controlled temperature and humidity. All the samples were coded with three random numbers and presented randomly to assessors in odour-free covered plastic cups. Distilled water was used to clean their mouth between the samples. The samples were evaluated in duplicate.

2.3. Statistical analysis

The measured and computed data were statistically compared by the analysis of variance (ANOVA). The analysis was done with the probability of 5%. The data were analysed by the STATISTICA 12 software (StatSoft, Tulsa, Oklahoma, USA).

3. RESULTS AND DISCUSSION

3.1 Osmotic drying

The samples dehydrated in the saccharose solution of 65^{o}Bx had lower moisture content at the end of the process. The moisture contents of samples after 180 minutes of osmotic process in the 50^{o}Bx-40^{o}C; 50^{o}Bx-60^{o}C and 65^{o}Bx-40^{o}C; 65^{o}Bx-60^{o}C saccharose solutions were 62,1%; 58,7%; 53,6% and 45,3% (wet basis), respectively. The results indicated that the most intensive decrease in moisture content occurred with an increase in the osmotic solution concentration. Similar results were obtained by Falade and Shogaolu [15] when using saccharose solutions in the osmotic dehydration of pumpkins. Kadam and Dhingra [16] also obtained similar results by using saccharose solutions in the osmotic dehydration of banana.

3.2 Mechanical properties

In Figure 1, changes in the parameter f during the osmotic drying of quince samples are shown. Increasing f values were recorded in all the treatments within the initial 60 minutes of the process. Following the initial period, the values increase and decrease separately. The explanation of these results should be found in the influence of turgor (water content) and physicochemical properties of cells and tissues. Quince tissue is characterized by a high content of fibers and large presence of brachysclereids (stone cells). A large amount of fibers and their orientation (anisotropy) in some samples can results in high tissue strength. This may be the reason for the variability of force ratio values and significant deviations. These changes occur due to the heterogeneity of fruit tissue and the lack of internal uniformity of such biomaterials.

Major changes in the f values and slighter deviations were measured in the treatment with the solution temperature of 60^{o}C. Greater softening of quince cubes was determined as well.

The values of modulus of elasticity are shown in the diagram (Figure 2). Decreasing modulus of elasticity was recorded in all the treatments within the initial 40 minutes of the process. After this period the values increase and decrease separately. In the treatment with the 50^{o}C final values did not differ from values in 40 or 60 minutes. In the treatment of 60^{o}C, neglecting the variability of values, there has been a decline by the end of the process. In the treatment with the 50^{o}C final values did not differ from values in 40 or 60 minutes. Major changes of elastic modulus were measured in treatment with solution temperature of 60^{o}C. It could be a result of thermal softening, too. Variability of results and slighter deviation in treatments with the 60^{o}C, may be explained in the same way as the changes of rapture force. Changes of modulus of elasticity showed similar behavior as force ratio (rupture force) during osmotic drying.

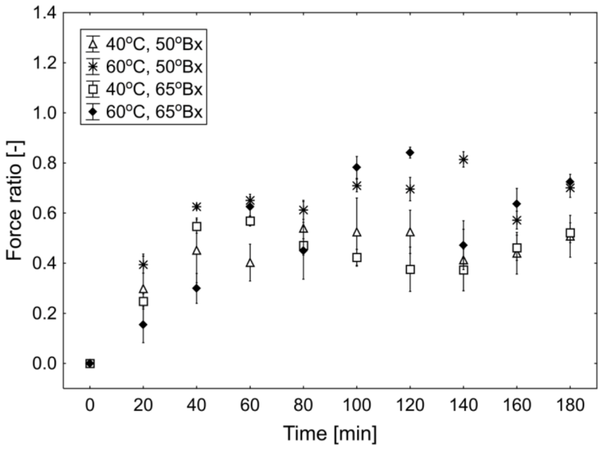

Fig. 1 Force ratio during osmotic drying

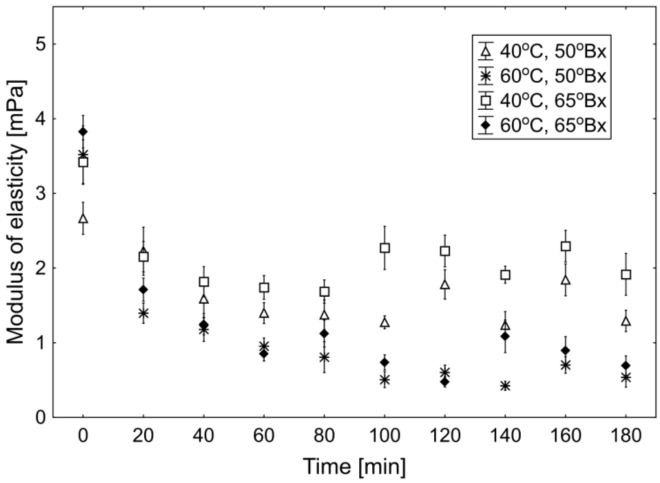

Fig. 2 Modulus of elasticity during osmotic drying

The effects of osmotic drying parameters on mechanical properties of final products are very important. Table 1 shows the measured mean values of quince hardness after combined drying. The values were obtained by the TPA test [17]. Therefore, this test can be applied to consumable food products because it simulates the process of mastication. The highest force value 145.62±26.42 N was measured in the first treatment. The hardness decreased from the first to the fourth treatment. The lowest force value 66.05±28.45 N was measured in the fourth treatment. The lowest and highest values of the parameters (temperature and concentration) caused the lowest and highest forces. All the samples had similar moisture contents.

The effects of osmotic pre-treatment on mechanical properties after convective drying can be expressed by such indicators as cohesiveness, springiness, gumminess, chewiness and adhesiveness (Table 1) [18]. Cohesiveness is the energy necessary for food mastication. The measured cohesiveness is in accordance with hardness. The lowest values were measured in the fourth treatment (60^{o}C; 65^{o}Bx). Springiness is correlated with the moisture content of materials. Increasing the moisture content, increases the springiness. The highest value was measured at the lowest moisture content of quince, and the smallest at the highest moisture content. Springiness depends on the properties of fruit tissue and the moisture content of samples.

Adhesiveness depends on the effects of adhesive and cohesive forces, viscosity and elasticity [18]. The obtained results depend on the moisture content of the samples and the amount of solution retained on the samples. Adhesiveness values are similar at the solution temperature of 40^{o}C. Gumminess is the energy necessary for disintegrating food to the swallowing point. Gumminess is obtained by multiplying hardness and cohesiveness. Due to slight changes in cohesiveness, the changing trend is similar to the change in hardness.

The results of the TPA analysis indicate that some parameter values do not follow the changing trend of the most important factors (temperature and concentration). These results indicate a very complex texture of the dried quince tissue.

Table 1 Texture profile analysis parameters of quince samples

Treatment	Moist. content [%]	Hardness [N]	Cohesiven.	Springiness [mm]	Gumminess [N]	Adhesiveness [mJ]
40°C;50°Bx	35.7	145.62±26.42^{b}	0.40±0.16^{ab}	2.15±0.11^{a}	57.94±25.38^{b}	0.22±0.04^{a}
60°C;50°Bx	33.8	89.60±17.04^{a}	0.37±0.05^{ab}	2.97±0.71^{b}	32.65±6.10^{ab}	0.71±0.12^{b}
40°C;65°Bx	34.6	84.26±9.87^{a}	0.43±0.04^{b}	2.61±0.44^{ab}	47.32±26.38^{ab}	0.26±0.18^{a}
60°C;65°Bx	36.7	66.05±28.45^{a}	0.25±0.07^{a}	2.17±0.27^{a}	17.61±11.13^{a}	0.51±0.30^{ab}

The values are expressed as mean values ± standard deviation

3.3 Colour

After osmotic drying, a small increase in the parameter L^* was recorded followed by a decrease after convective drying (Table 2). In the treatment with a 65°Bx solution, the increase was somewhat larger ranging from 8 to 10. Increase of L^* values was probably caused by the higher aggregation of solution on the surface of the fruit due to the greater absorption at higher concentration. Osmotic process caused structural changes in surface of fruit tissue and that condition allows easier retain of osmotic solution. Changes occurring during drying process, which significantly affect colour, are therefore considered as the major quality determining factor, and their levels strongly depend on temperature-moisture-time of the product. By interpreting the changes in the L^* value can be concluded that they are small and that the application of sulphur dioxide and osmotic pretreatment can successfully preserve the lightness of quince. After convective drying, only in the second treatment was the increase in this value recorded. However, it was a very small increase. The values in other treatments displayed a small decrease. The changes in L^* after convective drying were slight and within the range from 1 to 2. The analysis of variance determined significant differences in the change in L^* values among the fresh samples and the samples after osmotic and convective drying in the third and the fourth treatment ($P<0.05$). After convective drying, these values decreased and therefore it can be concluded that the lightness of quinces did not change significantly after combined drying. Osmotically pre-treated papaya fruits have similar colour to fresh fruits as stated by Rodrigues et al. [19]. The values of the parameter $-a^*$, indicating green colour, were within the range from 1 to 5. The increase in this parameter was recorded in all the treatments after convective drying. The increase is small so the differences in comparison with fresh (raw) samples are within the range from 2 to 4. Significant changes in the $+b^*$ parameter were recorded, indicating yellow colour. The significant value increase occurred after osmotic drying and it was within the range from 5 to 13. More notable changes were measured in the third and the fourth treatment with a 65°Bx solution. The increase in these changes followed the sequence of the treatments as shown in the Table 2. The smallest increase occurred in the first treatment and the largest occurred in the fourth. The trend of the parameter $+b^*$ increase continued after convective drying. The statistical analyses determined significant differences among the fresh samples and the samples in all the treatments of osmotic and convective drying ($P<0.05$). Moreover, all combinations of osmotic drying parameters affect the change of $+b^*$ values during combined drying.

Table 2 Values of colour parameters

Colour paramets	Stage	$40^oC;50^oBx$	$60^oC;50^oBx$	$40^oC;65^oBx$	$60^oC;65^oBx$
L*	Raw	74.50	68.40	68.70	74.00
	After OD	76.30	71.02	77.86	79.16
	After CD	75.25	69.93	77.44	74.57
a*	Raw	-4.09	-5.06	-3.91	-4.96
	After OD	-4.37	-4.84	-1.94	-3.89
	After CD	-0.96	-1.08	-1.61	-2.81
b*	Raw	30.60	28.40	29.07	28.19
	After OD	36.17	36.23	39.15	39.65
	After CD	41.64	42.25	40.19	39.83
ΔE	After OD	5.84	8.25	13.73	12.61
	After CD	13.56	15.78	16.89	15.36

The total colour change ΔE^*ab, comprising all three colour parameters, is usually used for the measurement of food colour change. In all the treatments, there were changes in the total colour. More significant changes were recorded after osmotic drying in the third and the fourth treatment. The statistical analysis of the data confirmed that the concentration of a solution affects the total colour change ΔE^*ab during osmotic drying ($P<0.05$). The changes of these values exceed 10. Although there is not a scale for assessing the quality of dried quinces according to colour, it can be stated that the measured changes are significant. For instance, the difference between two categories of meat quality based on the L^* colour parameter is 6. Based on the value change of some parameters, it was determined that the parameter $+b^*$ has the greatest effect on the total colour change. The parameter $+b^*$ also affects the change of chromaticity (chroma). Higher values of the chroma parameter indicate"purer" and more intense colour. Therefore, the increase in the b^* value, accompanied by slight changes in the a^* parameter, results in quince samples with purer and more intense colour. After convective drying, slightest differences in the change of the total colour (in comparison with the values after osmotic drying) were recorded at the solution temperature of 60^oC and concentration of 65^oBx. At higher temperatures and concentrations of osmotic solution, greater amounts of solution are retained in the pores of fruit tissues. This can serve as an explanation for the total colour change after convective drying. Rahman and Mujumdar [20] stated that formed saccharose layers on the surface of the samples prevent fruit tissue darkening. Saccharose layers are barriers between fruit tissue and surrounding air.

Quince fruits are very susceptible to intensive and rapid browning [21]. Guiné and Barroca [21] found that the colour change of quince tissue exposed to air is faster in the first 30 minutes. After that period, it tends to reach the equilibrium value of total colour change ΔE. The total color change was $\Delta E=30$. Due to the colour deterioration during the processing, the samples treated with sulfur dioxide were used in the experiment, whereby change in color parameters is considered in relation to the color of the fresh fruit.

3.4 Sensory analysis

The score attributes of the dried quinces are shown in Table 3. The samples were evaluated as having very low intensities of bitterness, astringency and off-taste. This is considered as very good since these sensory properties have negative impact on products acceptability. Sample 4 had the highest scores for astringency. The highest total phenol content was measured in the sample 4. The scores of sweetness are not related to the increase in solid gain. The highest solid gain was measured in sample 4, in which sweetness was not scored as the highest. Based on all the scores, sample 2 has the best quality scores. Azoubel et al. [22] scored sweetness of osmotically pretreated cashew apple with 6.00 on a scale from 0 to 9. Cashew apple is characterized by astringency, too. Statistical analysis of the obtained data of sensory analysis showed no significant ($p < 0.05$) differences between the sensory properties of the samples of dried quinces.

Table 3 Sensory scores for quality parameters of dried quince

Treatment (samples)	Parameters	Sweetness	Bitterness	Astringency	Sourness	Off-taste	Quince flavour
1	40°C; 50°Bx	4.50	0.19	0.58	3.24	0.32	5.66
2	60°C; 50°Bx	5.04	0.15	0.24	2.46	0.00	6.04
3	40°C; 65°Bx	4.82	0.04	0.45	3.62	0.27	6.17
4	60°C; 65°Bx	4.68	0.17	0.66	3.43	0.29	5.56

4. CONCLUSION

The effect of the solution concentration on the total colour change during osmotic drying was determined. Greater amount of saccharose that retain on the surface of samples prevent fruit tissue darkening during convective drying. Applied processes of sulphurisation and osmotic drying positively affect the preservation of the dried quince colour. The solution temperature was found as a factor which affects the force ratio (f) and modulus of elasticity during osmotic drying. The temperature of osmotic solution caused the softening of osmo-convective dried quince, but without degradation of structure and shape. According to sensory analysis results, temperature of osmotic solution 60 °C affect positively on quality of dried quinces. In general, osmotic pre-treatment has positive influence on physical properties and quality of dried quinces.

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First (Short) Comunication

SOME PHYSICAL PROPERTIES OF JUNIPER SEEDS (*JUNIPERUS COMMUNIS* L.)

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Abstract. *The physical properties of seeds and grain are significant tools to be used in farming, harvest, processing, packaging and storage of these seeds and grains. Knowledge on these parameters plays important roles in machinery design and process chain from grain to food. Accurate design of machines and processes in the food chain from harvest to table requires an understanding of physical properties of row materials. This study was carried out to determine the effects of moisture content on physical properties (basic dimensions, porosity, bulk and true densities, angle of repose and sphericity) of juniper seeds. As the moisture content increased from 10.79 to 24.79% dry basis (d.b); mean height, diameter and geometric mean diameter increased respectively from 8.16 to 8.51 mm, from 9.37 to 9.90 mm and from 8.95 to 9.41 mm. In the same moisture range, surface area, 1000-seed weight, true density, bulk density and porosity increased respectively from 251.70 to 278.39 mm^2, from 201.77 to 260.79 g, from 638.82 to 712.52 kgm^{-3}, from 325.59 to 354.64 kgm^{-3} and from 49.03 to 50.23 %. As the moisture content increased from 10.79 to 24.79% d.b., sphericity decreased from 95.48 to 95.05 %, whereas angle of repose increased from 22.80 to 29.61°.*

Key words: *Juniper seed (Juniperus communis L.), Physical properties, angle of repose, porosity.*

1. INTRODUCTION

Junipers are coniferous plants in the genus *Juniperus* of the cypress family *Cupressaceae* (scale leaf) family. Junipers include 60 species and they are evergreen trees or shrubs widespread over very large temperature ranges from Northern Hemisphere to Africa (South Africa). There are 10 juniper taxon naturally growing in Turkey [5].

In Europe and several other countries of the world, Juniper species have great significance because of extractive substances they contain and the substances used in medicine, especially in pharmacology.

Juniper roots, especially the fruits and leaves have been used as antiseptic in various illnesses like pain, cough, rheumatism, tuberculosis and etc. Juniper species are quite rich in essential oils, tannin, flavonoids, resin, lignin and triterpene [15].

Technical properties of products or biological material play significant roles in design of agricultural machinery and tools, product processing, quality control as well as operational success of relevant machinery and quality of end products served to consumers [1]. In recent years, various studies have been performed on physical properties of seeds and fruits of several plants like sesame seeds [14], grain legume seed [2], chickpea seed [9], locust bean seed [13] laurel seeds [18], guar seed [16], nigella seed [11] and anise seed [12].

Juniper is classified among medicinal and aromatic plants. The present study was conducted to investigate moisture-dependent physical properties of juniper seeds.

2. Material and methods

The juniper seeds (*Juniperus comminus* L.) used in this study were made free of dust, dirt, stick or any other debris.

Natural moisture contents were determined through the weight difference by drying juniper seed in an oven at 105±1 °C for 24 hours [4,3].

The following equation was used to reach the desired moisture content (Saçılık et al., 2003). Juniper seeds were separately placed into polyethylene bags and bags were supplemented with pre-determined amount of distilled water to get the desired moisture content levels. Then the samples were kept in a fridge at 5 °C for 7 days. Before the initiation of experiments, sufficient amount of juniper seeds were removed from the fridge and thawed at room temperature for 24 hours.

$$Q = \frac{W_i\left(M_f - M_i\right)}{\left(100 - M_f\right)} \qquad (1)$$

Where; "Q" is the amount of water to be added to the product (kg), "W_i" is the initial weight of the product (kg)," M_i" is the initial moisture content of the product (%) d.b., "M_f" is the desired moisture content of the product (%) d.b.

Entire physical properties of juniper seeds were investigated at 10.79, 14.29, 17.79, 21.29 and 24.79% moisture levels. Experiments were conducted in 3 repetitions in each moisture level.

A digital calipers (±0.01 mm) was used to measure dimensions of the seeds. Heights and diameters of randomly selected 100 seeds were measured with the calipers (Figure 1).

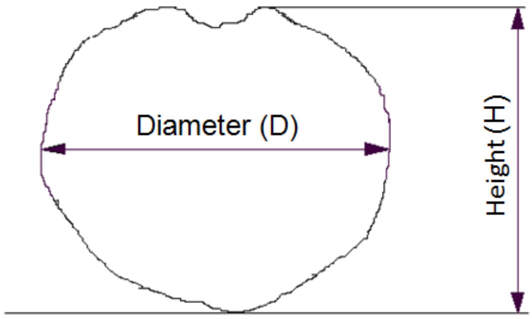

Fig. 1 Juniper seed dimensions

Geometric mean diameter (D_g) and sphericity (ϕ) were calculated by using the following equations:

$$D_g = (HD^2)^{\frac{1}{3}} \tag{2}$$

$$\varphi = \frac{(HD^2)^{\frac{1}{3}}}{D} \tag{3}$$

Where; "H" is the seed height (mm), "D" is the seed diameter (mm). Surface area was calculated by using geometric mean diameters. The following equation was used to calculate surface areas;

$$s = \pi D_g^{\,2} \tag{4}$$

Where; "S" is the surface area (mm^2), "D_g" is the geometric mean diameter (mm).

Among the seeds with desired moisture levels, randomly selected 100 seeds were weighted with a digital balance to calculate 1000-seed weight [8.18]

Bulk densities of juniper seeds with five different moisture levels were determined with 150 mm high 500 ml graduated measuring cylinder. The material was not compacted in any way, placed in loose fashion. The weight of the measuring cylinder full of loose seeds was measured. Then, bulk density was calculated by using the volume of the cylinder and weight of the material.

True density was calculated by using the relationship between actual volume and weight of the seeds. Liquid exchange method was employed to calculate mass density. Toluene (C_7 H_8) was used as the liquid since juniper seeds absorbs toluene less than water. The juniper samples with pre-determined weight were placed in glass tube full of toluene and exchanged toluene was used to calculate true density [10,8].

Porosity of juniper seeds was calculated by using true density and bulk density with the equation of Mohsenin (1970) as follows;

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho_t}\right)100 \tag{5}$$

Where; "ε" is the porosity (%), "ρ_b" is the bulk density (kg/m^3), "ρ_t" is the true density (kg/m^3).

Angle of repose was measured with 300 x300 mm box with an open bottom. The box was placed over a flat surface and filled with the material. Then, the box was swiftly removed and juniper seeds formed a pile over the flat surface. The height of the pile and the half the width of the base of the cone were used to calculate angle of repose.

$$\theta = \tan^{-1}\left(\frac{2H}{D}\right) \qquad (6)$$

Where; "θ" is the angle of repose (°), "H" is the height of cone (cm), "D" is the base diameter of cone (cm).

3. Results and discussion

Dimensions, standard deviations and mean diameters of juniper seeds with different moisture contents are provided in Table 1.

Table 1 Mean dimensions of juniper seeds and standard deviations

Moisture contents % d.b.	Dimensions, (mm)		Mean diameter, (mm)	
	Height (H)	Diameter (D)	Arithmetic mean (H+D)/2	Geometric mean $(H.D^2)^{1/3}$
10.79	8.16±0.51	9.37±0.66	8.76	8.95
14.29	8.46±0.47	9.75±0.61	9.10	9.30
17.79	8.48±0.46	9.81±0.51	9.14	9.34
21.29	8.49±0.55	9.84±0.50	9.17	9.37
24.79	8.51±0.50	9.90±0.44	9.20	9.41

Increasing seed dimensions were observed with increasing moisture contents from 10.79 to 24.79%.

Decreases were observed in sphericity of the seeds with increasing moisture contents from 10.79 to 24.79%. The model equation developed based on the relationship between moisture contents and sphericity values and coefficient of determination are presented in Figure 2.

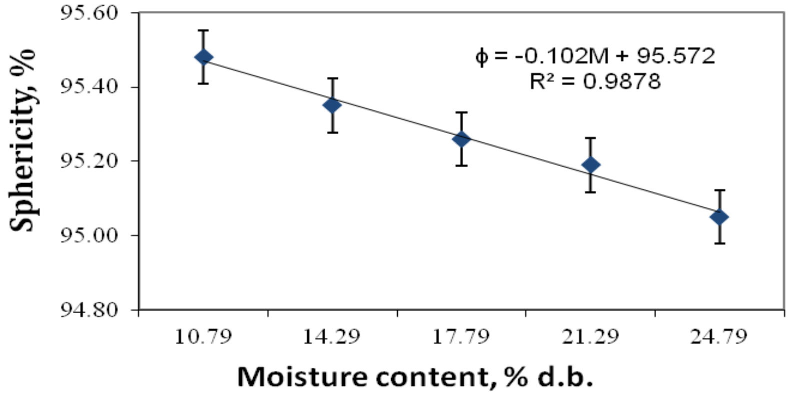

Fig. 2 Effect of moisture content on sphericity

Increasing seed surface areas were observed with increasing moisture contents from 10.79 to 24.79%. The equation indicating the relationship between moisture content and surface area together with coefficient of determination is presented in Figure 3.

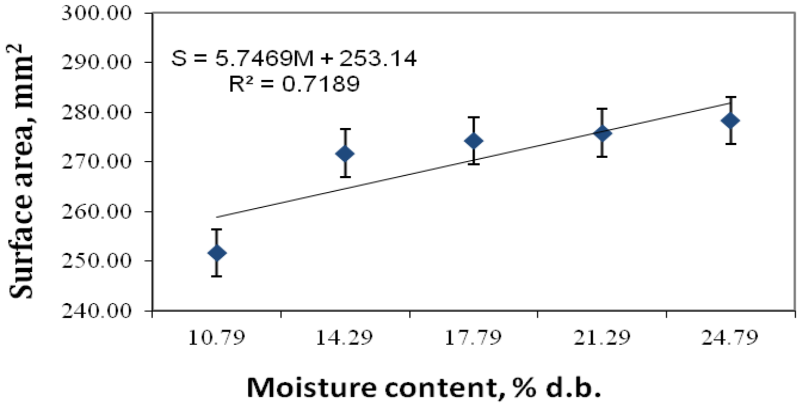

Fig. 3 Effect of moisture content on surface area

While the thousand seed weight was 0.202 at 10.79% moisture content, the value was observed as 0.261 kg at 24.79% moisture content. The relationship between moisture content and thousand seed weight together with coefficient of determination is presented in Figure 4.

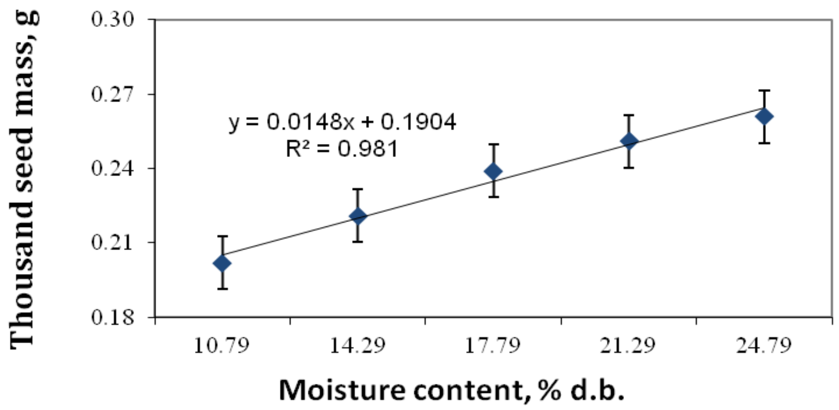

Fig. 4 Effect of moisture content on 1000-seed weight

True density of juniper seeds increased with increasing moisture contents from 10.79 to 24.79%. The equation of the relationship between moisture content and true density of juniper seeds together with coefficient of determination is presented in Figure 5.

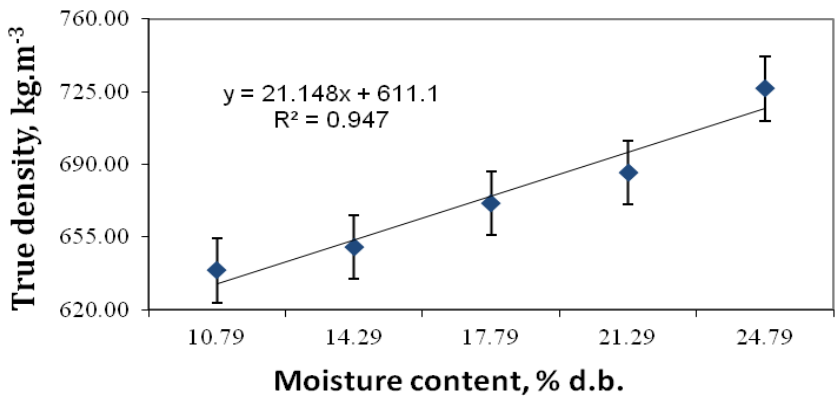

Fig. 5 Effect of moisture content on true density

Increasing bulk densities were observed with increasing moisture contents of juniper seeds. The relationship between moisture content and bulk density of juniper seeds is presented in Figure 6.

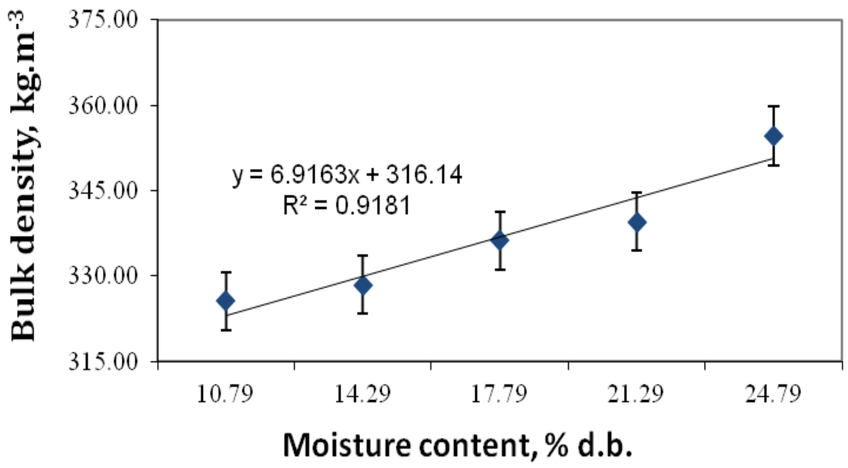

Fig. 6 Effect of moisture content on bulk density

Porosity values of juniper seeds increased from 49.03 to 51.19% with increasing moisture content from 10.79 to 27.79%. The equation indicating the relationship between moisture content and porosity of juniper seeds together with coefficient determination is presented in Figure 7.

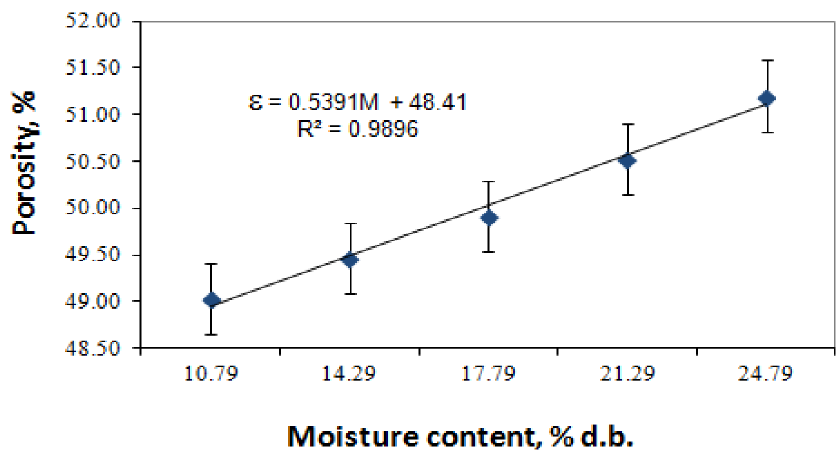

Fig. 7 Effect of moisture content on porosity

Increasing angle of repose values were observed with increasing moisture contents from 10.79 to 24.79%. The relationship between moisture content and angle of repose values of juniper seeds together with coefficient of determination is presented in Figure 8.

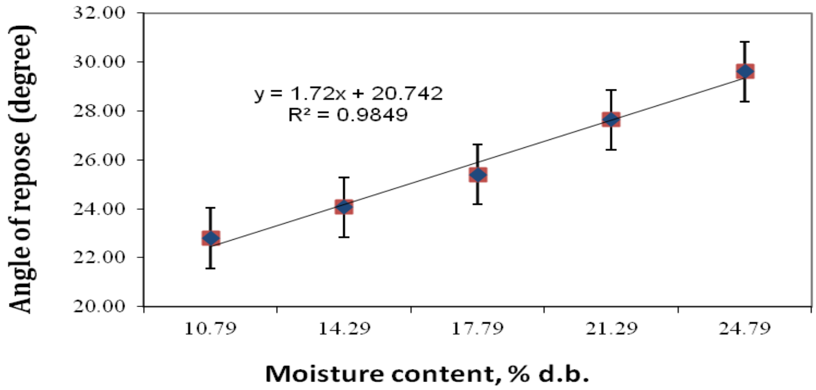

Fig. 8 Effect of moisture content on angle of repose

4. CONCLUSIONS

Some physical properties of juniper seeds with five different moisture levels were determined in this study. The following conclusions were drawn from the present study:

(1) With increasing moisture content from 10.79 to 24.79%, mean diameter increased from 8.16 to 8.51 mm, mean height increased from 9.37 to 9.90 mm and geometric mean diameter increased from 8.95 to 9.41 mm.

(2) With increasing moisture content from 10.79 to 24.79%, sphericity decreased from 95.48 to 95.05%.

(3) With increasing moisture content from 10.79 to 24.79%, 1000-seed weight of juniper seeds increased from 0.202 to 0.261 kg and surface area increased from 251.72 to 278.38 mm^2.

(4) With increasing moisture content from 10.79 to 24.79%, true density increased from 638.33 to 726.51 kg/m^3 and bulk density increased from 325,59 to 354.64 kg/m^3.

(5) With increasing moisture content from 10.79 to 24.79%, angle of repose values increased from 22.80 to 29.61°.

(5) With increasing moisture content from 10.79 to 24.79%, porosity of juniper seeds increased from 49.03 to 51.19%.

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Original Scientific Paper

ANTIMICROBIAL PROPERTIES OF *MARRUBIUM VULGARE* ESSENTIAL OIL AND ETHANOLIC EXTRACT

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Abstract: *The interest in medicinal and aromatic plants with antibacterial properties has been renewed due to the current issues associated with microbial resistance to antibiotics. Essential oils and plant extracts, naturally occurring antimicrobial agents, are attractive alternative to synthetic preservatives used in food industry. Antimicrobial properties of the aerial parts of medicinal plant Marrubium vulgare, collected in Serbia, were investigated against some common food-born pathogens. The minimum inhibitory concentration (MIC), as well as minimum lethal concentration (MLC) of the plant essential oil (EO) and ethanolic extract (EE) were determined by broth microdilution assay against seven G (+) bacteria, eight G (-) bacteria strains and one yeast. The EO exhibited antimicrobial activity against Gram (+) bacteria with MIC and MLC values ranged from < 0.47 mg/mL to 7.50 mg/mL, whereas inhibitory and lethal concentration for Gram (-) bacteria ranged from 1.85 mg/mL to 7.50 mg/mL and from 3.75 mg/mL to 7.50 mg/mL, respectively. Ethanolic extract was active against Gram (+) and Gram (-) bacteria with MIC and MLC values in the range <0.12 - 3.75 mg/mL and 1.87 - 7.50 mg/mL respectively.*

Both M. vulgare EO and EE exhibited the most potent antibacterial effect against strains belonging to G (+) bacteria, such as Bacillus cereus, Staphylococcus aureus, Staphylococcus epidermis and Rhodococcus equi, with microbicidal effect of all the tested concentrations. None of the concentration tested had inhibitory effect on G (-) bacteria strain, Esherichia coli O157:H7. Moderate activity of M. vulgare EO (MIC= 3.75 mg/mL and MLC = 7.50 mg/mL) and EE (MIC= 1.85 mg/mL and MLC = 3.75 mg/mL) was observed against the yeast Candida albicans. The EO and EE obtained from aerial parts of medicinal plant Marrubium vulgare from Serbia could be considered as a potential source of novel antimicrobial agents in the food industry.

Key words: *Natural antimicrobials, Medicinal plants, Food preservation.*

1. INTRODUCTION

Medicinal plant *Marrubium vulgare*, commonly known as horehound, is considered the most representative among the *Marrubium* species. It is cultivated worldwide as a source for food flavoring and for medicinal purposes. It is also recognized in Serbian flora [1, 2, 3].

Marrubium vulgare displays important biological activities attributed to its different bioactive compounds such as flavonoids, diterpenoids, and phenylethanoid glycosides [3, 4, 5, 6]. The aerial parts of horehound have tonic, aromatic, stimulant, diuretic and many other properties. Also, various isolates obtained from *Marrubium vulgare* aerial parts have been proved to posses significant antioxidant activity [3, 7, 8]. Antimicrobial effect of this plant has been reported as well [1, 2, 9].

Increased demand for natural and safe food, without chemicals and artificial preservatives, provokes many researchers to consider the possibility of exploitation of plant derived products in the food industry. Because of the continual occurrence of pathogenic bacteria resistant to antibiotics, there has been growing interest for novel antimicrobial agents obtained from natural sources. In some cases medicinal plants can be more effective against pathogenic microorganisms than conventionally used antimicrobial drugs [10, 11]. In this regard, many studies have been focused on different medicinal plants extracts and essential oils which are considered to have encouraging potential as an alternative in food preservation.

This research was conducted to investigate the antibacterial properties of ethanolic extract (EE) and essential oil (EO) obtained from aerial parts of medicinal plant *Marrubium vulgare*, cultivated in Serbia.

2. MATERIAL AND METHODS

2.1. Chemicals

Ethanol (96%) was purchased from "Zorka pharma" Šabac, Serbia. Tryptic Soy Broth (TSB), Tryptic Agar Base, Müller Hinton broth (MHB), Müller Hinton Agar Base, Sabouraud Broth and Sabouraud Agar Base were ordered from HiMedia (Mumbai, India). Indicator color 2,3,5-triphenyl-tetrazolium chloride (TTC) was purchased from Sigma Chemical Co. (St.Louis, Missouri, USA).

2.2. Plant material

Herb of *Marrubium vulgar*e was collected during the full flowering period, in August 2012, at Deliblatska pescara, in the Banat region of Northeast Serbia. Voucher specimens were determined and deposited at the Department of Botany, Faculty of Agriculture, University of Belgrade, Belgrade. Aerial plant parts were naturally dried, cut up and stored in tight-seal dark containers until needed. Shortly before preparation of essential oil and extract, dried plant was finely grinded.

2.3. Isolation of the essential oil

About 40 g air-dried powdered aerial parts of *Marrubium vulgar*e were subjected to hydrodistillation for 2 h using a Clevenger type apparatus. The obtained oil was dried over anhydrous sodium sulphate and stored at low temperature (+4 ◦C) in amber vials for further analysis.

2.4. Preparation of ethanolic extracts

The air-dried powdered aerial parts (50 g) of *Marrubium vulgar*e were extracted with 250 mL 96% ethanol for 24 hours at room temperature. The extract was filtered and evaporated at 50°C under reduced pressure by vacuum rotary evaporator (BUCHI, Switzerland). Finally, it was stored at +4°C. For antimicrobial testing dry extract was used.

2.5. Microorganisms and cultures preparation

The study was conducted against 15 standard strains of bacteria: Gram - positive bacteria (*Listeria monocytogenes* ATCC 19111, *Rhodococcus equi* ATCC 6939, *Staphylococcus aureus* ATCC 25923, *Staphylococcus epidermidis* ATCC 12228, *Enterococcus faecalis* ATCC 29212, *Bacillus subtilis subsp. spizizenii* ATCC 6633 and *Bacillus cereus ATCC* 11778), Gram - negative bacteria (*Escherichia coli* O157:H7 ATCC 35150, *Proteus mirabilis* ATCC 12453, *Proteus hauseri* ATCC 13315, *Shigella sonnei* ATCC 29930, *Yersinia enterolitica* ATCC 27729, *Salmonella enteritidis* ATCC 13076, *Salmonella typhimurium* ATCC 14028, *Pseudomonas aeruginosa* ATCC 27853) and one standard strain of yeast *Candida albicans* ATCC 10259. Bacteria and yeast were prepared by sub-culturing 24-h-old colony from the agar plate to the 5mL of adequate broth and incubated for 18-24h at 37˚C for bacteria and 30˚C for the yeast. Final concentration of bacteria used for inoculation of microtiter wells was adjusted to 10^5 cfu/mL. Tryptic Soy Broth was used to prepare *Listeria monocytogenes* and *Escherichia coli* O157:H7 suspensions, Müller Hinton Broth for other bacteria, and Sabouraud Broth for the yeast [12].

2.6. Broth Microdilution Assay

Broth microdilution method was used to determine the antimicrobial activity of plant isolates *in vitro* [12]. The minimum inhibitory concentration (MIC) of EO and EE was determined using 96-well microtiter plates (Sarstedt, Germany). The EO and dried EE were dissolved in 5% DMSO. Concentrations in range of 7.50 mg/mL – 0.12 mg/mL for EE and 7.50 mg/mL – 0.12 mg/mL for EO were tested. Bacterial suspensions were supplemented 1.5% TTC to indicate the viability of MO. For EO testing Tween 80 (final concentration 0.5% v/v) was added as well, in order to facilitate EO solubility in broth. Final volume of 100 µl was achieved by adding bacterial and yeast suspensions into wells with different concentration of tested EO and EE. The last two wells were positive and negative controls, respectively. The positive control was inoculated with bacterial suspension only, while the negative well was blank broth without inoculation. The 96-microwell plates were sealed and incubated at 37 °C for 24 h. The MICs of EO and

EE were recorded as the lowest concentration where no change of colour was detected. The MIC procedure was done in triplicate.

Minimal lethal concentration (MLC) was determined by sub-culturing content of the wells with no visible growth on agar plates and incubation at 37°C for 18h -24h for bacteria and 30°C for 24-48 h for fungi. The lowest concentration of the EO or EE required to completely destroy test microorganisms (no growth on the agar plate) was reported as minimum lethal concentration (MLC) [2]. The MLC procedure was done in triplicate.

All experiments were conducted in the laboratories of the Faculty of Agriculture, Department of Food Technology.

3. RESULTS AND DISCUSSION

The EO and EE of *M.vulgare* displayed varied antimicrobial activity across the studied pathogens. As it can be seen on Table 1. and Figure 1., EO displayed antimicrobial effect in tested range of concentrations, except in case of *Esherichia coli* O157:H7. Minimal inhibitory concentrations ranged from < 0.47 mg/mL to 7.50 mg/mL for Gram (+) bacteria and from 1.85 mg/mL to 7.50 mg/mL for Gram (-) bacteria. Essential oil had also lethal effect on majority of microorganisms tested with MLC values in the range of < 0.47 - 7.50 mg/mL for Gram (+) bacteria and 3.75 - < 7.50 mg/mL for Gram (-) bacteria.

The strongest activity of *M. vulgare* EO has been observed against some Gram (+) bacteria, such as *Bacillus cereus, Bacillus spizizenii, Staphylococcus aureus, Staphylococcus epidermis* and *Rhodococcus equi,* where all the tested concentrations had microbicidal effect. The highest MIC and MLC values have been observed for *Enterococcus faecalis,* which makes this bacteria the least susceptible among Gram (+) bacteria.

The most sensitive strain in the presence of EO among Gram (-) bacteria was *Yersinia enterolitica,* followed by *Proteus mirabilis* and *Proteus hauseri. Pseudomonas aeruginosa, Shigella sonnei, Salmonella enteritidis* and *Salmonella typhimurium* showed sensitivity only at the highest concentration of EO in the broth (7.50 mg/mL). *Esherichia coli* O157:H7 showed the highest resistance among Gram (-) bacteria because no growth inhibition was achieved in tested range of EO concentrations.

Ethanolic extract of *M. vulgare* displayed antimicrobial activity against tested strains with MIC and MLC values for Gram (+) and Gram (-) bacteria ranged between < 0.12 mg/mL and 3.75 mg/mL and from 1.87 mg/mL to 7.50 mg/mL, respectively (Table 1. and Figure1.). As in case of EO, the highest susceptibility to EE among Gram (+) bacteria showed *Bacillus cereus, Staphylococcus aureus, Staphylococcus epidermis* and *Rhodococcus equi* where all concentrations tested caused bacterial death. Therefore, both *M. vulgare* EO and EE, in this study exhibited the most potent antimicrobial effect against mentioned strains, which is consistent with other studies [9, 13, 14, 15, 16]. *Bacillus spizizenii* and *Listeria monocytogenes* were less sensitive, whereas *Enterococcus faecalis* was the most resistant strain among Gram (+) bacteria

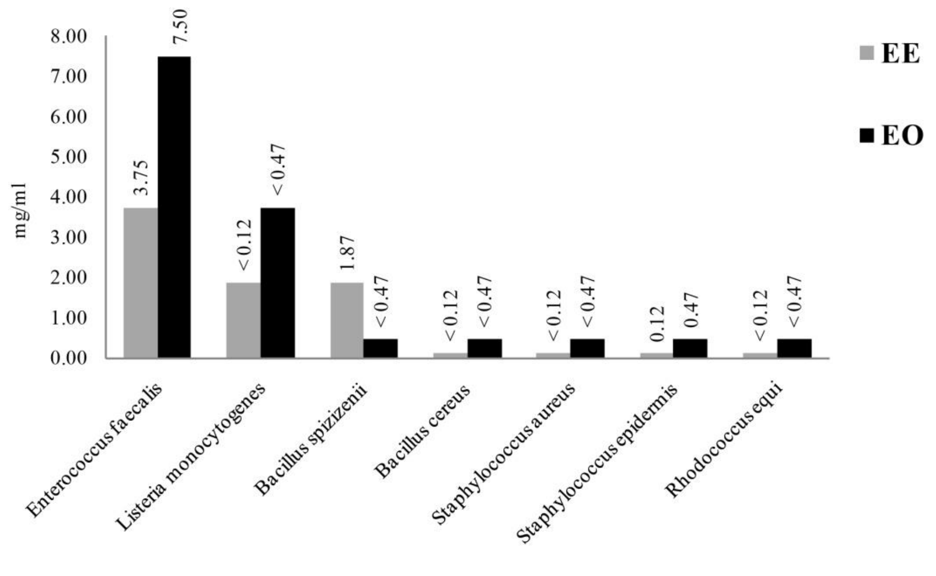
Table 1 MIC and MLC values of *Marrubium vulgare* EE and *Marrubium vulgare* EO

Test bacteria		*Marrubium vulgare* EE (mg/mL)[a]	*Marrubium vulgare* EO (mg/mL)[a]
Enterococcus faecalis ATCC 29212	MIC	3.75±0.00	7.50±0.00
	MLC	3.75±0.00	7.50±0.00
Listeria monocytogenes ATCC 19111	MIC	1.87±0.00	3.75±0.00
	MLC	3.75±0.00	3.75±0.00
Bacillus spizizeni ATCC 6633	MIC	1.87±0.00	**
	MLC	3.75±0.00	**
Bacillus cereus ATCC 11778	MIC	**	**
	MLC	**	**
Staphylococcus aureus ATCC 25923	MIC	**	**
	MLC	**	**
Staphylococcus epidermidis ATCC 12228	MIC	**	**
	MLC	**	**
Rhodococcus equi ATCC 6939	MIC	**	**
	MLC	**	**
Salmonella enteritidis ATCC 13076	MIC	7.50±0.00	7.50±0.00
	MLC	7.50±0.00	7.50±0.00
Salmonella typhimurium ATCC 14028	MIC	7.50±0.00	7.50±0.00
	MLC	7.50±0.00	*
Escherichia coli O157:H7 ATCC 35150	MIC	*	*
	MLC	*	*
Pseudomonas aeruginosa ATCC 27853	MIC	7.50±0.00	7.50±0.00
	MLC	7.50±0.00	*
Shigella sonnei ATCC 29930	MIC	3.75±0.00	7.50±0.00
	MLC	7.50±0.00	7.50±0.00
Proteus mirabilis ATCC 12453	MIC	1.87±0.00	3.75±0.00
	MLC	3.75±0.00	*
Proteus hauseri ATCC 13315	MIC	1.87±0.00	3.75±0.00
	MLC	1.87±0.00	3.75±0.00
Yersinia enterocolitica ATCC 27729	MIC	3.75±0.00	1.87±0.00
	MLC	7.50±0.00	3.75±0.00
Candida albicans ATCC 10259	MIC	3.75±0.00	1.87±0.00
	MLC	7.50±0.00	3.75±0.00

[a] Data are expressed as mean of three replicates ± standard deviation (n = 3).
*With highest tested concentration of samples (7.50 mg/mL) antibacterial activity was not determined.
** Tested samples showed antibacterial activity in concentration lower than 0.12 mg/mL for EE and 0.47 mg/mL for EO.

Among Gram (-) bacteria, EE showed the strongest effect on *Proteus mirabilis* and *Proteus hauseri*, followed by *Shigella sonnei* and *Yersinia enterolitica.* As in case of EO, EE was ineffective against *Esherichia coli* O157:H7 in tested range of concentrations. This strain, evidently, exhibited the highest resistance among all the microorganisms tested in this study. Some authors also revealed weak or no inhibitory effect of herbs EOs and extracts on some strains of *Esherichia coli* [15, 16, 17, 18].

a)



b)

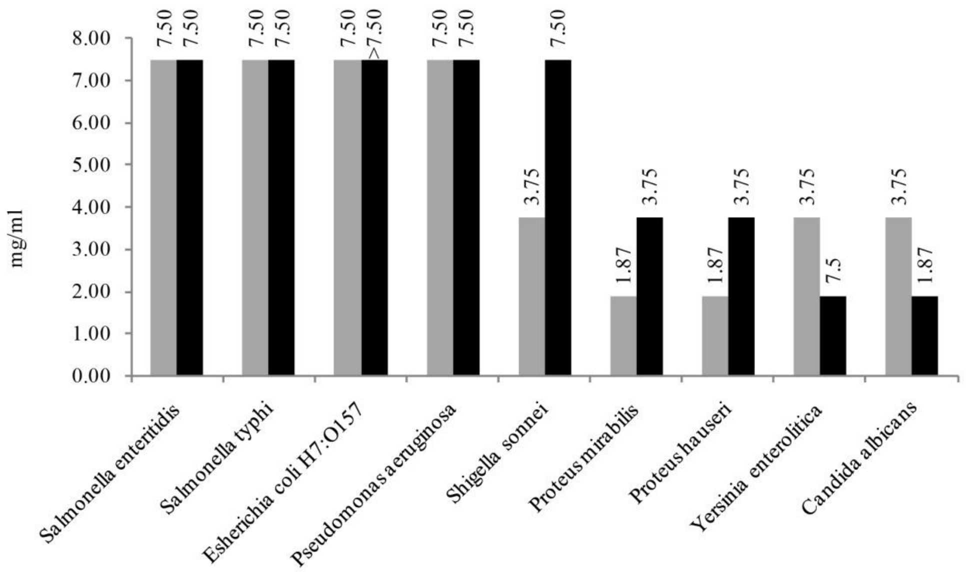


Fig. 1 MICs of EE and EO obtained for: a) Gram (+) bacteria and b) Gram (-) bacteria and yeast *C. albicans*

EO and had both inhibitory and lethal effect against the yeast *C. albicans* at concentrations of 1.87 mg/mL and 3.75 mg/mL, respectively. EE inhibited yeast at 3.75 mg/mL, whereas lethal effect was achieved at 7.50 mg/mL.

The antimicrobial activity observed in *M.vulgare* EE could be attributed to the presence of bioactive compounds, such as alkaloids, phenolics and terpenoids, found in this plant species [18]. These compounds have been reported to exhibit significant antimicrobial activities against a wide array of microorganisms [19, 20]. *M. vulgare* leaf extracts have been reported to contain valued contents of total phenolics, flavonoids, and tannins [3]. High TP and TF content was discussed before as a reason for antibacterial activity of *P. minus* extracts [21]. Flavonoid organic extracts from *M. Vulgare* were proved to show remarkable antimicrobial effect against Gram (+) bacteria [22]. In addition, tannins recently isolated from this plant by some authors displayed significant antibacterial activity against some generally very resistant strains [23]. There are assumptions that complex polyphenols, such as flavonoids and tannins might interact with cellular proteins, enzymes, polysaccharides and microbial adhesins, thus inhibiting vital processes in microbial cell [19, 24].

The antimicrobial properties of plants' EOs are also mainly associated with their chemical composition [25]. It is possible that various components take part in antimicrobial activity by producing synergistic effect, especially between major and minor components [13]. The compounds responsible for antimicrobial features of EO are phenolic compounds, such as oxygenated mono- and sesquiterpenoids (volatile terpenes), as well as non-phenolics and aliphatic compounds [25, 26, 27, 28].

Antibacterial activity of EOs is usually not related with one specific mechanism. Lipophilic nature of EO enables interactions with cell wall and membrane components, permeabilizing them and leading to the leakage of ions and other important molecules from cell [13, 25 ,29, 30, 31]. There are also some speculations that EO can damage the cell by lipids and proteins coagulation, enzyme inhibition, interference with the energy-bearing molecules (ATP) etc [13, 25] .

Despite the fact that several authors reported stronger antimicrobial activity of EO in comparison to EE of some herbs, this pattern was not observed in this study. Majority of microorganisms tested were more susceptible to M. *vulgare* EE than EO. This finding corroborates with several authors, who suggest higher antimicrobial potential of solvent plant extracts when compared to their EO [29, 32, 33]. This might be due to possible insufficient solubility and suspension of the oil in the broth. Another reason might be the evaporation of critical components responsible for antimicrobial actions during the storage period of the EO.

Presented results indicate higher susceptibility of Gram (+) than Gram (-) bacteria to both M. *vulgare* EO and EE. This finding corroborates with the previous studies on *M. vulgare* and other spices and herbs [13, 18]. Generally higher resistance among Gram (-) bacteria could be ascribed to the presence of the outer membrane, surrounding the cell wall, which restricts diffusion of hydrophobic compounds through its lipopolysaccharide covering. However, presence of porin proteins in the outer wall of this bacteria can create channels that allow access of small molecular mass compounds, such as substituted phenolics, to the inner cell layers and finally to the cytoplasmic membrane [25].

4. CONCLUSION

According to the results presented in this study EE and EO of *M.vulgare* aerial parts have shown promising antimicrobial properties. Therefore, tested plant isolates can be considered as potential alternatives to chemical preservatives in the food industry. In this regard, EE would be more efficient as food antimicrobial agent. Also, Gram (+) bacteria are more susceptible to both *M.vulgare* EE and EO.

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Original Scientific Paper

SAFETY OF HERBICIDE USE IN CHAMOMILE

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Abstract. *The common practice in chamomile production involves weed control using herbicides. Since, there are no authorized plant protections products for use in medicinal crops, there are no recommendations on concentration required for efficient weed control and crop safety. Linuron is selective herbicide used for control of broad-leaved weeds. It is foliar herbicide with some residual activity, so it enters the plants both via leaves and roots (from soil). This study investigated the residue level of linuron in chamomile flower, stalk and flower with 4 cm long stalk attached. Linuron was applied in spring in two concentrations. After harvest, samples of chamomile plants were air dried, and herbicide residues were determined by LC-MS/MS using the QuEChERS method. Linuron residues in chamomile flower were below official maximum residue level (MRL) of 0.1 mg/kg, but significantly higher in chamomile stalk and flower with 4 cm stalk (average over concentrations: 1.7685 mg/kg and 1.409 mg/kg, respectively).*
Key words: *chamomile, weed control, crop safety, linuron, herbicide residues*

1. INTRODUCTION

Chamomile (*Matricaria chamomilla* L.) is one of the oldest medicinal plants in the world that has been used in traditional medicine throughout history. Chamomile is a native of the old World and is a member of the *Asteraceae* family. Its flowers are currently used in the production of a medicinal tea; steam-distilled essential oil that is used in flavor, fragrance, pharmaceutical and cosmetic industries; and a solvent extract of the flowers used primarily in the cosmetic and pharmaceutical industries. The dried flowers are used to produce herbal teas both alone and mixed blends. The market requires that these flowers have specified levels of the pharmaceutically active compounds and that the product is free from weeds and other debris [7].

In Serbia, chamomile is predominantly cultivated in Banat region, on fertile and slightly alkaline soil. Chamomile can tolerate heavier soils, but prefers a well-drained sandy loam. It will tolerate a wide range of pH and is possibly quite salt tolerant [7]. As germination appears to be inhibited by high temperature, and crop established better under cooler conditions, it is a common practice that chamomile is sown in autumn. Chamomile is relatively pest and disease free so there is no need for fungicides and insecticides use. However, weeds are of serious concern, since contaminants in the final product (flowers, oil or extract) will detract from the specified quality. Crop growth in the early stages is particularly slow and there is a need for early weed control in spring. Herbicide application is of no use once canopy closure is achieved since mature chamomile plants are very competitive. The only problem in later growth stages could be grass weeds. The narrow plant spacing and spreading nature of crop make manual weeding difficult, and it may cause considerable damage to crop plants. Since predominant weed flora in Banat region consisted of robust annual broadleaved weeds, some of them being strong competitive plants, it is necessary to use herbicides in order to preserve flower yields. Post-emergence herbicides should not be applied until the crop has reached the rosette state. Experience shows that there are quite selective herbicides for chamomile, but none is registered for such use in Serbia [10].

Chamomile requires warm to hot weather for best yields and dry weather at harvest, particularly for the production of dried flowers. The optimum harvest time is when the majority of flowers present are in full bloom, meaning that at this stage the crop appears white. Chamomile has continuous flowering habit and two harvests are possible in Banat region, depending on weather conditions. These harvests will be spaced about 15 days apart.

Linuron [3-(3,4-dichlorophenyl)-1-methoxy-1-methyl urea] is a selective N-methoxy-N-methyl substituted phenylurea used as a pre- and post-emergence herbicide for the control of annual grass and broad-leaved weeds, and some seedling perennial weeds in several crops. It is absorbed principally by the roots but also by the foliage, with translocation primarily acropetally in the xylem. Linuron acts as photosynthetic electron transport inhibitor at the photo system II receptor site.

Linuron has a very low rate of volatility. Its sorption is guided more by organic matter content than clay content [3] and it has been determined that linuron had been increasingly sorbed to soils that were augmented with organic matter, such as the addition of compost or humic acid to crop soils [21].

Linuron is moderately persistent in soils. Hydrolysis is considered to be a minor degradation pathway because of the stability of linuron in the presence of sterile water, although the intermediate products are more prone to hydrolysis than the parent compound [6].

Biodegradation is primarily responsible for the disappearance of linuron from soils, with a half-life range between 38 and 67 days [4, 5, 11]. Complete mineralization of linuron in laboratory and natural environments is concomitant with *Variovorax* sp. bacterial strains [16]. In the presence of oxygen in soil (aerobic conditions in the lab), linuron's half-life was 75 days, while it was up to 230 days under field conditions. In nonsterile soil, herbicide degradation was significantly influenced by soil moisture level, with half-life being 1,8 times higher in flooded then in nonflooded soil [1]. Generally, linuron half-life varies from 30 to 150 days for different soil types, with an estimated average half-life of 60 days [8, 17, 19].

Soil conditions are important to predict the degree to which linuron will adsorb, including organic matter content, moisture content, temperature and soil type. It is classified as a potential threat to groundwater based on persistence and mobility characteristics [9, 14, 15]. Although linuron is moderately persistent and relatively immobile in soil, runoff and leaching can result in the migration of this compound to surface and groundwater bodies, with attendant environmental risks [20]. Linuron is considered to be toxic to highly toxic to aquatic organisms [13].

In addition, linuron is suspected to act as an antagonist for androgen receptor affecting the male reproductive system and therefore is also of concern for human health [12]. Therefore, understanding of the natural attenuation of linuron in the environment is important.

Linuron accumulates and metabolizes differently in different plants. Susceptible plants transport linuron through the foliage, while tolerant plants can metabolize linuron into inactive products. Linuron inhibits photosynthesis in susceptible plants causing them to lose color, wilt, and die. In crops, linuron has low residual action and persistence.

Accumulations of herbicides in chamomile plants in field conditions have not yet been estimated. It was therefore the main aim of the present research to evaluate the residue level of linuron in different parts of chamomile plant in relation to concentrations applied. Analyses were conducted in order to determine the safety of herbicide use in medicinal plants.

2. MATERIAL AND METHODS

2.1 Field experiment

The trial was conducted on location of Bavaniste during 2014. Bavaniste is situated in Banat region, and the trial was set at nearby field with coordinates: latitude N= 44° 52' 09.47"; longitude E= 20° 54' 50.94" and altitude = 92 m. Chamomile cultivar “Banatska” was established in October 2013, on sandy loam type of soil (61.28 % sand, 22.24 % silt, 16.28 % clay; humus content 3.2 and pH 8.7). The seedling rate was 1.5 kg/ha. The experiment was laid out in complete randomized block design with four replications and individual plot size of 2m x 5m. Commercial formulation of linuron was used. Treatments included an untreated check and two linuron rates: 675 and 900 g a.i./ha. The trial treatments and evaluations were performed according the EPPO guidelines. Treatments were applied on 23rd of April using a backpack sprayer delivering 240 l/ha at 2 bars, with Tee jet XR 11002 flat fen nozzles. Meteorological data for vegetating period were obtained from nearest station and are presented as weekly average (Fig. 1).

Efficacy and phytotoxicity assessments were performed on May the 7th and 21st. At harvest time (May the 31st) plant samples of chamomile (whole plants/m^2 in two replications / each individual plot) were collected for laboratory testing on residue level.

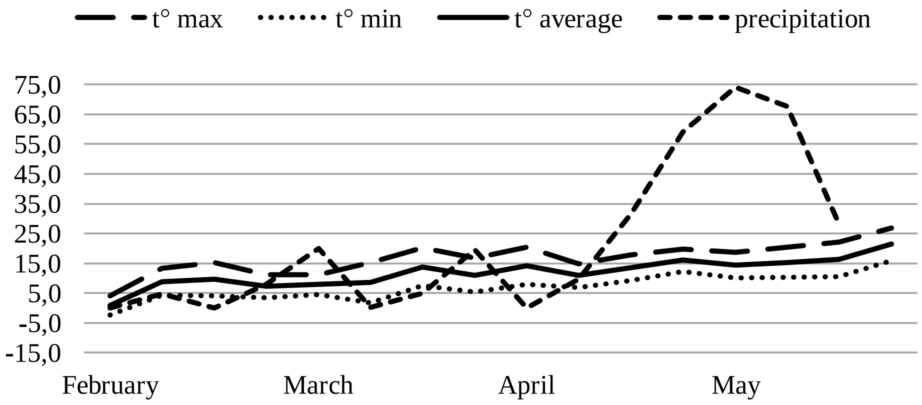

Fig.1 Meteorological conditions in Bavaniste for vegetation 2014

2.2 Sample preparation

Linuron was extracted from chamomile flower, stalk and flower with 4cm long stalk using an extraction procedure based on the QuEChERS methodology [2]. The amount of air dried flower, stalk and flower with 4cm stalk was reduced to 2 g of fine homogenized samples. Internal standard solution (100 µl) was added and samples were shacked and left for 30 min. Then, 8 ml of water was added and mixed on vortex. The extraction was done with 10 ml of acetonitrile. After extracting on vortex mixer for 1 minute, 6.0 g of magnesium sulfate anhydrous, 1.5 g of sodium chloride, 1.5 g of trisodium citrate dihydrate and 0.75 g of disodium hydrogen citrate sesquihydrate were added and the mixture was shaken vigorously for1 min and centrifuged for 5 minutes at 4000 rpm. Then, 1 ml of supernatant was transferred into a clean-up tube containing 900 mg of $MgSO_4$ and 150 mg of PSA. After the mixing on vortex and the centrifugation for 5 minutes at 5000 rpm, 0.5 ml of supernatant was evaporated to dryness and reconstituted in 1 ml of mobile phase [18].

2.3 Chemicals and apparatus

Solvents used for analysis were of chromatography grade and were obtained from Merck (Darmstadt, Germany). The certified analytical standard of linuron (99.5%) was purchased from Dr. Ehrenstorfer (Augsburg, Germany). The internal standard isoproturon–d6 was purchased from Sigma Aldrich (99.8%). Concentration of internal standard was 10 µg/ml in acetonitrile. The analytical standard of linuron was dissolved in acetonitrile for preparation of stock standard solution (1mg/ml). The working standard was obtained by diluting the stock standard with acetonitrile. Magnesium sulphate, disodium hydrogen citrate sesquihydrate, trisodium citrate dihydrate, sodium chloride and formic acid (analytical reagent grade) were purchased from Fisher Scientific UK (Loughborough, UK). Bondesil primary secondary amine (PSA, 40µm) was obtained from Agilent Technologies (Australia Pty Ltd). Agilent 1200 (Agilent Technologies, USA) HPLC system with a binary pump was used for LC analysis. System was equipped with a reversed-phase C18 analytical column of 50×4.6mm and 1.8 µm particle size

(Zorbax Eclipse XDB-C18, Agilent). The mobile phase was methanol (solvent A) and Milli-Q water (solvent B), both with 0.1% formic acid in gradient mode, with the flow rate of 0.3 ml/min. The elution program was started with 50% B. It was linearly decreased to 90% B in 10 min and held constantly for 2 min with the post run of 3 minutes. An Agilent 6410 Triple-Quad LC/MS system was applied for the mass spectrometric analysis. For data acquisition and processing Agilent MassHunter B.04.00 software was used. The analysis was performed in positive ion modes. The ESI source values were: drying gas (nitrogen) temperature 300 °C, vaporizer 200 °C, drying gas flow rate 5 l/min, nebulizer pressure 50 psi and capillary voltage 2500 V. The detection was performed using triggered multiple reactions monitoring (tMRM).

Linearity was done based on the injections of working standard solutions in mobile phase (1 – 200 ng/ml) and in extract of blank chamomile flowers, blank chamomile stalk samples, and blank chamomile flower with 4 cm stalk in the same concentrations. Internal standard isoproturon–d6 was added in all samples in the concentration of 0.1 μg/ml. The method precision is expressed as the repeatability (RSD, %) of the recovery determinations at four different spiking levels of blank sample of chamomile flower with 4 cm stalk (0.05, 0.25, 0.5 and 2.5 mg/kg).

2.5 Statistics

The data were subjected to analysis of variance. Differences significant at the $P = 0{\cdot}05$ level were determined and discussed.

3. Results and discussion

The predominant weeds at trial site were annual weeds: *Chenopodium album*, *Xanthium strumarium*, *Lactuca serriola*, *Helianthus annuus*, *Bilderdykia convolvulus*, *Sonchus oleraceus*, *Polygonum lapathifolium*, and perennial: *Cirsium arvense*. Since linuron efficacy is well known, this data are not included.

Phytotoxicity assessments confirm that linuron is selective for chamomile and could be use without concern of crop damage. There were no visual injuries on chamomile plants at any time from application till harvest. There was no sign of phytotoxicity on treated plants regardless the herbicide concentration.

Residue analysis has shown that herbicide presence in chamomile samples is both dose and plant part depended (Table 1).

For all calibration curves linearity was over 0.99. The recovery was within the range of 108 – 130 %, except for the lowest level (181 %) and a RSD ≤ 18.8 %.

According to Serbian regulations that are harmonized with EU legislation, maximum residue level (MRL) of linuron in chamomile flower is 0.1 mg/kg. As results show, residue level of linuron was below MRL for flower, and there were no statistical differences in regard to concentrations applied.

The amount of linuron residues in chamomile stalk is well above MRL, but the obtained values were not statistically different regarding applied concentrations.

Of our special interest were results of linuron residues in flower with 4 cm stalk attached, having in mind that this is so called II technological class and as such acceptable in processing industry. Our findings indicate that linuron residues are significantly above MRL, and that they depend on concentrations applied.

Table 1 Linuron residue level in different parts of chamomile plants

<table>
<tr><th rowspan="3">Linuron treatments</th><th colspan="6">Linuron residues (mg/kg)</th></tr>
<tr><th colspan="2">Flower</th><th colspan="2">Stalk</th><th colspan="2">Flower with 4cm stalk</th></tr>
<tr><th>four replications average</th><th>average</th><th>four replications average</th><th>average</th><th>four replications average</th><th>average</th></tr>
<tr><td rowspan="4">675 g a.i./ha</td><td>0,014</td><td rowspan="4">0,050 [a]</td><td>1,167</td><td rowspan="4">0,997 [bc]</td><td>1,186</td><td rowspan="4">1,273 [b]</td></tr>
<tr><td>0,114</td><td>1,786</td><td>1,123</td></tr>
<tr><td>0,074</td><td>0,381</td><td>1,470</td></tr>
<tr><td>0,000</td><td>0,652</td><td>1,313</td></tr>
<tr><td rowspan="4">900 g a.i./ha</td><td>0,320</td><td rowspan="4">0,080 [a]</td><td>4,635</td><td rowspan="4">2,542 [bc]</td><td>1,426</td><td rowspan="4">1,545 [c]</td></tr>
<tr><td>0,000</td><td>1,613</td><td>1,619</td></tr>
<tr><td>0,000</td><td>2,290</td><td>1,601</td></tr>
<tr><td>0,000</td><td>1,630</td><td>1,534</td></tr>
</table>

[a, b, c] – means followed by the same letter do not differ significantly according to LSD test at 0,05 level

Based on the results achieved there is a need for further research both on what are the main factors that can limit herbicides residues to acceptable level and make the herbicide applications safe.

4. CONCLUSIONS

Chamomile is one of the most important and mostly cultivated medicinal plants in Serbia. Since there are no official herbicides for use in chamomile, and common practice includes linuron application in spring, there are no data on eventual herbicide residues in usable plant parts. The paper presents that herbicide use in medicinal plants needs our attention, since residue level was considerably higher than MRL in flower with 4 cm stalk, which represents a raw material in processing industry. We intend to continue our research hoping to find out what are the main factors inducing high residue problem.

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Original Scientifi Paper

POSTHARVEST CHANGES OF THE APPLE VARIETY IDARED

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Abstract. *Postharvest losses of fresh fruits and vegetables are very high, especially in undeveloped countries. Therefore, modern postharvest treatments such as modified and controlled atmosphere storages are increasingly used to prolong shelf life. In this work we analyzed postharvest changes of cold stored apples under air and in controlled atmosphere. Other conditions were the same in both cold chambers, ie. temperature was 1°C and relative humidity was maintained in the interval 85 to 90 %. Changes in gas composition of cold chamber atmosphere as well as chemical composition of fruits have been monitored during four months of storage. The obtained results have shown significantly less changes in contents of relevant quality parameters of apples stored in controlled atmosphere compared with air stored apple variety Idared. After four months of storage in refrigerated chamber under air, apples had significantly lower firmness than apples stored in controlled atmosphere. Furthermore, total mass loss was higher in apples stored under air, that is in natural atmosphere conditions.*

Key words: *apples, postharvest technology, storage, low temperature, controlled atmosphere, quality.*

1. INTRODUCTION

Fruits and vegetables have a significant place in the total value of agricultural production in Serbia. In recent years, an increasing amount of fresh fruits and vegetables has been exported. For a significant placement of fresh food on foreign markets it is necessary to provide quality protection in the postharvest period. Postharvest losses of fruits and vegetables in developed countries are ranged from 5 to 25 %, and in developing and undeveloped countries, this range increases up to 25 % (Gladon, 2006). The most important environmental conditions to be provided in storage areas are temperature and humidity. The intensity of metabolic processes in fresh fruits is slower at low temperatures, therefore quality changes and diseases are lower. The main goal in postharvest period is to slow down the process of respiration and transpiration of fresh products and to extend their storage life (Janković and Mašović, 2000). Since, the intensity of respiration is in exponentially dependent on temperature values in the storage area, it is necessary to reduce temperature as much as possible. Temperature has mainly been maintained in the range of 0-4°C, while the range of 4-10°C has been used for a shorter period of storage (Marković, et al. 2011). Freezing temperature is a key reference for determining the appropriate storage temperature of the bioproducts (Wang, et al. 2003). When the fruits are stored at the temperature which is near their freezing temperature, tissues of the fruit are not able to continue normal metabolic processes. If the effect of low temperature was prolonged, improper functioning of tissues will lead to the emergence number of symptoms, such as loss of firmness, freezing injury, lesions on the surface of fruits, the impossibility of proper maturity, and so on.

As postharvest treatment, controlled atmosphere is increasingly used for longer storage, especially for exported fresh food products. Controlled atmosphere is defined as an environment with decreased oxygen levels and elevated carbon dioxide as compared with air. It has been used in association with refrigeration to extend the storage life of certain fresh food products (Janković and Mašović, 2000). Long-term controlled atmosphere treatment for apple storage retains fruit quality and reduces decay (Sitton and Patterson, 1992). Generally, oxygen is decreased from the normal 21% in air to 1–10%, and carbon dioxide is increased from 0.03% to 1.5–5%, depending on the commodity. This atmosphere can potentially reduce respiration rate, ethylene production, decay and physiological changes, namely, oxidation (Smyth, et.al 1998; Gorris and Tauscher, 1999; Kader, 1986, 2002). Controlled atmosphere is mostly used for apples storage all over the world. There is a range of optimum levels for each variety as a result of the regional climatic differences, different strains of a particular variety and the current level of technology available within a region (Kupferman, 2001). Some authors recommended 1.5–5.0 % O_2 and less than 2.0 % CO_2 for storage of apples (Olsen, 1980; Keder, 2002; Gross, et al, 2004).

The aim of this paper was to determine and compare quality changes that occur during storage of apples in refrigerated chambers under air and in controlled atmosphere. We also tested changes of firmness, as well as total mass loss of apples in terms of different postharvest treatments.

2. MATERIAL AND METHODS

The examinations have been realized on apple fruits of the variety Idared. The same quantity of fresh apple fruits was stored in two chambers: with controlled atmosphere (CA) and under air, natural atmosphere (NA). In both of them, the temperature was 1^oC and the relative humidity (RH) of air was 85-90%. During storage in controlled atmosphere, the concentration of oxygen was about 5 vol % and the concentration of carbon dioxide was kept below 2 vol %.

Firmness was measured by a penetrometer (11 mm diameter probe) on pared surfaces from opposite sides of each fruit.

Total solids were determined by drying the samples at 105 ^oC to constant weight;
pH value was measured by TTT2, Radiometer, Copenhagen, Denmark;

Content of total acids were determined by neutralization method using NaOH (Trajković, et al. 1983);
Content of total sugar - by Luff -Schorl method (Trajković, et al. 1983);
Content of starch - by the method of acid hydrolysis (Trajković, et al. 1983);
L-ascorbic acid - by iodine method (Trajković, et al. 1983);
And the content of total pectin matters was determined from the extract by colorimetric method on 525 nm (Trajković, et al. 1983).
Total mass loss was determined by measuring mass of fruits before and after storage.

3. Results and discussion

The results of chemical composition of fresh apples and after storage under air (NA) and controlled atmosphere (CA) have been presented in Figures 1 and 2.

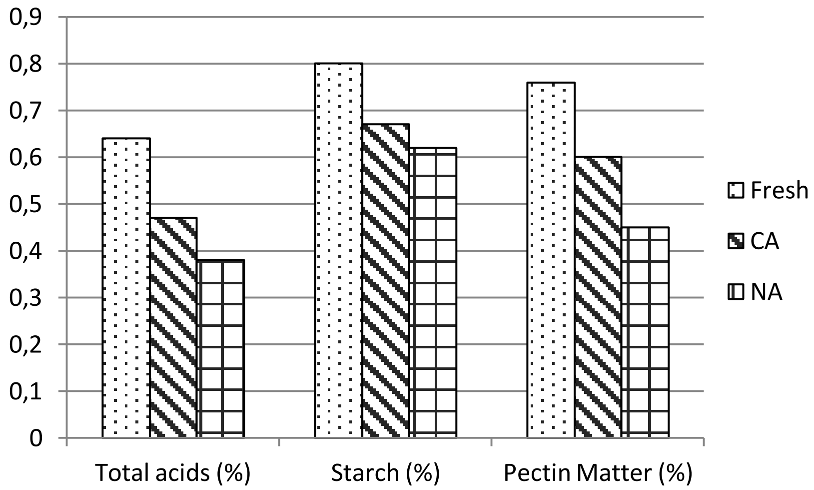

Fig. 1 Total acids, starch and pectin matters content in apples

The presented results indicate that content of total acid and starch of apples has been reduced after four months of storage. In postharvest period, metabolic processes of fruits still occurred, respiration continued and organic matter decreased, mostly carbohydrates and organic acids (Janković and Mašović, 2000). That is confirmed by the results obtained in our study and significantly lower total acid and starch contents were obtained after four months of storage. Results presented in Figure 1 show more changes when apples were stored in the refrigerated chamber under air, than in controlled atmosphere. In low oxygen atmosphere, respiration has been less intensive and reduction of organic matter has been lower. Reduced content of pectin matters may be accounted by the same explanations and their presence is related to the firmness of apples. In Fig. 1 it may be seen that the apples stored four months in controlled atmosphere had a higher retention of pectin matters than those stored in NA. These data are correlated with the measured firmness of the apples, Table 1. Reduction of protopectin content decreases fruit firmness that is confirmed by the results in Table 1. The lowest firmness was measured in apples stored for four months in NA, 4.48 kg/cm^2.

Table 1 Dry matter content, pH, firmness and total mass loss of apples

Samples		Dry matter (%)	pH	Firmness (kg/cm^{-2})	Total mass loss (%)
Fresh apples		13.52	3.2	6.50	-
After 4 months of storage	CA	13.81	3.3	5.55	1.88
	NA	14.17	3.4	4.48	4.84

Results of dry matter content are presented in Table 1. and fresh apples had 13,52 % of dry matter content. Obtained results for dry matter of storaged apples indicate its slight increase, which occurs as a result of evaporation and soluble solids concentration. Fikiin and Velkov (1982) also reported the increase in total sugar and dry matter content in apple variety Golden Delicious stored for six months. This coincides with the results obtained in our study, Fig. 2.

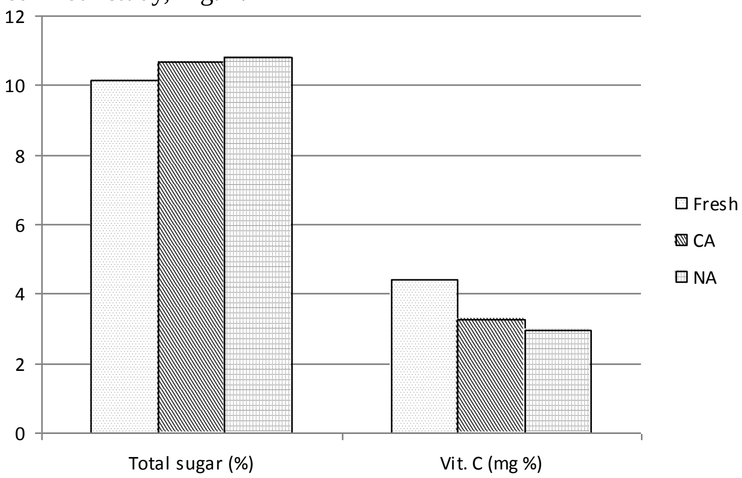

Fig. 2 Total sugar and L-ascorbic acid content in apples

Results indicate that content of total sugars increased after both storage treatment, but more total sugars were found in apples stored in the NA, which may be explained by higher starch hydrolysis, due to more intensive metabolic and biochemical processes in NA, than in CA. Reduced content of starch was in correlation with the increase of total sugars in stored apples. Changes in content of starch and total sugars were less in apples stored for four months in controlled atmosphere. It is difficult to compare obtained results with data of other authors, because experiments have been performed under different storage conditions, on different varieties of apples, or storage time has been significantly different.

The obtained results of L-ascorbic acid (vitamin C) content in apples before and after four months of storage (Fig.2) show its decrease after the mentioned storage period. However content of vitamin C was higher in apples stored in controlled atmosphere than in NA. Day et al. (1998) reported that modified storage atmosphere had beneficial effects on the retention of ascorbic acid. Similar findings were presented by Kader (2002).

Results of the total mass loss after both storage treatments are presented in Table 1. Higher total mass loss was determined after four months of storage in a cold chamber under air (NA). Considering that all samples of the same ripening degree have been stored at the same temperature and relative humidity, in refrigerated chambers of the same volume, with approximately the same evaporations of apples surface, the observed differences in quality changes and total mass loss can be explained only by the differences in chamber atmosphere content.

4. CONCLUSIONS

The results obtained in these examinations show that the controlled atmosphere can be effectively used for storage of apple variety Idared. There were less changes in chemical composition of apple fruits stored in controlled atmosphere, compared with apples cold stored in air. The loss of total acids, starch, pectin matter and l-ascorbic acid was lower in apples stored in controlled atmosphere. After four months of storage in cold chamber under air, apples had significantly smaller firmness than those stored in controlled atmosphere. Due to minor changes in chemical composition, fruits stored in controlled atmosphere had better taste, firmness, as well as freshness. Furthermore, total mass loss of apples was higher in the chamber with NA.

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Popular paper

ULO STORAGE OF APPLES

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Abstract. *"Ultra Low Oxygen" (ULO) storage system is applied throughout the world, especially for storing apples. ULO is the most contemporary system of preserving fresh apples up to 300 days. The main advantage of the ULO atmosphere storage is the slowing down of the ripening and aging processes of the stored fruits. In this paper were presented technical details of ULO storage system, and a respectable example of ULO storage. As example of the newest and most advanced ULO cold storage for apples in Serbia can be found in Celarevo. The new (second) ULO storage was increased the total storing capacity at "Podunavlje" estate to 13,000 tons and that is the biggest in Southeast Europe.*

Key words: *cold storage, ULO, capacity, apples, long-time storage*

1. INTRODUCTION

Contemporary technology of storage of fruit and vegetables, aims to control the process of breathing - respiration, maturation and aging of herbal products. By controlling the physiological, physical and microbiological spoilage significantly reduce losses while prolonged storage time, with maximum quality preservation [4].

Controlled atmosphere implies maintaining optimal low temperature and the optimum composition of the atmosphere, which slows down the respiration rate of fruits, transpiration - reducing mass loss and hinders the development of of molds and rotting fruit during storage. In controlled atmosphere usually keeps fruit, especially apples.

ULO (Ultra Low Oxygen) is one of the types of controlled atmosphere, which is technologically and technically most demanding because it requires: very good gas isolation, devices for achieving and maintaining the composition of the atmosphere and increasing energy consumption.

Today, almost two-thirds of the total apple production in the world is kept in refrigerated chambers with controlled atmosphere.

Some apple cultivars are susceptible to physiological damage if kept at temperatures below +3 °C, and in such cases the intensity of breathing can lower the reduction in oxygen concentration. The low oxygen concentration could lead to physiological damage or suffocation living cells and anaerobic fermentation [12].

Low concentrations of oxygen in the atmosphere of cooling chamber is the extremely unfavorable conditions for the growth of microorganisms. This storage mode to maintain higher relative humidity, in order to reduce drying of stored products, without increasing the risk of rotting.

Controlled atmospheres has advantages compared to the normal atmosphere:

- Prolonged storage time for 1-3 months,
- Increased total mass loss (evaporative mass loss and rotting)
- Preventing the appearance of physiological damage,
- Better preservation of the quality and organoleptic characteristics.

2. STORAGE OF APPLES

Regarding the storage of apples, following types can be distinguished: natural storage, cold storage and CA storage. ULO storage may also be considered as an independent storage method [6].

Natural storage

This method usually consists of putting fruit into a simple a chilled cellar, which preferably has high air humidity. However, this method of storage only plays a role only in the domestic and with fruit growin for a hobby. If thin transparent bags from polyethylene, which may occasionally need airholes are used a kind of CA storage may be achieved in the household.

Cold storage

In a cold storage is achieved by by refrigerating at a consistent tempature, which best suits the variety on a value from 1 °C to +4 °C. Apples and pears are stored between -1 °C to +0 °C. This is done to slow down the ripening process. Additionaly, cold storage equipment have an air humidification feature, which guarantees an air humidity between 90 % and 95 % to slow down the drying up of the fruits.

CA storage

A CA storage (Controlled Athmosphere) is a method of storage that is airtight cold storage. This process, in addition to controlling the temperature and air humidity, the composition of the air with reference to oxygen and carbon dioxide is controlled. The oxygen level in the air is reduced and the carbon dioxide level is increased to slow down the maturation process. The desired values in oxygen and carbon dioxide are technically adjusted or originate after some time through the ripening process of the fruits in airtight storage because as maturation (respiration) takes place, oxygen is consumed and carbon dioxide is generated.

ULO storage

A further development of the CA storage is the so-called ULO storage (Ultra Low Oxygen), which limits amount of oxygen to the necessary minimum limit for the maintenance of the biological ripening activity and thereby radically can be reduces the maturation process.

Dynamic CA

In DCA storage the levels of gases are monitored on the basis of the physiology of the fruit and data are passed to the control mechanism, which then adjusts the atmosphere in the cold storage.

2. 1 About ULO regime

Ultra Low Oxygen (ULO) technology represents the latest achievement in long-term storage of fresh fruit segment. ULO regime in chambers provides the storing of the entire apple crop and offer to the market at any time of the year. ULO (Ultra Low Oxygen) technology enables the apple to maintain unchanged properties for a long period without any chemical intervention [3].

ULO (Ultra Low Oxygen) technology cold storage is the third generation cold storage for long term storing of fruit and vegetables. It is used in developed countries of Europe (Germany, Denmark, France, Italy, Holland, etc.) for storing the total of 70 % of fruit, and around 50 % in the USA [1]. The first generation of cold storages in the world, Europe and in our country had a simple technology and was based on lowering the temperature in the cooling space and increase of relative humidity of air. In such storage conditions, the period of preservation of some products can be up to 3 months. Currently the majority of storages in Serbia and Vojvodina are of the first generation excluding the deep freeze cold storages. ULO cold storage technology, especially the one of the third generation, prolongs the season of fruit demand and guarantees the national population fruit and vegetable consumption in fresh state during the entire year, which is of great importance for the preservation of health of the population and large economic use and increase of the GDP of the country.

Second generation of the cold storages, or cold storages with controlled atmosphere (CA) bring further progress in the fruit and vegetables storing technology. Low temperature is controlled in these cold storages with moisture increase in the cooling space, gas participation is controlled, that is, oxygen share is reduced, and carbon oxygen level is increased, which slows the biological process of the fruit, and the storage period is prolonged from previous 3 months (1st generation) for additional 1 to 3 months, to a period of fruit storing of 6 months.

The third generation of cold storages or ULO (Ultra Low Oxygen) cold storages is the result of further research of fruit physiology. Basic principle of ULO cold storage operation is the temperature control, air moisture, oxygen and carbon dioxide. Plus cooling temperature is reduced in these cold storages and air moisture is increased depending on the fruit species with simultaneous control of oxygen presence parameters within the limits of 0.8 – 3 % and carbon dioxide of 0.7 – 5.0 % depending on the species of the fruit, sort and atmosphere area of the storage. This technology differs from cold storages of the second generation by reducing the intensity of fruit breathing for 30% thus eliminating harmful influence of carbon dioxide, by lowering the oxygen and carbon dioxide share in the cooling chamber atmosphere, which could not have been done in the second generation cold storages. In such storage conditions, all biological processes in the fruit are slowed down, so certain fruit species like apple can be stored for 12 months and more, without significant loss of quality of fruit from the moment of picking, except for significant reduction or elimination of certain physiological diseases of the fruit appearance.

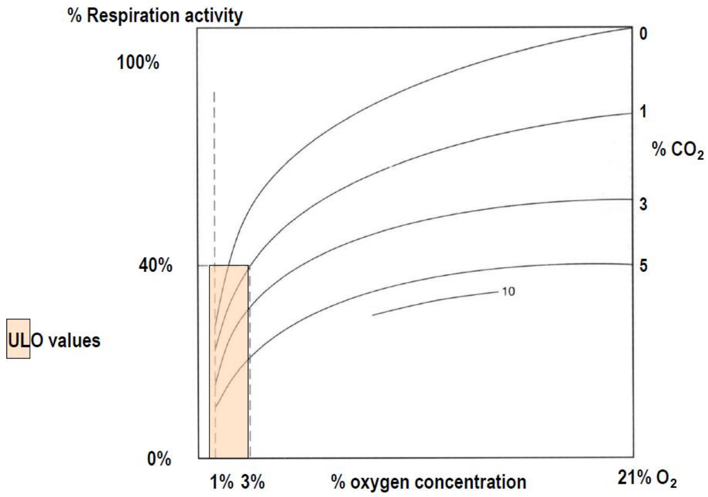

Fig. 1 Respiration graphic

The effect of oxygen and carbon dioxide levels on respiration activity during storage

Aim: minimal respiration in the fruit without choking it. Solution: storage in the maximum CO_2 level and minimum O_2 level (these levels are different for each variety

2. 2 reliable gas-tight storage system

Reliable gas tightness of the storage is of utmost importance for creating a controlled atmosphere with a level of oxygen. It is obtained by means of a precise construction system, adequate insulation panels, a gas-tight system and a gas-tight door.

Reliable refrigeration and humidification system

The installed equipment ensures efficient storage of fruit and minimal moisture loss during storage. Many years of experience have shown that in order to reach the desired parameters of cooling, a system with indirect cooling is the best choice.

The dedicated Computer Control System provides fully automatic operation of the entire system.

Energy efficient CO_2 scrubber, N_2 generator and analysing system

Should be installed energy efficient devices that ensure low levels of oxygen and carbon dioxide in the storages and maintain their concentrations at the desired levels with low consumption of energy. In this way, the controlled atmosphere storage constantly monitors and adjusts the CO_2 and O_2 levels within the gas-tight stores and slows down the metabolism of the fruits as well as preventing the development of potential storage diseases.

The storage capacity of individual storages depends on needs. The selection of individual storage chamber capacity depends on the amount of the fruit that it is possible to place on the market in certain period of time [9, 10, 11].

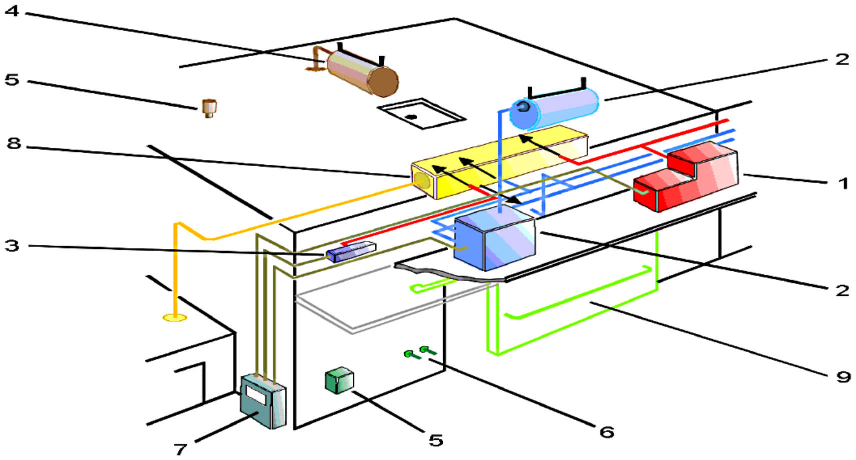

Fig. 2 General plan ULO - installation

1 - N_2-generator, 2 - CO_2 adsorber, 3 - Aeration unit, 4 - Pressure compensator, 5 - Pressure securities, 6 - Additional connections for (hand) analysis, 7 - Central control system, 8 - Cooling system, 9 - ULO-door

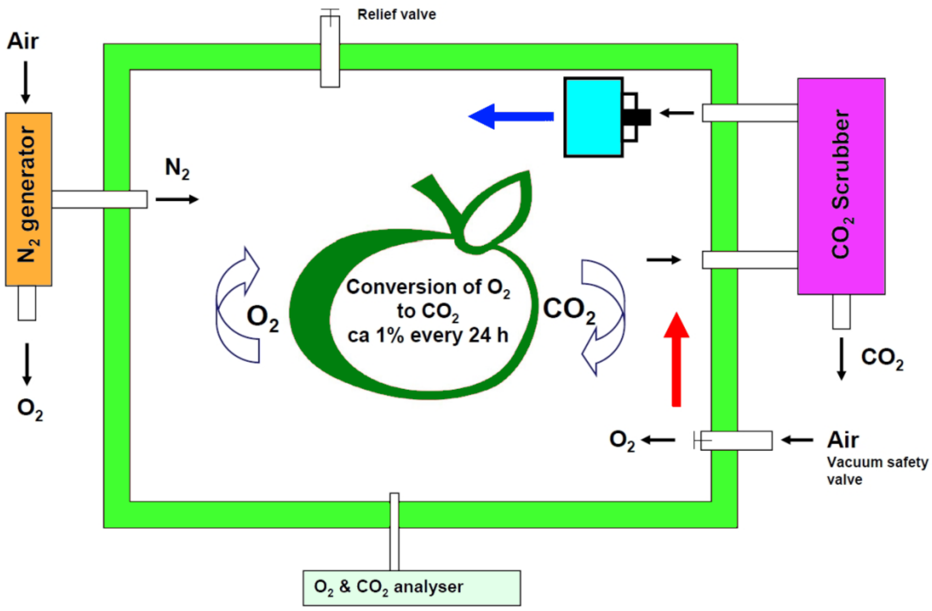

Fig. 3 Working principle of the cold storage

Cooling-down of the warm fruit

Reduction of oxygen level by blowing in nitrogen (N_2) from the nitrogen generator.

The fruit itself will also consume O_2, and transfer it into CO_2 (respiration).

CO_2 level controlled with the CO_2 adsorber (adsorption with active carbon).

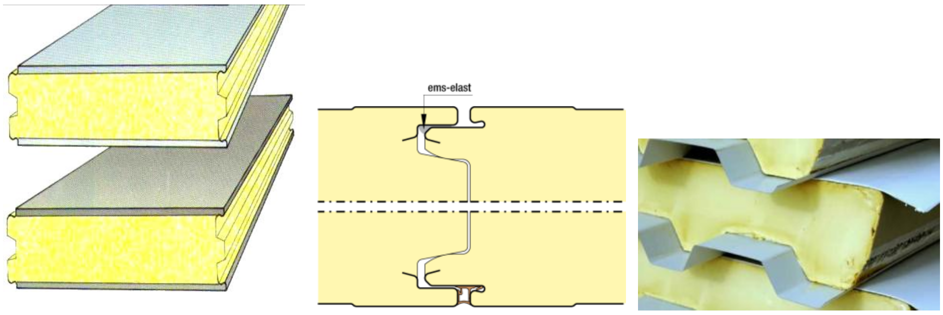

Fig. 4 Polyurethane insulation panels (PUR)

PSA (Pressure Swing Adsorption) nitrogen generator

Fig. 5 PSA (Pressure Swing Adsorption) Nitrogen generator

By lowering the level of oxygen in the cold store, respiration is slowed down and the ‘metabolism’ of important nutrients in fruits and vegetables is reduced. The objective is to keep the oxygen level in a cold store as low as possible in order to maintain quality and delay the ageing process as much as possible [2, 4].

The reduction of the oxygen level in a cold store can be accelerated using a PSA (Pressure Swing Adsorption) nitrogen generator. A PSA generates pure nitrogen from normal ambient air which will be used to expel the oxygen from the cold store.

The PSA nitrogen generator consists of two vessels fitted with extremely high-quality CMS (carbon molecular sieve). A CMS is capable of adsorbing oxygen molecules for a particular length of time. When saturation is reached, the system automatically switches to the other vessel by means of valves. The saturated vessel is prepared for the next cycle by depressurizing it, after which the adsorbed oxygen molecules are released and purged. Thanks to this simple principle, the reliability and lifespan of the PSA nitrogen generator is extremely high.

All our PSA nitrogen generators are provided with filters and automatic drains so no fluid or oil can reach the CMS.

The capacity of PSA nitrogen generators is chosen/determined depending on the volume and number of the cold stores.

CO_2 adsorber

Fig. 6 CO_2 Adsorber

Fruit and vegetables ‘breathe’, a natural process in which oxygen is converted into CO_2 (carbon dioxide). An increased CO_2 level in a cold store ‘calms’ the fruit, but an excess will cause damage and must therefore be removed [4].

A CO_2 adsorber, also known as a scrubber, removes carbon dioxide from cold stores, along with a small portion of the harmful ethylene present. The CO_2 adsorber contains active carbon, which has the characteristic of adsorbing CO_2 molecules (binding them to it). By efficiently transporting the air from the cold store, passing it over the active carbon and returning it to the cold store, the CO_2 is effectively removed from the air in the store.

Besides a user-friendly control panel for setting the actions per cold store, the adsorber is equipped with an ‘adsorber lung’. This patented system guarantees absolute low oxygen operation which means that virtually no oxygen can enter the cold store (ideal for storage under ULO and/or DCA conditions).

A frequency-controlled ventilator reduces energy consumption to a minimum – an important benefit because an adsorber runs for the majority of the day. In addition, the diameter of the pipe is matched to the size of the ventilator so no heat can enter the cold store as a result of friction.

Every fruit and vegetable variety has its own CO_2 production and maximum permitted CO_2 value.

Ethylene converter

Fig. 7 Ethylene converter

Ethylene gas is produced by fruit and vegetables and accelerates the growth, development, ripening and ageing of the product. Some fruit varieties, are extremely sensitive to ethylene. The ethylene converter removes this harmful ethylene gas. In this way, products retain their 'eternal youth' [4].

The ethylene converter consists of two columns, each with a heat storage medium, a catalyst, heating elements and one ventilator. In turns, cold store air is guided upwards and heated per column. The air then passes through the catalyst bed where the ethylene gas is broken down. Finally, the air flow passes through the second catalyst bed, where the remaining ethylene is broken down and the air cooled back down.

With the ethylene converter, an ethylene level of 1 ppb (0.0000001%) can be achieved without making use of chemicals. This makes the process extremely environmentally-friendly. Thanks to heat recovery and accurate control of the optimum temperature, the converter consumes minimal energy.

Measurement and control technology

Measurement and control system (MCS) can be used to control cold storage facility fully automatic. Only need to set the required values and the system will measure, control and maintain your chosen atmosphere.

MCS can easily be expanded with the addition of a cooling module that allows any type of cooling system to be managed. It controls the cooling valves, defrost valves and ventilators, based on target values which you can set yourself. Besides temperature, relative humidity can also be measured and regulated, as can the quantity of defrost water, if required. Thanks to this total concept, MCS is capable to control your entire cold storage facility.

The analysis system can be connected to a PC with Win Software. In this way settings can easily be changed and the measured data are stored automatically. The registered data can be graphically displayed and printed, making it possible to generate various reports and, for example, compare different periods.

There are also portable measuring equipment for manual measurement of O_2 and CO_2 values.

Cold storage protection

During a storage season, a cold storage facility is constantly exposed to changing conditions that can directly affect the atmospheric conditions inside.

Breather bag / Bufferlung; As a result of changing air pressure and the temperature fluctuations inside the cold store, the air volume is constantly subject to changes. In order to neutralize these variations, a breather bag is fitted onto the cold store. The bag stores the excess air of the cold store and if necessary (in case of low pressure) returns it to the store. This prevents ingress of oxygen-rich outside air into the cold store.

Overpressure / underpressure protection; Under extreme conditions, a breather bag only is not sufficient anymore. For this reason, cold stores must also be equipped with overpressure and underpressure safety valves which starts operating at an overpressure / underpressure of 10 mm water column. Without this safeguard, the ceiling and/or walls of the cold store can be severely damaged.

Aeration ventilator; Based on measurement, the aeration ventilator keeps the CO_2 percentage low during the loading / cooling period and allows oxygen to enter the store in a controlled manner during CA storage.

2.3 Optimum storage conditions for apples

The optimum storage conditions for apples depend on the variety, harvesting moment, regions, location of orchard, etc. The advice below [7] provides general storage conditions that are scientifically recommended but not specific for a particular region.

Table 1 The optimum storage conditions for apples

Appel variety	Temp. °C	Rel. Humidity %	C.A.	Storage time
Braeburn	0,5 – 3	90 – 95	3 weeks cooled, then 1% CO_2 1.5% O_2	6 – 9 months (ULO)
Elstar	0 - 4	90 – 95	first month 1 – 2.5% CO_2 1.3% O_2 then 2.5% CO_2 1-1.2% O_2 or DCA	3 months (just cooled) 7 months (ULO) and 8 months (DCA)
Fuji	0 - 1	90 - 95	1 – 2.5% CO_2 1 – 2.5% O_2	1-7 months (just cooled) 8-11 months (ULO)
Gala	0 – 2	90 – 95	2% CO_2 1.2% O_2	3,5 months (just cooled) 6,5 months (ULO)
Golden Delicious	0 – 4	90 – 95	First month 4 % CO_2 1.3% O_2 then 4 % CO_2 1-1.2 % O_2	3 months (just cooled) 10 months (ULO or DCA)
Granny Smith	-0.5 – 2	90 – 95	1 % CO_2 1 % O_2	1 – 6 months (just cooled 7 – 11 months (ULO)
Jonagold	0 – 2	90 – 95	First month 4 % CO_2 1.3 % O_2 then 4 % CO_2 1-1.2% O_2 or DCA	3 months (just cooled) 9 months (ULO)
Red Delicious	-1.5 – 1.1	90 – 95	1.5 % CO_2 1 % O_2	3 months (just cooled) 10 months (ULO or DCA)

Braeburn: susceptible to a series of storage deficiencies that can be inhibited by CA (Ultra Low Oxygen)
Elstar: low susceptibility to storage deficiencies with the exception of spots on the peel.
Fuji; If harvested late, do not store in high CO_2; at 0.5% CO_2, internal brown discolouration is possible. Susceptible to Scald; this risk is significantly reduced with ULO conditions.
Gala: Very susceptible to Scald; this risk is significantly reduced under ULO conditions.
Golden Delicious; CA storage is perfect for Golden Delicious. Very susceptible to Scald; this risk is significantly reduced under ULO conditions.
Granny Smith; At lower temperatures, there is less chance of Scald and Core flush. Not very susceptible to storage deficiencies with the exception of Scald and this risk can be eliminated under ULO conditions.
Jonagold; not especially susceptible to deficiencies < 1 % O_2 can cause flavour deterioration.
Red Delicious; susceptible to Scald, which can be combated with ULO storage.

3. Cold storage of Delta Agrar in Čelarevo

As one example of the newest and most advanced ULO cold storage for apples in Serbia can be found in Čelarevo.

At “Podunavlje”, estate of Company Delta Agrar in Čelarevo, which is located at North - West of Serbia, there was built a new cold storage in 2014.

Fig. 8 Aerial view of orchard and cold storage in Čelarevo

The new (second) ULO cold storage was increased the total storing capacity at “Podunavlje” estate to 13,000 tons and that is the biggest cold storage in Southeast Europe.

In 2014 Delta Agrar is produced 16,000 tons of apples in Čelarevo orchard and about 8,000 tons in cooperation, while the largest part is intended for exports, and that 85-90% of yield contains first-class apples.

ULO cold storage is the most contemporary system of preserving fresh apples up to 300 days. Picked apples enter the chamber directly and without any chemical treatment, which is the practice with standard cold storages.

Fig. 9 Ultra Low Oxigen (CA) atmosphere storages - outside view

The orchard at “Podunavlje” estate in Čelarevo currently covers the area of almost 400 hectares. Upon the completion of the construction Delta orchard in Čelarevo will have the area of 600 hectares.

Podunavlje Estate has 200 full-time and 1.000 seasonal workers.

Apple production

In Čelarevo, company Delta Agrar on its agricultural estate „Podunavlje“ organizes intensive production of different apple varieties: Gala, Breaburn marriri red, Golden delicious, Red delicious, Granny smith, Gold rush and club apples Modi and FUJI KIKU. High and stable yields on big acreage, extraordinary quality, together with ideal climat conditions, makes this orchard significantly different comparing which other orchards in this region.

This orchard is build up under the Italian SUDTIROL tehnology, which means that varieties are carefully chosen, that apples are planted in large number per hectare – over 3,900 plants per hectare, that there is irrigation and fertigation system in orchard as well as anti hail and anti frost systems.

The apple is planted in dense spacing of 3.2 x 0.8 m, which ensures that the one hectare is 3,900 plants, as a prerequisite for obtaining high and stable yields. In addition to planting density, the high and stable yield more influence: high-quality planting materials, protection from adverse climatic factors and quality of irrigation. Irrigation system and weather station located in the GPRS system and allows remote control and monitoring parameters.The orchard is equipped antifrost system (the system against freezing), irrigation system (irrigation system), fertigation system (system of nourishment) and anti-protection system, making it the largest and most modern orchard this kind in Europe.The average yield of orchards in the fifth year of production is 60-70 t.

Fig. 10 Controlled atmosphere storages – manipulation corridor

Complete apple production take place applying the GLOBAL GAP standard, which besides the field production process control, also refers to the storage itself and provide export quality of apples.

Further step of production and sales of Delta Agrar's apples is presented with modern Ultra Low Oxigen cool storage with capacity of 13,000 tons [5]. Total annual yield of apples from our orchard can be stored in ULO cool storage up to 300 days and we can offer quality apples to market continuosly all over the year.

The cooler itself is installed Awetina line calibration and sorting of apple (in color, the diameter and Weight), capacity 10 t/h, which consists of the receiving part in which the robotic system with a defined places automatically takes the full range of Apple, is empty and returns to the second position blank range. Apples are the water during transport to the device for calibration of apples.

Fig. 11 Controlled atmosphere storages – ULO cold room

Beside their apple production, they organize the system of cooperation, thanks to which they are able to provide more apple varieties to the market, such as: Idared, Granny smith, Golden and Red Delicious, Jonagold, Jonagored, Cadel, Mucu in aproximate annual quantity of 10 – 15,000 tons in addition to their own.

On their second agricultural estate named „Jedinstvo“ in Apatin, was organized nursery for apple plant tree production. Nursery has production of over 250,000 plants per year. The plants are produced by italian technology from where certificated and no virus rootstocks are purchased. The bud woods are purchased from couple of Italian mother orchards. The varieties which Delta Agrar can offer are: Granny Smith, Golden Delicious Reinders, Gala, Breaburn and Red Delicious. Available packaging for apples are wooden, cardboard and plastic packaging.

The process of storage apples in cold storage

The steps are as follows:

1. Weighing and record the boxes brought from orchards
2. Entering into the chamber on cooling (temp. in the chamber is about 1.5 °C)
3. After the cooling chamber is closed and check pressure (as recommended, max = ΔhH_2O -3 mm for 30min, at an initial hH_2O = 10 mm)
4. If the Chamber meets starts the ULO regime (O_2 = 0.8 to 3 %, CO_2 is the most up to ½ of O_2), or DCA (O_2 <0.8 %)

5. When the need for raw materials, then turns off ULO regime, the chamber is ventilated (open both windows, and then open the door). When content of O_2 is safe, we bring a raw material in the production

At the end of the season cold storage is washed:

1. It starts with the removal of coarse impurities
2. Then, the panels wash with detergent (if need be)
3. Rinse detergent
4. Washing with water under pressure
5. Drying chambers
6. Disinfection with sodium hypochlorite. For security reasons for the success of disinfection using concentrations greater than 80 ppm
7. Wash of disinfectants
8. Closing and drying chamber

4. FUTURE DEVELOPMENTS IN APPLE STORAGE

We are constantly looking for new ways to improve storage performance. In the area of DCA (Dynamic Controlled Atmosphere) storage, there are several systems;

Besseling - Fruit Observer [4]; Like humans, fruit and vegetables respond to changes in their environment. When it is cold we get goose bumps and if there are not enough oxygen molecules in the air, we gasp for breath. In fruit and vegetables, we can see a reaction to the environment in the activity of chlorophyll, a substance which is naturally present in fruit, vegetables and plants. The Fruit Observer has been developed to determine the overall condition of fruit and vegetables. We are not only looking for an extremely low oxygen level. We can also show which other parameters cause stress – for example, excessive CO_2 values or too low temperatures.

DFR – Dynamic Fruit Respiration; DFR measures the respiration ratios of fruit and vegetables (O_2 consumption and CO_2 production). A simple calculation shows whether the oxygen level in the cold store is too high or too low, so that immediate action can be taken.

4.1 DCA – Fruit observer

The Fruit Observer determines the physiological condition of fruit and vegetables. Like humans fruit and vegetables respond to changes in their environment. When it is cold we get goose bumps and if there are not enough oxygen molecules in the air we gasp for breath. In fruit and vegetables we can see a reaction to the environment in the activity of chlorophyll, a substance which is naturally present in fruit, vegetables and plants.

The activity is measured by chlorophyll fluorescence, a natural phenomenon. Chlorophyll fluorescence changes rapidly when anaerobic respiration has been triggered due to lack of oxygen. Once the anaerobic point has been detected by the Fruit Observer the oxygen level has to be increased to a safe level so fruit and vegetables will return to aerobic respiration. By determining the lowest possible level you can store above this threshold and avoid harmful stress or even worse….

Low oxygen levels have proved their effectiveness during the storage of fruit and vegetables. The lower the oxygen level, the less the fruits respire and the less they deteriorate in quality. Moreover, disorders like scald can be reduced significantly. There is however a lowest limit to the oxygen level. The lowest possible oxygen level differs dependent on variety, season and the quality of the fresh produce.

The Fruit Observer™ software provides continuous information about the physiological condition of the observed fruit and vegetables. The initial screen of the software is split into two graphs showing:

1. Actions – levels of O_2, CO_2 , temperature and relative humidity
2. Reaction – chlorophyll response

The upper graph shows which parameter triggered the reaction of chlorophyll which is simultaneously displayed in the lower graph. This enables you to react adequately in order to prevent damage to your valuable produce. The Fruit Observer software operates stand-alone. This makes it possible to use the Fruit Observer technology also on projects equipped with other CA equipment brands.

Changes in the chlorophyll can also provide you valuable information about the quality of fruits and vegetables and helps you getting the best possible price for your produce.

4. 2 Dynamic CA Storage

The Dynamic CA system from Van Amerongen [7] applies CA conditions dynamically during the storage period (instead of setting this in advance). The equipment used for the 'Dynamic CA Storage System' responds to the physiological condition of the fruit in the cell and then automatically adjusts the storage conditions accordingly (storage, based on product response). Oxygen percentages of less than 1% are no problem because the oxygen concentration will be immediately amended if it threatens to get too low.

It is a huge challenge to ascertain the best and lowest oxygen concentration for storing fruit, given the various factors that influence this;

- Fruit variety
- Moment of harvesting (ripeness)
- Leak-proof capacity of cool cell
- Season/climate
- Growth location (micro-climate and geography)

All of these factors impact upon how active the fruit is (i.e. its respiratory activity). Determining the optimum oxygen concentration is, therefore, extremely difficult.

In general, the lower the oxygen concentration, the longer the fruit can be stored. There is, however, a lower limit in terms of oxygen concentration, at which point fermentation will commence; this can reduce the quality of the fruit (and its shelf life, as a result). This is why ‘safe’ O_2 concentrations, i.e. usually slightly over 1%, are usually used for storage.

Dynamic CA storage means that the fruit is automatically stored at optimum conditions which are constantly adjusted on the basis of the fruit’s respiratory activity. Oxygen percentages of less than 1 % are no problem because the oxygen concentration will be immediately amended if it threatens to get too low.

This provides maximum shelf-life.

Differences with other dynamic (CA) storage systems;

The term ‘Dynamic CA storage’ is not new. There are numerous systems on the market for Dynamic CA storage. What they have in common is that they all respond to the fruit and then adjust the storage conditions accordingly. How they respond to the fruit, however, differs in a fundamental way.

Overview DCA systems

Differences with other dynamic (CA) storage systems;

The term ‘Dynamic CA storage’ is not new. There are numerous systems on the market for Dynamic CA storage. What they have in common is that they all respond to the fruit and then adjust the storage conditions accordingly. How they respond to the fruit, however, differs in a fundamental way.

Conditions for DCA storage;

- conditions for gas-tightness of the cool cell are even stricter (if gas tightness is insufficient, DCA storage is not possible). Leak-proof capacity may not be over 0.1 $m^2/100m^3$.
- a cool cell is not a hospital; a product will not get better in a storage cell. The art is to reduce quality losses to practically zero.
- DCA storage requires not only the very best cell cooling but also efficient company logistics and picking disciplines.
- DCA storage is only possible if the product is homogenous in the cell; in short – 1 variety per cell and minimal differences in terms of development and ripening. In other cases, the most sensitive product in the cell may become damaged.

Below is an overview of the most well-known methods and the ways in which they work.

Harvest Watch TM

HarvestWatch TM is based on fluorescence technique, which is used to determine the extent to which the fruit is suffering stress (as a result of low O_2 or high CO_2). To this end, 6 individual samples of the fruit must be fitted with a sensor and a special monitor can then read out any changes in fluorescence. The system operator can then decide which amendments to implement in terms of the cool cell climate. HarvestWatchTM works with a minimal number of fruits for measurement.

DCS – Dynamic Control System (WUR)

This method is based on the (manual) measurement of alcohol in the flesh of the fruit. To this end, at the beginning of the storage period, several samples of fruit are sent to a laboratory once or twice a week; the laboratory then measures the alcohol percentage in the fruit and provides recommendations on the CA conditions. Van Amerongen conducted a three-year study into this system with Wageningen University.

ILOS (Initial Low Oxygen stress)

ILOS is not a storage system as such but a storage protocol. The protocol is used for apples and involves a significant reduction of oxygen at the beginning of the storage period. The 'stress' that is thus created in the form of alcohol production often seems to be an effective method for preventing scald. The ILOS protocol is followed with regular CA storage.

5. CONCLUSIONS

Optimal technical and technological solution for the storage of fresh apple fruits today represent the ULO cold storage. During the last few years, in Serbia was built more ULO cold storage. Building such capacity is a significant to fruit production in Serbia. Particular attention needs to be paid to the quality of the fruits which are entered in the ULO cold storage, because only the storage of fruits Extra and First Class economically feasible.

Apples can be stored in cold storage from harvest until the next harvest, but remains the question of profitability of such storage. The fruits lose quality (hardness, acidity, aroma), and the actual costs of the refrigeration drive are very high. To reduce the breathing rate, and thus extend shelf life of apples, despite the low temperature is applied and ULO technology (Ultra Low Oxygen), which means that it reduces the level of O_2. Composition ULO cold storage allows maximum slowing down of these processes. In this way prolongs shelf life while maintaining a high level of product quality. Thanks to ULO cols storage to the market can deliver the fruit in a very good quality.

DCA (Dynamic Control Atmosphere) cold storage is new technology applied for fruit conservation. It dynamically control the atmosphere and allows storing fruit at its lowest respiration rate. With DCA technology we can create the ideal conditions for the medium-long term storage of apples.

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Popular Paper

THE RISE OF SMARTPHONES ANDROID APPLICATIONS FOR AGRICULTURE MACHINES, NEW REVOLUTION OF FARM MACHINERY - FIELD COMMUNICATION?

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Abstract. *This paper explains the increase of smartphone Android applications use in agricultural machinery and equipment.*
According to a report published by the American Life Project Pew Internet 83% of adults in the United States have a mobile phone of some sort. Research shows that 35% of all American adults have a smart phone. In fact, one out of every two adults aged between 18 and 50 years old used one mobile phone. This is a huge potential for increasing use of these devices and the Android software in different areas and agriculture. Smart phone technology and free or very small price software application, creates new opportunities for the implementation and management of activities in agriculture, especially for small farms.
Increasing scarcity of water in semi-arid areas, due to population growth and drought, increase the need for more efficient use of resources in agricultural production. Make use of the smart phone provides emergency mode when the user can access and use information on land, water resources and rainfall. Some application also has the ability to reduce the use of fault records of irrigation water usage and duration of irrigation crops that consume a lot of water in the season.
This modern technology can be applicable in the near future in progressive cultural practice of Republic of Serbia, Republic of Srpska, and Montenegro.

Key words: *Smart phone, Android software, Agricultural equipment and machines.*

1. INTRODUCTION

According to research by International Data Services Inc. [7], more than 300.000 mobile applications have been developed in the last three years (2012-2015). Those applications have been downloaded more than 12 billion times. Smartphone application fit into four basic categories:

News applications have many rational applications for easily retrieve and organize updates and information from local news headlines to the latest market reports.

Calculators. The pocket calculator had a good run for three or four decades but today's smartphone applications can do a lot of the formulations for you. Whether calculating quantities of inputs, square footage of fields or the impact of grain costs on breakevens.

Social Media. Social media are tools that enable greater social interaction. It is possible to connect with your circle of friends, family and acquaintances in a broadcast format, while also enabling them to respond and interact with you in real time [10]. Social media platforms such as Facebook, Twitter, Four-square and LinkedIn are among the most popular. Farmers across the country are telling the story of agriculture by providing updates on farm day activities. For past decades the CB radio was the high-tech lifeline of agriculture, allowing farmers to communicate with their family or home base when out and about on the farm [6].

Record Keeping. For example: from pasture grazing records to serial numbers and check book register, applications are available to help you keep track of important information quickly and easily for operation in Agriculture. But with the advance of cellular networks and mobile computing technology, farmers can do a lot more than CB radio talk from the cab of their trucks and tractors [2].

Smartphones are loosely defined as mobile devices with more advanced computing capability and more connectivity than single-purpose cellular phones. Common platforms for smartphones include the Android, IOS, and Symbian [15].

The advance of these relatively inexpensive hand-held computers that can be used virtually anywhere, gives users access to all the information of the internet and puts tools such as calculators and record keeping literally in the palm of one's hand.

According to a report published by the Pew Internet and American Life Project [12], 83 % of adults in the United States have a cell phone of some kind. The survey finds that 35 % of all American adults own a smartphone. In fact, one in every two adults between the age of 18 and 50 is using one. Today software and internet applications allow users to perform an amazing variety of functions using a smartphone [11, 13]. In year 2010, projected number of cell phones is around 1.7 billion, and smartphones around 500 million. Smartphone have growth 300% in next three years [3]. But, today (2015), there are 7 billion mobile phones in use around the World. This is great potential and basis for the increase of use of these devices and the use of Android software in different areas [1]. While there are thousands of applications available for smartphone users, the most utilized function, according to surveys, is the web browser tool that allows users to connect to the internet over the cellular bandwidth or via wireless internet connections,

[4]. Accessing online banking, shopping, information and news is no longer the sole domain of desktop computers. Smartphones are becoming the tool of choice [14].

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Technology available to support a real-time irrigation smartphone application for turf that would result in more efficient irrigation scheduling which is needed to reduce water volumes applied and increase irrigation water conservation [9]. Study treatments included different irrigation scheduling methods: time-based schedule, smartphone application, and two on-site evapotranspiration (ET) controllers. Results indicated that the app and ET controllers resulted in significantly lower irrigation depths compared to the time-based treatment, ranging in water savings from 42% to 57% [9].

2. WHICH PROGRAMS ARE IN AREA: FARM MACHINERY - FIELD COMMUNICATION?

There are many programs of Android applications for smartphones are designed to communicate agricultural machinery - work conditions with the movement of machines in the field [16]. Applications of Android platform for agriculture can be very complex nature of the field of control and quality of machines to the way the use of working machines elements in the concrete conditions of an agricultural production [1]. This paper presents some of most important top Android applications for machines in some operations: machine maintenance, operating safety of machines, crop protection, fertilizing crops, irrigation equipment and registration of irregularities parameters exploitation of these machines.

Tyre Pressure Application. Firestone has introduced a free Europe-wide Android and iPhone application to help farmers maintain their tractor tyres at the right pressure. When the Tyre Pressure Calculator application is downloaded, users simply select their tyre size and then see the correct tyre pressure for the load and speed of their tractor. Operating a tractor on incorrect pressure shortens tyre life and can unnecessarily increase soil compaction, which reduces crop yield (Fig. 1).

When changing farming activity (for example between field work and road transport) the app can help farmers maximize tyre life by adjusting to recommended tyre pressure. Although iPhone users are already able to download the IOS app throughout Europe, Firestone plans to extend the service to smart phone users and other devices in the coming months through an Android platform and web-based version.

Tire Advisor. Now you can access all of Bridgestone's commercial tire products in one easily searchable application. Included are truck and bus tires (e.g., Bridgestone, Firestone, Dayton), Bandag retreads and off road mining and construction tires (e.g., Bridgestone and Firestone). There are several ways to quickly find the products you want to view. Each product selection provides useful information including, features/benefits, product images, technical specifications, and warranties. There are three easy ways to search for products: a step-by-step guided search, a filtered search and a keyword search that allows you jump quickly to a product you already know by pattern name.

Fig. 1 Application Tire Pressure screen

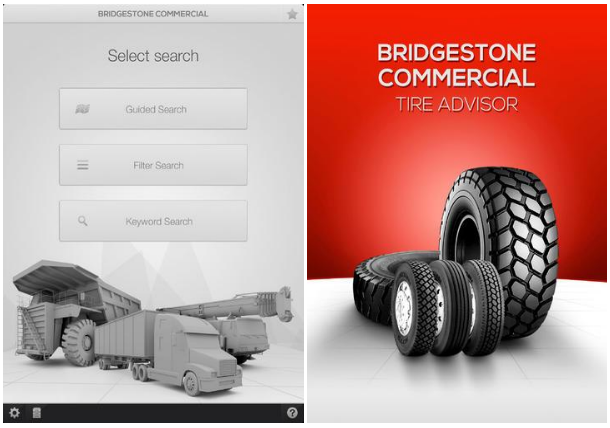
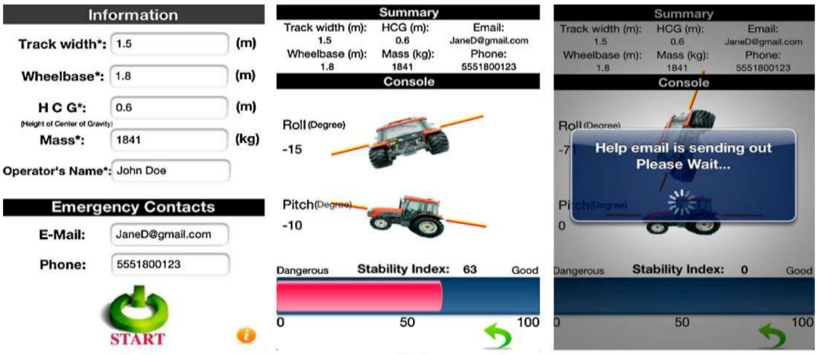


Fig. 2 Application Tire Advisor screen

The Functionality of Tire Advisor (Fig.2) includes: Three easy ways to search for products; Full product information traditionally found in a product book or website can now reside on your device and be available offline; Ability to compare products side-by-side within the same brand; Share product information with others by email. Save products to favourite’s folder with the ability to create multiple folders.

VRPETERS (Vehicle Rollover Prevention Education Training Emergency Reporting System) is developed by University of Missouri, USA. This application can detect vehicle collisions, side and rear overturns and rollovers due to centrifugal forces while turning curves. In case of an accident, VRPETERS transmits emergency notifications to predefined contacts automatically. VRPETERS can save lives by changing the human behaviour as a training tool; providing warning messages to the operator to prevent an accident; reducing the deployment time of rescue teams; and providing the GPS coordinates, the date and time of an accident. Application description a tractor rollover detection and emergency reporting software application, Safe Driving, developed for iOS-based mobile electronic devices (smartphones and tablet computers). The Safe Driving application uses a mathematical model to calculate the stability of a tractor using the physical parameters of the tractor and the data from the inbuilt sensors of the mobile electronic devices or the data from the external sensors attached to the tractor. When the Safe Driving application detects an accident, it sends automated email and phone messages with the GPS location, date, time and other critical information (Fig.3 c). The functions of the Safe Driving application VRPETERS were tested on a small-scale model tractor in laboratory conditions and on a 45 HP utility tractor in field conditions. The field-upset tests with the utility tractor were conducted for 10 times at 10.8 km/h and 21.6 km/h. During all these tests applications was successfully worked.

The Safe Driving application illustrated how a mobile electronic device can be used to monitor the stability of a tractor (Fig.3). The experiments in laboratory and field conditions showed that the proposed method to predict/detect an accident and displayed caution messages when stability status of the vehicle was poor. The phone number of the emergency contact was called automatically. The accident coordinates with a location map, the date, time and other important information were sent to the emergency contacts with the email message. The Safe Driving application is suitable for various motorized vehicles and it can be used for safety training of new tractor operators in classrooms and laboratories. The on-going research activities on Safe Driving application VRPETERS will include developing a database so that the user can select the make and model of the tractor to enter the physical parameters of the tractor rather than entering them separately.



(a) (b) (c)

Fig. 3 Application VRPETERS screenshots: (a) The user input screen, (b) real time vehicle stability monitoring screen, and (c) sending an email when accident is detected

Maximum Return to Nitrogen (MRTN) Calculator. Developed by the University of Illinois Extension and the Illinois Council on Best Management Practices, the app helps farmers and crop advisors determine the optimum nitrogen rate for corn and plan for split applications of nitrogen (fall, pre-plant, and post-applied). The MRTN calculator (Fig.4), also enables users to choose from various sources of nitrogen, add in stabilizers and calculate the corresponding application costs.

Fig. 4 Application MRTN Calculator screen

JD Link. This equipment management (Fig.5), application from John Deere is a telematics system designed to remotely connect owners and managers to their equipment, providing alerts and machine information including location, utilization, performance and maintenance data to manage where and how equipment is being used.

Fig. 5 Application John Deer Link screen

Mobile Farm Manager. This application from John Deere (Fig. 6), gives producers easier access to important farm and field information through their mobile device. The app also connects to customers' Apex farm management software. Features include field maps, historical reports, GPS tracking, field navigation and soil sampling grids.

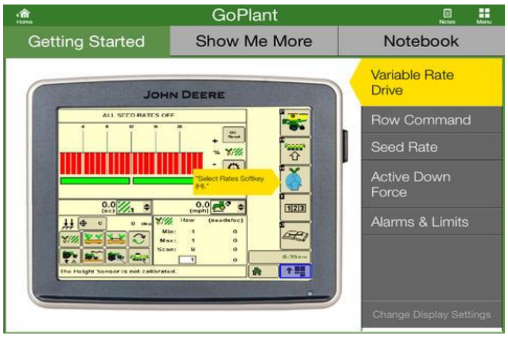


Fig. 6 Application John Deer Farm Manager screen

AgSeedSelect. This is Monsanto's first attempt at building an app for its seed brands: As grow, DeKalb and Delta pine. AgSeedSelect lets users create, store, e-mail and print a custom seed guide tailored to their specific geography and crops. Featuring videos by territory agronomists, the app provides detailed information on products for corn, soybeans, cotton and other crops (Fig. 7).

Fig. 7 Application AgSeedSelect Monsanto screen

TeeJet Technologies SpraySelect application enables users to quickly and easily choose the proper spray tip for a given application (Fig. 8). Enter speed, tip spacing and target rate, then select the droplet size category and a list of recommended tips is provided. Specific gravity input is also included for use when applying liquid fertilizers. SpraySelect allows you to quickly and easily choose the proper tip for your application. Just enter speed, spacing and your target rate, select your droplet size category and a list of tip recommendations are provided. US and Metric units are supported along with six languages – English, Spanish, French, Portuguese, German and Russian.

Fig. 8 Application TeeJet Technologies SpraySelect screen

Connected Farm. This application (Fig.9), from Trimble allows farmers and agronomists to map field boundaries, enter scouting attributes for pests (weeds, insects, diseases), take geo-referenced photos and manage collected data online through Trimble's Connected Farm. The app is flexible to use with any crop, including corn, wheat, soybeans and cotton.

Fig. 9 Application Trimble's Connected Farm screen

Trimble's Connected Farm have monitor for entire fleet from any location with a smartphone or tablet (Fig. 9). The application is a powerful management tool for viewing current equipment locations and status in order to increase fleet efficiency and productivity.

View the current status of equipment while overlaid on background imagery or road maps. Navigate to equipment from current position using turn-by-turn directions. Receive geo-fence and curfew alerts. View historical positions of equipment [5].

Trimble's Connected Farm have monitor and control of centre pivot irrigation systems (Fig.9), in real-time from any location with a smartphone or tablet. The irrigate application helps farmers reduce trips to the fields, manage multiple pivots, and ensure the right amount of fluid is applied in the right place. Screen has position: e status (on/off), direction, heading, pressure, voltage and material applied; Control the application schedule, start or stop, and the direction of each pivot and switch the type of material being dispersed.

LoadOut. This application from Lextech allows drivers to control grain loading from inside the cab, helping to streamline the process and increase driver safety (Fig. 10). LoadOut enables drivers to view a camera positioned above the grain loader from their iPhone while in the truck. From a push of the button, they can begin – or stop – the loading process.

Fig. 10 The Camera and Application LoadOut and screen

Field NET Mobile from Lindsay. Allows users to control and monitor their irrigation pivots from anywhere. The interface features real-time text alerts, water usage reports and more. Field NET (Fig. 11.), Mobile would require a Field NET account and the wireless solutions that work with Lindsay's plug and play equipment. Field NET Mobile provides growers that have a Field NET account and wireless control hardware, the ability to remotely monitor and control their irrigation equipment.

Key features of Field NET: Fast and easy control of centre pivots, lateral move systems, and drip/micro-irrigation systems; Monitor and control pumps; Graphical real-time status (icon shows) of all equipment; Monitor sensors for pressure and flow; Map view shows location of equipment;

Advanced functions of Field Net: Control water on and off; View alert history; Real-time irrigation plan progress; Sort equipment by predefined groups; Help index; Quick link to full website English and metric units; Text message alerts; Integrates with Watertronics pump stations; Graphical status of pressure, showing current pressure and set point; Graphical status of flow, showing current irrigation demand and available pump capacity; Graphical status of power consumption; Monitor other sensors, such as inlet pressure, and water level; Control pumps; Pump station alerts; Monitor and control features may vary based on irrigation controller types and sensor options; Secure access with Field NET username and password for any person.

Fig. 11 Application Field NET screen

PureSense Irrigation Manager. Allows users to monitor their real-time field conditions and irrigation activity from their phones (Fig. 12).

Fig. 12 Application PureSense Irrigation Manager screen

PureSense [8] is a premier real-time irrigation intelligence company providing remote monitoring, control and decision-support tools to the agricultural industry. Since 2006, PureSense has supplied useful, innovative technology and unparalleled service and support to more than 400 growers with over 50 crop types across 14 states.

PureSense empowers growers to make better irrigation decisions that enhance crop health and yield and reduce cost. In addition, PureSense soil moisture and water pump monitoring solutions enable growers to leap forward in efforts to achieve resource sustainability goals.

3. CONCLUSION

Efficiency in agriculture, process control, and communications are all closely related to the use of information and communication technologies (ICT). The global network, the Internet, mobile (smartphones) communications are crucial for advanced of contemporary agriculture.

A Smart phone technology and Android software application creates new opportunities for farm management applications in agriculture, especially for small farms in the country around of World.

Smartphones/precision farming systems are expected to play an important role in improving farming activities.

A Smart phone technology and Android software application created for irrigation technologies offers the convenience of alerting users when irrigation changes are needed using real-time and forecast weather data. Since these recommendations are sent via push notifications, users are informed when changes are necessary providing useful interaction without overburdening with information.

The authors of this paper believe that in the near future should be as soon as possible consistent application of such Android software application for many agricultural users. Now the implementation of the program barely registered with small farmer's agriculture of the Republic of Serbia, Republic of Srpska and Montenegro.

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Popular Paper

ANDROID SMART PHONE APPLICATION FOR CONTROL PROCESS IN PROGRESSIVE AGRICULTURE PRODUCTION

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Abstract. *This paper explains the development and implementation of a mobile application to make fieldwork easier. The application uses a number of devices in a Smartphone such as a GPS or a camera to collect information and broadcast it to an office in real time. Smart phone technology and Android software application creates new opportunities for farm management applications in agriculture, especially for small farms in EU and USA and the other country of World. Farmers working in agriculture now are able with a low cost smart phone and the specialized different Android application to obtain facilities that could not have before. The use of the Android software application in a smart phone can overleap the high difficulties of Agriculture management requirements which were stand as obstacle for many years so far. The downloading mobile application is staggering, and there appears to be no slowdown in the future. In fact, iOS application download could exceed 100 million per day by 2017. The otherwise this download has also had a huge impact on agriculture in USA and EU, with mobile applications. However for every useful application, there are likely several that will be abandoned after one use. Consider 53% of vendors say they are using less than 20% of the total number of agriculture-related applications they have ever downloaded on their tablets on -at least a weekly basis, according to a recent Crop Life Media Group study for year 2015.*

In this paper present only some top Android smart phone application for 2014. and 2015 (applicable in the near future in modern and progressive agriculture of Serbia, Montenegro and FYR. Macedonia).

Key words: *Android software, Smart phone, Application, Progressive agricultural*

1. INTRODUCTION

A smart phone is not only the device that allow us to make telephone calls [4], but also has additional features and capabilities that, in the past, you would have found only in a personal digital assistant or a computer such as the ability to send and receive e-mail and edit Office documents, internet access, Wi-Fi and modem ability, easy touch screen operation and most of all the capability to run powerful custom software. In fact this opportunity has been identified and several mobile applications have been developed for data acquisition in the field [9], livestock management [2] and several other that appeared as commercial mobile applications for farm management (e.g. John Deere Mobile Farm Manager, Farm Works mobile [6]).

According to the literature, mobile applications are used successfully in the areas of health care, traffic monitoring tourism, education [3]. Mobile services in the agricultural sector are a fact today. Collected information such as climate data that can be applied to production management [5]. Theodoros L., et al. [10], have an Android application for the management of small farms.

A smart phones make it possible to work with real-time data; this is an important factor in decision support systems and in documentation and traceability systems to track products or product properties [1]. The studies mentioned show how different sectors can benefit from mobile services in different ways, given their diversity of needs and conditions.

Smart phones (and operation system Android) are the product of the convergence between regular mobile phones and PDAs [3]. Our working lives have been changed by the increasing use of these devices, whose small size and low weight provide convenience and portability. From a social point of view, mobile communication has an unquestionable relevance. It has also created new forms of business [3]. In recent years, the interest of the scientific community in such communication has increased. The small farms [10], have many complications: A small farming size (3 up to 60 hectares), and High fragmentation fields (many small fields (0.3, 0.5, 0.8 hectares), scattered average in 15 miles radius. Many hired fields from different owners that are changing annually and no specialized employees for supporting the farming process. No clear views of keeping records of past year processes, and any relational information about seed - field - field type - processes - production results. So no information about results of practices been taken on the fields (e.g. percent of success of an applied chemical, and no ability for easy estimations of project and process planning. Most small farms and farmers [10], have not detailed record keeping of the equipment obtained - sold and its maintenance been performed, ability for exact calculations of production cost per hectare, and have not ability for cost estimations for a planning year.

The above characteristics constitute the difficulties that small farms are facing daily. Many farmers who try to be organised put a lot of effort to keep written records of their management approach but most of these notes are hand written notes which are not well organised, cannot be easily linked and compared to data from previous farming years, and in many cases are lost in the cabs of the tractors and other machinery. Obviously, this interest has been raised primarily because a smart phone using specialized software for various farm management processes is the ideal solution for small farm managers. A smart phone can be a mobile office that is very handy, can be carried on in a pocket, stand on at any agriculture machine (different tractor, combine, car). Smart phones have another characteristic that is very important for small farm managers. This is the 'user interface'. A smart phone touch screen with abilities to zoom in and out with the combination of the simple interface 'buttons, menus and forms' with the support of qwerty keyboard makes them easy to operate for people who are not very familiar with ICT technology. In this category belong most farmers. Especially, old farmers are not very familiar with technology.

Thus, even the best software if it is supplied with bad user interface and not easy operation, it will never be adopted by farmers. Farmers require software that is easy to operate and ask only for the specific data required to complete an operation or a process. Farmers have no time to waste for recording an operation on a field. They will prefer to perform the operation rather than recording it. Thus, software has to be very simple as you can talk to a machine about the operation. To this end it must be said that mobile devices are coming with accompanying tools such as GPS, accelerometer, proximity measurement, etc.

All the above characteristics make the smart phones the future of computing in modern societies but also give a hand to small size farmers in order to have a weapon to walk with their management difficulties for an easy, fast and up to date knowledge extraction that can boost their production.

2. HOW DOES OPERATE ANDROID APPLICATION FOR AGRICULTURE

The major objective of the present research was to develop and implement an application using the GPS, camera, accelerometer and Wi-Fi/GPRS devices of Smart phones so that technical staff can use it as a tool in fieldwork when inspecting agricultural plots.

The product developed was GeoFoto an Android applications for agriculture [7]. A GeoFoto session begins by starting the program from the application menu (Fig. 1a). The first step is to select the main menu or the settings menu (Fig. 1b). In the settings menu (Fig. 1c), user can select between storing coordinates in geodesic or UTM projection mode, time interval between epochs and the number of epochs. If the user is working indoors, inside a building, for example, he/she should select "working without connection". In this case, the photograph will be taken without GPS information. Finally, the user can decide how the information is stored.

Fig. 1 GeoFoto screenshots: (a) access to the application, (b) initial screen accessed by the user (c) settings menu, (d) main menu and (f) digital blackboard, (e) possible application in the identification of pests and diseases

Data can be sent by e-mail or stored in an SD card. When the user starts to take photographs, a new window appears, showing the image recorded by the camera in full screen (Fig. 1d). Four buttons are shown at the bottom of the screen. The first one on the left shows or conceals the coordinates on the screen. The second button is the compass and shows the orientation of the Smartphone. The right button shows a new screen where the user can enter additional data (Fig. 1e). This information is later printed on the image and included in a text file and in an e-mail. The camera button is used to take photographs. This button is only enabled once the GPS coordinates have been obtained. If the user selects the settings menu to work indoors, this button is enabled immediately.

Each camera shot generates two files; an image and a text file. Files are named using the concatenation of date and time values. The e-mail subject is also generated using this rule, which prevents any confusion when managing the data. All the recorded data are processed and automatically e-mailed in real time to the office or laboratory, where the information is received and analyzed. This makes it possible to verify that the user has visited the correct plot or that the number of samples collected is enough. Thus, if something goes wrong the problem can be corrected in real time.

3. Applicable of Android Smart phone mobile application for control process in progressive Agriculture Production (applicable in R. of Serbia)

In the introduction to this work has notes about downloading mobile Android applications is staggering, and there appears to be no slowdown in the future.

In fact, iOS application download could exceed 100 million per day by 2017. Therefore these Android smart phone mobile application for process control in

Agriculture Production in the www.market, are different in terms of quality, relevance, cost and accessibility in some regions and countries.

In this paper display Android smart phone mobile application are important for Balkan region and level of development of actual agricultural production.

The Farm Manager is an Android application which is developed at the labs of the Technological Education Institute of SERRES. The main feature of Farm Manager is that, unlike the other tools mentioned before, it is specialized in Greek farming because it is designed and developed to respond to the needs and. Here, we will present the key characteristics of the Farm Manager software that it makes it usable and useful for many agricultural management needs. The Farm Manager (Greece, Thessaloniki), is a useful Android mobile application software tool for small farm management specialized in the needs of Greek farming and potentially other countries which share common characteristics. Farm Manager is currently available since April 2013 and there are more than 347000 people who read about it (http://web2.teiser.gr/web-programming/FarmManager/welcome.html). It is currently used by more than one thousand farmers in Greece from which we have received initial positive feedback. This is very much in line with a finding reported in an ICT adoption study back in 2005 [8]. Then the authors analyzed and contemplated: Probably in Greece and in other countries, which have such high adoption rates of mobile phone technology, it can be used and deliver to farmers IT applications and services that are easily accessible and easy to use. Especially with the new high speed cell network protocols such as 3G and GPRS which promise fast multimedia delivery and fast connection to the Internet, mobile phones can be proved as the best devices for Greek farmers.

Farm Manager is an important step towards this development and its adoption rate is very impressing so far. Currently the tool is expanded to support high management requirements such as accountant facilities, ground analysis, store management, production result and annual use knowledge extraction. An initial version for Windows mobile is available and iPhone edition is under development.

Tractor Pal. This application (Fig.3), keeps inventory and maintenance records for all your personal agriculture machines and attachments, including cars and trucks of all brands. Tractor Pal enables you to log all of your large and small machinery and automobiles including tractors, pickups, lawn mowers, cars, combines, sprayers, loaders, skid-loaders, backhoes, attachments, and more.

Fig. 3 Application Tractor Pal screen

Application Tractor Pal record each item's maintenance (e.g., changing oil, filters, tires, and irregular repairs), and will remind you when service is required. (*Applicable for:* Android).

Machinery Guide. You can use your tablet or smart phone as a precision tractor GPS system using the Machinery Guide application (Fig.4). It is one of the first guidance software programs that functions as a precision farming application using an antenna. These antennas are capable of receiving and processing free corrections (e.g., EGNOS, WAAS).

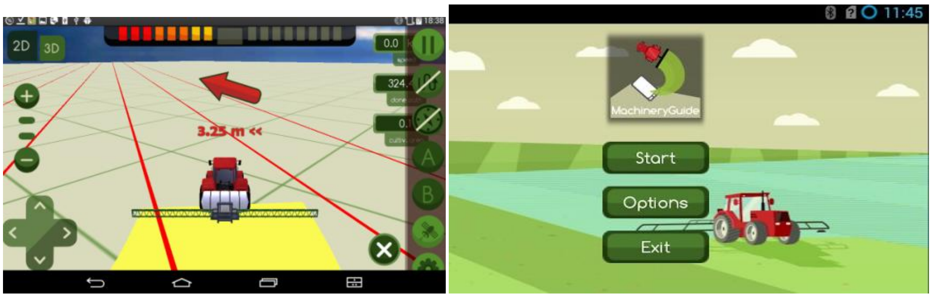

Fig. 4 Application Machinery Guide screen

It can be used for any farming activity which is done by tractor or other agricultural machinery, including fertilization, manure application and spraying. It even can be used for land measurements as well. *(Applicable for:* Android*).*

Agrivi Application. Based on best-practice production processes for more than 60 crops, Agrivi application (Fig.6.) guides farmers to improve their production and increase productivity.

Its features include project-oriented farm management with a simple and fast way of planning, monitoring and tracking all farm activities and inputs usage, advance sales and expense tracking ensures taking control over farm finances, inventory management with low inventory alarms removes delays in production caused by lack of inputs and weather monitoring with detailed 7-day weather forecast and 3-year weather history for each field and smart disease risk detection alarms. *(Applicable for:* Android, iPad, iPhone).

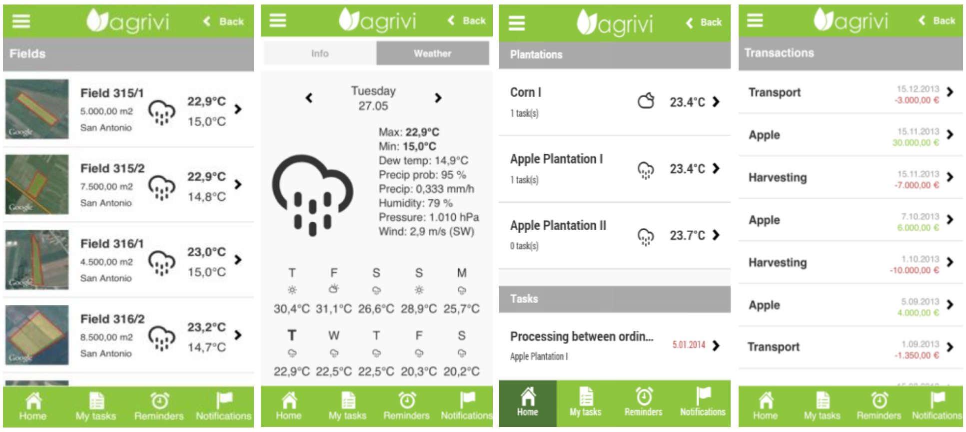

Fig. 5 Application Agrivi application screen

The Corn Yield Calculator, developed by lifelong farmers, allows you to quickly estimate the amount of corn in a given field (Fig.6.). Once in the field, simply “pick” three ears and determine if you have small, medium, or large kernels of corn. Next, provide specific field data for that field, including row spacing and row length, and the app will calculate the yield. *(Applicable for:* Android, iPad, iPhone).

Fig. 6 Application the Corn Yield Calculator screen

4. CONCLUSION

A Smart phone technology and Android software application creates new opportunities for farm management applications in agriculture, expecialy for small farms in EU and USA and the other country of World. Farmers working in agriculture (EU, USA) now are able with a low cost smart phone and the specialized different Android application to obtain facilities that could not hove before . The use of the Android software application in a smart phone can overleap the high difficulties of Agriculture management requirements which were stand as obstacle for many years so far.

Recent advancements on smartphones (Andriod Application) and the capabilities of the related software, can offer great easiness and wider access and extend the reach of agricultural information and services to the public. However, the use of smartphones and application programs for all agricultural operations and tehnologies associated with other public services is not yet on a widespread level.

The authors of this paper believe that in the near future should be as soon as possible consistent application of such Android software application for many agricultural users. Now the implementation of the program barely registered with small farmers agriculture of the Republic of Serbia, Montenegro and Republic of Macedonia.

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Case Study

FUNCTION OF INFORMATION AND COMMUNICATIONS TECHNOLOGIES IN AGRICULTURAL EDUCATION

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Abstract. *The objectives of agricultural education are achieved at all levels through comprehensive updating of the instruction approach, which includes both conventional teaching and the use of information-and-communications technologies (ICT). In Serbia, agricultural education is offered at secondary (secondary agricultural schools) and tertiary levels (academic and professional studies at junior colleges and universities). In order to identify the role of ICT in secondary and tertiary education, as well as to get opinions of the staff and students, a survey was conducted among secondary school teachers and professors at the University of Belgrade, Faculty of Agriculture (UBFA). The respondents included 18 secondary agricultural school teachers, and 57 UBFA professors and teaching assistants and 441 students. There are many opportunities for ICT use for instruction at secondary agricultural schools (SAS) and in academic studies at all levels. The secondary schools and the UBFA have considerable ICT resources at their disposal, and there is a favorable mindset of both the educators and students. However, electronic sources are still rare in Serbia's electronic cataloguing system, which uses COBISS bibliographic management software, but their number is increasing from year to year. The use of various forms of ICT is widespread in agricultural education. A high percentage of SAS and UBFA educators use computers often or regularly, to design courses (94.5% and 85.9%, resp.), teach (55.6% and 64.9%, resp.), and evaluate knowledge (44.4% and 54.4%, resp.). The educators largely rely on ICT (e.g. PowerPoint presentations) as a teaching aid and to communicate with students via email. The majority of SAS teachers (61.1%) have received some form of ICT training in the field of education, since the obligation to continually upgrade their level of professional competence systemically motivates educators to undergo training. In contrast, UBFA professors have generally acquired their ICT skills indivudually (54.4%), with only a limited number benefiting from international projects (e.g. TEMPUS, WUS, FP6). However, e-learning is rather underdeveloped at this time; its expansion at both secondary and tertiary levels in the*

field of agriculture still lies ahead. Educational projects play a significant role in the application of ICT in instruction.
Key words: *education, electronic resources, multimedia, ICT, e-learning*

1. Introduction

Societal development, accelerated population growth and increasing demand for food require the development and application of appropriate technical solutions and new technologies in agriculture. Apart from the need to increase crop output, globalization and new tendencies in agricultural production and trade impose new requirements on producers, such that the knowledge and the skills acquired during agricultural education are extremely important for the application of appropriate traditional and modern farming techniques and technologies.

As a result, agricultural education, as a process through which knowledge, skills and values are passed on to new generations, is a major driver of intensified and profitable farming. Agricultural education serves to develop general and special technical competences. Regardless of the type, each level of learning plays a role in the qualifications that define the knowledge and skills acquired through education. Apart from formal education, all forms of learning aimed at ongoing updating and application of acquired knowledge are extremely important for good agricultural practices, increased crop output and environmental protection.

Today, the tendency is to achieve agricultural education objectives, at all levels of education, through comprehensive updating of instruction, which, in additional to conventional teaching, includes modern interactive methods, aimed at creative learning and acquiring practical and directly applicable skills, not purely theoretical knowledge. Information and communications technologies (ICT) can be a major facilitator of the transfer of knowledge at different levels of formal education, but also a valuable tool in the dissemination of knowledge to people employed in the agricultural sector, or those who are directly involved in farming. The European Commission [8] *(2003) has compiled a list of key competences, essential for acquiring skills that will ensure long-term learning. One of them is digital competence, which refers to multimedia technologies to search, assess, store, produce and exchange information, as well as to communicate and network via the Internet*. In 2013, the National Education Council of the Republic of Serbia released Guidelines for Enhancing the Role of ICT in Education [19]. The Serbian Government has recognized the importance of including ICT in educational process, and the educational value of e-learning, and incorporated ICT in strategic documents relating to education in Serbia [33, 34]. It should be emphasized that ICT is not a substitute for the existing, conventional learning process, but its integral part (i.e. its upgrade).

1.1. ICT in education

Rapid ICT development has dramatically changed the world we live in. On the one hand, it has contributed to the development of increasingly less costly and more accessible hardware, and, on the other hand, to accelerated generation, availability and diverse uses of information.

ICT include computer hardware and software, and electronic communication tools used to collect, process, store and exchange information, along with relevant functionalities and services. The goal of introducing ICT into the instruction process is to promote and enhance conventional teaching, facilitate the understanding and application of methods and procedures in various disciplines, and develop skills of analytical observation, planning and evaluation. As a teaching aid, ICT offers broad-ranging possibilities to educators and develops student skills. There are several theoretical interpretations of the impact of ICT on education, but the most important theories are: behaviorism, cognitivism and constructivism [20, 27, 29, 31, 32,].

E-learning refers to the application of new student-oriented multimedia technologies and the Internet, aimed at improving the learning process and providing easier access to materials and services, as well as supporting the exchange of materials and ideas at a distance [7].

There are three-types of e-learning:

1. Face-to-face: use of elementary ICT tools in conventional instruction;
2. Blended, mixed mode or hybrid: a combination of conventional teaching in the classroom and instruction using advanced ICT tools (independent use of prepared materials on another location);
3. Fully on-line: instruction using ICT and organized fully at a distance.

While working with students (and entrepreneurs in the future), it is up to each professor, depending on the course taught, to recognize and apply the type of e-learning suitable for the area or level of study (or target group).

LMS (Learning Management System) refers to software comprised of a series of standardized learning components, which connect learning with the existing information system within an organization or by means of a learning web portal. Such systems are used for online instruction. Widely used are commercial products (*BlackBoard, Desire2Learn* ...), but also open-source LMSs (*Moodle, Sakai,* etc.).

1.2. Electronic sources and their role in education

Development in the field of ICT has led to a rapid expansion of e-publications. The National Library of Serbia catalogs e-publications applying pre-defined standards. In that regard, UDC (Universal Decimal Classification) is the best documented and highly detailed. UDC is governed by rules and thesauruses for various fields. The classification of electronic sources [28] includes:

1. Textual documents
2. Digital photographs
3. Audio electronic sources
4. Audio-visual electronic sources (videos, animations)
5. Multimedia, application software

E-publications in education

The e-publications used in education can be divided into two categories, depending on the functionality and multimedia level:

1. Simple e-publications, a digital copy of printed literature and supplemental teaching materials, which can be viewed on different hardware platforms; and
2. Multimedia aids that use certain hypertext functionalities, include audio-visual content and support user interaction.

1.2.1. E-publication standards in education

As they are still not available, national standards need to be established to assist future authors and publishers of e-publications in education. These standards pertain to:

- Technical requirements for digital publications;
- Media types and formats, multimedia elements, metadat;
- Validity of content;
- Cataloging of e-publications;
- Access to and possession (purchasing) of e-publications; and
- Copyrights and citing of sources.

1.2.1.1. SCORM standards for multimedia publications

Standards enable a quick and painless switch from one courseware tool to another. Several standards are currently available in the market for content sharing by means of courseware tools. The most popular is SCORM (Shareable Content Object Reference Model), whose basic idea is to create a unique "content model" [30].

1.3. Multimedia content in education

Microsoft's Computer Dictionary [17] defines multimedia as a "combination of sounds, graphics, animation, and video." The use of ICT and multimedia content diversifies instruction and facilitates learning, as it engages several senses more fully [2, 3, 4, 9, 18, 21, 22, 24].

Planning and application of ICT in instruction, as well as the use of multimedia, depend on the design of the course, or the study program as a whole, in the traditional manner. E-learning through multimedia also requires that account be taken of all key elements that describe a course, which applies to traditional instructing (defining the objectives and outcome of learning, the course content, student load, teaching methods, types of tests, etc.), and which determine the compulsory reading list and supplemental reading. According to the Serbian Law on Textbooks and Teaching Aids [26], textbook standards address pedagogical, psychological, didactic, methodical, ethical, linguistic, educational, artistic and graphical aspects. The standards that apply to printed textbooks also apply to e-publications, and consequently to multimedia materials used in the instruction process to achieve course objectives and expected outcomes.

The use of multimedia in teaching, whereby instruction is aided by computer or Internet presentations, allows students to deal more easily with the world in which they have previously encountered multimedia content on a regular basis in their daily lives and free time. Mayer [12, 13] introduced the term *multimedia principle* and concluded that multimedia support the way in which the human brain learns, believing that knowledge is assimilated more efficiently if presented by means of words and images, instead of words only. Computer presentations can be made in the classroom or anywhere where computers are, with or without screen projectors. With regard to the Internet, if users are allowed access to a multimedia project anywhere and at any time, then we have multimedia networking. Multimedia networking is a simple and quick way for users to gain access to a large number of information sources and plays a very important role in education – in the creation of “virtual schools” and learning at a distance.

1.4. ICT and agricultural education

Agricultural education in Serbia is provided at secondary (SAS) and tertiary levels (academic and professional studies at junior colleges and universities). In elementary schools, students encounter elementary agricultural concepts (relating to the soil, plant production, land uses, types of crops, etc.), beginning in the early stages of schooling. This is only elementary knowledge, which helps students assimilate basic ideas about the world that surrounds them and about agriculture.

However, the *Guidelines* of the Education Council [19] state that “...the new Elementary Education Law allows, for the first time, learning at a distance, which crosses certain barriers – spatial, temporal, social and economic. Opinions can be found in relevant literature that online instruction, largely at a distance, is not recommended for children under the age of 12 because social (physical) contact is key to the development of young children...” Further, the same document of the Education Council says: ... “Secondary education offers much better preconditions for effective online instruction for at least two reasons: a) students have reached a significantly higher level of mental and cognitive abilities and skills, and b) computer literacy, a prerequisite for using online instructions resources, is high among secondary school students.”

Despite the claims put forward in the *Guidelines*, they are in fact rather questionable. Above all, is this actually necessary in Serbia, given that there are vacancies in secondary schools? Online instruction cannot have priority over conventional education, where students establish social contacts and schools address socialization aspects, in addition to providing instruction. Additionally, the claim that computer literacy is high cannot be a general conclusion, applicable to all students. Furthermore, neither the educational system nor the geographical location of Serbia are such that spatial barriers would be a reason for introducing online instruction.

Various agriculture-related disciplines are studied in different courses at the secondary level, in vocational schools. There are three levels of tertiary agricultural education: bachelor’s, master’s and doctoral, at which a broad range of agriculture-related courses are offered. These courses are specialized; students learn about soil science, farming, crop-growing methods, etc. Most of the specialized courses in the field of agriculture are suitable for presentation by means of images, words or sounds, where some phenomena, experiments, processes and practical applications are more easily shown in a suitable format than through conventional lectures or PowerPoint (PP) presentations. The objective of multimedia presentations is to draw and retain student attention, and facilitate assignments. Students are more audio-visually engaged in such classes, and their interest and activity are greater than in the case of conventional instruction.

Although ICT is primarily a support tool used to design and provide instruction, it is also very useful in knowledge evaluation. Additionally, for the purposes of research reports and theses, students are able to use Internet content independently, as well as to create multimedia content, and upon completion of education they can soon find themselves in the role of educators for employees in the agricultural sector and at educational institutions, such that experience of this kind can be extremely valuable.

2. MATERIAL AND METHODS

2.1. ICT resources of the UBFA

The use of ICT requires the availability of suitable hardware and software tools, and the ability to develop, design and implement ICT in agricultural education. The first requirement – hardware resources – is for general-purpose hardware and Internet access equipment.

According to the accreditation documents [35], the UBFA has the following ICT resources:

- Local area network (LAN), comprising more than 500 Ethernet ports (Cat 5e) and active network equipment: more than 20 L2 switches, two L3 routers, 7 Wi-Fi APs, more than 20 local standalone Wi-Fi APs, and two firewalls – Cisco ASA5100 and Cisco PIX.
- The LAN is linked with the AMRES (Academic Network of Serbia) by means of a GB optical link via the IT Center of the University of Belgrade.
- The LAN infrastructure includes more than ten logically distributed special-purpose servers, operating under Windows and Linux operating systems, with more than 800 active PC work stations and notebook computers registered in the Active Directory and logically distributed in about 20 sub-networks.

The LAN supports seven computer classrooms and one professors' reading room, with a total of 124 computers used to provide course-specific instruction and tutorials and handle tests and mid-term exams at all levels of study.

Listing of available services:

1. E-learning system, based on the Moodle platform, intended for both professors and students as a learning support tool.
2. Eduroam service, integrated with AMRES network resources, which allows each academic user (local or international), who has an Eduroam account, to access the academic network with automatic authentication on the parent institution's server;
3. VPN service, integrated with the AMRES network, which allows access to the academic network at a distance, whereby users can search the COBSON database from their home;
4. WEB portal of the UBFA, with a MySQL database support;
5. UBFA email service, accessible from any point to all users via the web, or via email client using a secure, encrypted connection;
6. COBISS bibliographic system – the library became a member in 2012. The entire bibliographic content is currently being transferred and a listing will be available via the Internet.

2.2. Methodology

The research conducted at SASs and the UBFA was based on experience and a quantitative approach (surveying). The survey collected opinions about the use of ICT in instruction. The main objective was to identify the condition in the application of ICT in secondary and tertiary education. Semi-structured questionnaires were prepared. They included 20 open- and closed-type questions and were distributed in hardcopy and electronic format. The questions were grouped by topic and formulated to be simple and straightforward.

Eighteen teachers of specialized courses from nine SASs in Serbia (from the cities of Valjevo, Požarevac, Ruma, Svilajnac, Aleksandrovac, Čačak, Požega, Futog and Obrenovac), and 57 UBFA professors and teaching assistants and 441 UBFA regular undergraduate students took part in the survey. The students were evenly distributed by year and area of study. The survey was conducted in May and June 2015.

COBISS was used to search and analyze the prevalence of electronic sources in the electronic cataloging system.

3. RESULTS AND DISCUSSION

3.1. E-publications in the field of agriculture

Today's libraries increasingly offer electronic resources. With ICT development, their intensified use is becoming a priority in many areas, primarily education.

To meet user demand, it is first necessary to suitably describe such publications in the electronic catalog, classify them by content and subject matter, and prepare an inventory of this type of materials, so that they can be made available to users, which is the ultimate goal of producing, procuring and organizing the materials.

E-publications should not be treated as other types of non-book materials, whose share is minimal and which are largely not duly classified. E-publications, especially in the field of education, are not only becoming a trend, but they represent the future that needs to be recognized on time and addressed accordingly. Active use of existing electronic materials also depends, to a large extent, on the skills of the librarian and proper promotion of such materials and related services. The application of ICT in tertiary education also raises doubts about how to select relevant sources among vast and increasingly voluminous information. In this regard, the role of the library, as a go-between, is extremely important and a place where users will be assisted when they access databases, select relevant information, and analyze and evaluate network resources. This makes the library a facilitator of inter-personal communication within the organization. This role equally includes objectified information resources and human interaction.

The analysis of the prevalence of electronic sources in Serbia's electronic cataloging system, which is supported by COBISS, shows that from 2010 to 2014 the total number of electronic materials (e-publications) decreased both in general and in the field of agriculture (Fig. 1, Table 1). At the same time, the number of electronic sources in the field of agriculture registered a multiple increase (from 4 in 2010 to 27 in 2013 and 26 in 2014), indicating a growing share (Table 1).

Table 1 Number of publications in the electronic cataloguing system, 2010-2014

Year	All materials	El. sources *	El. materials **	Agricultural materials	El. sources* in agriculture	El. materials** in agriculture
2010	68370	2770	1858	1148	179	4
2011	68955	4653	2226	1466	384	11
2012	64127	5150	1648	951	201	21
2013	59505	5793	899	837	224	27
2014	39827	3954	760	630	99	26

*El. sources: materials (in hardcopy or electronic format), available at any electronically accessible Internet location.

**El. materials = e-publications, materials published in electronic format.

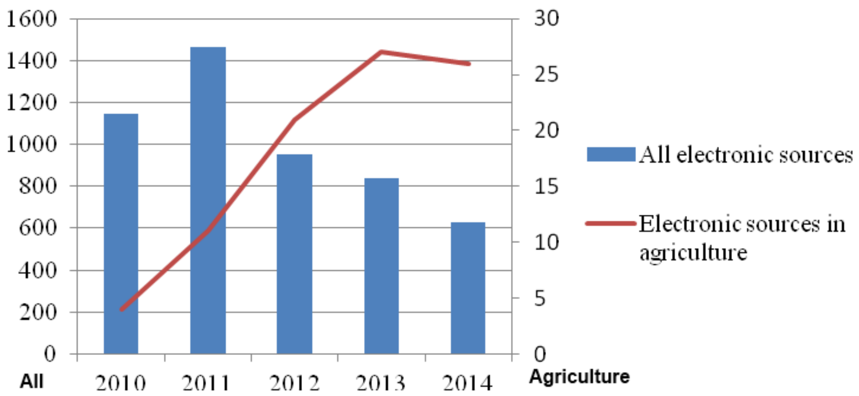

Fig. 1 Number of electronic sources/materials, 2010-2014.

3.2. ICT in Serbia's secondary agricultural schools

Most of the surveyed teachers (83%) have computers with a Windows 7 operating system (i.e. new generation hardware and software). Secondary school teachers have no doubt about the preferred method of instruction. All (100%) of those surveyed believed that students assimilate knowledge better if there is a combination of traditional and computer-assisted learning, but also that the area of study is of the overriding importance (77.5%).

SAS teachers demonstrated a very positive ICT mindset: 67.1% of the teachers felt that ICT is extremely important for learning, while 77.8% believed that students accept new learning technologies very well or extremely well. ICT support in schools was deemed excellent by 38.9% of the teachers, while 50% responded that it was good or very good. Similarly, as many as 61.1% of the teachers felt that the conditions for applying e-learning in schools were excellent. The teachers also had a good opinion about their ICT skills: 50% believed that their skills were very good and 44.4% that they were good. A large number of the teachers (61.1%) acquired their ICT instruction skills at training courses. It should be noted that one of the national institutions engaged in ICT development and application in the field of education is the Institute of Education Improvement (ZOUV), which offers teacher-training programs [10].

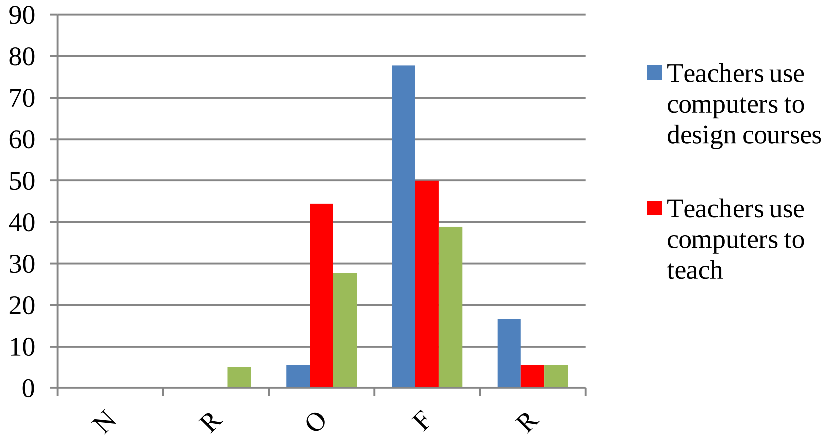

Fig. 2 Use of ICT by SAS teachers in Serbia to design courses, teach and evaluate knowledge

The largest proportion of accredited training courses deal with ICT-based instruction skills. A very high percentage of the surveyed teachers use computers frequently or regularly to: design courses (94.5%), teach (55.6%), and evaluate knowledge (44.4%); there were none that did not use computers or used them rarely (Fig. 2).

Despite the above, the survey showed that very few teachers rely on online learning: 83.3% responded that they never relied on online learning, 16.7% that they used the web, and none that they used Moodle or any other learning platform. At the same time, 44.7% responded that they communicated with students via email and 10.6% via Facebook, while 44.7% did not use any form of electronic communication with students.

3.2.1. E-learning in secondary schools

There are specialized websites created by teachers or secondary school associations, which contain instruction materials. This is a large step towards ICT application in agricultural education. A good example of such an e-learning website is that of the Secondary School Association, Division of Agriculture and Food Production, where there are Moodle-based tests for a category F driver's license [25]: http://upps.edu.rs/index.php/kontakt/9-uncategorised/4-sajt-za-elektronsko-ucenje.

An interactive approach allows students to prepare for a tractor driver's test in a simple, interesting and straightforward manner.

3.3. ICT at the UBFA

Out of the 441 surveyed students, more than 94.6% had their own computer at home, and most of them (86.1%) were using Windows 7 OS. A somewhat larger proportion of professors used an older operating system – XP (59.6% Window 7 vs. 39% XP).

Most of the surveyed students acquired their learning-related ICT skills on their own (80.5%) or with the assistance of others (9.5%), while only a small proportion, only 7.7%, acquired such skills at the UBFA. As expected, older students had more skills (15.6% of the seniors) than the freshmen and sophomores (7.7% and 6.0%, respectively), owing to the fact that certain professors required them to be trained and to use different learning software tools.

It was interesting to note that a large proportion of the students (41.3%) preferred conventional learning, as opposed to e-learning (4.2%), but the majority (56.1%) opted for a combination of the two. This suggests that students do not find the e-learning-only option attractive, such that ICT-based learning approaches that exclude the presence of an educator should be planned very cautiously (e.g. in creating online courses). The survey also led to the conclusion that the *blended* e-learning option, which is a combination of conventional instruction and advanced ICT functionalities, is the type of instruction that the students described as most desirable. This outcome of the survey is consistent with earlier research of different learning styles [1, 11, 16, 23]. With regard to respondents by year of study, freshmen preferred conventional learning but the number declined from year to year (Fig. 3). This suggests that after enrolling, university students were still under the influence of secondary school-type learning and that their preferences changed in later years.

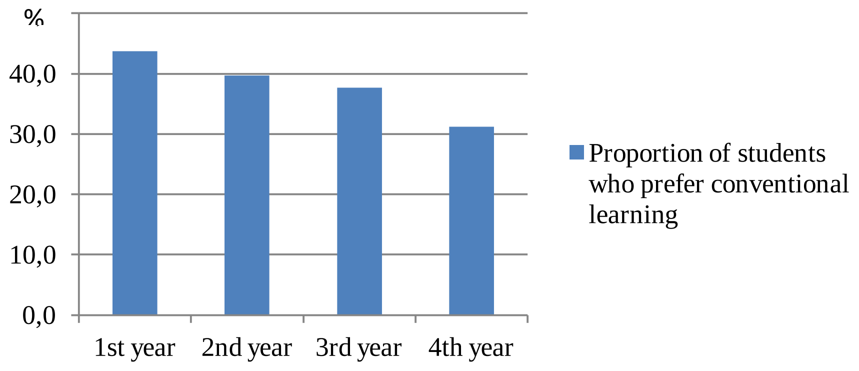

Fig. 3 Proportion of students who preferred traditional learning, by year of study

Consistent with the above, the majority of respondents (57%) felt that computer-aided classroom presentations attracted more attention than conventional lectures, albeit depending on the course. When asked to compare the two methods, the respondents preferred conventional lectures (23.8% vs. 18.8%). With regard to learning, the majority (44%) responded that they preferred to study at home, or to combine home and class (44%), while only 12% stated that the easiest way for them to learn was in class, listening to the professor and viewing presentations. The number of those who preferred to learn in class declined from year to year: freshmen 13.9% and seniors 3.1%. It follows that students should make use of the (compulsory) time spent in class much better than before, while updating of the instruction process should be mandatory and one of the most important tasks of all professors.

It should be noted here that students encounter primarily PP presentations in class: 80.3% responded that professors make PP presentations frequently or regularly (Fig. 4a), while other software programs appear to be used to a much lesser extent (13.4% of the respondents said “never”, while 60.08% stated “rarely” or “occasionally”). Such widespread use of PP presentations and the fact that a large proportion of students preferred conventional instruction, as opposed to the PP presentations themselves, shows to what extent attention should be focused on the design of efficient and effective ICT presentations. Materials not designed or presented in accordance with the basic principles of instruction (if uninteresting or with too much information on a slide, inappropriate distribution of text and animations, etc.) could have a negative impact on the learning process, cause boredom or overload, and discourage students from learning [14, 15]. (Mayer and Moreno, 1998, 2002). This is especially the case where the professors (77.2%) acquired instruction-related ICT skills on their own or with the help of others; only a small proportion of the professors were formally or informally educated or trained.

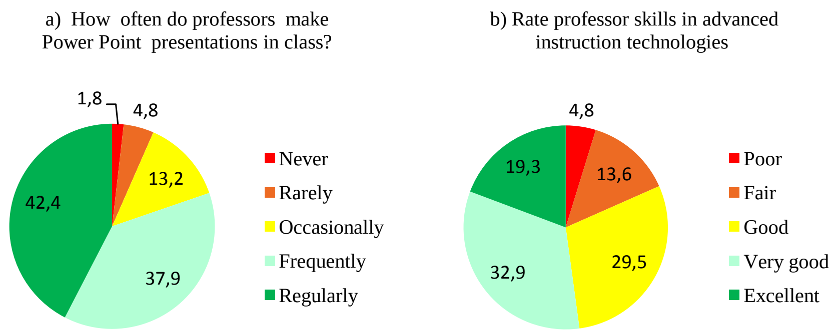

Fig. 4 Student responses regarding ICT use in teaching

When asked about the importance of ICT for knowledge assimilation, 50.9% of the professors said that it was important and 49.1% that it was very important, while the same answers were given by 34.1 and 33.1% of the students, respectively. Both the students (75.4%) and the professors (82%) believed that students were very to extremely interested in e-learning. The professors appeared to have a better opinion about the use of ICT and student motivation, and they were more enthusiastic about the role of ICT in the instruction process.

It was interesting to note what the students and the professors thought about professors’ ICT skills. Compared to the students, the professors had a better opinion about their ICT skills: 18.4% of the students and only 8.1% of the teachers stated that professors’ ICT skills were poor or fair. At the same time, 45.1% of the professors and 52.2% of the students felt that professors’ skills were very good to excellent, such that in this case the professors were modest.

The students and the professors had similar opinions about UBFA’s ICT resources (computers, Internet access, etc.): 29.4% of the students and 40.4% of the professors felt that they were very good to excellent (Fig. 5a). At the same time, 28.1% of the professors and as many as 41.5% of the students believed that these resources were poor or fair. As such, the professors had a much better opinion about UBFA's ICT resources than the students.

More than 90% of the students used social networks frequently to regularly, and 78% used instant messaging and audio/video communication apps. On the other hand, students did not appear to use interactive web tools as much: 43.1% of the students responded that they used such tools rarely or never (Fig. 5b). Most students (more than 86%) believed that ICT improved communication among students and between students and professors; the most frequent form of communication was email: 49.2% of the students exchanged emails with professors frequently or regularly, and 23.6% did so occasionally.

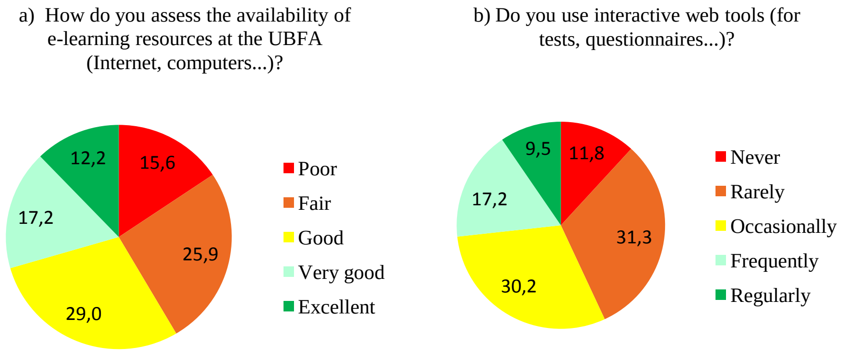

Fig. 5 Student responses regarding UBFA's ICT resources

A large proportion of the professors stated that they used a computer to design courses (85.9%), teach (64.9%) and evaluate knowledge (54.4%), (Fig. 6).

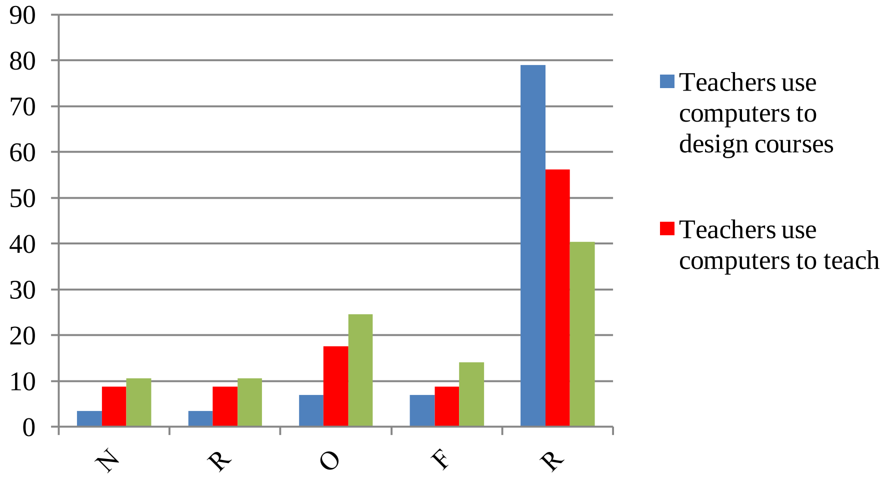

Fig. 6 Use of ICT for course design, teaching and knowledge evaluation by UBFA professors

When asked whether they use domestic literature from the Internet, a large proportion of the students (58.7%) responded that they did so frequently or regularly (Fig. 7a), while the number of those who used literature in English was rather small: 52.6% used such literature rarely or never, and 23.1% only occasionally (Fig. 7b). The reason for this could be inadequate knowledge of the English language or reliance on sources in the mother tongue.

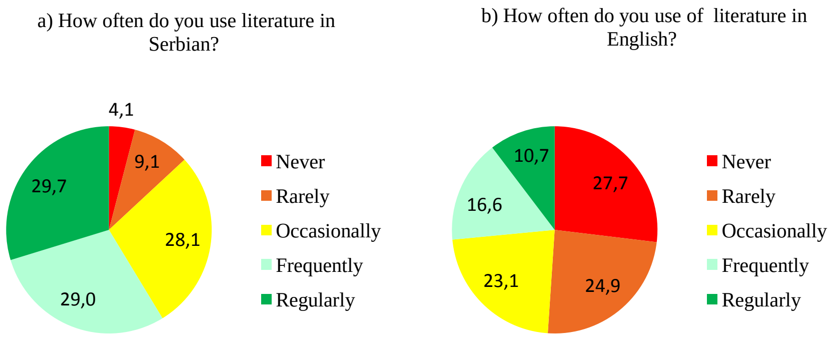

Fig. 7 Student responses regarding the use of literature

Online-only instruction is not available at the UBFA, because there are no accredited online programs and most professors are not familiar with the specific teaching methods applied in an online environment [6]. However, e-learning platforms are being used increasingly, primarily owing to international education projects at the UBFA (TEMPUS, WUS). A number of professors have completed such training courses and implemented the acquired skills, such that the use of some forms of e-learning is growing. The UBFA has recognized the educational value of e-learning: UBFA's 2012 Self-evaluation Report states, under *Measures and Activities Aimed at Improving Educator Skills*, that new training courses need to be identified for ongoing training of professors, including ICT courses.

The above shows that both the SASs and the UBFA exhibit a significant ICT application potential.

However, when the state of affairs at the SASs and the UBFA is compared, there appear to be major differences.

On the one hand, despite relatively modest resources, SAS teachers believe that ICT is a major contributor to instruction, even more so than UBFA professors. As previously stated, 72.3% of the teachers responded that ICT was important and 83.4% that it was extremely important, compared to UBFA's professors 50.9 and 49.1%, respectively. On the other hand, the UBFA has considerable instruction-related ICT resources and the ICT mindset of both the professors and students is favorable. However, mostly PP presentations are made at both the SASs and the UBFA, and they are not a true example of e-learning. The use of online learning at the UBFA is increasing (14% of the professors on a regular basis and 38.6% occasionally). There is considerable room and interest of both students and educators in different forms of e-learning, but also in further development of underdeveloped forms of ICT application in the instruction process.

The proportion of online learning at the SASs is very small: 83.3% of the surveyed teachers did not resort to any form of online instruction. PP presentations in class remain the most frequent form of computer use. Still, significant progress has been made over the past few years.

SAS teachers have largely undergone some form of training in instruction-related application of ICT (61.1% of the teachers have acquired ICT skills at specialized training courses and 22.2% on their own). At the UBFA, the percentage of "self-taught" professors was 54.4%. Educational projects are significant contributors to the increase in UBFA's application of ICT in teaching; some of these projects directly address e-learning in agriculture [5]. A certain number of professors have completed such training courses and, thanks to them, there is increasing reliance on some forms of online instruction.

Ongoing improvement of educator competences is mandatory, such that they are systemically encouraged to undergo training in the field of ICT. Given the importance of ICT in the future, consideration should be given to the inclusion of ICT in professional examinations. Similarly, it should be mandatory for UBFA professors to complete e-learning courses and thus acquire skills related to the online learning environment and the creation of multimedia and digital teaching materials.

3.3.1 E-learning at the UBFA

There are two e-learning management systems at the UBFA: A-Tutor and Moodle. The active open-source LMS at the UBFA is *Moodle* (Modular Object-Oriented Dynamic Learning Environment), which has been in use since 2009. A total of 3018 student accounts have been created so far. The number of accounts that were accessed at least once in the school year 2014/15 was 1320, of which 808 were freshmen's. Eighty-three professors also had accounts, 40 of which were accessed at least once in the same school year. The number of courses registered in Moodle was 102. The number of those accessed more than 100 times during the year was 51. The e-learning opportunities offered by the Moodle platform at the UBFA are much broader than actually used.

4. Conclusion

The importance of introducing new methods and information technologies into the education process is inherent in the national ICT development strategy and identified in the strategic documents related to education in Serbia [33, 34].

One of the objectives of agricultural education at all levels is comprehensive updating of the teaching approach, including both conventional instruction and modern interactive teaching and learning methods, aimed at creative learning and acquiring practical skills, not only assimilating theoretical knowledge. Information and communications technologies (ICT) can facilitate the transfer of knowledge at different levels of formal education, but also to those employed in the agricultural sector (i.e. directly involved in agriculture).

The number of electronic sources in Serbia's electronic cataloging system, which uses the COBISS bibliographic management system, is still small. However, an upward trend is being noted from year to year.

Serbia's secondary agricultural schools (SASs) and the University of Belgrade Faculty of Agriculture (UBFA) offer a broad range of possibilities for ICT application.

They have considerable IT resources, which support the use of ICT in agricultural education at both secondary and tertiary levels. A large proportion of SAS and UBFA educators use computers frequently or regularly to design courses (94.5% and 85.9%, resp.), teach (55.6% and 64.9%, resp.), and evaluate knowledge (44.4% and 54%, resp.). However, the SASs and UBFA largely use ICT as an instruction support tool (PowerPoint presentations), and to communicate with students via email. A large number (61.1%) of the SAS teachers have completed instruction-related ICT training courses, as part of the mandatory requirement to improve their skills on an ongoing basis. In contrast, UBFA professors have generally acquired such skills on their own (54.4%), and only a limited number have benefited from international projects in this area (TEMPUS, WUS, FP6).

E-learning is not sufficiently widespread. At the UBFA, only 14% of the professors use e-learning, while 47.4% never do so. The proportion of SAS teachers who never use online learning is 83.3%. At the UBFA, the use of e-learning is beginning to grow, largely thanks to international projects.

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Original Scientific Paper

EVALUATION OF VARIOUS TURBULENCE MODELS PERFORMANCE FOR GREENHOUSE SIMULATION

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Abstract. *The objective of this paper is to evaluate the performance of various turbulence models on solution of computational fluid dynamics (CFD) greenhouse simulation. For this purpose, temperature and velocity distributions inside the greenhouse are calculated using three different turbulence models (the standard k-ε model. the renormalization group (RNG) model and the realizable k-ε model). The simulations are then compared against each other. The results of simulations show that temperature and velocity distributions inside the greenhouse are quite different and confirm the importance of the appropriate turbulence model choice. Standard k-ε model was recommended as the most suitable turbulence model.*

Key words: *greenhouse, nano-roughness, mathematical model, simulation, cell wall.*

1. INTRODUCTION

Initially, greenhouses were built with aim to protect plants from unexplained extremes in weather. But todays, greenhouses were designed not only to protect from adverse weather conditions, but also to provide optimal climate and growing conditions. Many factors interact to create greenhouse environments. Air temperature, relative humidity, air movement, light intensity and carbon dioxide concentration may be considered controllable aerial parameters. These climatic elements have significant impact on plant growth and production [2].

In agricultural system such as greenhouses or farms, two methodologies are used to analyze the indoor climate conditions: experimental method (direct measurements by using the suitable electronic instrumentation) and simulation method (Computational

Fluid Dynamics (CFD) techniques) [11]. The drawbacks of direct measurements for agricultural systems are as follows:

1) Only limited parameters can be measured and therefore measurements may not be representative of the entire area.

2) Experiments are costly and time consuming.

3) Experiments require existence of small scale building (prototype) or actual building [7].

As result of these disadvantages, CFD techniques can be applied to predict indoor climate conditions. Because not only can simulation modeling save on equipment, training and time, but it can also allow to visual analysis.

In recent years, the different application of CFD in tunnel greenhouse has carried out to predict indoor environment conditions with various turbulence models. Roy and Boulard (2005) [18] found that RNG k-ε model predicted velocity the best when compared with the other models. The prediction was not validated by experimental method. Bartzanas et al. (2007) [6] compare four turbulence models for the prediction of airflow in agricultural buildings. The accuracy of CFD models (simulations) are validated by comparison with real conditions (experimental). They reported that the accuracy of the computational predictions was found to be good when used RNG k-ε model. Brugger et al. (2005) also found notable differences air exchange rates predicted by RNG k-ε model and standard k-ε model. They concluded that the standard k-ε is the most appropriate model to cope with the turbulence nature of the flow.

The objective of this study is to compare three turbulence (the standard k-ε model. the renormalization group (RNG) model and the realizable k-ε model) models for the prediction of temperature and air velocity in greenhouse.

2. MATERIAL AND METHODS

2.1. Characteristics and climate of region

The study area is city of Samsun that is located in the central Black Sea coastal region (41^o 17’ latitude and 36^o 18’ longitude) in Northern Turkey. The average of climate data from 1975-2009 year were used as climate properties (Table 1).

In this study greenhouse internal temperature values were computed as heat balance equation (Equation 1). According to this, using the average values of the climate of Samsun province in the years 1975-2014, the months that need ventilation were selected. In comparing the need for air conditioning in Samsun province in terms of greenhouse, there is no need for mechanical cooling systems because the threshold values for natural ventilation are 12-22 ^oC [13].

According to this, the simulation of the measurement is taken into account months of May, June, September and October. Four months of climatic conditions and the greenhouse internal temperatures are given Table 2.

Table 1. Climate average values between the years of 1975-2009 in Samsun

Months	**Avg. Temperature, ^0C**	**Avg. Relative Humidity, %**	**Avg. Wind Speed, ms^{-1}**	**Sunshine duration, $kwhm^{-2}d^{-1}$**
January	7.01	67.42	3.29	1.57
February	6.64	69.50	2.93	2.20
March	7.98	74.89	2.43	3.06
April	11.24	78.97	1.95	4.06
May	15.35	80.24	1.67	5.13
June	20.14	75.97	1.97	5.97
July	23.27	74.04	2.35	5.96
August	23.59	73.50	2.34	5.22
September	19.97	75.54	2.15	4.02
October	15.96	76.24	2.12	2.64
November	11.84	69.95	2.47	1.78
December	8.86	65.85	3.17	1.37

Table 2. Climate values of four months

Months	May	July	September	October
Soil Temperature, ^oC	21.00	27.00	25.00	21.00
Greenhouse Cover Temperature, ^oC	20.00	25.00	19.00	20.00
Greenhouse Inside Temperature, ^oC	21.20	26.10	24.80	19.90
Greenhouse Outside Temperature, ^oC	15.30	20.10	20.00	16.00
Wind speed, ms^{-1}	2.00	2.00	2.00	2.00

2.2 Heat Balance Equation

The heat balance was calculated as follows [5];

$$(1-E)\tau)\tau\ _f = UA_c(t_i - t_o) + \left(\frac{Q_v A_f c_{pex}}{v_{ex}}\right)(t_{ex} - t_{inlet}) \ , \tag{1}$$

where, E is evapotranspiration coefficient, dimensionless; τ is solar transmissivity of cover, dimensionless; I is solar radiation, W/m^2 of floor area; A_f is floor area, m^2; v_{ex} is specific volume of air leaving greenhouse, m^3 /kg air; Q_v is ventilation rate, $m^3/(s\cdot m^2)$ of floor area; c_{pex} is specific heat of air leaving greenhouse, J/(kg·°C); t_{ex} is temperature of exhaust air leaving greenhouse, °C; is temperature of air entering greenhouse, °C .

2.3. Greenhouse Simulation

Geometry

Ansys Fluent software program [4] is composed of geometry, mesh and Fluent. Geometry was created in an appropriate manner using 1/1 scale (Fig. 1). Boundary conditions were determined as velocity inlet, pressure outlet and wall.

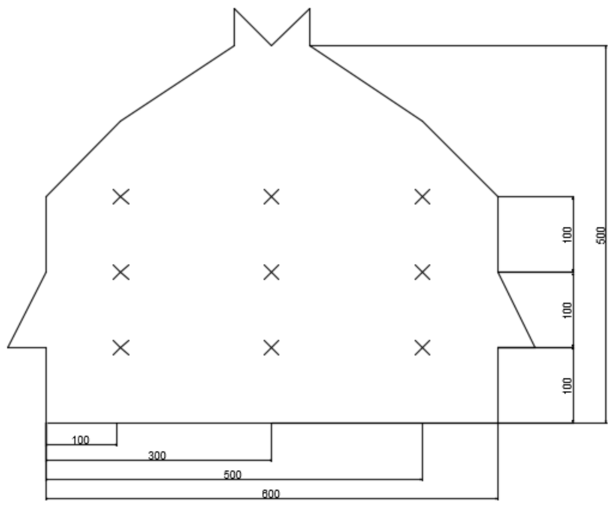


Fig. 1 The size of the greenhouse model

The flow field is divided into certain networks called grid or mesh. In this study "Tetrahedron" network structure is used as mesh formation. Once the appropriate network structure was generated for greenhouse models, these models were solved in Fluent. This technical solutions used are given in Table 3.

Table 3. The methods used in the software Fluent

Solver	Type Velocity Formulation Time	Pressure Based Absolute Steady
Model	Energy Viscous	On RNG k-ε, Standard Wall Functions
Material	Air	Density= 1.225 kg/m^3, cp= 1006.43 j/kg.K Thermal Conductivity= 0.0242 w/m.K
Boundary Conditions	Inlet Outlet Wall	Velocity inlet Pressure outlet wall
Solutions Methods	Gradient Pressure Momentum Turbulent Kinetic Energy Turbulent Dissipation Rate Energy	Least Squares Cell Based Second Order Second Order Upwind Second Order Upwind Second Order Upwind Second Order Upwind
Solutions Controls	Momentum Turbulent Kinetic Energy Turbulent Dissipation Rate Turbulent Viscosity Energy	0.7 0.8 0.8 1.0 1.0
Iterations	Number of iterations	100

2. 4 Numerical Method

In this work, commercial CFD software Fluent, which is based on a finite-volume method, was employed to analyze temperature and air velocity in the greenhouse. The finite volume method is a discretization technique for partial differential equations based on physical conservation laws [14]. Whole domain is divided in a number of finite volumes (cell or grid) and conservation equations are applied for each volume [19]. The grids are used to approximate a set of non-linear partial differential equations that corresponded to conversation of mass (Equation 1), momentum (Equation 2) and energy (Equation 3) equations [17, 12].

$$\frac{\partial p}{\partial t} + \nabla(p\vec{v}) = S_m \,, \tag{2}$$

$$\frac{\partial}{\partial t}(p\vec{v}) + \nabla(p\vec{v}\vec{v}) = -\nabla P + \nabla(\bar{\tau}) + p\bar{g} + \vec{F} \,, \tag{3}$$

$$\frac{\partial}{\partial t}(pE) + \nabla(\vec{v}(pE + P)) = \nabla\left(k_{ef}\nabla T - \sum_j h_j \vec{J}_j + (\overline{\tau\vec{v}})\right) + S_h \,, \tag{4}$$

where Sm is mass source (kg.m^{-3}); ρ is density (kg·m^{-3}); t is time (s); u, v, w are velocity (m·s^{-1}); P is pressure (Pa); τ is stress tensor (Pa); g is gravitational acceleration (m·s^{-2}); E is total energy (J); kef is heat transmission coefficient; F is external force vector (N·m^{-3}); J is component of diffusion flux; T is temperature (^{o}C); h is specific enthalpy (J·kg^{-1}); Sh is total entropy (J·K^{-1}).

Turbulence model

The flow of liquid is called turbulent when the direction and the magnitude of the velocity at a given point change continuously and haphazardly (Agrawal et al., 2008). It is known that the indoor air in the greenhouse is fully turbulent. Therefore, in this article the standard k-ε model, the renormalization group (RNG) model and the realizable k-ε model were used.

Standard k-ε model

$$\frac{\partial}{\partial t}(pk) + \frac{\partial}{\partial x_i}(\rho\rho k_i) = \frac{\partial}{\partial x_j}\left((u + \frac{u_t}{\sigma_k})\frac{\partial k}{\partial x_j}\right) + G_k + G_b - \rho\varepsilon - Y_m + S_k \,, \tag{5}$$

$$\frac{\partial}{\partial t}(\rho\varepsilon\text{p}+\frac{\partial}{\partial x_i}(\rho\rho\varepsilon_i)=\frac{\partial}{\partial x_j}\left((u+\frac{u_t}{\sigma_\varepsilon})\frac{\partial\varepsilon}{\partial x_j}\right)+C_{1\varepsilon}\frac{\varepsilon}{k}(G_k+C_{3\varepsilon}G_b)$$
$$-C_{2\varepsilon\varepsilon}\frac{\varepsilon^2}{k}-R_\varepsilon+S_\varepsilon \tag{6}$$

The turbulent viscosity u_t is computed by using the turbulence kinetic energy and its dissipation rate as follows:

$$u_t=\rho C_u\frac{k^2}{\varepsilon} \tag{7}$$

where C_u is a constant (0.09).

As standard k-ε model was developed for high Reynolds number flows, performance of the model is weak for low Reynolds airflows in indoor environment conditions.

RNG k-ε Model

This turbulence model is derived from Navier-Stokes equations, using renormalization group theory. This models' form is similar to the standard k-ε model, but this model was improved the prediction of low Reynolds airflows. RNG k-ε model were used many studies have suggest that the model performs well [16, 17, 22, 20].

The RNG k-ε model is defined as [21]:

$$\frac{\partial}{\partial t}(\text{p}k)+\frac{\partial}{\partial x_i}(\rho\rho k_i)=\frac{\partial}{\partial x_j}\left((\alpha_k u_{eff}\frac{\partial k}{\partial x_j}\right)+G_k+G_b-\rho\varepsilon-Y_m+S_k\,, \tag{8}$$

$$\frac{\partial}{\partial t}(\rho\varepsilon\text{p}+\frac{\partial}{\partial x_i}(\rho\rho\varepsilon_i)=\frac{\partial}{\partial x_j}\left((\alpha_\varepsilon u_{eff}\frac{\partial\varepsilon}{\partial x_j}\right)+C_{1\varepsilon}\frac{\varepsilon}{k}(G_k+C_{3\varepsilon}G_b)$$
$$-C_{2\varepsilon\varepsilon}\frac{\varepsilon^2}{k}-R_\varepsilon+S_\varepsilon \tag{9}$$

The turbulent viscosity is calculated in this case using differential equation:

$$d\left(\frac{\rho^2 k}{\sqrt{\varepsilon u}}\right)=1.72\frac{\hat{v}}{\sqrt{\hat{v}^3-1+C_v}}d\hat{v} \tag{10}$$

$$\text{where}:\hat{v}=\frac{u_{eff}}{u}$$

Realizable k-ε model

Although realizable k-ε model is similar to standard k-ε model, the difference of this model is that coefficient C_u is no longer constant. One of the weaknesses of the standard k-ε model or other traditional k-ε model lies with the modeled equation for the dissipation rate (ε).

$$\frac{\partial}{\partial t}(\rho\varepsilon p + \frac{\partial}{\partial x_i}(\rho\rho\varepsilon_i) = \frac{\partial}{\partial x_j}\left((u + \frac{u_t}{\sigma_z})\frac{\partial\varepsilon}{\partial x_j}\right) + \rho C_1 S_\varepsilon - \rho C_2 \frac{\varepsilon^2}{k + \sqrt{v\varepsilon}}$$
$$+ C_{1\varepsilon}\frac{\varepsilon}{k}C_{3\varepsilon}G_b + S_\varepsilon \tag{11}$$

Where ƙ is turbulent kinetic energy ($m^2 \cdot s^{-2}$); and σ_k are σ_ε the inverse effective Prandtl numbers for ƙ and ε, respectively ; u_{eff} is effective viscosity ($m^2 \cdot s$);G_k is the generation of turbulent kinetic energy due to the variations of the components of the average velocity of the flow ($kg \cdot m^{-1} \cdot s^{-2}$); G_b is the generation of kinetic energy by boundary push ($kg \cdot m^{-1} \cdot s^{-2}$); Y_m is contribution of the pulsatile expansion associated to the compressible turbulence ($kg \cdot m^{-1} \cdot s^{-2}$); R is the gas-law constant (8.314×103 $J \cdot kg \cdot mol^{-1} \cdot K^{-1}$); $C_{1\varepsilon}$ and $C_{2\varepsilon}$ are constant of 1.42 and 1.68; $C_{3\varepsilon}$ is tanh (u1/u2), u_1 and u_2 are components of the flow velocities parallel and perpendicular , respectively, to the gravitational vector; S_k and S_ε are source terms.

3. RESULTS AND DISCUSSION

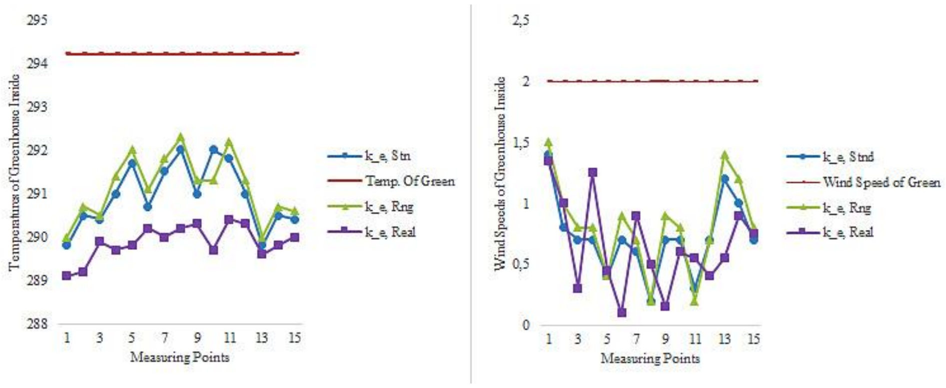
The effect of turbulence models on wind seeped and temperature distribution inside greenhouse has been utilized with direction nearly parallel to greenhouse axis (North to South). Four different climatic value of the month requiring natural ventilation have been obtained different values held in Ansys simulation software in mind. Velocity vectors in a horizontal plane 1 m greenhouse height, when using the standard k-ε, RNG k-ε and Realizable k-ε turbulence model. A similar airflow pattern was tested in a greenhouse [8, 15]. Similar patterns were beholded for the three other measured turbulence models.

Table 4 shows the standard k-ε turbulence model and k-ε RNG turbulence model obtained temperature and wind speed of greenhouse inside on May. A high correlation was found between the two models (r^2T: 0.87; r^2U: 0.96)

Table 4 The comparison of turbulence models greenhouse internal temperature and wind speed for May

	$T_{k\text{-}\varepsilon\ stndr}$	**$T_{k\text{-}\varepsilon,\ Rng}$**	**$T_{k\text{-}\varepsilon,\ real}$**
$T_{k\text{-}\varepsilon.stndr}$	1.00		
$T_{k\text{-}\varepsilon.Rng}$	**0.87**	1.00	
$T_{k\text{-}\varepsilon.Real}$	0.16	0.38	1.00
	$V_{k\text{-}\varepsilon,stndr}$	**$V_{k\text{-}\varepsilon,\ rng}$**	**V, $_{k\text{-}\varepsilon,\ real}$**
$V_{k\text{-}\varepsilon.stndr}$	1.00		
$V_{k\text{-}\varepsilon.Rng}$	**0.96**	1.00	
$V_{k\text{-}\varepsilon.Real}$	0.19	0.14	1.00

Fig. 2a shows referring to the results obtained by simulation study than the temperature inside the greenhouse in which the temperature values calculated greenhouse were observed to be lower. The wind speed in the value of the greenhouse used in the simulation was observed wind speed is lower than the boundary condition (Fig. 2b).



(a) (b)

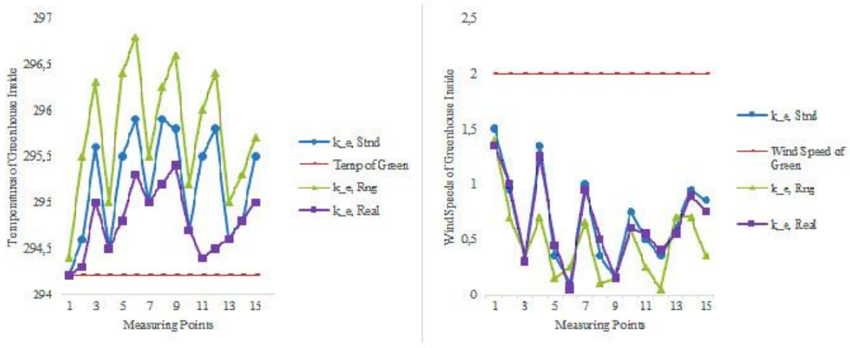
Fig. 2 The distribution of the different models of turbulence in greenhouse conditions on May

Table 5 shows the standard k- ε turbulence model and k- ε Rng turbulence model obtained temperature of greenhouse inside on June (r^2T: 0.9). the standard k- ε turbulence model and k- ε Realizable turbulence model obtained wind speed of greenhouse inside (r^2U: 0.96).

Table 5 The comparison of turbulence models greenhouse internal temperature and wind speed for June

	$T_{k-\varepsilon\ stndr}$	$T_{k-\varepsilon,\ Rng}$	$T_{k-\varepsilon,\ real}$
$T_{k-\varepsilon.stndr}$	1.00		
$T_{k-\varepsilon.Rng}$	**0.90**	1.00	
$T_{k-\varepsilon.Real}$	0.47	0.43	1.00
	$V_{k-\varepsilon.stndr}$	$V_{k-\varepsilon.\ rng}$	$V_{k-\varepsilon.\ real}$
$V_{k-\varepsilon.stndr}$	1.00		
$V_{k-\varepsilon.Rng}$	0.73	1.00	
$V_{k-\varepsilon.Real}$	**0.96**	0.65	1.00

Fig. 4 compared simulation value with the calculated values in greenhouse inside on June. The simulation results are greater than the calculated value both temperature of greenhouse inside (Fig. 3a) and wind speed of greenhouse inside (Fig. 3b)



(a) (b)

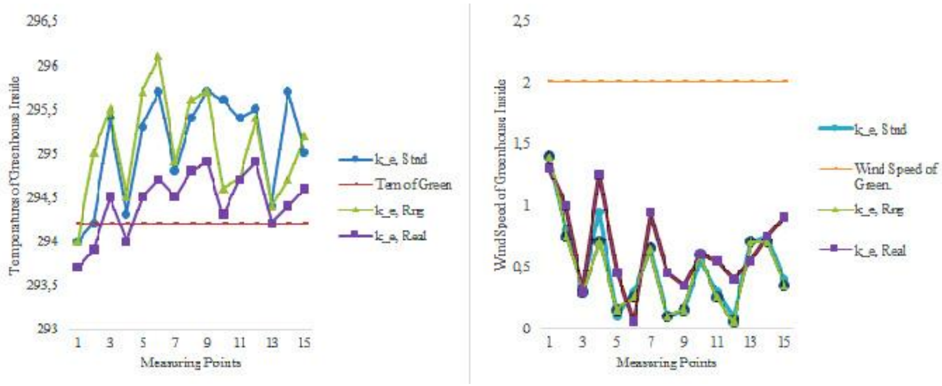
Fig. 3 The distribution of the different models of turbulence in greenhouse conditions on June

Table 6 shows the standard k- ε turbulence model and k- ε Realizable turbulence model obtained temperature of greenhouse inside on September (r^2T: 0.68). The standard k- ε turbulence model and k- ε Realizable turbulence model obtained wind speed of greenhouse inside (r^2U: 0.96).

Table 6. The comparison of turbulence models greenhouse internal temperature and wind speed for September

	$T_{k-\varepsilon\,stndr}$	$T_{k-\varepsilon,\,Rng}$	$T_{k-\varepsilon,\,real}$
$T_{k-\varepsilon.stndr}$	1.00		
$T_{k-\varepsilon.Rng}$	0.41	1.00	
$T_{k-\varepsilon.Real}$	**0.68**	0.54	1.00
	$V_{k-\varepsilon.stndr}$	$V_{k-\varepsilon.\,rng}$	$V_{k-\varepsilon.\,real}$
$V_{k-\varepsilon.stndr}$	1.00		
$V_{k-\varepsilon.Rng}$	**0.96**	1.00	
$V_{k-\varepsilon.Real}$	0.67	0.61	1.00

Fig. 4 compared simulation value with the calculated values in greenhouse inside on September. The simulation results are greater than the calculated value temperature of greenhouse inside (Fig. 4a) but are least than the calculated wind speed of greenhouse inside (Fig. 4b).



(a) (b)

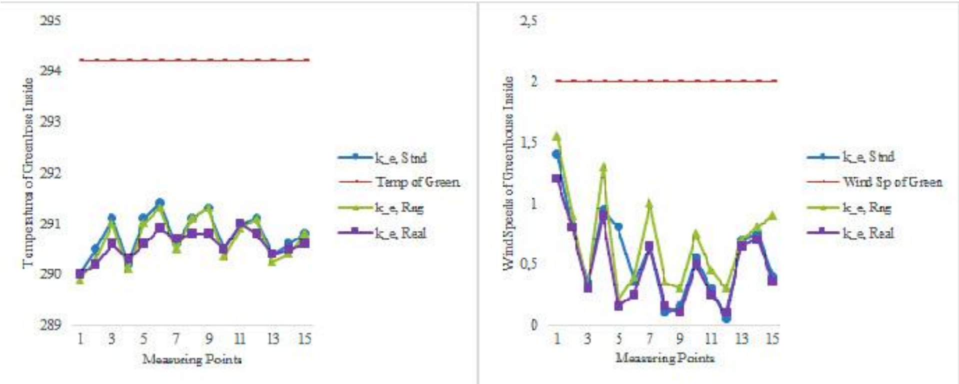
Fig. 4 The distribution of the different models of turbulence in greenhouse conditions on September

Table 7 shows the standard k- ε turbulence model and k- ε Rng turbulence model obtained temperature of greenhouse inside on October (r^2T: 0.98). The standard k- ε turbulence model and k-e Realizable turbulence model obtained wind speed of greenhouse inside (r^2U: 0.87).

Table 7 The comparison of turbulence models greenhouse internal temperature and wind speed for October

	$T_{k-\varepsilon\ stndr}$	$T_{k-\varepsilon,\ Rng}$	$T_{k-\varepsilon,\ real}$
$T_{k-\varepsilon.stndr}$	1.00		
$T_{k-\varepsilon.Rng}$	**0.98**	1.00	
$T_{k-\varepsilon.Real}$	0.74	0.74	1.00
	$V_{k-\varepsilon.stndr}$	$V_{k-\varepsilon.\ rng}$	$V_{k-\varepsilon.\ real}$
$V_{k-\varepsilon.stndr}$	1.00		
$V_{k-\varepsilon.Rng}$	0.63	1.00	
$V_{k-\varepsilon.Real}$	0.79	**0.87**	1.00

Fig. 5 compared simulation value with the calculated values in greenhouse inside on October. The simulation results are least than the calculated value temperature of greenhouse inside (Fig. 5a) but are least than the calculated wind speed of greenhouse inside (Fig. 5b).



(a) (b)

Fig. 5 The distribution of the different models of turbulence in greenhouse conditions on October

Fig. 6 compared to four months of temperature with three different turbulence models. Here showed high correlation with the standard RNG (r^2: 0.97)

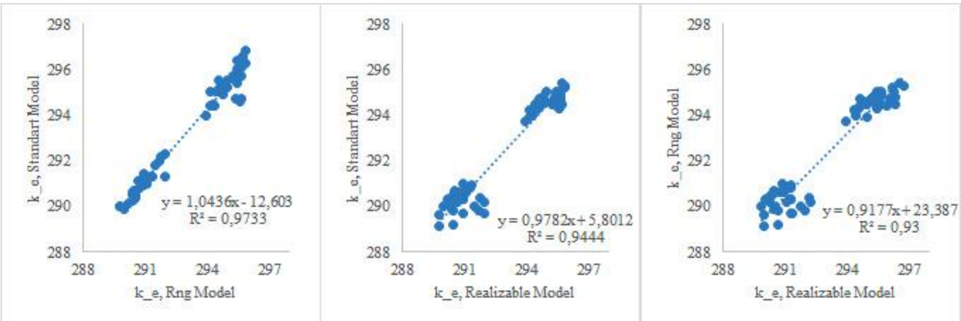


Fig. 6 Comparison of the temperature the greenhouse inside with four different turbulence model for four months

Fig. 7 compared to four months of wind speed with three different turbulence models. Here showed high correlation with the standard RNG (r^2: 0.71)

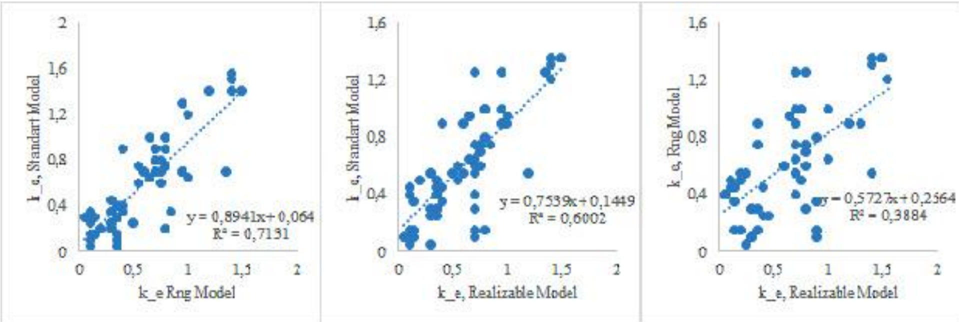


Fig. 7 Comparison of the wind speed the greenhouse inside with four different turbulence model for four months

4. Conclusions

In this study, experimental data concerning temperature and wind speed of naturally ventilated greenhouses have been measured. Three turbulence models have been tried to project the temperature and wind speed. From validations of the temperature and wind speed of the measured greenhouse, the k-ε RNG turbulence model and the standard k-ε turbulence model showed the best movement concerning the accuracy of the estimate. Determination and agreeable accuracy is achieved from the k-ε realizable turbulence model, especially when the ventilation is determinated by low air velocities. Finally, the standard k-ε model supplied the simplest convergence. Recently, predictive laminar to turbulent flow transition model has been conjugated in a commercial CFD code (Ansys, 2006).

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Case Study

CONTRIBUTION OF GREEN WALLS TO BUILDING MICROCLIMATE CONTROL

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Abstract. *The Urban Heat Island (UHI) effect induces an excessive use of building cooling systems, increasing the energy consumption, airborne pollution concentration and greenhouse gas emissions into the atmosphere. The Green Walls can be used as passive energy savings systems for controlling the solar heat gain for the buildings in summer and for increasing their thermal insulation in winter, contributing to the UHI effect mitigation. Experimental tests were carried out at the University of Bari (Italy), from August 2014 to February 2015, aimed to analyze the contribution of green walls with two different plant species (Pandorea jasminoides variegated and Rhyncospermum jasminoides) to the building thermal performance. Three prototypes of building vertical wall were built; two walls were covered with plants and the third was kept uncovered for control. The collected data analysis pointed out that in warm days the maximum daylight temperatures observed on the external surface of the walls covered with plants were lower up to 4 °C than the respective temperatures measured on the control wall and during the nighttime of cold days the minimum temperatures measured on the external surface of the walls covered with plants were higher up to 2°C than the ones of the control wall.*

Key words: *Energy savings, Passive systems, Urban heat island, Surface temperature, Solar radiation, Green technology*

1. INTRODUCTION

The implementation of urban green infrastructure (UGI), such as public parks, street trees, urban forests, turf-grass, private gardens, sporting fields, green roofs and green façades, can provide several environmental benefits as pollution reduction, biodiversity habitat restoration, storm-water management and water run-off quality improvement [13, 3]. Moreover UGI can contribute to reduce the temperature in urban areas, the frequency and magnitude of the heat events due to urban heat island (UHI), and can improve human thermal comfort [3, 13, 14, 21]. The UHI phenomenon causes negative outdoor comfort conditions, increased pollutants concentration and risks for human health, an increase of energy consumption for building conditioning and a consequential raise of peak electricity demand [8, 10, 11, 16]. The effectiveness of UGI, both at urban scale and at building scale, is mainly influenced by the climate of the region, the characteristics of the growing media, the water availability, the plants selection and position, the level of building insulation, the building indoor usage. In detail plant peculiarity, such as height, coverage ratio, leaf area index (LAI), foliage physical and radiometric characteristics, plant's biological processes, can strongly affect the overall performance of the vegetation [7, 17]. Nevertheless the greater relative cooling benefits have been demonstrated for Mediterranean regions or warm temperate climates applications [13].

Greenery systems can be used as passive sustainable systems for mitigating building energy consumption. They induce evaporative cooling by evapo-transpiration from the plants and the substrate on their surroundings; the vegetation layer reduces the building solar heat gain and consequently the energy consumption for air cooling in summer by intercepting the solar radiation. The various layers composing the greenery system, such as the growing media, the plants, the air in the plant layer, provide additional thermal insulation in winter depending on the climate conditions and on the greenery system typology. The vegetation and its supporting structure influence the wind speed and intensity on the building envelope [1, 6, 14, 21]. The greenery systems can be categorized in green roofs, green walls, green balconies, sky gardens and indoor sky gardens depending on the building surfaces used to host green layers (roofs, walls, balconies, man-made structures separated from the ground level on intermediate floors or rooftops, internal courts) [14, 17]. Greening the walls of a building in densely urbanized areas has potentially more effect than greening roofs due to a high wall to roof ratio with regard to the UHI effect mitigation [14].

Green roofs can be further distinguished in extensive, intensive and semi-intensive roofs depending on the thickness of the growing medium, on the plants selection, and on the irrigation and maintenance costs [17]. Extensive green roofs are characterized by a thickness of the growing media less of 15-20 cm, plants like sedum, moss, herbs and grasses, very low irrigation and maintenance needs. The semi-intensive green roof involves a growing medium not thicker than 25 cm, plants like grass-herbs and shrubs and moderate irrigation and maintenance needs. The intensive green roof requires a growing medium depth of about 20-100 cm, vegetation like trees, shrubs and lawn, high irrigation and maintenance needs [14, 17].

Green walls can be further distinguished in green façades and living walls [17]. In a green façade climbing plants are rooted directly in the ground or in pots placed at different height levels, growing up to 25 m or even more. In the case of plants climbing on a structural support, the resulting air gap between the vegetation layer and the building improves the system thermal performance [14, 17]. The living walls are realized by means of modular pre-cultivated panels, already containing the growing medium for a wide range of plants like ferns, shrubs and perennial flowers too [17].

Green roofs and walls can sustainably improve the building energy efficiency showing different performance over cooling and heating seasons [2, 14, 20], even if in winter the efficacy of greenery systems is heavily influenced by the climatic area and conditions. Most of the studies carried out concern their energy performance during the summer period, on buildings with a high level of thermal transmittance, and by means of analytical simulations [4, 5, 9, 12, 14, 15, 17, 18]. Santamouris et al. [19] performed simulations for a nursery school building in Athens, non-insulated and insulated; the study reported in both cases a significant reduction of the building's cooling load during summer and any significant influence on the heating load, however providing also significant environmental benefits. D'Orazio et al. [5] showed that the use of green roofs on a highly insulated building, that respects the actual national building standards, is thermally less effective, while green roofs can be more suitable for the existing building retrofitting. Perez et al. [14], with regard to green façades reported a reduction of the external building surface temperature in summer from 1.7 °C to 13 °C in warm temperate climate region and 7.9 °C to 16 °C in snow climate region; with regard to a green wall the temperature reduction range was 12 °C - 20.8 °C in summer and 5 °C - 16 °C in autumn in warm temperate climate region.

There is a need to extend knowledge and experimental tests for defining suitable plant species and system design for the green roofs and green walls suitable for the Mediterranean regions.

The research carried out at the University of Bari (Bari, Italy) as a part of the research activities in progress at the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), aims to give a contribution by exploring the effects of green façades realized with different climbing plants species on the thermal regime of a south exposed wall, subjected to solar radiation, during winter season. The experimental external surface temperatures and climatic data were analyzed during several months for evaluating the reduction of the wall surface temperature by means of a vertical green.

2. MATERIALS AND METHODS

The experimental tests were carried out at the experimental farm of the University of Bari in Valenzano (Bari, Italy), having latitude 41° 05' N, longitude 16° 53' E, altitude 85 m ASL. A prototype of building vertical wall was realized with perforated bricks joined with mortar and finished with clear plaster, among the simplest closure wall typologies commonly used in Mediterranean civil construction. The bricks have a thickness of 20 cm, an height of 25 cm and a length of 25 cm. Bricks are characterized by a thermal conductivity λ (following UNI EN 1745:2012) equal to 0.282 W m^{-1} K^{-1}, a specific heat capacity C equal to 840 J kg^{-1} K^{-1} and an average weight of the masonry work (including plaster) equal to 695 kg m^{-3}.

Three south facing vertical walls were built, each with a width of 1.00 m, a height equal to 1.55 m, and a thickness of 0.20 m. Two walls were covered with different evergreen climbing plants directly rooted in the soil: one with *Pandorea jasminoides* variegated, the second with *Rhyncospermum jasminoides*. The third wall was kept uncovered and was used as a control. A supporting structure for the climbing plants, made of an iron net, was placed at a distance of 15 cm from the vertical wall (Figure 1). The plants were transplanted on June 18, 2014. The drip irrigation method was used for all the plants; the fertilization was performed with N: P: K 12:12:12.

Each wall was insulated on the backside by setting up a sealed structure in order to better evaluate the influence of the plants on the effects of incident solar radiation. The sealed structure was realized with sheets of expanded polystyrene, with a thickness of 30 mm and a thermal conductivity equal to 0.037 $Wm^{-2}K^{-1}$. Furthermore a blue shading net was positioned onto the structure in order to reduce the effect of the incident solar radiation.

The experimental field was equipped with a meteorological station consisting of a data logger (CR10X, Campbell, Logan, USA) and several sensors for measuring the following climatic parameters: the solar radiation incident on the vertical surface and the external air temperature, the surface temperature of the wall on the external plaster exposed to the solar radiation. The data were measured with a frequency of 60 s, averaged every 15 min and stored in the data logger.

The solar radiation falling on the wall was measured by a pyranometer (model 8-48, Eppley Laboratory, Newport, RI, USA) in the wavelength range 0.3-3 mm; the external air temperature was measured by an Hygroclip-S3 sensor (Rotronic, Zurich, Switzerland), adequately shielded from solar radiation; the temperature of the surfaces of the external plaster exposed to the solar radiation was measured using thermistors (Tecno.el s.r.l. Formello, Rome, Italy).

Fig. 1 The three walls at the experimental field of the University of Bari; the right wall is covered with Rhyncospermum jasminoides, the central wall with Pandorea jasminoides variegated and the left wall is the uncovered control.

3. RESULTS AND DISCUSSION

The two climbing plants sufficiently covered the walls from mid August 2014. Data were shown from August 2014 to February 2015.

Table 1 shows the average values of the maximum daily external air temperature and surface temperature of the external plaster of the three walls exposed to solar radiation during some of the hottest days of September 2014, the warmest month of the examined period: the green layer allowed to mitigate the quantity of solar radiation absorbed by the walls and to maintain the external surface temperature of the green walls at values lower than the control wall in the warmest periods, with recorded differences of about 2-3 °C and maximum values of the solar radiation falling on the walls in a range of about 315-640 W/m^2. The differences between the highest temperatures recorded for the control and for the wall covered with the green layer vary during summertime from 3 to 4 °C (data shown in [21]).

Table 2 shows the average values of the minimum daily external air temperature and surface temperature of the external plaster of the three walls exposed to solar radiation during some of the coldest days of February 2015. In the examined period, the presence of vegetation increased the thermal insulation of the wall by keeping the external surface temperature of the green walls at values higher than the control wall in the coldest periods, with recorded differences of about 2 °C.

Table 1 Average values of the maximum daily external air temperature and surface temperature of the external plaster of the three walls exposed to solar radiation in 19-22 September 2014.

Exposition period	Average Maximum Temperatures			
	Rhyncospermum jasminoides external wall temperature (°C)	*Pandorea jasminoides* external wall temperature (°C)	control external wall temperature (°C)	external air temperature (°C)
19-22 September 2014	30.6	29.5	32.6	31.8

Table 2 Average values of the minimum daily external air temperature and surface temperature of the external plaster of the three walls exposed to solar radiation from in 18-21 February 2015.

Exposition period	Average Minimum Temperatures			
	Rhyncospermum jasminoides external wall temperature (°C)	*Pandorea jasminoides* external wall temperature (°C)	control external wall temperature (°C)	external air temperature (°C)
18-21 February 2015	2.6	2.9	1.0	2.7

Figures 2 and 3 show the surface temperatures of the external plaster exposed to solar radiation (external wall) for the two walls covered with vegetation and for the control wall, and the solar radiation falling on the walls during 22 September 2014 (Figure 2) and 21 February 2015 (Figure 3).

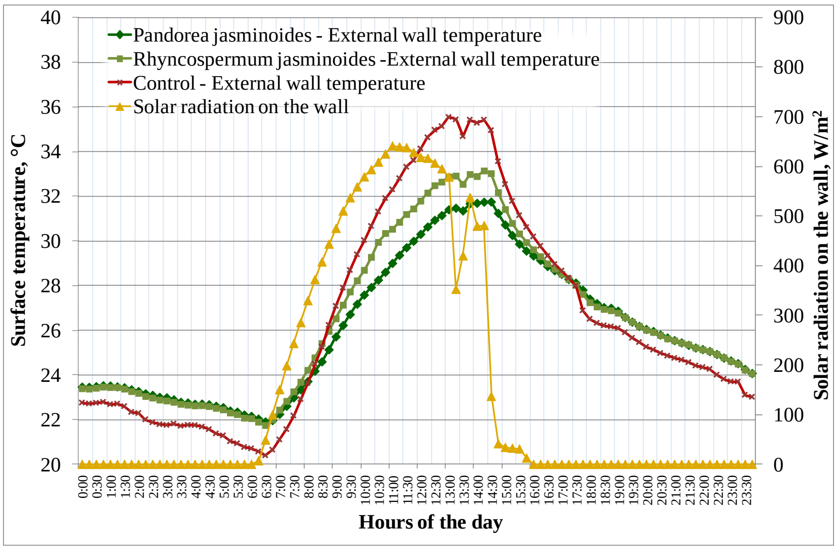

Fig. 2 Solar radiation falling on the walls, surface temperatures of the external plaster exposed to solar radiation (external wall) for the three walls, 22 September 2014.

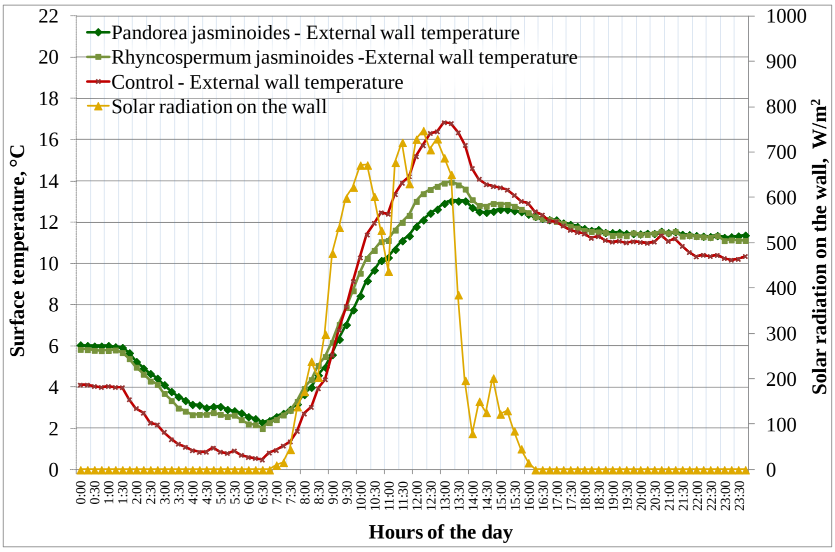

Fig. 3 Solar radiation falling on the walls, surface temperatures of the external plaster exposed to solar radiation (external wall) for the three walls, 21 February 2015.

The temperatures registered for the surface of the green walls were always lower during the daytime than the temperatures recorded in the same hours for the control wall. Conversely the surface temperatures of the green walls were always higher during the nighttime than the temperatures recorded in the same hours for the control wall. The presence of the green wall decreased the exposure of building construction materials to large temperature fluctuations. The vegetation did not completely cover the surface of the experimental walls due to the transplant performed in June 2014 thus reducing the shading effect of the green layer; research is continuing with the aim of analyzing the green wall effects also during a whole year.

4. CONCLUSIONS

The research, carried out on experimental green vertical systems from August 2014 in a Mediterranean area, examined periods of different seasons. The use of the greenery vertical systems effectively permitted to reduce the external surface temperature values of the walls, due to the solar radiation heat gain cutting.

The green walls offer several benefits in dense urbanized areas such as the reduction of air pollution, greenhouse gases in atmosphere and noise, the improvement of the aesthetical impact of buildings, urban biodiversity preservation, health and well-being improvement. However the green roofs technology additionally represent a sustainable solution for existing buildings retrofitting by improving their thermal performance and lowering energy consumption for buildings cooling systems and for mitigating the Urban Heat Island.

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ON A CLASS OF PARTIAL DIFFERENTIAL EQUATIONS OF PARABOLIC TYPE

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Abstract. *The great advances of technology and computers during the last sixty years have spread to agricultural equipment. The key objective in the maintenance of the agricultural machinery is to minimize the defects and disorders. In this paper results are presented of a tractor engine durability examination on Serbian farms. The experimental results had been used and the engine durability of the popular heavy-tractor model, Massey-Ferguson 8160, was examined. A partial differential equation, which describes the tractor engine lifespan, was used and solved, thus providing the new method for describing the tractor engine durability.*

Key words: *agricultural machinery, engine, defects, partial differential equations*

INTRODUCTION

The great advances of technology and computers during the last sixty years have spread to agricultural equipment, for example even tractors. In [4] preventive technical maintenances of agricultural machines are analyzed. The key objective is to minimize the defects and disorders of the machines. A rule-based electronic test system which compares the present performance of the tractor had been applied to the reference values specified by the appropriate standard [1]. This system analyzes the differences of real (measured) and optimal values of all tractor relevant parameters. Furthermore, the system also tells what could be the reason why. Costs relating to equipment, repair and maintenance are important parts of total costs. So it is financially important to have the tractor in good condition. Furthermore, it is also available that the tractor engine works with its optimum, in order to correctly perform work that requires power and torque reserves [3].

In this paper results are presented of a tractor engine durability examination on Serbian farms. The experimental results had been presented in [2]. In [5] the engine durability of the popular heavy-tractor model, Massey-Ferguson 8160, was examined.
In this paper a partial differential equation, which describes the tractor engine lifespan, is solved.

MATHEMATICAL MODEL

The study of finding a very new model for describing this process leads to the equation

$$\frac{\partial^2 y}{\partial t^2} - \frac{8}{w^2}\frac{\partial y}{\partial T} = 0. \tag{1}$$

This partial differential equations is among equations of two independent variables of parabolic type. $y(t,T)$ corresponds to the tractor engine lifespan. t, $t > 0$, is the lifespan, e.g. the number of working hours before the overhaul of the engine. The second variable T, $T > 0$, is the actual year of tractor manufacturing. Equation (1) is a diffusion equation. w is constant, does not vanish and is called the coefficient of diffusion.

Since the solving of ordinary differential equations is much easier than of partial differential equations, it is tried to reduce the partial equation (1) to a ordinary one. This means that only one variable is allowed. So a relationship between the independent variables t and T must be found. This corresponds to the mathematical problem: For which a, p and q is $y(a^p t, a^q T)$ also a solution of equation (1), if $y(t,T)$ represents a solution of (1)? Inserting $y(a^p t, a^q T)$ into the diffusion equation gives

$$a^{2p}\frac{\partial^2 y(a^p t, a^q T)}{\partial (a^p t)^2} - \frac{8}{w^2}\, a^q \frac{\partial y(a^p t, a^q T)}{\partial (a^q T)} = 0, \tag{2}$$

e.g.:

$$q = 2p$$

with arbitrary p or q. Using $p = 1$ implies

$$y(at, a^2 T).$$

Since the number of variables should be reduced to one and a is still arbitrary it may be required $a^2 T = 1$, or:

$$a = \frac{1}{\sqrt{T}}.$$

Now, the function

$$g(z) := y(z,1), \qquad z = \frac{t}{\sqrt{T}}, \tag{3}$$

is introduced as a new unknown function which includes only one variable. This provides the ordinary differential equation

$$g''(z) + \frac{4z}{w^2}\, g'(z) = 0 \tag{4}$$

instead of the partial differential equation (1). (4) also has the advantage that it is only a first-order equation in $g'(z)$. Integrating (4) implies

$$g'(z) \;=\; C\exp\,[-\frac{2z^2}{w^2}],$$

where C is any arbitrary constant. Further integration provides

$$g(z) \;=\; C\int \exp\,[-\frac{2z^2}{w^2}]dz\,.$$

This gives the full solution of $y(t,T)$

$$y(t,T) \;=\; C\int \exp\,[-\frac{2z^2}{w^2}]dz\,, \qquad z=\frac{t}{\sqrt{T}}. \tag{5}$$

For this integrand $f(x) = exp(-x^2)$ a function $F(x)$ does not exist, whose derivative is $f(x)$. So Taylor series are used. Inserting the infinite series for the exponential function into solution (5) and integration by parts gives

$$y(t,T) \;=\; C\sum_{n=0}^{\infty}(-1)^n\frac{2^n}{w^{2n}n!\,(2n+1)}\,z^{2n+1}\,, \qquad z=\frac{t}{\sqrt{T}},$$

or

$$y(t,T) \;=\; C\frac{t}{\sqrt{T}}\sum_{n=0}^{\infty}(-1)^n\frac{2^n}{w^{2n}n!\,(2n+1)}\,\frac{t^{2n}}{T^n}\,. \tag{6}$$

These series converge for all $z=\frac{t}{\sqrt{T}}$.

In practice (see [6]), the variable $t-t_c$, t_c is constant, is needed. It can easily be shown that in the formula (6) on the right side all t can be replaced by $t-t_c$. E.g., $z=\frac{t-t_c}{\sqrt{T}}$.

DISCUSSIONS

The general purpose of this paper is to present and solve a partial differential equation which describes the durability of the tractor engine. For this the tractor model Massey Ferguson 8160 was taken because it was used on larger Serbian farms. It is one of the most popular models in the category over 140 kW and was imported from western countries.

The engine durability of more than 100 tractors had been monitored. Such results are presented in [5]. The fitting function of the probability density function of engine lifespan is the normal Gaussian function. (The experimental values are slightly steeper rising as falling, i.e., not quite symmetrical as the normal Gaussian distribution.) But this fitting function $y(t,T=1)$ also is a special solution of the differential equation.

CONCLUSIONS

Since it is difficult to solve partial differential equations analytically, but because almost all technical processes are described with them, a quite new way of solving such a equation is presented in this paper. The main point of this new calculation of solutions is to find one variable which includes the two other variables t and T and reduces the partial differential equation to a ordinary differential equation. It is much easier to find solutions of a ordinary differential equation. Such approaches also can be used for quite other partial differential equations than (1) and adequate mathematical problems. This will be certainly in future the case.

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MATHEMATICAL PHYSICS FOR THE DURABILITY OF A TRACTOR'S ENGINE ON SERBIAN FARMS

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Abstract. *Equipment, repair and maintenance costs are important issues for agricultural concerns. Motivated by the investigation of the engine durability of the popular heavy-tractor model, Massey-Ferguson 8160, a partial differential equation had been derived by engineers. In this publication, a whole new method of solving this equation is presented. Since it is difficult to solve partial differential equations analytically, but because almost all technical processes are described with them, a quite new way of solving such a equation is presented in this paper.*

Key words: *Tractor engine durability, differential equation, solution*

1. INTRODUCTION

Keeping tractors in good condition is financially important. It is also important to hold the engine of the tractor in the optimum achievement level to carry out the work, the achievement and torque reserves correctly [1,3,4]. In [2,5] results of a tractor engine durability check on Serbian farms are treated. With questionnaires data were acquired from various Serbian farms. Thus, the frequency distribution and the probability and probability density function of the engine were found. For this purpose a differential equation was derived. In this publication, the equation is solved.

2. THE DIFFUSION EQUATION

Considering $y(t,T)$, which is the probability density function of tractor engine's lifespan, the differential equation

$$w^2 \frac{\partial^2 y}{\partial t^2} - 8\frac{\partial y}{\partial T} = 0, \qquad (1)$$

can be employed. The variable t is the lifespan of the engine. This is the number of working hours before the overhaul of the engine. The actual year of tractor manufacturing is noted by $T > 0$. Both variables are positive. The known parameter w is constant.
The partial differential equation (1) possesses an infinite number of polynomials $y(t, T)$ with two variables as a solution, for example:

$$y = a_1, \qquad y = a_1 + a_2 t, \qquad y = a_1 + a_2 t + w^2 a_3 T + 4a_3 t^2,$$
$$y = a_1 + a_2 t + w^2 a_3 T + 4a_3 t^2 + 3w^2 a_4 tT + 4a_4 t^3, \; \ldots \; .$$

The coefficients a_j are arbitrary real numbers. But no function $y(t, T = 1)$ which results from all these polynomials corresponds to the fitting function $y(t, T = 1)$ in [5], which is calculated with the experimental measurements. Therefore, a completely different solution $y(t, T)$ has to be determined.

3. THE SOLUTION OF THIS PARTIAL DIFFERENTIAL EQUATION

Since the solving of a ordinary differential equation can be obtained easier than of a partial differential equation, it is tried to reduce the partial equation (1) to a ordinary equation. This suggests the possiblity of finding a relation $z_1(t, T)$ which appears in the solution of (1). It can be shown that if $y(t, T)$ is a solution of equation (1), the function

$$y(t, T) = y(\lambda t, \lambda^2 T) \qquad (2)$$

also satisfies this given partial differential equation for all t and T. λ is arbitrary. Now, for any arbitrary value of T, λ can be set

$$\lambda = \frac{1}{\sqrt{T}}.$$

So (2) means that

$$y(t, T) = y(\lambda t, \lambda^2 T) = y\left(\frac{t}{\sqrt{T}}, 1\right) =: g(z_1) \qquad (3)$$

with $z_1 = \frac{t}{\sqrt{T}}$. In practice, it is necessary to replace the t by $t - t_c$. This is allowed, because t_c is constant. Doing that the new variable is defined by

$$z = \frac{t - t_C}{\sqrt{T}}.$$

Substitution of $y(t, T) = g(z)$ into (1) yields the ordinary equation

$$g''(z) + \frac{4z}{w^2} g'(z) = 0. \qquad (4)$$

It easily can be shown that (4) gives

$$g'(z) = C \exp\left[-\frac{2z^2}{w^2}\right]. \tag{5}$$

C is a arbitrary integration constant. A integral free representation of (5) cannot be obtained. But the following fact can be found:

Lemma

If $y(t,T)$ is a solution of the diffusion equation (1), then y_t also represents a solution of (1).

This easily can be shown by differentiation of (1). Calculation of y_t, gives

$$y_t = \frac{\partial}{\partial t}\left[g\left(\frac{t - t_c}{\sqrt{T}}\right)\right] = \frac{C}{\sqrt{T}}\, g'\left(\frac{t - t_c}{\sqrt{T}}\right) = \frac{C}{\sqrt{T}} \exp\left[-\frac{2(t - t_c)^2}{w^2 T}\right].$$

So

$$y(t,T) = \frac{C}{\sqrt{T}} \exp\left[-\frac{2(t - t_c)^2}{w^2 T}\right] \tag{6}$$

represents the required solution.

4. THE NORMALIZATION CONDITION

To calculate the arbitrary constant C the normalization condition

$$\int_0^\infty y\,(t, T = 1) = 1$$

is used. Inserting (6) in this relation gives

$$C = \frac{1}{w}\sqrt{\frac{2}{\pi}}.$$

Since only derivatives of $y(t,T)$ appear in the differential equation (1), $y(t,T)$ can be represented in (7) by $y(t,T) - y_0$. y_0 is any constant. Therefore, formula (6) then takes the form

$$y(t,T) = y_0 + \frac{1}{w}\sqrt{\frac{2}{\pi T}} \exp\left[-\frac{2(t - t_c)^2}{w^2 T}\right]. \tag{7}$$

5. DISCUSSION

The general purpose of this paper is to present and solve a partial differential equation which describes the durability of the tractor engine. For this the tractor model Massey Ferguson 8160 was taken because it was used on larger Serbian farms. It is one of the most popular models in the category over 140 kW and was imported from western countries.

The engine durability of more than 100 tractors had been monitored. Such results are presented in [5]. The fitting function of the probability density function of engine lifespan is the normal Gaussian function. (The experimental values are slightly steeper rising as falling, i.e., not quite symmetrical as the normal Gaussian distribution.) But this fitting function $y(t, T = 1)$ also is a special solution of the differential equation.
Since it is difficult to solve partial differential equations analytically, but because almost all technical processes are described with them, a quite new way of solving such a equation is presented in this paper.

CONCLUSION

The main point of this new calculation of solutions is to find one variable which includes the two other variables t and T and reduces the partial differential equation to a ordinary differential equation. It is much easier to find solutions of a ordinary differential equation. Such approaches also can be used for quite other partial differential equations than (1) and adequate mathematical problems. This will be certainly in future the case. The second important point of this publication is to recognize that y_t already represents a solution of (1) (see Lemma). This saves a lot of calculations. Experimental results for the durability of a tractor are given in [2,5].

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PARTIAL DIFFERENTIAL EQUATIONS FOR DESCRIBING THE WATERBORN SOLID IMPURITIES SIZE DISTRIBUTION

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Abstract: *This paper presents a partial differential equation, which describes the waterborn solid contaminants size distribution which was previously experimentally verified. The solution of a diffusion equation which describes a density function is derived. The solution includes a exponential function.*

Key words: *Partial differential equation, waterborn contaminants*

1. Introduction

This paper presents a partial differential equation, which describes the waterborn solid contaminants size distribution which was experimentally verified in [1,2,3]. Particular sizes had been measured with a microscopic morphometric method. The empirical probalility density function of particle sizes had been established with experimental data. For this non-linear data fitting with using a iterative algorithm, according the exponential function, had been used.

In this paper the differential equation accompanied with the appropriate additional conditions, which describes such kind of distributions, has been formulated and presented. Since the solving of differential equations with not constant coefficients is complicated, a quite new approach had to be found. The solution includes a exponential function.

2. Diffusion Equation

The parabolic partial differential equation

$$\frac{\partial}{\partial x}[\nu x\,\frac{\partial y}{\partial x}] - \frac{\partial y}{\partial t} = 0, \tag{1}$$

describes this process. $y = y(x,t)$ denotes the size distribution of solid contaminants with particle diameter x. $t > 0$ is the time. The constant ν is the drift velocity. The differential equation (1) also can be written in the form

$$\nu x \frac{\partial^2 y}{\partial x^2} + \nu \frac{\partial y}{\partial x} - \frac{\partial y}{\partial t} = 0\,. \tag{2}$$

Looking at equation (1) it easily can be seen that it represents a one-dimensional diffusion equation.

Remark:

The diffusion equation is a partial differential equation which describes density dynamics in a material undergoing diffusion. It is also used to describe processes exhibiting diffusive-like behaviour, for instance the 'diffusion' of alleles in a population in population genetics. The most general one-dimensional diffusion equation which is homogenous has the form

$$\frac{\partial}{\partial x}[d(x)\frac{\partial y}{\partial x}] = c(x)\frac{\partial y}{\partial t}, \quad y = y(x,t)$$

with given functions $c(x)$ and $d(x)$. Here $d(x)$ is called the coefficient of diffusion and $c(x)$ represents a material coefficient. The coefficients in (1) and (2) are $d(x) = \nu x$ and $c(x) = -1$.

Since till today no approach for the general diffusion equation could be found, the given differential equation in this paper also has to be solved separately. To get an idea of how the solution of (1) repectively (2) might look like, equations (1) and (2) are simplified to

$$\frac{\partial^2 y}{\partial x^2} - \frac{\partial y}{\partial t} = 0\,. \tag{3}$$

This partial differential equation (3) is the simplest diffusion equation and possesses the particular solution

$$y(x,t) = \frac{D}{\sqrt{t}}\exp\left(-\frac{x^2}{4t}\right), \tag{4}$$

where D is any arbitrary constant (see [4], [5]). Since differential equation (3) is similar to the equation (1) and (2), the solutions of (3) also could be similar to the solutions of (1) and (2). Therefore, a solution of the form

$$y(x,t) = C\, t^p e^{a x^n t^q} \tag{5}$$

is sought. Here the numbers a, p, q and n represent still unknown real numbers, while C is any arbitrary real number.

For the calculation of the four real constants a, p, q and n the function (5) is inserted in the partial differential equation (2). That provides the conditional equation

$$p + aqx^n t^q = \nu\, an^2[1 + ax^n t^q]x^{n-1}t^{q+1} \tag{6}$$

for the four unknown numbers. Comparing the coefficients with respect to x-powers in (6) implies five different cases for the determination of the four unknown constants that could be useful:

Case 1: $n = 0$
Then (6) reduces to

$$p + aqt^q = 0\,. \tag{7}$$

For this equation two different cases are distinguished. If q vanishes, only one equation for the three unknown constants a, p and q is given. So they are any arbitrary undeterminded constants and (5) also is not determinded. In the case $q \neq 0$ equation (7) implies $p = 0$ or $aq = 0$. Since the assumption $q \neq 0$, a vanishes and $y(x,t) = y(t) = Ct^p$ with arbitrary p. This result cannot be used.

Case 2: $n = 1$
Now (6) has the form

$$p + aqxt^q = \nu a\,[1 + axt^q]t^{q+1}. \tag{8}$$

Comparing the coefficients of x-powers in (8) gives the two equations

$$p = \nu a\, t^{q+1}, \qquad q = \nu a\, t^{q+1}.$$

Here two further cases have to be distinguished. The first case, $q \neq -1$ implies $p = q = a = 0$ and $y(x,t)$ is a arbitrary constant C. In the second case, if $q = -1$, then $p = a\nu$ and $-1 = a\nu$. Taking the second of theses relations gives $a = -\nu^{-1}$. Therefore, $p = -1$. So the solution (5) of the diffusion problem (1) is

$$y(x,t) = \frac{C}{t}\exp\left(-\frac{x}{\nu t}\right). \tag{9}$$

Case 3: $2n - 1 = 0$ resp. $n = \frac{1}{2}$
Here (6) becomes

$$p + aq\sqrt{x}\,t^q = \frac{\nu a}{4}\,[\frac{1}{\sqrt{x}} + at^q]t^{q+1}. \tag{10}$$

Equating the coefficients of x-powers yields

$$p = \frac{\nu a^2}{4}\,t^{2q+1}, \qquad aq = 0, \qquad a = 0.$$

Using the third equation with $a = 0$ the second equation is satisfied and the first equation gives $p = 0$. This is pointless, because $y(x,t)$ reduces to a constant.

Case 4: $n = 2n - 1$
Hence, if $n = 1$, the general conditional equation is given by (8) with solution (9), because this is Case 2.

Case 5: $n - 1 = 2n - 1$
So $n = 0$ and this corresponds to the first case which cannot be used.

Since all cases except the second and fourth provide trivial solutions which can be ignored.

3. The Normalization Condition

The arbitrary constant C can be calculated with the normalization condition

$$\int_0^\infty y\,(x, t = 1) = 1\,.$$

By substituting the solution (9) into this integral gives

$$C\; = \frac{1}{\nu}.$$

Thus the final solution

$$y(x,t) = \frac{1}{\nu t}\exp\left(-\frac{x}{\nu t}\right) \tag{11}$$

of the diffusion equation is calculated.

4. Discussion

The mathematical modeling of different processes in agriculture had been strongly intensived during the last decades. Therefore, not only the experiments but also the calculations in this field have increasingly grown. An example of these many is the counting of particles in a liquid or gaseous medium. This can be carried out experimentally.

This paper presents a partial differential equations which describes the waterborn solid contaminants size distribution. A special solution $y = y(x, t = 1)$ of this differential equation corresponds with the empirical probability density function of the particle sizes. The solution is for positive and constant t, as i.g. $t = 1$, a strongly falling graph.

Conclusions

The main purpose of this paper is to show that the analytic solution of the differential equation which describes this process complies with the approximation of the experimentally determined probability density function. The experimental results are published in [1], [2].

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Popular Paper

ASPECTS REGARDING THE CONSERVATION SOIL TILLAGE SYSTEMS USING ON THE WORLD– A REVIEW

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Abstract. *The maintenance and conservation of the properties of soil can be also achieved by performing adequate agricultural works, conducted in the optimal period, complying with the technology related to the respective crop. The paper presents the most important conservative works used in Romania and worldwide, which can lead, on a medium and long term, to maintaining and restoring the physical-chemical properties of soil.*

Key words: *sustainable development, conventional, organic agriculture, system, sustainable*

1. INTRODUCTION

Soil works were an integral part of agriculture since the beginning and have served a few important purposes: preparing the seed bed, reducing soil compaction in order to increase aeration and a better development of the root system, reducing de degree of weeds, incorporating fertilizers and amendments, plant waste management [1, 2, 25].

The conventional agricultural system – product of super industrialized society, with heavy polluting effects, hard to control and unpredictable to the ecological balance, is the efficient but unsustainable type of agriculture, situated in an alarming stage, because of the exhaustion of fossil natural resources and due to the multiple negative effects on society. The beneficial result of industrial agriculture is only constituted by the increase of work productivity and increasing yield, which in the last 4-5 decades have doubled and even tripled in numerous European countries. It is the dominant agricultural system in our days, whose change in the XXI century is imminent [3].

The expression “**sustainable development**” was first given by the Norway prime-minister, Gro Harlem Brundtland [13]. As President of the World Commission of Environment and Development, she presented the report *"Our Common Future" in which she defined sustainable development as "the development that meets the necessities of the present without compromising the ability of future generations to meet their own necessities".* Sustainable development implies ensuring simultaneous progress on three fronts: economic, social, and ecological [4].

For the term "**sustainable agriculture**" a detailed definition that is universally accepted was not yet developed because farming practices that come under this concept aiming to provide sustainable development in rural areas vary in space and time, their effectiveness being possible to evaluate properly especially retrospectively [5, 37].

- **Organic agriculture** (ecological, biological) is a management system for agricultural production that favors renewable resources and recycling and does not harm the environment. Organic agriculture avoids the use of pesticides, herbicides, synthetic fertilizers and genetic manipulation practices. Regarding livestock, the prophylactic use of antibiotics and growth hormones is avoided and there is a focus on animal welfare and ensuring food from natural products. The focus is directed towards using management practices in agreement with using inputs from outside the farm, taking into consideration the regional conditions to which the systems have to adapt [6].

The concept of „**precision agriculture**” refers to the use of information and technology in crop management. Precision agriculture represents a management system, based on information and technologies regarding the intensification, analysis and directing the variability in the fields, optimal profitability, sustainability and protection of the soil resources. An agricultural system can be durable if the production, the nutrients contained in the harvest and the natural fertilizers, or lost by erosion are equaled by those introduced in the form of artificial fertilizers and created by the decomposition of rocks in the base layer. All supplementary entries, such as energy, water, chemical preparations should also be durable products [7].

- **Extensive agriculture with low inputs – of subsistence**, gives a productivity that is low competitive. It can affect to a certain degree the environment, including the quality of biomass, especially by the nutrition unbalances. Mineral fertilizers and other agro-chemical products (herbicides, insect-fungicides, mineral amendments etc.) are not practically applied or are applied only in very small quantities (except for the vegetable crop sector) [8].

- **The concept of soil conservation** This concept comprises o set of activities, measures and technologies that contrite to maintain the fertilization status of soil, without a significant decrease in crop yields or without high costs. This system covers a wide range of agricultural methods that have as primary purpose to keep the plant waste on the surface of the arable land in order to reduce erosion. Technologies for soil conservation are characterized by the fact that they leave on the surface of soil more that 30% of the plant waste from the previous crop. Plant waste protects the surface of the soil against water erosion by absorbing the energy of the raindrops, thus reducing the possibility of detaching soil particles. The layer of plant waste also reduces the compaction of soil by the raindrops and the possibility of forming a crust, thus increasing the capacity for the water to infiltrate the soil. By creating small dams and obstructions along the waterbed flow, plant waste decreases the water's flowing speed, reduces the quantity of soil transported and the quantity of additional substances detached by the water [9].

Technologies for soil conservation that leave a great part of the plant waste on the surface of the soil reduce erosion by 95% (no-till) compared to the classical soil processing systems. Plant waste that is evenly distributed on the surface of the soil and in a larger quantity on slope lands, where erosion is more profound, by intercepting raindrops, absorb their energy and reduce the process of detaching soil particles (the first step in the process of erosion), slow down water drainage on the surface of slope terrains and reduce the transportation of soil particles (the second step in the process of erosion) [10].

In the field of agricultural production, plowing has been the main work for establishing crops for a long time, due to its undisputable advantages. With the assessment and due to some negative consequences of plowing, practiced mainly in an intensive agriculture, like the one in the USA, has emerged the idea of reducing the number or works – "*minimum tillage*" or of eliminating them – *"no tillage"*. The scientific basis of the new concepts regarding the soil works substantiated by the American science and practices were developed generating various options, adapted and adopted in diverse soil and climate areas of the world.

The introduction of these concepts was determined by the fact that the intensive soil working, apart from the immediate negative consequences, has generated different negative processes whose reminiscent effects have accumulated in time leading to increased soil erosion especially in the arable and sub arable layer [21, 31, 33, 36].

The development of these systems was sustained, on one hand, by the progresses registered in the field of mechanization, in the construction of efficient agricultural machinery for working the soil and for seeding, and on the other hand, by the progresses in the field of agro-chemistry and agricultural technique that allow efficient ways and alternatives for fertilization, weed and pest combat. Increased fuel prices and the necessity to optimize energy consumption in the purpose of increasing the economic efficiency of soil cultivation was another reason that led to significant changes in the concept of working the soil [22, 23, 24, 28, 30, 32, 35, 38].

Defining the options of the conservation system of working the soil in different geographic areas is tied both the manner and intensity of loosening but also by the presence and the degree of covering with plant residues (mulch). The indicator – plant residues – is used in all the areas where precipitations are moderate and the potential for evapotranspiration is high and where are actually situated the majority of surfaces recommended for applying the soil preservation system.

Since they emerged and until now, the new ways to work the soil have been called "optimal systems, rationalized systems, alternative systems, work systems for soil preservation".

Presently, soil works performed in a conservative manner (unconventional) define extremely varied, from seeding directly in unprocessed soil until deep loosening without turning the furrow. Between these two extremes are found options such as: reduced works (classic rationalized), minimum works (with under 30% plant residues covering), minimum works with plant mulch (with over 30% covering), seeding in ridges, seeding in strips, etc.

In the last decade of the 20^{th} century, for the definition of the conservative system of working the soil have been outlined three directions:

- *rotation work*: is the possibility by which the intensity of soil loosening is reduced, very well correlated with the crop rotation. This modality is justified by the following arguments: plants cultivated in rotation have different demands for the manner in which the soil is processed; soil demands regarding the work is not constant and soil characteristics are modified progressively with positive or negative consequences.

- the concept of *reduced works* or *minimum works* starts from the idea that numerous types of soil show a certain demand for loosening in order to ensure favorable conditions for a normal development of certain processes in the soil and for crop development. Minimum works imply basic loosening without turning the furrow, at a normal working depth, without necessarily smaller than the one in the conventional system. Also, in some cases, a minimum of works can be necessary for the mechanical fighting of weeds, facilitating some biological processes and developing the root system. The main characteristic of such a system is the reduction of energy consumption of the time frame awarded to conducting all the works compared to the conventional system.

- *direct seeding* (no-tillage) refers to introducing the seeds in a soil that practically has not been processed, because soil working is limited only to opening some very small grooves by the working organs of the seeding machine. In practices, it is custom that before direct seeding to make a very superficial loosening in order to improve the degree of soil grinding and to better arrange the plant residues.

3. RESULTS AND DISCUSSION

The conservative soil working system has various options among which the most used are:

- *Rationalized systems* for working the soil, with two options: *plowing-seeding* system and *seeding cultivating* system [26, 27, 29, 34, 40, 41];
- *Minimum work system* (minimum tillage) – covering with plant residues in a share of 15-30% [19, 20, 39, 40, 41];
- *Minimum work system with mulch* (mulch tillage) – covering with plant residues in a share of more than 30 % [19, 20];
- *Working system with protective layer* (cover crops, catch crops) [19, 20];
- *Working system with in bands or narrow strips* (strip till, zone till) [14, 15, 17, 18];
- *No working system or direct system* (no-tillage, direct drill) [26, 27];
- Vertical tillage (shallow and deep) [42, 43];
- Traffic Controlled Farming [31, 33, 36].

1. *Rationalized systems* for working the soil: reducing the number of works for processing the soil and executing them in optimal conditions of humidity is inscribed in the general objectives followed regarding the preservation of physical characteristics. Rationalized systems for processing soil keeps plowing with the moldboard plow as main soil processing work, but compared to the classic system, it implies using combined aggregates that at a single crossing perform multiple technological processes. Depending on the soil characteristics, pedological and climate conditions, the cultivated plant, the fertilization system, weed combating and machinery used, are distinguished two options:

Plowing-seeding system consists in executing, in a singles crossing, using a combined aggregate, the works of preparing the soil (plowing and preparing the seed bed) and of seeding. The aggregate can be provided with equipments for applying fertilizers, herbicides and for compacting the soil on the seeded row.

Seeding-cultivating system consist in conducting two operations: at the first crossing fertilizers are applied and the plowing is performed, and in the second crossing, the seed bed is prepared (cultivator for total processing, disk harrow, combined rotary harrow) simultaneously with seeding. As an option, equipment for applying herbicides can be applied.

2. Minimum work system: also called the reduced work system implies conducting the basic work without turning the furrow, keeping plant residues in a share of 15-30% at soil surface (as mulch) or incorporating them superficially. Plowing with the moldboard plow is accepted to be conducted after a period ranging between 3-5 years. The most frequently used machines executing the basic work are: the heavy disk harrow, chisel, paraplow, the combined rotary harrow, the mill, the cultivator for total processing and different combined aggregates.

a) Disk harrow work: when processing the soil using this option (fig. 1), harrows with heavy discs are used (the weight for each disc is 30-50 daN), with active bodies (concave discs) having contiguous or discontinuous (dentate) edge. During operation, discs reach a depth of 10-12 cm, cut a layer of soil that is grinded and partially turned over. In order to execute the work, the optimal moment of humidity should be chosen, because it is known that this work contributes highly to the deterioration of structure, and that is why, the excessive use of disc harrow should be avoided.

Fig. 1 Working with the disc harrow [11]

b) Working with the chisel: the main soil work is conducted (fig. 2), in this case, with machinery for soil loosening. The chisel is a heavy cultivator that performs the work of loosening the soil at a depth of 15-20 cm or maximum 40 cm (for deep soil loosening).

Fig. 2 Working with the chisel [11]

The working bodies of the chisel cultivators are similar to those of cultivators for total processing and are shaped as a chisel or as a claw for loosening, mounted on elastic holders (lamellar springs). Working with the chisel creates soil loosening without involving mixing, turning or reversing the layers of soil.

c) Working with the plow without moldboard (fig. 3): where the regular moldboard plow bodies are replaced with active bodies that loosen the soil without turning the furrow and are generally called paraplow or plow without turning the furrow (PWTF). The working depth is 22-25 cm (30 cm maximum). Several different constructive options of paraplow plows are used, the effect of mobilizing the soil depending on the geometry of the working bodies.

Fig. 3 Plow without moldboard (plow without turning the furrow– PWTF) [11]

d) Working with the rotary combined harrow (fig. 4): is destined for preparing the seed bed at depths of 8-18 cm. it is carried and actuated from the shaft from the PTO of the tractor with which it work in aggregate. The working bodies can be: spikes for processing plowed soil or blades for processing unplowed soil, mounted on the vertical rotors followed by a Packer type cylinder or by a rod cylinder. Soil processing is done without bringing from the depth wet soil layers to the surface, thus maintaining the humidity in the soil for good seed germination. Packer cylinder ensures an additional grinding and a light compaction and leveling of soil.

Fig. 4 Work with combined rotary harrow [11]

e) Working with the cultivator: it is used for processing the upper soil layer, the main purpose being to loosen it and destroy weeds (fig. 5).

Fig. 5 Working with the cultivator [11]

f) Combined aggregates (fig. 6): are used in the minimum work system and allow to perform, at a single crossing, the following works: soil loosening without turning the soil at a depth of 40 cm; preparing the seed bed; seeding and compacting. Usually, these combined aggregates perform these works on unplowed fields. As an option, they can be used only for loosening the soil and preparing the seed bed on unplowed fields (without the seeding equipment), or only for preparing the seed bed and seeding on unplowed fields (without the loosening bodies).

Fig. 6 Combined aggregate for seeding cereals / weeding plants [11]

- **Minimum work system with mulch (mulch tillage)**: is performed in the same conditions as in the case of minimum works (minimum tillage) with the difference that plant residues remaining on the surface of the soil should be at least 30% from their total. This option is recommended especially in dry areas and on terrains susceptible to structural degradation and erosion.

- **Work system with protective layer** (cover crops, catch crops): implies to ensure at soil surface a protective plant layer. It is recommended on slope fields to contain surface erosion and as a means of limiting soil losing structure due to raindrops.

- **Work system with ridges:** was elaborated by researches from Yowa State University (USA) and was applied for weeding crops (fig. 7). This system is preferred on slopes and on cold soils with poor internal drainage. On slopes, the work system with ridges (the orientation of ridges is on the direction of level curves) allows the retention of precipitation water between the ridges, favoring infiltration and reducing erosion.

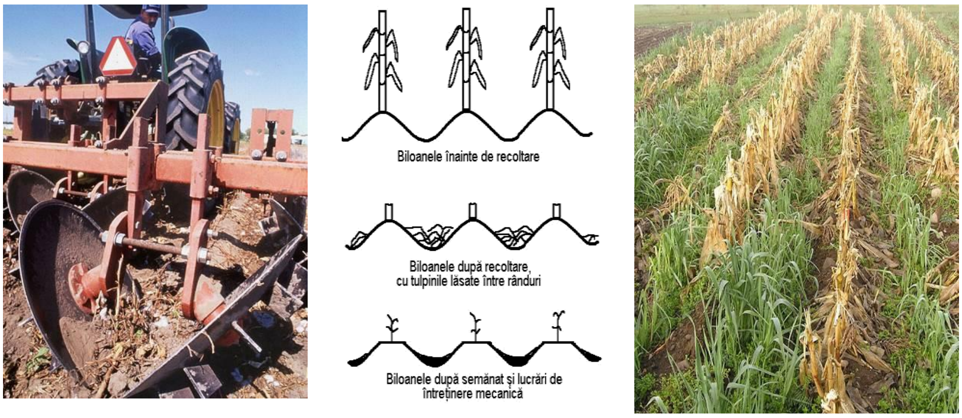

Fig. 7 Work system with ridges [Source: Yowa State University- S.U.A.]

- **Work systems in bands or in narrow strips:** consists in processing the soil in the form of narrow bands with a width 15-20 cm simultaneously performing the seeding (fig. 8). The work is performed by a combined aggregate with organs for processing the soil of the rotary harrow type or with loosening bodies' specific for chisel cultivators. The plowshares of the seeding machine open the channel at the established seeding depth and place the seeds in the middle of the processed area.

Fig. 8 System for working in strips [12]

- **System "without works" or direct seeding (no – tillage):** direct seeding means placing the seed in the unprocessed soil, meaning the renunciation of any tillage. The only "processing" is a slot machine created by sowing coulters where the seeds and fertilizers are introduced. In this system the seeding is direct into stubble or plant debris field from the previous plant.

"No – tillage" system ellaborated by Phillips and Young (SUA), in 1960 for corn crops, doesn't represent a manner of preparing the seed bed, but a system in which any intervention (fertilizing, applying herbicides) is executed according to prescriptions. In the USA and Canada, direct seeding is performed on 52% of the arable surface, in South America on 44%, in Australia on 2% and in Europe, Asia and Africa on about 2%.

Direct seeding can be used for a wide range of crops, except for the potato crop, intensive vegetable crops and some special crops. When passing from the classic technology to the technology for direct seeding is necessary to have a period of transition of about 3-4 years. In this period, production decreases, but the soil is prepared for the new working system. From the agricultural technology point of view, the structure of the soil is improved, the humus content is increased due to increased mineralization, and porosity and the quantity of water available for plants also increase.

Passing to the direct seeding system implies to undergo the following stages:

- *choosing the field*: the soil should always have a clayey or loam-clayey texture, to be well structured, adequately aerated, and biologically active, to have a high content of humus. From the types of soil that fulfill these conditions we can enumerate: brown soil, chernozem, cambic chernozem, clay-illuvial chernozem, brown-red soil, brown clay-illuvial soil, cambic marshes. Depending on the type of soil, are applied solid, liquid mineral fertilizers or organic fertilizers;
- *performing basic works during summer* (plowing, loosening) simultaneously with the work of fertilizing;
- *applying a total herbicide* to destroy annual and perennial weeds, applied pre emerging;
- *preparing the seed bed* and seeding autumn cereals;
- *harvesting in the next year*, and plant residues (straws, stubble) remain on the soil;

- *are combated the perennial weeds* that are in the stubble seeding is executed directly, without performing any other soil work.

Machines for direct seeding should built as to operate both on dry soils and on wet soils, in the conditions of having large quantities of plant residues. The working bodies of the machines for direct seeding perform the following operations:

- grinding plant residues and processing the soil in the area of the row;
- cleaning the row of plant residues;
- opening the slit (channel) where the seeds will be placed;
- gentle pressing the seeds, covering with soil and compacting the row in order to fix the seeds.

Because the soil remains covered with plant residues from the previous crop and the processing is done only on the strips for seeding, an adequate control is ensured against water and wind erosion and work force and fuel are saved.

A machine for direct seeding cereals should perform a loosening and a mixing of soil in a degree as small as possible and to place the seed in the soil so that it has optimal conditions for germination and growing. The conception of working bodies of these machines should allow performing the work in the conditions imposed both on dry soils and on wet soils, in the presence of a high quantity of plant residues.

Research and agricultural practices have shown that seeders with double plowshare eliminate the danger of clogging, even in the case of large quantities of plant residues. Shortcomings were found in the manner of operating on wet fields where the discs do not cut the plant residues, but roll over them, pressing them on the bottom of the furrow and placing the seed on top of them. In the case of large quantities of plant residues and in drought conditions, after seeding, takes place a worsening of the germination, until plant roots are developed and pierce through the plant layer.

For the operation of fragmenting plant residues in the area of the rows, a special efficiency is observed in the case of the “corrugated” disk knife. In optimal humidity conditions, with fewer dry and breakable plant residues, machines for direct seeding equipped with double disk plowshares are used, giving very good results. In order to ensure that the double disk plowshares penetrate the soil, at the seeding depth, a pressing force at least 200 daN should be applied on them, meaning that a machine for seeding cereals with a working width of 3 m will have a weigh of at least 3 tons. Seeding machines with chisel type blades require a more reduce load (around 80 daN / plowshare) making them lighter. These machines perform a more powerful mixing of the soil in the area of the row, a better aeration, favoring worming and a better water infiltration around the seeds. In recent years, companies constructing seeding machines have focused on developing numerous models of machines for direct seeding that answer all exigencies. Some of the most popular machines for direct seeding used for cereal crops are DIRETTISIMA and DIRECTA (fig. 9).

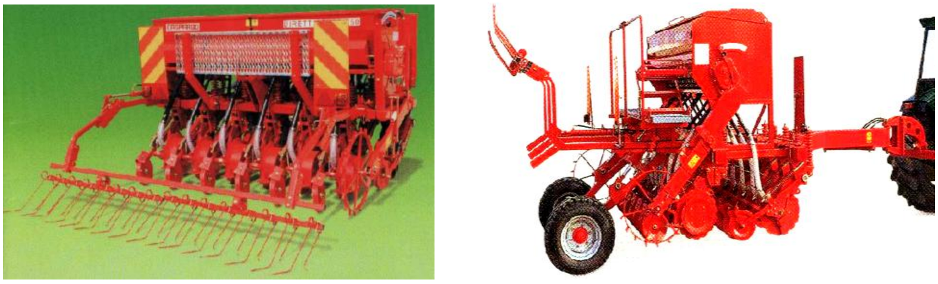

Fig. 9 DIRETTISIMA / DIRECTA seeding machines [11]

DIRETTISIMA seeding machine is destined for seeding autumn cereals (wheat, barley), but also for spring crops, for small and medium farms, being built in the carried or towed version, requiring energy sources of 80 ÷100 HP. The stations of the machine are provided with disc plowshares limiting the seeding depth, organs for fixing seeds and organs for covering with soil. DIRECTA model (fig. 9) belongs to the machines for direct seeding in unprocessed soil. It is a seeding machine with mechanical distribution and is destined for seeding cereal crops, soybean, rape seed, fodder, etc. a representative model for a machine for direct seeding used for corn crops is the Gaspardo machine (fig. 10).

Fig. 10 Machine for direct seeding of corn Gaspardo [11]
1 – seed box; 2,3 – organs for opening the channels; 4 – double disc plowshares; 5 – wheels for closing the channels; 6 – distribution device; 7 – tube for driving the seeds

4. CONCLUSIONS

Soil tillage system that does not include plowing implies a soil processing from 3 to 25 cm. choosing the working depth is determined in a wide range by the texture of the soil. Light soil benefit from bigger working depth, meanwhile, for heavy soil it is the opposite. In systems for processing the soil with minimum crossings, cultivators are used for loosening the soil at depths of 10…15 cm. the main reason for applying such a system is the low risk of soil sliding and o forming a crust, low risk of erosion and also the possibility to achieve high yields. Despite the working depth of 10…25 cm, relatively large quantities of straws remain at the surface after a deep soil mobilizing in the depth, compared to the plow. A positive effect of this organic layer is the low erosion and the fact that humidity is kept in the soil. However, this leads to a risk of fungal attacks, creating a big necessity to introduce crop rotation. Problems do not arise when spring crops are seeded, because there is enough time between harvesting in the summer and seeding in the spring, when straws and plant residues have time to decompose.

Important factors that influence the success of mobilizing work without a plow are:

- Plant residues must be evenly distributed;
- A proper crop rotation decreases the phyto-pathological risk;
- Crop without diseases and pests attacks, with no apparent fungal attack.

Benefits of applying the work:

- Improving the structure of the soil;
- Low risk of forming erosion crust or sliding, due to the organic layer at the surface;
- Even fields;
- Low time consumption for executing the work.

In all crop establishment systems straw control is important. Straw chopping and their uniform distribution is a basic requirement for an appropriate result. However, the large volume of soil involved in deep tillage possibility that the cultivator chisels to mix means that a larger amount of straws can be accepted, compared to superficial processing. An indicative rule of deep tillage is to work at a depth of 2 cm per ton of straw. This means that if we have an output of 6 tons per hectare, we need to work the soil to a depth of 12 cm to incorporate straw in an appropriate manner.

Soils with little or no clay are unstructured and, as a consequence, the stability of the aggregates is small compared to those with high clay content. Without loosening, these soils become compact and impenetrable in time. Consequently, deep tillage is one solution to not resort to plowing and not having decreases in production. Also, in soils with more clay, processing is needed to eliminate compaction after harvesting in excessively humid conditions.

A cultivator has somewhat a higher tensile strength than a plow, in order to move the same volume of soil. But we do not always need to mobilize the same volume of soil. Instead, we want to mobilize and create space at a certain depth. In practice, most farmers alternate deep mobilization with superficial processing, which also leads to significant savings.

Deep tillage can sometimes be below the depth of plowing (35-50 cm), which is known as scarification. Frequency of mobilization at high depths is usually 3 or 4 years, or even more often.

Scarification offers a series of advantages especially when the soil is very compacted, or before specific crops. The work is also relevant on soils with sandy structure that requires seldom loosening in order to have proper results.

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First (Short) Comunication

EVALUATION OF THE SECONDARY TILLAGE EFFECTS

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Abstract. *The paper is focused to quality evaluation of mechanized secondary soil tillage, using the comprehensive own experimental results of dry sieving of soil test samples. Proposed approach is based on detailed analysis of the mean weight diameter distributions of soil aggregates. Test samples were taken at two standard-depth layers (0-5 cm and 5-10 cm) of the test plot, previously exposed to the secondary autumn tillage specified for wheat seeding. In this study are evidenced large discrepancies between distributions of soil aggregates dimensions, taken at various locations (denoted here as "test-points") and within the two depth layers over the experimental plot square area of 100 m in length and 70 m in width. It is shown that tillage effects may strongly differ over the parcel area and depth and therefore can be accurately evaluated only after thorough analysis of large number of samples tightly acquired over the whole parcel area and depth layers of interest.*

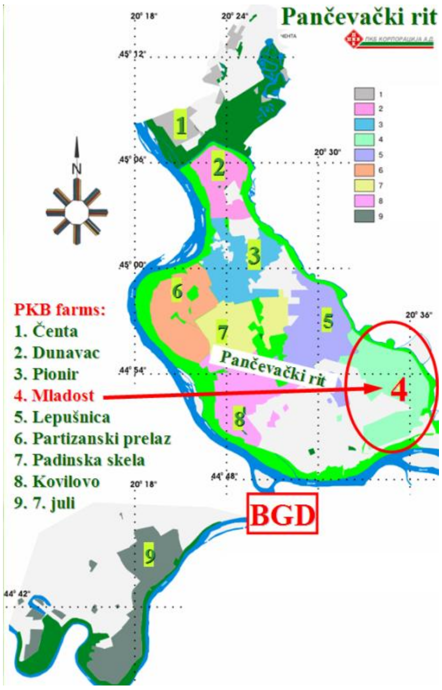
Key words: *Tillage, wheat, quality evaluation, multi-tiller, disc-harrow.*

1. INTRODUCTION

Appropriate agricultural land maintenance and rigorous control of soil properties at optimal level is crucial for sustainability and efficiency of agricultural plant production. [11], claimed that agricultural mechanization crucially influences the contemporary agricultural production. However, it may provide benefits only if adequately applied. In opposite, improper application of mechanization may decrease crops growth and yield. These authors also emphasized that excessive application of heavy machines results in strong soil compaction and degradation of its structure.

Therefore, advancing the mechanized plant production demands introduction of modern accurate, efficient and reliable procedures for tillage effects evaluation. Further improvement of existing methods of such kind is also needed [14].

The term “tillage” denotes a complex process that comprehends various mechanical mechanisms of recomposing soil structure. It is intended to optimize soil properties in order to provide adequate conditions for a crop growth and development. These goals can be achieved only if tillage process is carefully controlled. Properly performed tillage should generate optimal distributions soil aggregates sizes – the aggregates having sizes in the range 0.25-10 mm are the most preferable. Larger participation of aggregates larger than 5 mm is necessary at lands that are irrigated. In opposite, larger participation of smaller aggregates, having sizes between 1 mm and 2 mm, are suitable for dry soils without irrigation. Therefore, a variety of researchers worldwide has paid special attention to investigation of soil structure [9].



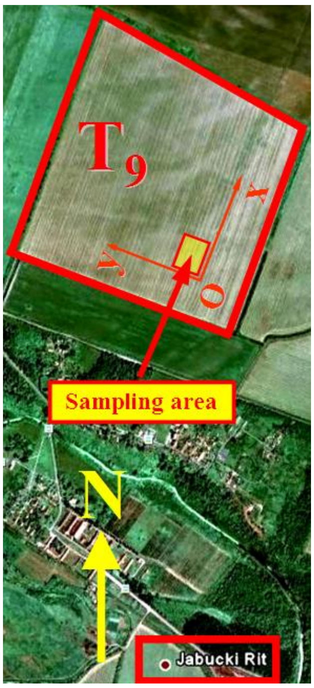


Fig. 1 General disposition plan of PKB farms (left). *Adapted from original PKB map.*
Fig. 2 Experimental plot (right)

Some experimentalists, like [5] among many others, highlighted the important role of accurate analytical modeling of soil aggregate size distribution for estimation of tillage effects the soil quality. Typical example for the approach of such kind is the report of [6]. They have developed a special procedure for evaluation of aggregate sizes. Their procedure is based on real-time digital image analysis. Among many others, [10] also focused their attention to soil aggregate size distributions after tillage. They reported large excursions of real aggregate size distributions from the most commonly used normal Gaussian function.

2. MATERIAL AND METHODS

The paper presents results of field experiment performed at parcel "T-9" of the farm "Mladost", located near village Jabučki Rit, (Fig. 1). This parcel belongs to PKB Corporation in Belgrade, Serbia and is schematically presented in Fig. 2. According to [13], the experimental soil is of a non-carbonate Humogley type.

Performed analysis of acquired soil samples showed (among many others) that soil possesses low content of coarse sand (1 % in average). Simultaneously, fine sand particles are dominant in plowing horizon, 29.8 % in average, while the silt fraction occupies 30.7 % and clay fraction content in A horizon took 38.5 % in average. With respect to widely accepted soil classification declared by the International Society of Soil Science [1], soil at the experimental plot is light clay type.

(a) (b)

(c) (d)

Fig. 3 Tillage technique: (a) Tractor "Fendt" 936 Vario 4x4S, (b) Multi-tiller "Gaspardo", (c) Disc harrow "Kverneland" and (d) Chisel plough "Gaspardo"

In the analyzed case, the fore-crop was silage corn. After finalizing its yearly production cycle, i.e. after harvesting the fore-crop, the following autumn secondary tillage operations were conducted in order to prepare soil for wheat seeding: stubble cultivation, chisel ploughing, disc harrowing and seedbed preparation. Agricultural mechanization used, is presented in Fig. 3: Tractor "Fendt" 936 Vario, equipped with the engine of 243 kW nominal power and 4x4S driving system, has been aggregated with following implements: disc-harrow having the operational width of 4.5 m; chisel plough characterized by operational width of 5.5 m and multi-tiller having the operational width of 6 m.

Maintenance of adequate soil properties is an extremely complex process that demands continuous control, careful planning and tedious work. However, many unpredictable or at least hardly predictable factors have strong influence on the soil properties, including climate factors. Therefore, Belgrade region monthly average temperatures and rainfalls, in the period starting from 2004 and ending at 2009 year, reported by [4], are given in Figs. 4 and 5.

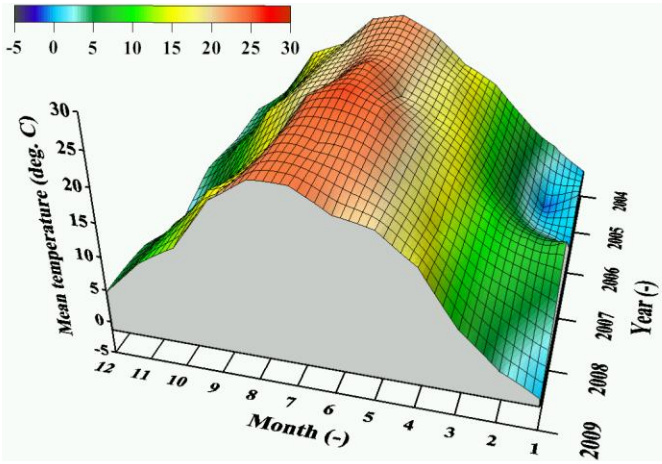


Fig. 4 Mean monthly temperatures for the Belgrade region, in the period 2004-2009

Within the years of interest, comprehended in the analysis illustrated in Fig. 4, air temperatures exhibited generally stable drift, with some ordinary present variations. Consequently, nearly all (except for the year 2005) of these temperatures were higher with respect to the average (11.9 ^{o}C) for the period including years between 1961 and 1990. Although disagreements between scientists with respect to this phenomenon still exist, the temperature raise is widely accepted as a general belief of global trend of planet Earth (over)heating.

Cumulative monthly rainfall deposits at the region that covers experimental plot, expressed in millimeters of water layer depth formed by rainfall during the specific month and assuming no ground absorption of rainfall water, are presented in Fig. 5. As it can be seen from this figure, rainfall deposits during different months over the years of interest (2004-2009) were unstable, varying between 586.9 mm/year and 839.0 mm/year.

Experimental raw material was collected on October the third 2010, characterized by mean daily air temperature of 14 ^{o}C and average relative atmosphere humidity of 50 %. Soil samples were taken within the inner part of the plot (Fig.2), at 70 equidistance locations designated as “*measuring points*” or “*referent points*” in this paper. They represent centers of quadrates arose as intersections of 7 rows and 10 columns having the equal widths of 10 m, as it is sketched in fig. 6. This way, longitudinal and lateral distances between the proximate “*points*” were always 10 m. Two probes were taken at each “*measuring point*” from two layers comprehending standard soil depths of 0-5 cm and 5-10 cm, thus giving the total number of 2 x 70 = 140 soil test samples.

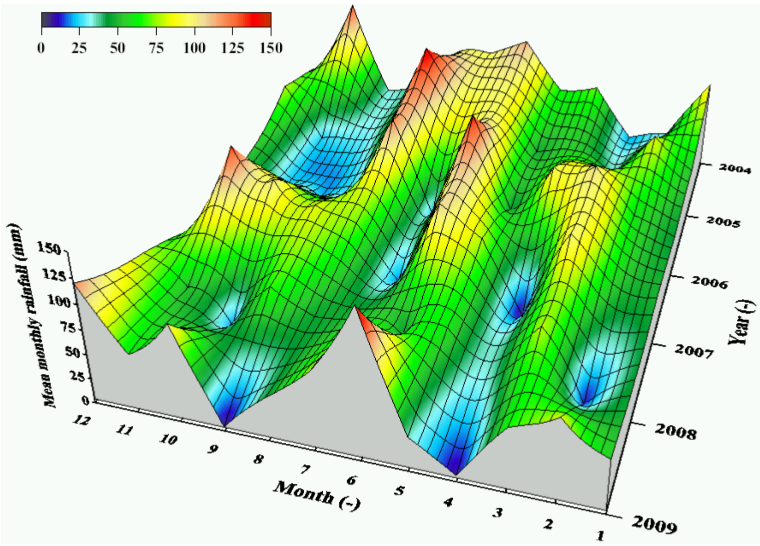


Fig. 5 Monthly rainfall depositions in Belgrade region, in the period 2004-2009

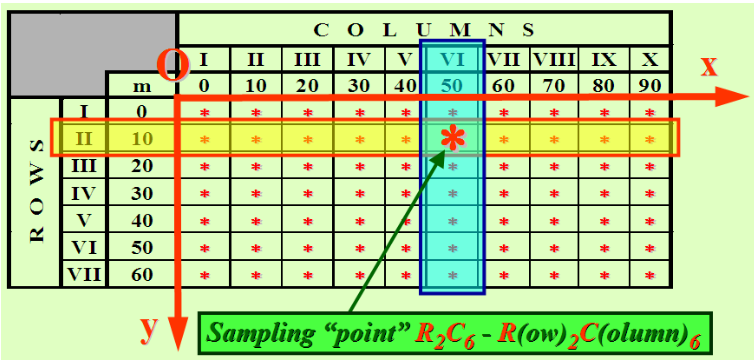


Fig. 6 Pick-up scheme of soil test samples

In the study are analyzed soil bulk density, measured by core method [12], aggregate size distribution based on dry sieving modified method of Savinov (see [8]), penetration resistance measured by hand penetrometer Eijkelkamp (Set A) having the measuring range up to 10 MPa and soil moisture content determined by the method of Kachinskiy (Качинский) [7]. The so-called “*mean weight diameters*” of the dry sieved aggregates were finally calculated using the procedure explained in [3].

3. RESULTS AND DISCUSSION

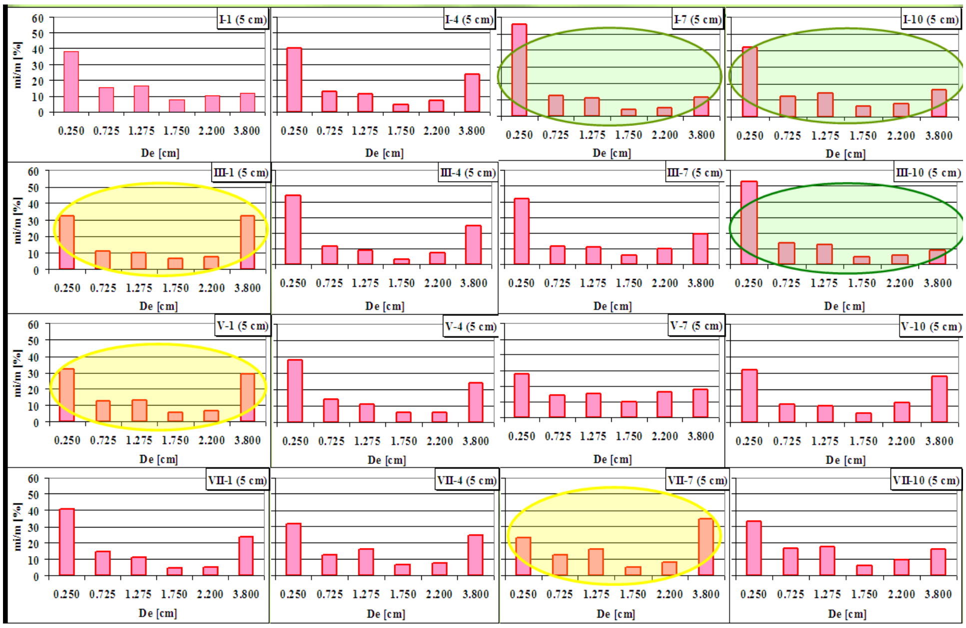


Fig. 7 Mass distributions of soil fractions within the surface soil layer (0-5 cm)

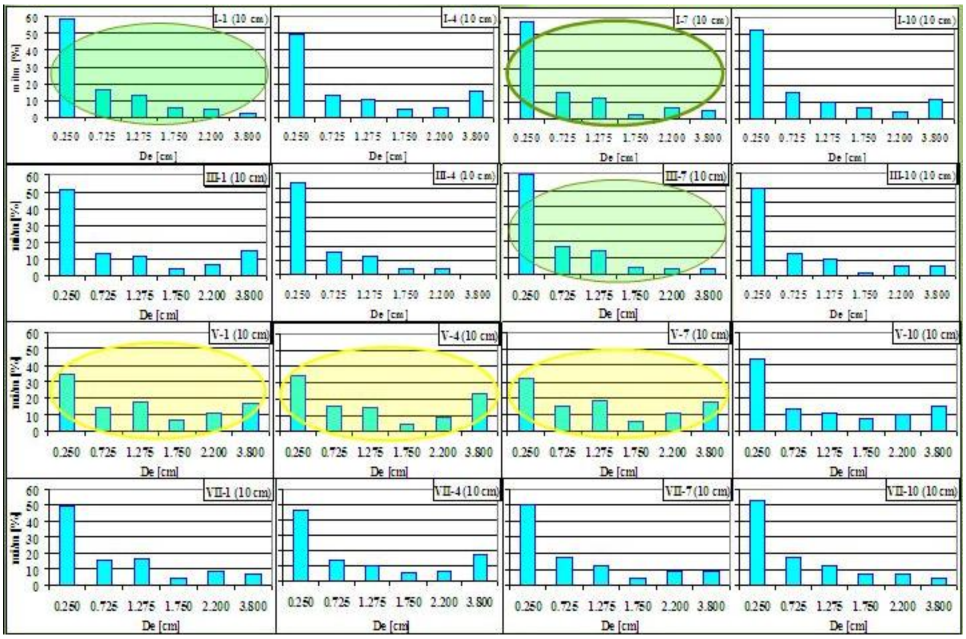


Fig. 8 Mass distributions of soil fractions in the layer placed between 5 cm and 10 cm

Average values of bulk density, penetration resistance and soil water content in the surface layer (0-5 cm) were 1.22 g/cm^3, 0.87 MPa and 15.68 % vol, respectively. In the lower layer (5-10 cm), these properties took the values 1.24 g/cm^3, 1.26 MPa and 20.70 % vol, respectively.

Fig. 7 illustrates percentile mass distributions of soil fractions, extracted by dry sieving of samples acquired at surface layer comprehending depth of up to 5 cm. In analogue, fig. 8 presents analogue data for the second layer, located within depths of 5 cm and 10 cm. Both figures clearly show large discrepancies of the soil mechanical structure over the test area of the experimental plot. To additionally illustrate the phenomenon, samples expressing widely recognized and approved suitable properties for plants growth and development are marked with light-green ellipses, while those having improper mechanical structures are covered by light yellow ellipses. Among others, it is also evident that structures of these two layers are weakly correlated. This means that structure of the upper layer cannot be used to evaluate the quality of the invisible lower soil layer (depth 5-10 cm).

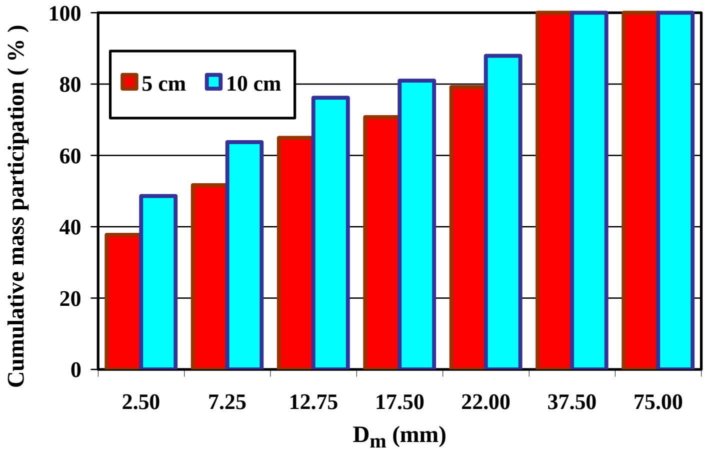
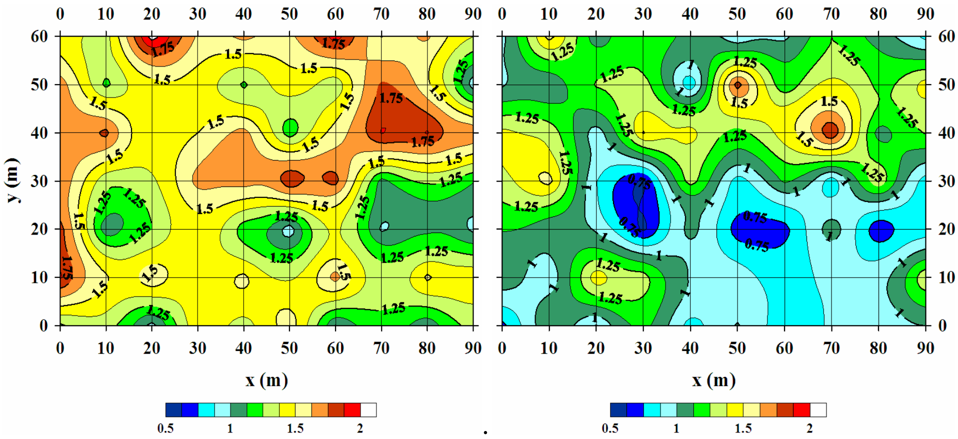


Fig. 9 Cumulative mass distributions of overall mean aggregate size distributions at soil layers comprehending depths ranges of 0-5 cm and 5-10 cm

Cumulative mass distributions of soil fractions, averaged over the whole test area (100m x 70m – see figs 1, 2 and 6) of the experimental plot, are presented in fig. 9. Following recommendations of [2], results presented in this figure shows the high mass participation of small structural aggregates indicating soil deteoriation and degradation: mean percentage of aggregates having the mean weight diameter below 5 mm were 37.74 % at surface layer (depth of 0-5 cm) and 48.61 % within the second lower layer (depth between 5 cm and 10 cm).

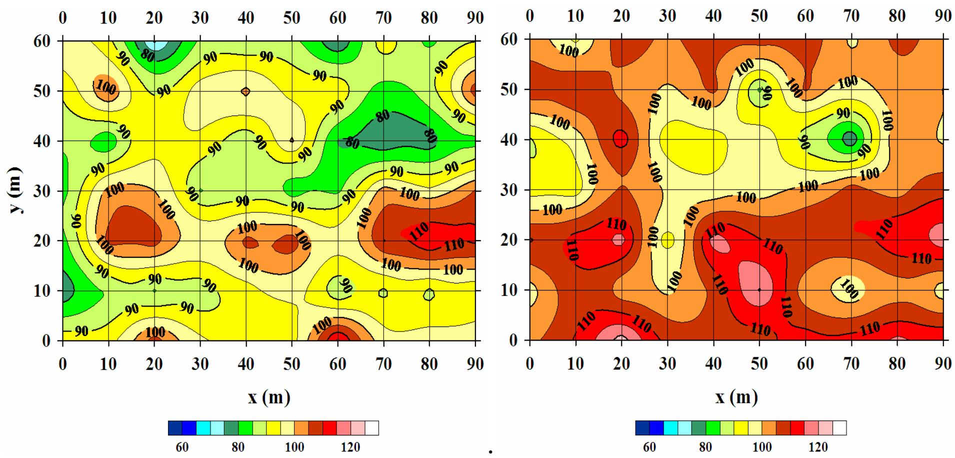
The largest evidenced fraction in present experiment comprehended aggregates having sizes in the range between 25-50 mm: 20.82 % at depth of 0-5 cm, and 12.08 % in the lower layer (depth range 5-10 cm). This is a consequence long draught in 2010, which resulted in the unsuitable soil conditions for optimal secondary tillage.



(a) (b)

Fig. 10 Topographic presentation of the mean weight diameters of soil aggregates taken over the experimental plot at depth of: (a) 0-5 cm and (b) 5-10 cm

Two-dimensional distributions of dry mean weight diameters D_m (cm) of soil aggregates collected over the sampling area of experimental plot at depths of 0-5 cm and 5-10 cm are presented in Figs. 10a,b. Coordinate axes “x” and “y” are defined according the sampling map shown in fig. 6.



(a) (b)

Fig. 11 Topographic presentation of the variation coefficients of the aggregates means weight diameters distributions, sampled at depths: (a) 0-5cm and (b) 5-10 cm.

In the upper analyzed layer (depth of 0-5 cm), Fig. 10a, the mean weight diameter was in the range between 0.91 cm and 2.07 cm, having the overall average value of 1.44 cm. Simultaneously, the corresponding coefficients of variation *Cv* (Fig. 11a) of the fraction sizes took the values in the range between 69.31 % and 116.31 %. Situation was fairly analogue, but still different in the lower tested soil layer (depth of 5-10 cm). The minimum, maximum and average values of the mean weight diameter were 0.59 cm, 1.88 cm and 1.09 cm, respectively (Fig. 10b). In this layer, the variation coefficient *Cv* (Fig. 11b) also had high values: between 75.67 % and 122.51 %.

Comprehensive field experiment and detailed analysis of 140 soil samples, presented in this study, clearly shows large differences of mechanical soil structure over the experimental plot area within each of two tested soil layers. In addition, Figs. 9, 10, 11 also shows that strong differences of aggregate size distributions also exist between these two layers, located between depths 0-5 cm and 5-10 cm, respectively.

It follows that effects of secondary tillage and, therefore, the resulting mechanical structure of arable soil strongly vary over an area and depth of the parcel exposed to tillage. From this reason, descriptive statistics of soil aggregates size distributions must be carefully measured at large number of “sampling points” that completely cover each of arable soil depth-layers of interest.

4. Conclusions

In this study are analyzed effects of the secondary tillage, specified for further wheat sowing, on the mechanical properties (aggregates size distributions primarily) of the non-carbonated hymoglay soil. Mass participation of prevailing soil fraction having sizes up to 9.5 mm was 51.67 % in the upper layer (depth range of 0-5 cm), and 63.75 % in the lower layer (depth range of 5-10 cm). Fractions having sizes over 50 mm were not evidenced within these two soil layers (0 %). This way, it is verified that applied mechanization and performed secondary tillage of heavy clay soil at the test plot follow standard and widely accepted quality criteria for wheat production. Consequently, these facts verify the reliability of conducted experiment and its outcome.

Carefully controlled field experiment and final testing of 140 soil samples, indicates large dispersion of aggregate size distributions over the test plot area within each of two soil depth layers. Strong differences of aggregate size distributions between the layers located at depths of 0-5 cm and 5-10 cm, respectively, were also evidenced.

It can be concluded that, especially in the case of heavy soil types, secondary tillage effects (and resulting mechanical structure of arable soil) express large variations over area and depth of arable experimental plot. These results impose the necessity of detailed acquisition of soil test probes at large number of sampling locations (“points”), which have to cover whole test areas of each of arable soil depth-layers of interest.

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First (Short) Comunication

INFLUENCE OF SOIL COMPACTION ON SOIL CHANGES AND YIELD OF BARLEY AND RYE AT THE HEADLANDS AND INNER PART OF PLOT

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Abstract. *The moving of tractors and mobile systems leads to intensive soil compaction, poor conditions for the root system development, and poor microbiological activities, which results in a reduction of yields. The paper presents the results of few years of research of the impact of compaction on changes in soil and the yield of crops of barley and rye on headlands and inner part of parcel. Tests were carried out in agro ecological conditions of central Serbia in the period 2011/14, on the soil type vertisol (smonitza). Based on these results it was concluded that soil compaction compared to the interior of the plot during the germination was on average 43.32 – 44.51% higher, while before harvest, increase soil compaction compared to interior grounds was on average 51.76 – 53.28%. The yield of barley in the inner part of the plot was 36.16 % higher compared to headlands, while the yield of rye in the internal part of the plot compared to yields that are measured on the headland was 35.48% higher .*

Key words: *soil compaction, headland, barley, rye, yield.*

1. INTRODUCTION

The movement of tractors and mobile systems on the plot can be divided into two groups: moving around the interior of the plot and moving on the headlands. The excessive soil compaction makes very unfavorable soil conditions for the development of crop and the use of modern production technologies, which significantly affect the yield and increase production costs by 20-40%. Due to the lower speed when turning and the large number of passages, soil compaction is higher on headland than in the inner part of the plot. Due to the moving of agricultural machinery land is particularly compacted on a depth of 0.5 m, and the consequences are reflected in the difficulty of adopting water and nutrients and a significant reduction in yield [1, 6, 4, 3]. Compacting is one of the main forms of land degradation and is present in the total degradation with 11% [9]. Soil compaction caused by the movement of heavy vehicles and machinery results in soil structure deterioration, in the top (surface) and lower (deep) layer of soil which increases the risk of soil erosion and increases the energy consumption for processing [12]. Agricultural mechanization is a key element in agricultural production, because its application brings many uses, but it is important because the proper application of unnecessary and excessive use of compacted soil and creates a number of problems that manifest negative impact on the growth and yield of cultivated plants [13]. A large pressure of mechanization are the main causes of the excessive soil compaction, which results in a reduction in yield by 10-25% and increased investment in machinery fleet, facilities and personnel by 10-25%. Realized losses incurred as a consequence of the excessive soil compaction are 224,5 USD ha^{-1} by year [10]. The resistance of the cone at a depth of 20-30 cm was 2 MPa, and to increase the resistance of the cone is due to the large load area during the movement of machinery [5]. Causes and consequences of soil compaction are complex, and for the revitalization it is needed to invest heavily in longer period of time. The average yield losses are up to 40% and increase specific resistance at plowing to 2.0-2.5 times [11, 8]. Soil compaction after sowing was 30.56% greater than in the inner part of the plot, while increasing soil compaction before harvesting was 37.65%, so that the yield reduction amounted to 31.55% in dry grain mass 26.39%. [14]. According to the same authors still emerging soil compaction was 14.45 daN/cm^2 at 7-21cm depth, while in the inner part of soil compaction was 10.48 daN/cm^2. The resistance of the cone in the measurement of soil compaction in the phase of collecting was greater on headland and amounted to an average of 3.82 MPa, while in the inner part of the lower and amounted 2.53 MPa, so that the resistance of the cone on the headland higher than in the inner part of the parcel for 50.97% [15]. Soil compaction during several years of testing was higher by an average of 32.56% compared to the inner part of the plot, while at the stage of collecting the average increase was 41.63%, while yields were lower by an average of 35.17-48.63% [2].

2. MATERIAL AND METHODS

During 2011/14. and agro-ecological conditions in central Serbia in the vicinity of Kragujevac (44^0 04' 00'' N, 20^0 51' 00'' E), research was conducted on the influence of soil compaction on the yield of spring barley varieties Novosadski 448 and winter rye varieties Raša, on the soil type smonitza. Soil compaction was measured with penetrologger Eijkelkamp hardware version 6.0, the software version 6.03. Measurement is carried out by pressing the cone surface area of 1 cm^2, with the top of the cone 60^0, in accordance with the standard NEN 5140, the penetration speed of 2 cm sec^{-1}, wherein the deviation was not higher than 0.5 cm s^{-1}. Cone is of a standard size and standard was defined according to ASAE standard (ASAE S313.1). Before the measurement the reference panel depth was set, determined the position of the plot (GPS) and soil moisture. When measuring soil compaction slope penetrologger did not exceed 3.50 in the vertical (plumb penetrologger was used), and the rate of penetration is monitored by a speed indicator on the display that was close to the middle position. Soil moisture at the time of measuring compaction is determined by Theta probe, and expressed in % vol. The measurements were carried out on the headlands and inner part of the depth of 0-20 cm, bearing in mind that the depth of the layer is treated with lathes. The resistance of the cone was measured in 5 repetitions, with a distance of 3 m between measuring points, where the mid-point was in the middle of the headland.

In order to address the real headland selected parcels along which the path, so that rotation of machine-tractor unit was carried out only on the land where that way rights headland was established. Headland width was 10 m. Measurements and sampling area were performed twice: at the time of crop emergence and the end of the vegetation during harvesting of crops, in order to determine the realized yield. The results are presented in tables and analyzed.

Fig. 1 The satellite snapshot of the research field

3. RESULTS AND DISCUSSION

Table 1 shows the measured values of soil compaction on the inside of the plot and the headland in the crop of spring barley and winter rye at the beginning of the measurement. Based on these results, it is observed that in the interior of the plot at all replicates measured significantly lower values of soil compaction in relation to the headland, in both crops. The measurement results show that soil compaction inner part of the crop of spring barley during the crop germination was on average 1.87 MPa, while the headland measured greater compaction and to average 2.68 MPa. If the difference is in percentage terms, it is observed that at the headland of soil density higher than in the inner part of the parcel for 43.32%. Broken down by years of study, it is observed that in the interior of the trial plot of soil density varied in the range of 1.84 MPa (2012) to 1.92 MPa (2014). On the headland of soil compaction was in the range of 2.62 MPa (2011), to 2.79 MPa (2014).

Table 1 Changes in soil compaction in the interior of the plot and the headland at depth 0-20 cm (MPa)

Crop	Year	Measuring Period	Soil Moisture (%)	Place of sample and soil compaction (MPa) Inner part	Headland	Increasing (%)
Barley	2011.	Germinating	25.94	1.85	2.62	41.62
		Harvest	16.21	2.68	4.12	53.74
	2012.	Germinating	22.85	1.84	2.64	43.48
		Harvest	14.93	2.73	4.21	54.21
	2013.	Germinating	23.18	1.87	2.67	42.78
		Harvest	11.97	2.76	4.29	55.43
	2014.	Germinating	25.92	1.92	2.79	45.31
		Harvest	15.74	2.80	4.16	48.57
	Average	Germinating	24.48	1.87	2.68	43.32
		Harvest	14.72	2.74	4.20	53.28
Rye	2010/11.	Germinating	24.58	1.83	2.62	43.20
		Harvest	12.31	2.86	4.35	52.10
	2011/12.	Germinating	23.47	1.77	2.66	50.28
		Harvest	11.56	2.98	4.44	48.99
	2012/13.	Germinating	25.83	1.76	2.55	44.89
		Harvest	12.10	2.70	4.16	54.07
	2013/14.	Germinating	26.92	1.92	2.69	40.10
		Harvest	13.11	2.79	4.27	53.05
	Average	Germinating	25.42	1.82	2.63	44.51
		Harvest	12.27	2.84	4.31	51.76

In winter rye lower values of soil compaction in the interior of the plot in relation to the headland were also measured. The average compaction measured in the interior of the plot under winter rye at the time of emergence was 1.82 MPa, while the headland average compaction was 2.63 MPa.If the difference is in percentage terms, it is observed that at the headland of soil density higher than in the inner part of the parcel for 44.51%. If the compaction is watched per year, we can see that in the interior compaction plots ranged from 1.76-1.92 MPa, a headland in the range of 2.55-2.69 MPa (table 1).

A large number of passages of tractors and mobile systems has resulted in higher soil compaction on the headland in regard to inside pitches in both examined variants in the time of collection. On the inner part of the crop of spring barley at the time of collecting the measured average soil density of 2.74 MPa (in the range of 2.68 - 2.80 MPa), while the headland averaged 4.20MPa (in the range of 4.12 - 4.29MPa). If the difference in terms of soil compaction between the plot interior and headland in percentage terms is obtained an increase of 53.28%.

A similar effect of a large number of crossings of tractors and mobile systems on soil density was observed in the crop of winter rye. On the inner part of soil compaction during the harvest of winter rye amounted to an average of 2.84 MPa (varied in the range of 2.70-2.98 MPa), while the headland averaged 4.31 MPa (varied in the range of 4.16 to 4.44 MPa, analyzing annually). Increasing soil compaction in headland than in the inner part of the parcel at the time of harvest of winter rye was an average of 51.76% (Table 1).

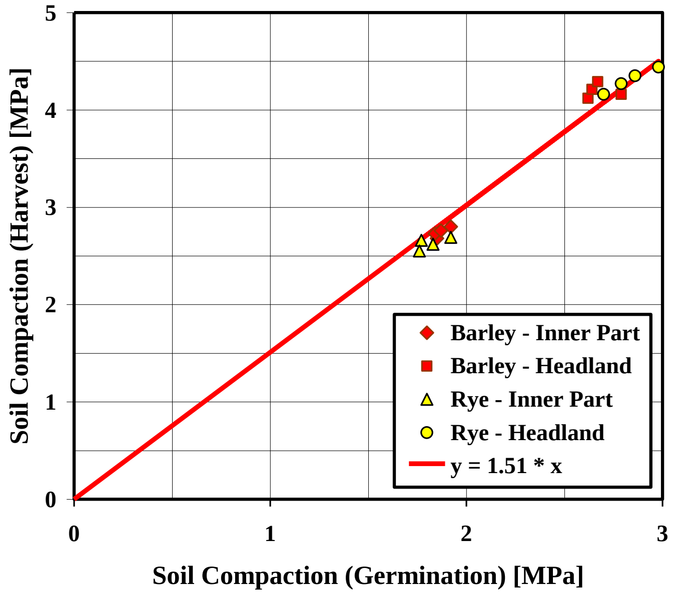

Fig. 2 Relationship between soil compaction over germination and harvest period.

Figure 2 presents clear linear relationship between soil compaction intensity over crop germination period and harvest period:

$$y = 1.51\,x \quad (R^2 = 0.97) \qquad (1)$$

Using this formula, the soil compaction over harvest can be estimated on the base of the soil compaction intensity over the crop germination period.

Table 2 shows the values obtained yields of spring barley and winter rye in the inner part of the plot and the headland.

Based on the results shown in Table 2 can be seen that increased soil compaction on the headland than in the inner part of the parcel significant effect on creating unfavorable conditions for the growth and development of crops of spring barley and winter rye, which is very significant impact on the amount of yield dry grain in all investigated variants.

The yield of dry grain of spring barley in the inner part of the plot was an average of 2.68 t ha^{-1}. Broken down by years of research, ranged from 2.42 t ha^{-1} in 2011 and to 2.85 t ha^{-1} in 2014. On the headland is measured significantly lower yield of spring barley at an average of 1.71 t ha^{-1} (varied in the range of 1.61-1.78 t ha^{-1}), representing an average reduction of 36.16%.

Table 2 Barley and Rye yield on headland and inner part of a field (t ha^{-1})

Crop	Year	Grain mass yield (t ha^{-1})		Yield decrease (%)
		Inner part	Headland	
Barley	2011	2.42	1.61	33.47
	2012	2.67	1.73	35.21
	2013	2.76	1.70	38.41
	2014	2.85	1.78	37.54
	Average	2.68	1.71	36.16
Rye	2010/11.	2.45	1.56	36.33
	2011/12.	2.40	1.54	35.83
	2012/13.	2.51	1.66	33.86
	2013/14.	2.54	1.64	35.43
	Average	2.48	1.60	35.48

A similar effect of soil compaction in the central part of the plot and the headland and the yield of winter rye. Higher yields of winter rye has been measured in the inner part of the plot and average 2.48 t ha^{-1} (2.40 t ha^{-1} in 2012, and 2.54 t ha^{-1} in 2014), while the headland yield of winter rye was smaller and amounted to an average of 1.60 t ha^{-1} (varied in the range of 1.54 - 1.66 t ha^{-1}), representing an average reduction of 35.48%.

Smaller values obtained yields of dry grain on headland than in the inner part of the plot were measured during all the years of study, at all tested variants.

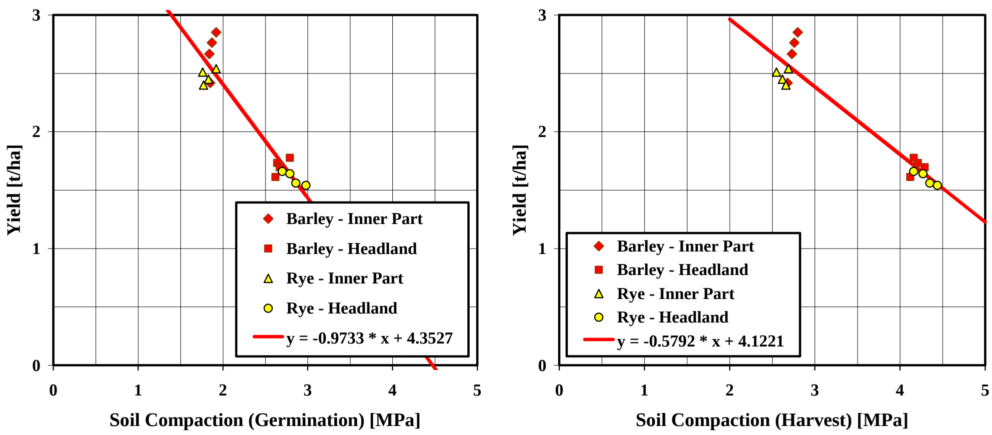

Fig. 3 Relationships between yield and soil compaction over germination and harvest period

Figure 3 illustrates the existence of linear relationships between yield and soil compaction intensity over crop germination period and harvest period, respectively:

$y = -0.97 x + 4.35 \quad (R^2 = 0.90)$ (2)

$y = -0.58 x + 4.12 \quad (R^2 = 0.91)$ (3)

Evidently, increased soil compaction intensity decreases the yield for both the barley and rye crops.

4. CONCLUSIONS

Based on the results of the impact of compaction on changes in soil and yield of barley and rye on headlands and inner part of pace can conclude it can be concluded the following:

- In the inner part of the parcel significantly less compression of soil in relation to the headland is measured at both crops during all the years of the study.
- Compression of soil on the still emerging crop of spring barley in the inner part of the plot was an average of 1.87 MPa and 2.68 MPa at the headland, which is an average increase of 43.32%. In crop of winter rye in the phase of eruption of soil density in the inner part of the plot averaged 1.82 MPa and 2.63 MPa at the headland, which is an average increase of 44.51%.
- During harvesting of barley on the inner part of soil compaction has averaged 2.74 MPa and 4.20 MPa at the headland, which is an average increase of 53.28%. In crop of winter rye in the phase of collecting soil compaction in the inner part of the plot averaged 2.84 MPa and 4.31 MPa at the headland, which is an average increase of 51.76%.
- Inside the parcel during all the years of tests measured significantly lower values of soil compaction in relation to the headland, in both crops.
- The yield of dry grain of barley in the inner part of the plot was an average of 2.68 t ha^{-1}, and on the headland 1.71 t ha^{-1}, which represents a decrease of 36.16%. The higher grain yield of winter rye has been measured in the inner part of the plot and 2.48 t ha^{-1}, while on the headland yield was averaged 1.60 t ha^{-1}, which represents a decrease of 35.48%.
- Lower values obtained yields of dry grain on headland than in the inner part of the plot were measured during all the years of study, at all tested variants.

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Scientific Review Paper

LAND FUND AS AN INSTRUMENT FOR AGRICULTURAL AND RURAL DEVELOPMENT

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Abstract. *Land is a limited resource needed for agricultural production. Due to the expansion of urban areas, infrastructure development, the effects of climate changes and many other factors, the area of land that cannot be used for agricultural production is increasing. Therefore, it is necessary to use the land in a way that will allow maximum production, meet social needs and have a minimal impact on the environment.*

In most European countries land funds are very important instrument in land management. As support to: land consolidation, land market control, infrastructure development, restitution, reduction of the abandoned land etc., land funds are necessary for efficient managing of land and sustainable rural development. European countries analyzed along the article are: Denmark, Spanish province of Galizia and the Czech Republic, whose similarities with Serbia were highlighted as well. Denmark is a country with very efficient land management, high price of land and agricultural production. Also, Denmark is a state that has successfully made the transformation of state-owned land. Galizia and Czech Republic in past had a similar political system and land policy as Serbia had. Through land fund these province and country solved a lot of problems related to the management of land. This article presents the role of land funds in agricultural and rural development in these countries, and possible role in land management in the Republic of Serbia.

Keywords: *land, land fund, land management, rural development*

1. INTRODUCTION

In recent decades, global agriculture faces a number of disparities due to differences among countries as to degree of development of agriculture, land management policies and the level of rural development. Number of countries that have recorded a declining of agricultural land and its productivity is increasing due to: the spreading of urban areas, soil quality declination, uncontrolled use of pesticides, erosion, impact of climate changes and so on. On the other hand, there are countries that manage agricultural land with a great care and implement measures that will enable its more efficient use and preserve the environment for future generations.

During the XIX and XX century, many European countries faced the consequences of frequent changes of agrarian relations. In most countries, the changes included the removal of the remnants of the feudal system, the distribution of land to farmers, collectivization of land, the implementation of measures for land management, restitution… Although these changes and their intensity vary between countries, their common feature is fragmentation of land parcels. Fragmentation of land parcels and their irregular shape significantly influenced the non-productivity agriculture [1]. Reducing of fragmentation of the parcels is traditionally achieved by implementation of the land consolidation projects. The main objectives of land consolidation are improving the farm's structure, which along with the relevant types of infrastructure and land reclamation should lead to the effective and rational use of land [2]. In addition to the fragmentation of farms, rural areas in most European countries have the other problems: the poverty, migration to the cities, lack of infrastructure, small farm's size etc [3].

In order for the land consolidation to be done successfully and to create increased number of possibility for merging land plots, many countries resorted to forming so-called land funds/land banks [4]. Land funds can be defined as land reserves that are formed with the objective of improving the structure of agricultural land and facilitating implementation of the land development projects [5]. An obstacle for studying the role of land funds in the agricultural and rural development is the lack of literature written in English. Important resources for studying this instrument are provided by the papers presented at conferences that Food and Agricultural Organization of the United Nations (FAO) organized started from 2002 (FAO began with the organization of conferences on the subject of land funding/land banking since 2004). In recent years, articles were published and doctoral dissertations were made that represent a significant material for studying of land funds and their importance in land management.

2. LAND FUNDS

2.1. Basic Characteristics

Land funds differ in their basic characteristics: the model of property rights, the organizational structure, the financing methods [6] and the main use of included land.

The model of property rights. By including the land in land fund, ownership structure of land may or may not be changed. Therefore, there are two different models of land funds. The model with the change of ownership rights exists in most of the European countries. Before getting included in the land fund, land can be in all forms of ownership. In land fund, land becomes state-owned and when removed from the land fund, land can be in different forms of ownership. In model without changing ownership rights, it is not necessary to change ownership rights when including the land in land fund. The model without change of title to land is not widely represented in Europe [6].

Organizational structure. The land banks have different organizational structure and in the majority of countries, this structure consists of managing unit at the state level and operative unit at the regional or local level [7]. Land banks also differ in a management structure - some land banks are organized as joint stock companies, while the other land banks are organized in the manner where rendering of all decisions is within the competence of the Directors or Ministers.

Financing. Land fund can be financed in three ways: from the state budget, from its own resources or combining these two methods. The financing method depends mainly on the way they are organized, so this feature is defined by their founding documents.

Land use. Land funds differ in terms of use of included land. Land funds manage agricultural, forest and urban land. Most land funds manage agricultural and forest land, while a minor number includes urban land.

2.2. Land Funds Goals

The objectives of establishing land funds in different countries mostly overlap – land consolidation, land regulation, land augmentation [4]. However, individual objectives are the reflection of the heritage and land management policies and can greatly differ.

The basic objective of land banks/funds is to promote agricultural land market, namely to increase its mobility in order to balance the offer and demand of land [7]. By using land banks/funds, it is possible to realize multifunctional objectives, such as support to: land consolidation, land market and its regulation, land management, land abandonment reducing, implementation of rural and urban development projects etc [8].

3. The Effects of Land Funds on Agricultural and Rural Development

Land funds have a major impact on agricultural and rural development in countries where they are established. In this paper, consideration of the effects that land funds have to agricultural and rural development is made on the case of land funds in two European countries – the Czech Republic and Denmark and in the Spanish province of Galicia. Managing the land in these countries has many specifics. Managing of land and the objectives that are thereby to be achieved in these countries are examples of good practice that could be used in creating an optimal model of land fund in the Republic of Serbia.

3.1. Land Fund in the Czech Republic

The Czech Republic and the Republic of Serbia have many similarities: similar political system in the second half of the XX century, the tendency to collectivization in agriculture in the same period, land privatization and restitution in late XX and early XXI century. From 1960 until 1989, the area of state-owned farms in the Czech Republic was gradually increased. A reform aimed to create the larger state-owned socialist agricultural units was carried out during the 1970s. In 1989, the Czech Republic commenced transformation of economy. In this period, the Czech Republic had a negligible area in the ownership of private farms in comparison with the area in state-owned farms and cooperatives.

Reduction of the area of state-owned farms and cooperatives and increasing the area of privately owned farms had commenced in 1989. In this period, the legal forms that did not exist before the period of transition had appeared - limited liability companies and joint-stock companies. The restitution of land was in charge of district land offices, which have collected requests for property restitution. Table 1 shows the area of agricultural land by the form of enterprise in the period from 1960 to 1998.

Table 1 The area of agricultural land in the Czech Republic by the form of enterprise (in 000 ha) [9]

Form of enterprise	1960	1980	1989	1995	1998
State farms	862	999	1 089	753	720
Agricultural cooperatives	3 099	2 666	2 636	1 666	1 253
Private farms	328	162	13	826	850
Limited liability companies	-	-	-	714	781
Joint-stock companies	-	-	-	269	650

Land fund in the Czech Republic was established in 1991 (adopting the *Land Fund Act*), which was responsible for administration, purchasing, selling and leasing state-owned land and land assigned for resource management. Land fund operates at national and regional level; activities are financed from its own operating income. Until 2000, district land offices returned 1,556,300 hectares to former owners and their successors. Then, these offices were deactivated and land fund, in addition to legally defined competences, was left with the task to privatize 117,800 hectares of agricultural land [9]. In 2012, the administering of state-owned land became the competence of the State land office.

The Czech Republic facilitated the process of privatization of land and constructions through the establishment of the land fund [10]. Land fund is also used to fund the projects for improving land and compensation in cases where natural restitution is not possible. According to the Law no 503/2012 [11][1], State land office set aside land for the common use without a fee at the request of a municipality or canton. In the other cases, transferring of land is possible after paying a fee.

According to *Land Sales Act* from 1999, a long-term lease of land was converted to ownership. Implementation of this law, as well as restitution and privatization, influences the decrease in area under state ownership. Because of that, the restitution process is slowed; the area of the land that could be used for the common needs is reduced; while the price of agricultural land rose due to its scarcity in the market [10].

By 2010, the Czech Republic had implemented 3,103 land consolidation projects, at the area of 665 485 hectares [12]. Land fund had a major role in implementation of these projects. The role of land fund was reflected in co-financing the projects and providing land for development of constructions and infrastructure for common use. The following

[1] Česke narodni rady (2012) *Zákon České národní rady o Pozemkovém fondu České republiky 503/2012* (in Czech)

measures that contribute to the development of agriculture and rural development were achieved during the implementation of these projects:

- 1,668 km of field and forest roads was built;
- measures for erosion prevention were implemented on 447 hectares of land;
- measures for effective water management were implemented on 483 hectares; and
- environmental measures were implemented on 1,050 hectares [12].

Land consolidation projects implemented, as well as managing of agrarian relations through the restitution, are indicators of state activities in providing conditions for agricultural development. Serbia is faced with the same task – the need for the regulation of land and the realization of restitution. Through the institutionalization of land fund, Serbia could respond to challenges easier and provide better conditions for rural development.

3.2. Land Fund in Denmark

The Kingdom of Denmark is a country where agricultural land is managed with great care. Since XVIII century, when abolition of feudalism began [5], Denmark seeks to implement a policy to prevent fragmentation of agricultural holdings. Consistency in implementation of these measures has led to the fact that Denmark has a higher productivity of agricultural production than many European countries. Due to the lack of agricultural land market, good land infrastructure provisions and its suitability for agricultural production, Denmark is one of the European countries with the highest price for the purchase or leasing agricultural land.

Land fund in Denmark was established in 1919, together with the land consolidation instrument as "part of an active land policy with the overall objective to develop commercial family farms" [13]. According to the law that regulates land consolidation in Denmark, there are three versions of land consolidation:

- improvement of location and structure;
- public projects; and
- land consolidation in connection with public works [14].

Implementation of land consolidation projects in Denmark aims to increase the structure of landholdings and the implementation of projects of common interest that will contribute to rural development. Participation in land consolidation projects is voluntary and success of the project depends on the existence of land reserves. Land Consolidation Unit within the Ministry of Food, Agriculture and Fisheries for the purposes of land consolidation project planning, has the authority to buy land with the aim of creating a land reserve. Land reserves are used during the implementation of project in order to achieve better land mobility. Land fund activities are financed from the state budget or from the fund for the implementation of rural development projects.

The role of land fund in land management in Denmark varied through different periods. Since its establishment and until World War II, the role was based on the establishing of conditions for the formation of farms. In this period, the most important role of the land fund was reflected in southern Jutland, where about 1 800 new farms were created from 25 000 hectares of state-owned agricultural land [5]. This area was returned to Denmark after the end of World War I and had a significant problem of fragmentation and low degree of infrastructure.

From World War II and until the 1990s, land funds have played an important role in increasing the mobility of land through implementation of land consolidation projects. Number of implemented land consolidation projects in this period was increased. The largest number of projects (and the largest covered area) was implemented in the period between 1980 and 1989, nearly 2.5 times more projects on 2.9 times larger area than in the previous decade (table 2).

Table 2 Implemented land consolidation projects in Denmark between 1950 and 1989 [13]

	1950-1959	1960-1969	1970-1979	1980-1989
Number of land consolidation projects	239	303	380	922
Land consolidation area (ha)	17 666	29 195	24 540	71 401

During this period, the number of farms has been reduced, increasing their average area. In 1970, Denmark had 148 600 farms, but in 2002 this number was 50 530 [15]. Hartvigsen [12] points out that in 2011, there were about 40 000 private farms in Denmark, with an average area of about 63 hectares.

The third phase in analyzing the role of land funds covers the period after 1990. During this period, land consolidation and land funds lost their importance as measures for increasing land mobility. The concept that these are important instruments for the implementation of environmental legislation and projects that lead to environmental protection, landscape and protected species became the most important at the time. Table 3 presents the number of land consolidation projects in this period and the area that they covered.

Table 3 Number of implemented land consolidation projects after 1990 [13]

	1990-1999	2000-2009	2010-2013
Number of land consolidation projects	208	189	38
Land consolidation area (ha)	39 182	35 121	4 592
Number of land consolidation projects with agricultural objectives	185	122	0
Area of land consolidation projects with agricultural development objective (ha)	33 635	22 309	0
Number of land consolidation projects with public objective (nature restoration, afforestation,…)	23	67	38
Area of land consolidation projects with public objective (nature restoration, afforestation,…) (ha)	5 547	12 812	4 592

The number of land consolidation projects with agricultural development objective was declining after 1990. No projects with this aim were implemented in Denmark after 2010. At the same time, the number of projects with public objective was increasing and after 2010, all land consolidation projects were implemented with this aim. Today, the land consolidation is realized through the implementation of projects aimed at water protection („The Water Environmental Protection Program") [5].

3.3. Land Fund in Galicia (Spain)

Spanish province of Galicia and the Republic of Serbia have a number of common characteristics in managing land. Galicia is province where only about 1/3 of the area is covered by agricultural land and agricultural production is the most important income source for the local population. In addition, Galicia is characterized by pronounced land fragmentation, mountainous relief and abandonment of land or impossibility of determining the owner of the land.

Although the projects of land consolidation in Galicia were implemented since 1950, the expected results have not been fulfilled due to: inefficient land information system, absence of landlords, extremely high costs of land consolidation and low participation of users in financing the projects [16]. Land consolidation is an essential instrument for land management in Galicia and changes in this field started at the beginning of XXI century. The aim of these changes was to create an environment conductive of achieving greater success in the implementation of land consolidation projects. The most important changes include the adoption of new legislation and the establishment of the land fund.

Land fund of Galicia (Banco de Terras de Galizia – BanTeGal) is one of the youngest land funds in Europe [4]. Legal basis for BanTeGal establishment is the *Act 7/2007 of May 21, Administrative and tax measures for the conservation of the utilized agricultural area and on the land bank of Galicia* [17]. In addition to measures related to the creation of land fund of Galicia, this law also prescribes measures related to a penalty regime for plots of land that are under conditions of abandonment [18]. BanTeGal was established as public company in 2007 within the Ministry of Rural Affairs of Galicia. Land fund of Galicia functions at all levels of state authority – province, regional and local [19], and its work is financed from the state budget and from its own resources.

The objectives for establishment of the land bank of Galicia were to prevent the abandonment of land and to make land available for farmers for improvement of agricultural production [19]. BanTeGal is a mediator between land owners and persons interested in the use of the land. At the same time, BanTeGal guarantees the adherence to the conditions in land lease contracts. During the first three years of its existence, the land fund achieved significant results in terms of providing land mobility. In this period, 8,726 land parcels (3,903 ha) were included in land fund. About 1,100 ha (39%) of agricultural land was leased [20]. Significant effects on improvement of farms structure and reducing the areas of the abandoned land were also achieved. The effects of land funds functioning may be more significant with the amendment of legislation and a greater degree of cooperation between land fund and institutions dealing with the promotion of rural development.

4. Possibilities for land fund establishing in Serbia

Republic of Serbia does not have an institutionally regulated land fund, but it has state owned land that is managed by the ministry in charge of agriculture. The agricultural land cover in the Republic of Serbia is about 5.05 million hectares, with state-owned land[2] accounting for 923 004 hectares[3]. Once the restitution process is completed, the quantity of state-owned land is expected to decline significantly. The reasons for the establishment of a land fund in the Republic of Serbia include, among the other things, reducing abandonment of land, land consolidation with more efficient mechanisms for land lease and development of the land market.

The Republic of Serbia faces an apparent problem of productivity of agricultural land that is abandoned, poor quality or unresolved ownership structure. It is estimated that every year around 7% of the total surface area of agricultural land is left uncultivated. Pastures, with fields and meadows being turned into pastures, cover a significant part of land[4]. The ownership structure is unfavorable. According to the data collected through the agricultural census conducted in 2012, the average property size is 5.44 hectares, while an agricultural property consists of six parcels on average. Fragmentation of land parcels would be even greater if it had not been regulated by legislation that the parcels cannot be fragmented below a pre-defined minimum (0.5 ha, i.e. 1 ha if the parcels were subject to land consolidation)[5].

Land that has been subject to consolidation thus far accounts for around 25% of the territory. With a view to increasing agricultural productivity, it will be necessary to change the structure of land ownership and develop infrastructural systems.

State-owned agricultural land can be used in procedures that involve lease, use of land without compensation (pursuant to the law), restitution, use in procedures of land consolidation, official use, exchange of property for the purpose of augmentation of property under the conditions defined by the law, etc [6]. State owned agricultural land can be leased for a period between one and 20 years, while the lease period for fisheries and vineyards can range from 1 to 40 years. Leasing of state owned agricultural land is conducted through public bidding procedures. The lease price is arrived at in the bidding procedure.

5. Conclusions

The need for establishing a land fund in Serbia will grow over time. The development of large infrastructural constructions and implementation of restitution will significantly deteriorate the structure of land plots and the need for regulating this area will grow.

[2] Pursuant to the *Law on Public Property* (Official Gazette of the Republic of Serbia no. 72/2011, 88/2013): Public property is comprised of movable and immovable property owned by the government, autonomous provinces and units of local self-government.

[3] According to the *Strategy of Agriculture and Rural Development (2014– 2024)*, Official Gazette of the Republic of Serbia no. 85/14

[4] According to the *Strategy of Agriculture and Rural Development (2014– 2024)*, Official Gazette of the Republic of Serbia no. 85/14

[5] According to the *Law on Agricultural Land*, Official Gazette of the Republic of Serbia no. 62/2006, 65/2008, 41/2009

Therefore, positive experiences of European countries can be applied and land funds can be used as instruments for regulating land [4].

Creation a land fund model in the Republic of Serbia takes into account the historical heritage, the legal framework for land management, the goals to be achieved, etc. Studying these parameters will provide for creating an optimal model of land fund, which should provide answers to the key parameters of the land fund:

- land fund model;
- organizational model;
- management of land fund;
- financing model;
- procedures for land management;
- model for determination of transactional prices etc.

Defining the optimal model of the land fund and its role in the managing of land in the Republic of Serbia are subject to scientific research of paper's authors. The implementation of an optimal model of land fund in practice will depend on the interests of the state to improve the agricultural land management structure. Strategies for the agricultural and rural development should provide guidelines for development in this area and are the default parameters in the analysis of the land fund's role in these areas.

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Professional (Expert) Paper

DRAINAGE OF FARMLAND ALONG THE IRON GATE 1 HPNS RESERVOIR ON THE LOWER DANUBE

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Abstract. *Before the Iron Gate 1 Hydroelectric Power and Navigation System was built, farmland along the river was partly protected from high stages of the Danube by means of levees and a low-density channel network with pumping stations whose purpose was to evacuate meteoric water and groundwater that rose to the surface. During dry periods, the river drained groundwater. Following construction of the Iron Gate 1 dam, the water levels of the resulting reservoir had a permanent adverse effect on the nearby farmland. In the Lower Danube hydraulic reclamation district, which is the subject matter of this paper, there are a large number of drainage systems which effectively drain riparian farmland along the right bank of the Danube. The scheme is comprised of an open drainage network (channels), subsurface drainage network (drain line, drain collectors, culverts, and concrete collectors), self-flowing wells, drainage wells, pumping stations, levees, and revetments. A case study of one such protected area, Godomin Field near the City of Smederevo, shows that the water table is under the dominant effect of the Danube's stages and that owing to the drainage scheme the farmland along the right bank of the Danube is effectively protected from excess water.*

Key words: *Danube, drainage systems, pumping station*

1. INTRODUCTION

The hydroelectric power plants operated by Đerdap (Eng. Iron Gate) Hydro Power Plants Co., including Iron Gate 1 Hydroelectric Power and Navigation System (HPNS) and Iron Gate 2 HPNS, were built on a complex river system comprised of the Danube and its tributaries, from rkm 943 to 862.8 of the Danube, along a river reach that defines the border between Serbia and Romania. Although the first turbines of Iron Gate 1 were placed online in 1970, the entire project was commissioned in 1972. Iron Gate 2 HPNS was constructed from 1977 and 1985, and achieved its design capacity in 1986. Additional hydroelectric power plants (HPPs), of the run-of-river type, were built in 1994 and 2000 on the Gogoš Arm of the Danube. The operating modes of Iron Gate 1 HPP are defined by water levels at characteristic river discharges, that is, the rating curves in the range from low to extremely high flows at check points at the mouth of the Nera River (rkm 1075 of the Danube) and the dam (rkm 943+000). During the period from 1972 to 1976, the HPP operated in the 68/63 mode, meaning that at discharges of the Danube less than 7350 $m^{3}\cdot s^{-1}$, the dam's headwater levels were such that at the mouth of the Nera the water level was maintained at 68.00 m above sea level, while at high discharges the dam's headwater level was maintained at 63.00 m and a natural water level was established at the mouth of the Nera. From 1997 to 1985, the HPP operated in the 69.5/63 mode, and after 1985 in the "69.5+" mode. The operating mode was updated in May 2005 to 70.30 m and has remained the same since then. The operating modes of this hydropower scheme are defined by international agreements. It is clear that higher headwater levels result in a higher hydropower generation potential, but, on the other hand, they have an adverse effect on the river channel and riparian lands, including farmland. The operating mode of Iron Gate 2 was defined at rkm 862+800 of the Danube's main stream and at rkm 933 (the town of Kladovo). The "41.00/39.50 m a.s.l." regime was created in 1985, after charging of the reservoir on the Danube between the dam of the existing Iron Gate 1 and the new dam of Iron Gate 2.

Before Iron Gate 1 was constructed and the Danube impounded, some farmland areas had been protected from high river stages by levees and a low-density channel network with pumping stations, whose purpose was to drain meteoric water and groundwater that rose to the surface from the direction of the river. Low-lying farmland downstream from the mouth of the Velika Morava River had no flood protection in place, and was thus often flooded by the Danube. As a result, farming used to be a challenge. Iron Gate 1 HPNS altered the economic, social, demographic and other circumstances in the area [12, 13, 14].

Some settlements, in whole or in part, have been relocated to higher elevations. All structures between the town of Golubac and the dam, at elevations below 71.50, were moved. This included the entire communities of Tekija, Malo Golubinje, Veliko Golubinje, Mosna, and Donji Milanovac.

In addition to the drainage scheme, the riparian lands are protected by pumping stations, which are the primary protection components of the scheme for low-lying farmland, as well as by drainage wells that are the main protection features for riparian settlements and industrial zones (communities of Dobra, Brnjica, Golubac, Usje, Vinci, and Veliko Gradište).

2. MATERIAL AND METHODS

Existing drainage systems

Drainage systems in the Lower Danube water [16] district and hydraulic reclamation area can be divided into two groups. The first group comprises drainage systems managed by JVP Srbijavode (Serbia Waters), and the second includes those managed by

Iron Gate HPNS. The latter group of drainage systems is part of the scheme that protects riparian lands from the effects of Iron Gate Dam [2,4,5,11].

Drainage systems managed by serbia waters

On the right bank of the Danube, between the City of Smederevo and Iron Gate 1, there are hydraulic reclamation systems designated by Serbia Waters as DD 1 through DD 19, including: HRS DD 1 – Smederevo; HRS DD 2 – Kulič; HRS DD 3 – Mlava (along with small reservoirs/retentions of Zaova and Smoljinac); HRS DD 4 – Veliko Gradište Marsh; and HRS DD 5 – Kučevo.

New drainage systems along the lower danube managed by iron gate 1 hpns

Following construction of the Iron Gate 1 project, new farmland drainage systems were put in place along the Iron Gate 1 reservoir on the Lower Danube, at the following locations: Dubravica flood cell; Gornji (Upper) Kostolac Island; Donji (Lower) Kostolac Island; Ram-Kličevac Marsh; Gradište Island; Gradište Marsh; and Vinci (mouth of the Pek River).

Drainage systems with pumping stations

The present case study focuses on drainage systems along the Danube, which evacuate water into the Danube by means of pumping stations. Along most of this reach there are flood protection levees.

HRS DD 1 – Smederevo

The hydraulic reclamation system "Smederevo" covers a land area of 1335 ha. The total length of the channel network is 25,482 m. The water in this area gravitates towards the Pumping Station (PS) of Smederevo.

HRS DD 2 – Kulič

The hydraulic reclamation area "Kulič" is 4405 ha. The total length of the channel network is 85,016 m. There is 365,490 m of horizontal pipe drainage. This area is serviced by two pumping stations: Kulič 1 and Kulič 2.

Gornji Kostolac Island including Dubravica flood cell

Gornji Kostolac Island and the Dubravica flood cell occupy an area of 2424 ha. Their location is between the Velika Morava River and the Dunavac Arm of the Danube (upstream from Kostolac Island to the mouth of the Velika Morava). Protection from high groundwater levels is provided by an open channel network with free-flowing wells along the channels near the Danube and its arm, which gravitate towards Rolište PS on the Dunavac.

Donji Kostolac Island and Ram-Kličevac Marsh

Donji Kostolac Island is located downstream from the mouth of the channelized Mlava River. This area includes the Ram-Kličevac Marsh and occupies 3690 ha. There are two drainage areas, of the Rečica and Zavoj pumping stations. Rečica 1 PS and Rečica 2 PS evacuate water from the channel network to the Dunavac. The gravitating channel network is 31,525 m long, between Kličevac and the old channel of the Mlava River. A channel connects the Rečica system with the drainage area of Zavoj PS.

The drainage area of Zavoj PS is the central and lowest part of the island. The alluvial plain of the Danube is a clearly defined geological/hydrogeological unit, where the alluvial aquifer's groundwater regime depends on the stages of the Dunavac. The gravitating channel network is 18,824 m long.

Veliko Gradište Marsh and Veliko Gradište Island

The extended drainage area occupies 3462 ha and is divided into two separate drainage fields: Veliko Gradište Island and Veliko Gradište Marsh. There are two separate systems in Veliko Gradište Marsh: Jaruga (J) drainage area and Main Channel (G) drainage area. Most of the water from the Veliko Gradište Marsh gravitates to Rit (*Marsh*) PS. In this area there are the Main Channel (6,884.4 long) and Duboki Dren (*Deep Drain*, 1,920 m long).

Vinci – mouth of the Pek River

The flood protection system on the Danube from the town of Veliko Gradište to the village of Vinci is comprised of levees and drainage channels with pumping stations. The area is divided into three functional units that gravitate to separate pumping stations: the area between the Pek and Veliko Gradište to Ušće Peka (*Pek Mouth*) PS; the area from Požeženo to the Pek with Požeženo PS, and the area from Vinci to Požeženo with Vinci PS.

Along each primary channel of the three pumping stations there are six free-flowing wells, which maintain slope stability and stabilize the channel beds.

There are 12,538 m of channels in the drainage area of Požeženo PS, which occupies 455 ha. The drainage area of Ušće Peka PS is 100 ha and the channels are 2,676 m long. The drainage area of Vinci PS is 597 ha and there is 7,868 m of channels.

Pumping stations in the study area

A large number of pumping stations have been built in the Lower Danube Water District, to protect riparian lands from water-logging. Some of them protect settlements and infrastructure (Vinci, Usje, Brnjica, Kladovo and Ljubičevac), while others are parts of farmland drainage systems. The latter are discussed below.

The following pumping stations that protect farmland from excess water are located along the Iron Gate 1 HPNS reservoir in the Lower Danube Water District: Smederevo PS, Kulič 1 PS, Kulič 2 PS, Kolište 1 PS, Kolište 2 PS, Zavoj PS, Rečica 2 PS, Dunavac PS, Rit PS, Ušće Peka PS, Požeženo PS, and Vinci PS.

Serbia Waters is the user of the pumping stations within Godomin Field (Smederevo PS and Kulič 1 PS), while Iron Gate Hydroelectric Power Plants Co. is the user of the remaining pumping stations identified above. The stations are remotely controlled from a central control center in the City of Požarevac [13] (Fig. 1).

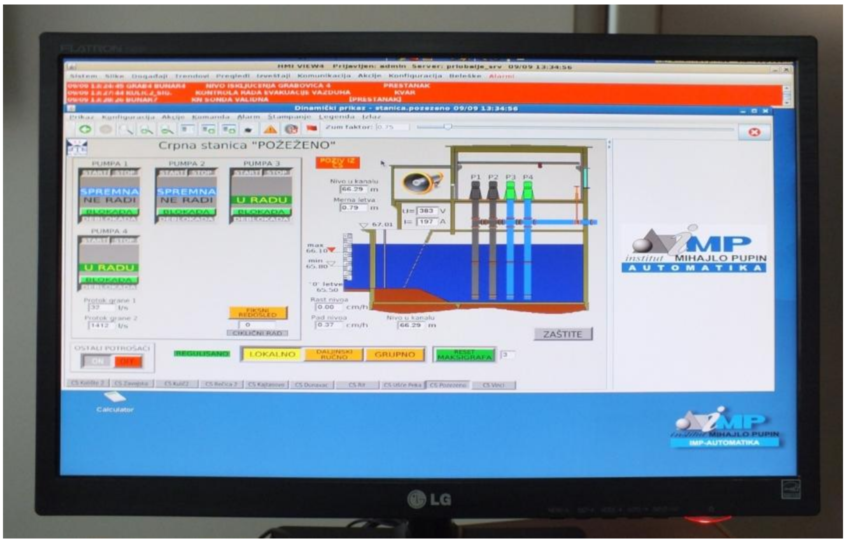

Fig. 1 Automated remote control of pumping stations from a control center in Požarevac.

Smederevo PS

Smederevo PS is located on a right-bank levee on the Danube, at rkm 1112+100. It was built in 1959 and reconstructed in 2012-2014. It is equipped with two pumps, 2x1.5 $m^{3} \cdot s^{-1}$.

Smederevo PS: 44° 41' 26.47'' N, 20° 57' 25.84'' E, alt. 69 m, Hmin=68.70 m a.s.l., Hmax=69.30 m a.s.l., old PS 2x1.5 $m^{3} \cdot s^{-1}$, new PS 4x0.75 $m^{3} \cdot s^{-1}$

Fig. 2 Smederevo PS

Kulič 1 PS

Construction of the drainage system in the Godomin Marsh area began back in the 1930's. The first phase of the project lasted from 1930 to 1935 and resulted in Kulič PS (now Kulič 1 PS). Its capacity is 2x1 $m^{3} \cdot s^{-1}$ and the length of the channel network about 30 km. The PS is located at rkm 1106+700. Prior to impoundment, this station was operated intermittently, except during periods of spring flood waves. The longest period of operation was recorded in 1970, as a result of a long-lasting flood. Since 1984, the pumping station has been operated only from time to time.

Following impoundment of the Danube, the capacity of this station became inadequate. Kulič 2 PS (capacity 3x0.5 $m^{3}\cdot s^{-1}$) was built in 1972.

Kulič 1 PS: 44° 42' 55.17'' N, 21° 00' 51.37'' E, alt. 67 m, Hmin=67.50 m a.s.l., Hmax = 68.70 m a.s.l., 2x1 $m^{3}\cdot s^{-1}$
Kulič 2 PS: 44° 42' 54.95" N, 21° 00' 53.37" E, alt. 68 m, Hmin=67.10 m a.s.l., Hmax = 67.50 m a.s.l., 3x0.5 $m^{3}\cdot s^{-1}$


Fig. 3 Kulič 1 PS and Kulič 2 PS

The pumping stations downstream from the mouth of the Velika Morava (except Rit PS) were built after the dam was erected. Their design is standardized and they are remotely controlled from the centralized control center in Požarevac (Iron Gate HPP Riparian Lands Maintenance Division). They were built in the 1970's and are used by Iron Gate HPPs Co.

Kolište 1 PS

This station is located on the Dunavac Arm of the Danube, near the town of Kostolac, at rkm 1096+000. It was built in 1972. Its drainage area is 2424 ha and the length of the channel network 28812 m. It evacuates water from Upper Kostolac Island and Dubravica flood cell.

Kolište 2 PS

Kolište 2 PS is located next to Kolište 1 PS, on the Dunavac. It was built in 1980.

Kolište 1 PS: 44° 42' 37.25" N, 21° 09' 13.48" E, alt. 70 m, Hmin=66.60 m a.s.l., Hmax = 67,10 m a.s.l., 4x0.36 $m^{3}\cdot s^{-1}$
Kolište 2 PS: 44° 42' 38.24" N, 21° 09' 13.76" E, alt. 70, Hmin=66.60 m a.s.l., Hmax = 67.10 m a.s.l., 850 l/s, 2x2.5 $m^{3}\cdot s^{-1}$

Fig. 4 Pumping stations Kolište 1 and Kolište 2.

Zavoj PS

The area downstream from the mouth of the channelized Mlava – Lower Kostolac Island and Ram-Kličevac Marsh – constitutes a separate zone of about 3690 ha.

Zavoj PS: 44^o 47' 08.95" N, 21^o 16' 38.06" E, alt. 67 m, Hmin=65.10 m a.s.l., Hmax = 65.60 m a.s.l., 2x2.5 $m^3 \cdot s^{-1}$

Fig. 5 Zavoj PS

Rečica PS

Rečica (*Small River*) PS was built in 1978 at rkm 1080 of the Danube. In mid-1983, the Rečica system was connected to the drainage area of Zavoj PS by Channel 6. The operating water levels of the latter are considerably lower (roughly by 80-90 cm) than those of the former.

Rečica PS: 44^o 47' 36.92" N, 21^o 18' 41.01" E, alt. 66, Hmin=66.20 m a.s.l., Hmax = 66.50 m a.s.l., 2x2.5 $m^{3}\cdot s^{-1}$.

Fig. 6 Rečica PS

Dunavac PS

Dunavac PS was built in 1972. It is located on the Dunavac, at rkm 1062 of the Danube. Water levels of the Dunavac are maintained in conjunction with those on Veliko Gradište Island, from which the channel network empties gravitationally into the Dunavac.

Dunavac PS: 44^o 45' 54.66" N, 21^o 28' 49.63" E, alt. 68 m, Hm a.s.l.=65.10 m a.s.l., Hmax = 65.30 m a.s.l., 3x0.86 $m^{3}\cdot s^{-1}$,

Fig. 7 Dunavac PS

Rit PS

Prior to impoundment, Gradište Marsh was protected by a levee and channel network that gravitated to Gradište Marsh PS. Rit (*Marsh*) PS was built in 1972 and reconstructed in 1982. It is located on the Danube, at rkm 1060.

Rit PS: 44^o 45' 52.35" N, 21^o 30' 10.86" E, alt. 67 m, Hmin=65.00 m a.s.l., Hmax=66.50 m a.s.l., 2x0.5 $m^{3}\cdot s^{-1}$**, 1x1.475** $m^{3}\cdot s^{-1}$

Fig. 8 Rit PS

Ušće Peka PS

This station was built in 1972 at rkm 1059. Its drainage area is 100 ha and the channel network is 2676 m long.

Ušće Peka PS, 44^o 46' 04.14" N, 21^o 31' 53.94" E, alt. 66 m, Hmin=66.30 m a.s.l., Hmax=66.70 m a.s.l., 3x0.35 $m^{3}\cdot s^{-1}$

Fig. 9 Ušće Peka PS

Poženo PS

Poženo PS was built on the Danube in 1972, at rkm 1055. It was reconstructed in 2006/07. Its drainage area is 455 ha and the channel network is 12.783 m long.

Poženo PS: 44^o 45' 45.602 N, 21^o 33' 50.23" E, alt. 66, Hmin=65.80 m a.s.l., Hmax=66.10 m a.s.l., 4x0.63 $m^{3}\cdot s^{-1}$

Fig. 10 Požeženo PS

Vinci PS

Vinci PS was built in 1972 at rkm 1049 of the Danube. Its drainage area is 597 ha and the channel network is 7868 m long.

Vinci PS: 44° 43' 31.55" N, 21° 36' 13.26" E, alt. 68 m, Hmin=66.20 m a.s.l., Hmax=66.70 m a.s.l., 4x0.4 $m^{3}\cdot s^{-1}$

Fig. 11 Vinci PS

From an agricultural perspective, management of the groundwater regime is of the utmost importance. The groundwater regime depends on a series of factors: natural conditions (hydrogeological and hydrological), regime of the reservoir on the Danube, and operation of drainage systems.

3. Results and Discussion

Case study: Godomin Field

Godomin Marsh is part of the alluvial plain of the Danube and the Velika Morava, whose average elevation is 69 – 72 m a.s.l. The Danube's reach from rkm 1106.0 to 1115.5 is its northern boundary, the Velika Morava its eastern boundary, the channelized Jezava (Red Water Channel) its southern boundary, and the old channel of the Jezava its western boundary. Further inland there is the hilly part of the City of Smederevo, from which water drains into this area.

The soil is waterlogged by surface water, groundwater and autochthonous water (seasonal excess precipitation). Surface water includes runoff from slopes and water delivered by streams (e.g. Vučak Creek) from higher elevations in the uplands. Groundwater is largely under the influence of the Danube, followed by the Morava and Jezava rivers.

Following construction of Iron Gate 1 HPNS at rkm 943 in the 1970's, a reach of the Danube was considerably modified and a reservoir created, which impacted the water table in the riparian lands upstream from the dam, including Godomin Field. Apart from elevating the water table, the project altered the direction of groundwater from the upland to the river. The Danube drained this area under natural conditions, except during wet periods when river water was infiltrated. The pre-existing pumping stations (Kulič and Smederevo) and the shallow channel network collected excess meteoric water. Following construction of Iron Gate 1, the direction of groundwater flow changed, from the Danube to Godomin Field. The water tables near the river rose, but in the central part of the protected area they remained at similar elevations, albeit with smaller fluctuation amplitudes.

The first structural drainage measures were introduced in the 1920's. After several decades of construction and reconstruction, the present drainage scheme includes an open drainage network (channels), a subsurface drainage network (drain line, drain collectors, culverts, and concrete collectors), free-flowing wells, drainage wells with submersible pumps, pumping stations (structural and electro-mechanical components), levees, and revetments.

Godomin Field is drained by a 110 km long channel network and appurtenances, which include pipe drainage, drainage wells, guard huts, collector drains and culverts. There are 106 box culverts and 71 pipe culverts, and along the channel network there are two guard huts (both in the Kulič area). [1,3,6,7]

After a channel called "Industrial Water" was built, Godomin Field was divided into two separate parts (drainage areas). The existing drainage system at Godomin Field is comprised of two hydraulic reclamation units (HRS DD 1 and HRS DD 2): Smederevo and Kulič [8, 9,16].

Before 1970, the drainage areas of Kulič PS and Smederevo PS were connected by channels and similar water tables were maintained in the entire area – between 68.0 and 69.0 m a.s.l. After the previously-mentioned channel was built, the entire area of 5740 ha was divided into two fields:

- Hydraulic reclamation field "Smederevo", 1335 ha (between the Industrial Water Channel and the old channel of the Jezava River); and
- Hydraulic reclamation field "Kulič", 4405 ha (between the Industrial Water Channel and the Velika Morava River).

The average modulus of surface water drainage in this area is q=0.62 l/s·ha. A depth-to-groundwater of 0.8-1.0 m was selected as the farmland protection criterion.

The average modulus of groundwater drainage is 0.6 l/s·ha. Groundwater is under the primary influence of the Danube, with minor effects of precipitation and evaporation, such that there are no large water level fluctuations (up to 1 m under normal conditions).

The total length of the channel network of HRS Smederevo is 25.482 m, of which 22.3792 m of the network is within the reservoir zone and the remaining 1690 m beyond its influence. The total length of the channel network of HRS Kulič is 85.016 m, of which 52.558 m is within the reservoir zone and the remaining 32.458 m beyond.

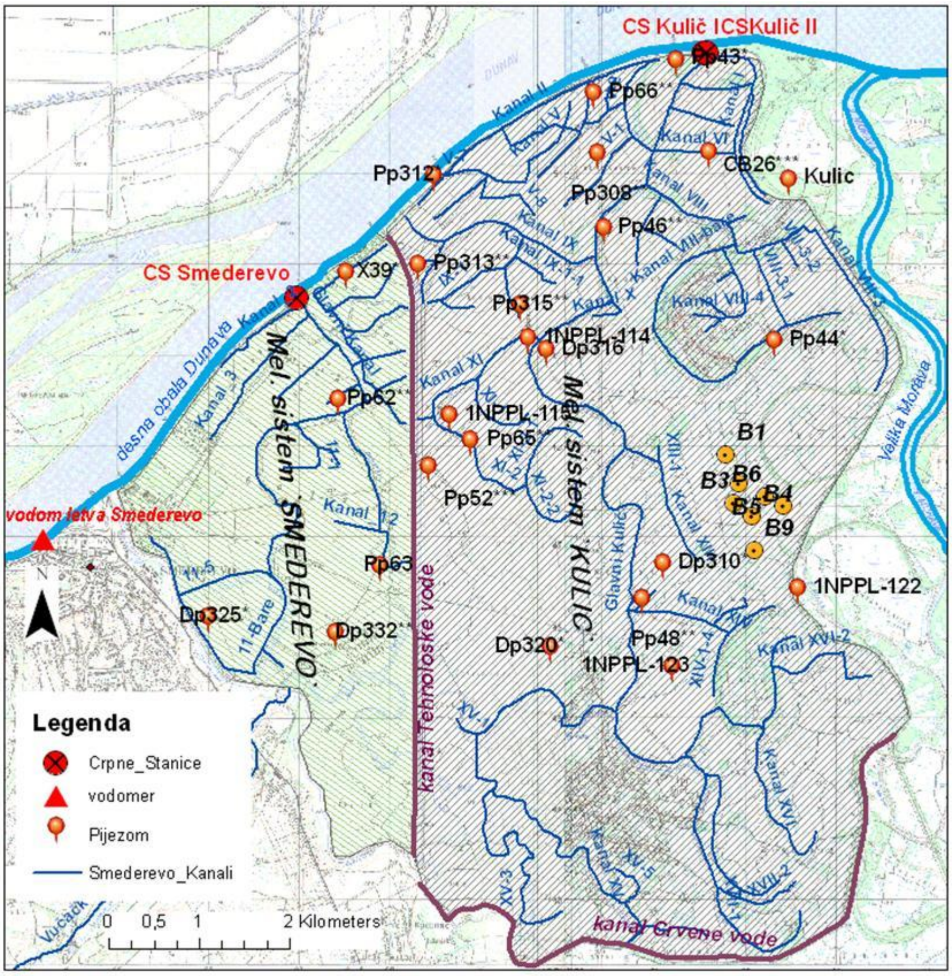

Fig. 12 Layout of Godomin Marsh: digitized channel network, pumping stations, piezometers, water gauge, and boundaries.

The representative hydrological stations for assessing hydrological conditions and the effectiveness of drainage are the gauging stations at Smederevo on the Danube (1116.230 km from the mouth) and at Ljubičevski Most on the Velika Morava (21.800 km), as well as the water level in the Industrial Water Channel.

However, for illustrating the effectiveness of the drainage scheme, the most important is the reach of the Danube where the pumping stations are located. The water level duration curve of the Danube (Fig. 13) for the period 1985-2013, shows that the water level fluctuation amplitude is 6.79 m. The stages of the Danube on this location range from 67.02 to 73.81 m a.s.l. However, more than 81% of the recorded data points are in a two-meter interval, 69-71 m a.s.l. (Fig. 14).

For comparison purposes, high and low operating water levels of the Main Channel at Kulic 2 (67,10 and 67,50 m a.s.l.) (Fig 15) are shown in the water level plot of the Danube at Smederevo, at only 4 km upstream from Smederevo PS, for the period for which Smederevo PS operating data were available. Since the Danube is a lowland river, its stages at this PS are some 10 cm lower than at the gauging station at Smederevo. It is apparent that the stages of the Danube are rarely lower than the high operating water levels of the channel at the pumping station.

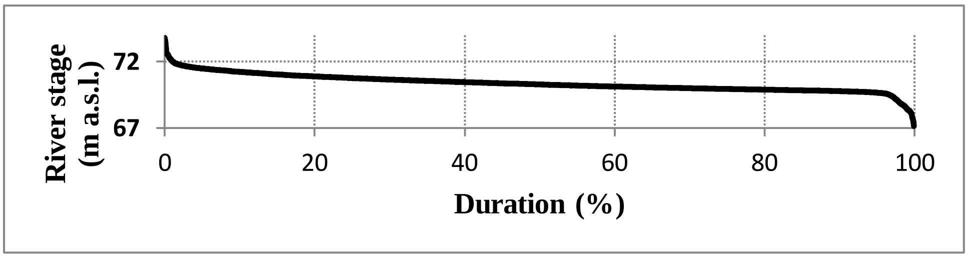

Fig. 13 Water level duration curve of the Danube at Smederevo (1985-2013)

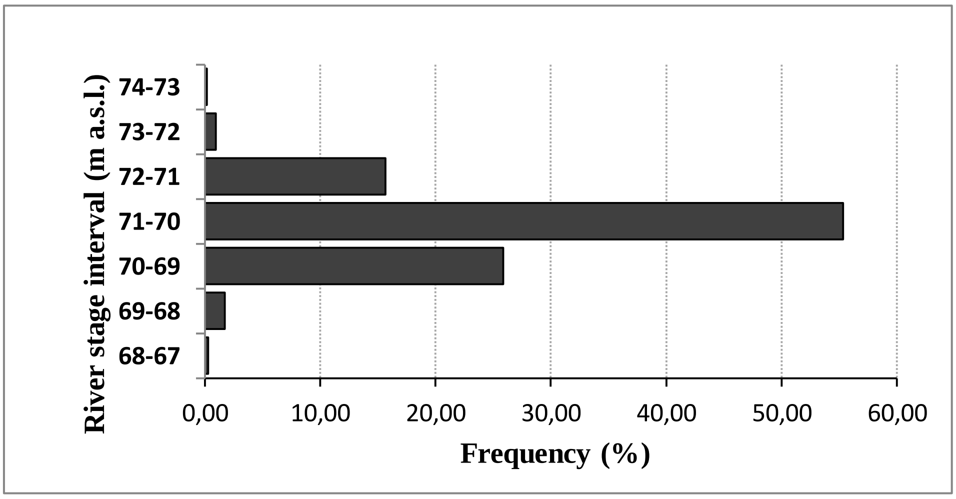

Fig. 14 River stage histogram of the Danube at Smederevo (1985-2013)

Groundwater plays a significant role in the study area's hydrology. Natural conditions (hydrogeological and hydrological), the reservoir, the operating regimes of the drainage systems HRS Kulič and HRS Smederevo, the operating regime of the water supply source "Šalinac", and the water level in the Industrial Water Channel all influence the groundwater regime.

Kulič 2 PS is in service all year (Fig. 16), as demonstrated by the 2009-2013. operating chart. On average, the largest volume of water has been delivered to the Danube by this pumping station in the month of March, and the smallest volume in September. During the considered period, the monthly high was recorded in March 2010 and the monthly low in August 2013.

Table 1 Monthly mean, low, and high stages of the Danube at the gauging station in Smederevo (1985-2013)

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Mean	70.33	70.32	70.65	71.14	70.85	70.61	70.29	70.09	70.04	69.98	70.11	70.30
High	71.62	71.74	72.30	73.81	72.98	72.72	72.70	71.36	71.40	71.26	71.78	71.65
Low	67.49	68.12	68.06	69.80	69.82	69.74	68.34	69.06	68.54	67.56	67.02	67.74

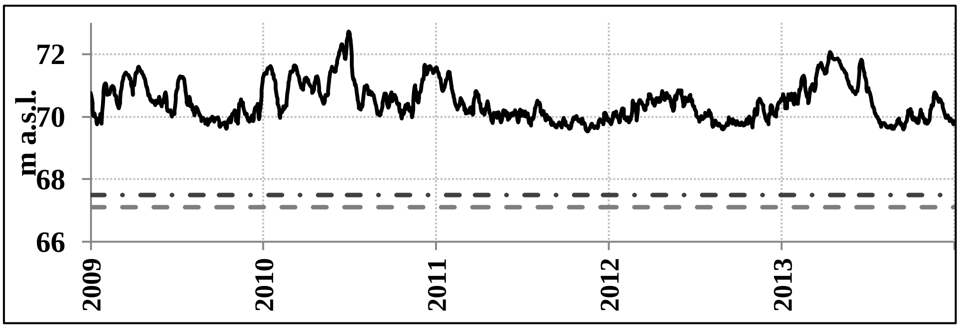

Fig. 15 Water level plot of the Danube at the gauging station in Smederevo, and high and low operating water levels of the channel at Kulič 2 PS

Data collected from the piezometers used to monitor the performance of the protection scheme in the HPP operating mode of 69.5+ m were used to describe the groundwater regime in Godomin Marsh.

In the study area (Water Body #63), the National Hydrometeorological Service of Serbia obtains data from several piezometers [17]. Data from observation well NPPL-114, located closest to the Danube (at about 2.3 km), were used in the present study. The well is at a distance of 3.8 km from the Velika Morava and its depth is 12.7 m. The depth to the water table of the shallow aquifer is measured. Generally recorded fluctuations have been between 66.2 and 67.5 m a.s.l. and up to 67 m in recent years (Fig. 18). The maximum water level recorded at this well is 67.53 m a.s.l., and the minimum 66.25 m a.s.l. The mean of all readings is 66.75 m a.s.l. The ground elevation is 69.19 m, which means that in recent years the water table never reached the rhizosphere. As such, the drainage system has been effective.

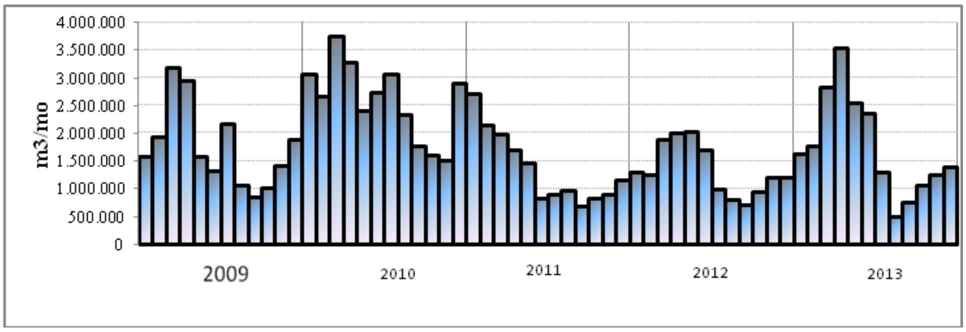

Fig. 16 Volume of water pumped by Kulič 2 PS into the Danube (2009-2013) (m^3/month)

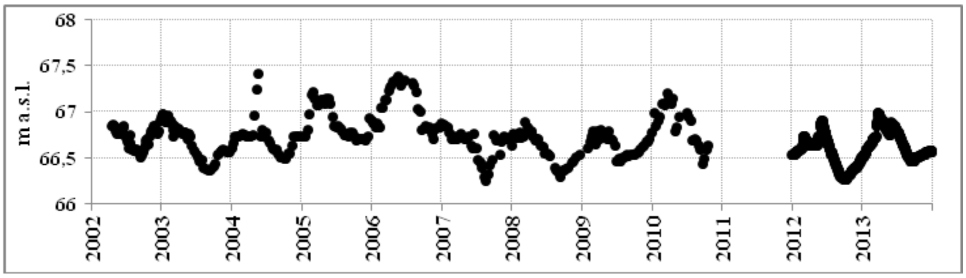

Fig. 17 Water level diagram of observation well NPPL-114

Figures 18 and 19 shows the volume of pumped water as a function of the Danube's stage and depth to water table, respectively. Due to a relatively short time series, it was not possible to conduct a statistical analysis, only assess the effect of the river and groundwater on the operation of the drainage systems. Even though channels evacuate meteoric water from the surrounding area, the stages of the Danube have the greatest impact on the pumping rates.

Based on the depths-to-groundwater (1.66-2.94 m, av. 2.4), in recent years the water table has never been in the rhizosphere zone, which leads to the conclusion that the drainage system in the area is performing its function effectively. This is due to the operation of the pumping station (Fig. 19), because the water table depends on the volume of water pumped by Kulič 2 PS (R^2 =0.7073).

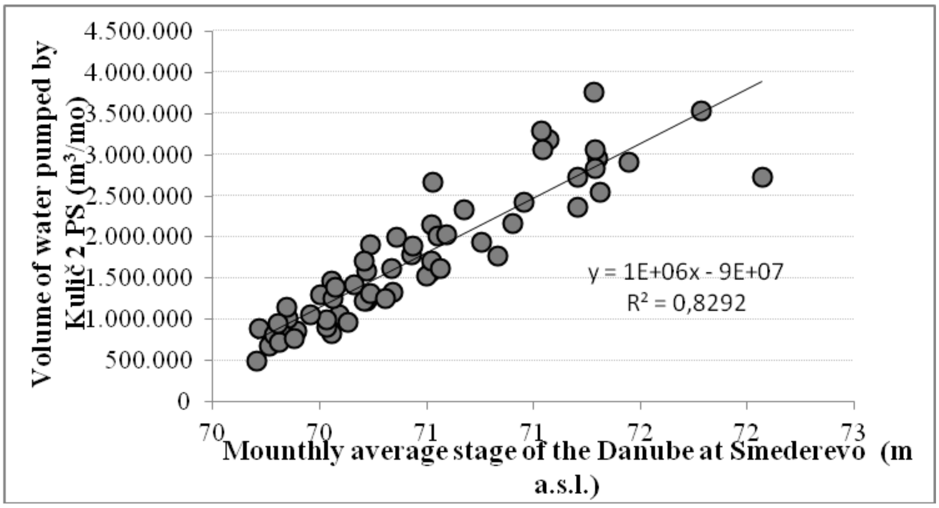

Fig. 18 Volume of water pumped by Kulič 2 PS as a function of the Danube's stage

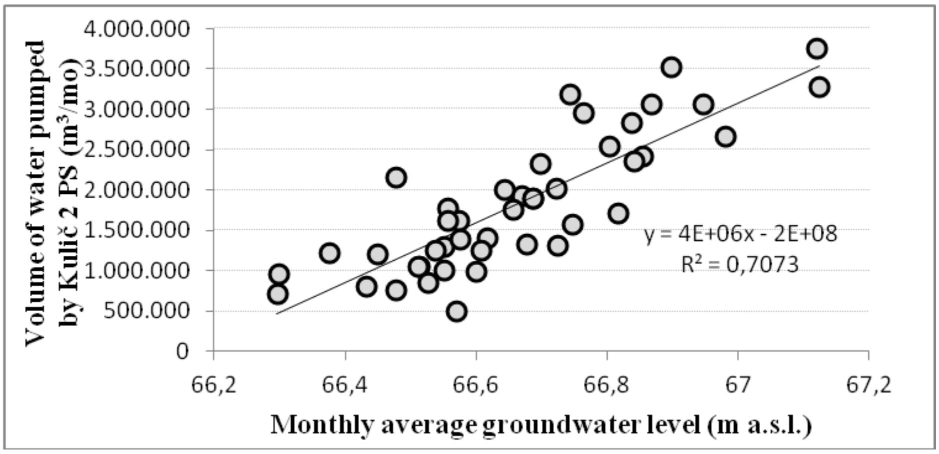

Fig. 19 Volume of water pumped by Kulič 2 PS as a function of groundwater level (2009-2013)

CONCLUSION

There are many drainage systems in the hydraulic reclamation district along the Lower Danube, which is under the influence of the reservoir on the Danube created after construction of Iron Gate 1 HPNS. These drainage systems are operated by Serbia Waters and Iron Gate HPPs Co. and have been effectively draining farmland in the riparian lands along the right bank of the Danube. The drainage scheme comprises an open drainage network (channels), subsurface drainage network (drain line, drain collectors, culverts, and concrete collectors), self-flowing wells, drainage wells, pumping stations, levees, and revetments. The depths-to-groundwater in the study area are largely affected by the Danube's stages. Owing to the drainage scheme, the farmland along the right bank of the Danube is effectively protected from waterlogging.

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Popular Paper

LOW-COST ALTERNATIVE WASTEWATER TREATMENT SYSTEMS: CONSTRUCTED WETLANDS

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Abstract. *Parallel to rapid increase in world population and nourishment needs, water demands are rapidly increasing. Agricultural, domestic and industrial water users are in continuous competition for limited water resources. Continuously polluted waters, decreasing water resources due to global warming and climate chance, increasing labor and energy costs all brought the water and treatment technologies into the first place of the world's agenda. To overcome the water-related problems, water losses in agricultural, domestic and industrial uses should be prevented, effective and efficient water use should be provided and possible use of wastewater and treated water should be investigated. Constructed wetlands are natural treatment systems employed as an alternative to conventional treatment systems because of their low construction, operation and maintenance costs, low energy demands, simple operation and low sludge generation. These systems are specially designed systems imitating the natural wetlands and include soil, plant and microorganisms to remove the pollutants from wastewaters. These natural treatment systems are mostly used for sewage treatment of villages in Turkey. Natural treatment systems are defined as the "primary treatment alternative" in rural development strategy document of State Planning Organization of Turkey. The present paper discusses the possible use of constructed wetlands for waste water treatment in rural parts of Turkey, especially in villages and possible use of treated water in irrigation. Current drawbacks observed in construction, operation and maintenance of these systems were also put forward in this study.*

Key words: *Wastewater, Treatment, Natural treatment, Constructed wetland.*

1. INTRODUCTION

Water and food demands are constantly increasing with rapid increase of the world population. There is an increased stress placed on water limited water resources. Besides, agricultural, domestic and industrial sectors are in continuous competition for limited water resources [10]. Continuously polluted waters, decreasing water resources due to global warming and climate chance, increasing labor and energy costs all brought the water and treatment technologies into the first place of the world's agenda. To overcome the water-related problems, water losses in agricultural, domestic and industrial uses should be prevented, effective and efficient water use should be provided and possible use of wastewater and treated water should be investigated [1].

Wastewaters are, most of the time, discharged into seas, rivers and other water bodies without any treatments due to high treatment costs both in Turkey and throughout the world. There are 3225 municipalities in Turkey. Of these municipalities, 2421 have a sewage system and 44.7% of 3.26 billion m^3 wastewater are discharged into sea, 43.1% into rivers, 3.5% into dams, 2.1% into lakes, 1.5% into lands and 5.1% into other receiving bodies. About 69% of discharged wastewater is treated with 236 treatment facilities serving to 442 municipalities. Of these treatment facilities, 29 are physical, 158 are biological, 32 are advanced and 17 are natural treatment facilities [3].

Constructed wetlands are treatment systems used as an alternative to conventional treatment systems because of their low construction, operation and maintenance costs, energy demands, easy operation and low sludge generation [18, 17]. Constructed wetlands with their cheap and easy construction, low energy and labor costs, easy operation, maintenance and monitoring were also specified as the primary issue in rural development strategy document of State Planning Organization of Turkey [2]. These systems are specially designed systems imitating the natural wetlands and include soil, plant and microorganisms to remove the pollutants from wastewaters. An excavated constructed wetland basin is lined with compacted clay or synthetic membrane and filled with graded sand-gravel substrate [4]. Today, constructed wetlands are widely used to treat domestic wastewaters [9], agricultural wastewaters [19], industrial wastewater and runoff waters [12].

In the present study, general issues to be considered in design, construction, operation and maintenance of sub-surface horizontal flow constructed wetlands commonly used in rural parts of Turkey for domestic wastewater treatment purposes were assessed and current implementations in Kayseri Province were investigated. Potential mistakes made in their design, construction, operation and maintenance of them were pointed out and possible solutions were proposed.

2. NATURAL WETLANDS

The natural wetlands are defined as transition zones between lands and water bodies and include sites with specific flora and fauna adapted to these regions and are characterized with their high water tables and high organic matter contents [11]. They usually have water depths less than 6 meters and include the sites of flood plains, shallow shores, lagoons, estuaries, sluggish sections of rivers, lakes with fresh, bitter or salt water [8]. Nutrient inflow to wetlands supports the growth of vegetation and such vegetation constitute the primary component of wetland food-chain and converts inorganic materials into organic materials [16]. Wetlands are the natural heritages of the world with their biologic diversity and provide the following functions [7];

- Wetlands provide a habitat for a rich flora and fauna,
- Wetlands are the ecosystems with the highest biological production like tropical rainforests
- Wetlands stabilize the water regimes of the regions where they are located through charging or discharging groundwater tables, storing floodwater, controlling floods, preventing see water intrusion,
- Wetlands purify waters through retaining residues and poisonous materials or using nutrients (nitrogen, phosphorus).
- Wetlands have a high economic value with their supports provided in fishery, agriculture, livestock, reed production and tourism,
- Wetlands raise the humidity of the region where they are located and have positive impacts primarily on local climate parameters such as precipitation and temperature.
- Wetlands are the ecosystems with the highest biological production like tropical rainforests.

Natural treatment systems purify waters and such functions bring the preservation of such sites into consideration. Although researches indicated high waste water treatment performance of natural wetlands [18, 17] such implementations may have some adverse effects with regard to preservation of these sites. Toxic elements in wastewaters, negative impacts of pathogens and additional hydraulic loading and nutrients can cause long-term degradations in these natural systems. Therefore, constructed wetland technologies have been developed instead of natural ones for wastewater treatment purposes

3. Constructed Wetlands (Natural Treatment Systems)

Constructed wetlands emulate the natural systems and contain soil, plant and microorganisms, commonly encountered in natural ones, within specially-designed and constructed basins to remove pollutants from wastewaters [13]. These systems are commonly composed of a compacted clay or synthetic liner overlaid with graded sand and gravel substrate material, reeds like aquatic plants and the other engineering structures adjusting hydraulic loading rates, retention times and water levels within the basin (Figure 1). Constructed wetlands, also called natural treatments systems, today are used for treatment of various wastewater resources.

Natural treatment systems have some advantages over conventional treatments systems. They are cheaper and easier to construct, require low energy and operational costs, do not require expert personnel, environment-compatible systems and provide habitat for various wetland organisms. Beside these advantages, they have also some disadvantages. They require larger areas and system performance is less stable and easily can be altered by changing climate conditions [14].

A successful constructed wetland design should take the following general criteria into consideration [14]:

- The design should be kept as simple as possible and complex technological approaches should be avoided to prevent possible failures.
- The wastewater flow should be supplied through gravitational flow,

- The design should be so performed as to require the least maintenance,
- The design should comply with the natural landscape and topography,
- Extreme weather and climate conditions should be considered in design,
- The systems should be allowed time to reach the desired performance values.

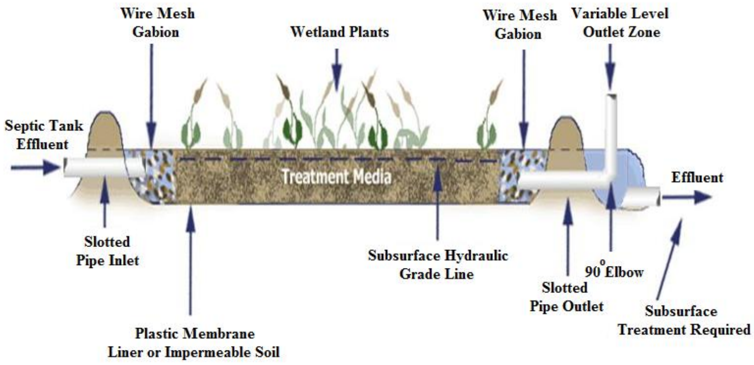

Fig. 1 Constructed wetland components [4]

Constructed wetlands can either be designed as the primary treatment unit or integrated into multi-stage treatment systems. They are commonly designed as surface flow and sub-surface flow constructed wetlands. Based on flow regime, sub-surface flow wetlands are also classified as vertical and horizontal flow constructed wetlands.

3.1. Surface flow constructed wetlands

The surface flow constructed wetland systems are typically composed of a bed or canal, a compacted impervious layer, soil or another media for plant rooting and relatively low water level flowing through the system (Figure 2). Water surface is above the filtrate or fill material. These systems resemble the natural wetlands and provide various benefits for wild life beside water treatment [20]. While the sections closer to surface are aerobic, deeper sections and substrate material are anaerobic. The primary advantage of these systems are their low investment, operation and maintenance costs, easy construction and operation and the basic disadvantage is the land requirement to construct such systems since they require significantly larger areas than the other constructed wetland or conventional treatment systems.

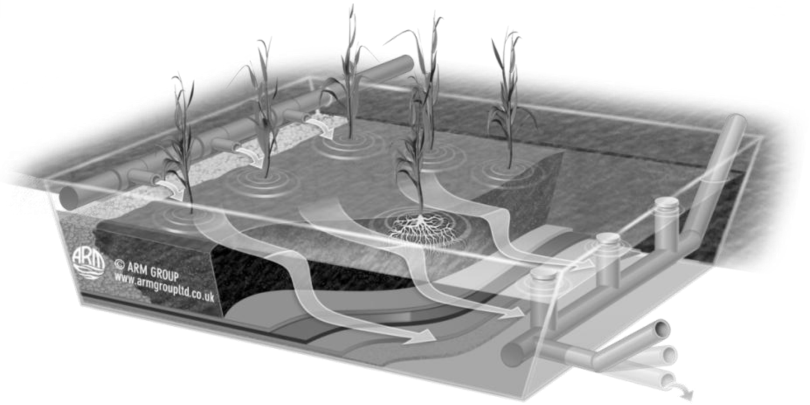

Fig. 2 Surface flow constructed wetlands

In system design, biological oxygen demand (BOD), total suspended solids (TSS), nitrogen (total Kjeldahl nitrogen, denitrification and ammonium nitrogen), phosphorus, coliform bacteria, metal and other particulate pollutant performances are taken into consideration. Some recommended design criteria for optimum performance from surface flow constructed wetlands are provided in Table 1 [15].

Table 1 Design parameters for surface flow constructed wetlands

Parameter	**Design Criteria**
Influent quality	BOD ≤20 – 30 mg L^{-1} TSS ≤20 – 30 mg L^{-1}
Pre-treatment	Oxidation basins
Design flows	Q_{max} (maximum monthly flow) Q_{ave} (average flow)
Maximum BOD loading	20 mg L^{-1} : 45 kg ha^{-1} day^{-1} 30 mg L^{-1} : 50 kg/ha^{-1} day^{-1}
Maximum TSS loading	20 mg L^{-1}: 45 kg ha^{-1} day^{-1} 30 mg L^{-1}: 50 kg ha^{-1} day^{-1}
Water depth	0.6 – 0.9 m (full plant cover sections) 1.2 – 1.5 m (Open water surfaces) 1.0 m (Inlet settling section)
Maximum HRT	2 days (full plant cover sections) 2 – 3 days (Open water surfaces)
Basin geometry	Optimum 3:1 – 5:1
Inlet settling section	In case of failed pretreatment in settling
Inlet	Uniform influent distribution in inlet
Outlet	Uniform effluent collection in outlet

3.2. Sub-surface flow constructed wetlands

Subsurface flow constructed wetlands are composed of a compacted clay or synthetic impermeable liner overlaid by graded gravel and sand substrate material planted with aquatic plants and water level control structures (Figure 3). They are designed in either horizontal flow or vertical flow and can be used with and without emergent plants [21]. Contrary to surface flow systems, water does not come out to surface in these systems and flows through a substrate material and reaches to outlet. Same parameters are considered in design and recommended design criteria are provided in Table 2 [15].

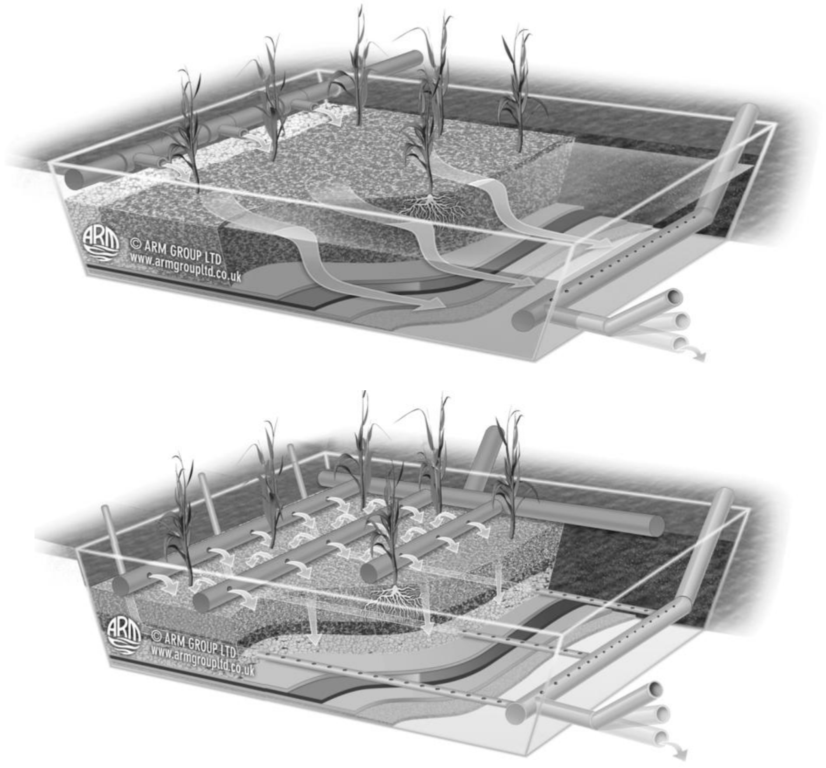

Fig. 3 Horizontal and vertical flow sub-surface constructed wetlands

The most significant component of these systems is the substrate material filtering the wastewater. The material both provides a medium for rooting of aquatic plants and distributes influent, directs and collects effluent, provides surface area for microbial activity and filters suspended solids. Although various size and composition of substrate materials have been tried, there are not any concrete evidences about which size or type of material is the best. The basic criterion is not to allow small particles settle into the pores of coarser ones. Substrate upper surface should be leveled and about 1% slope should be provided at bottom surface. Inlet pipes should be so arranged to prevent short-circuit and substrate clogging and provide an equal flow. Outlet pipes should also prevent short-circuits, provide equal water collection and allow the operators to arrange the water level and effluent drainage.

Table 2 Design parameters for sub-surface flow constructed wetlands

Parameter	**Design Criteria**
BOD	6 g m^{-2} day^{-1} – 30 mg L^{-1} for inlet
TSS	20 g m^{-2} day^{-1} – 30 mg L^{-1} for inlet
Depth	Substrate: 0.5-0.6 m Water 0.4-0.5 m
Length	Minimum 15 m
Width	Maximum 61 m
Bed bottom slope	0.5 – 1%
Bed surface slope	Flat or almost flat
Hydraulic conductivity	1000 m day^{-1} for the first 30% of length 10000 m day^{-1} for the last 70% of length
Substrate	Inlet section: 40-80 mm Process section: 20-30 mm Outlet section: 40-80 mm Planting section: 5-20 mm

In Turkey, sub-surface horizontal flow constructed wetlands are commonly used for domestic wastewater treatment in rural parts, especially in villages. Usually the type-projects designed by Special Provincial Administrations just by taking the total population to be served into consideration are implemented (Figure 4). Most of the time, local conditions, influent quality parameters, hydraulic loading rates, retention times and site-specific characteristics are not taken into consideration. Therefore, various failures occur because of such design errors and most of the already constructed systems are not either well-operating or not-operating at all [5]. The common failures are classified as: failures in site selection, inlet clogging, substrate clogging and consequent water poundings over the surface, outlet clogging, leakage through slopes, plantation failures, failures in operation and maintenance [6]. Effluents of properly operating systems can also be used for irrigation purposes. However, irrigation water quality parameters should definitely be taken into consideration before using treated effluents.

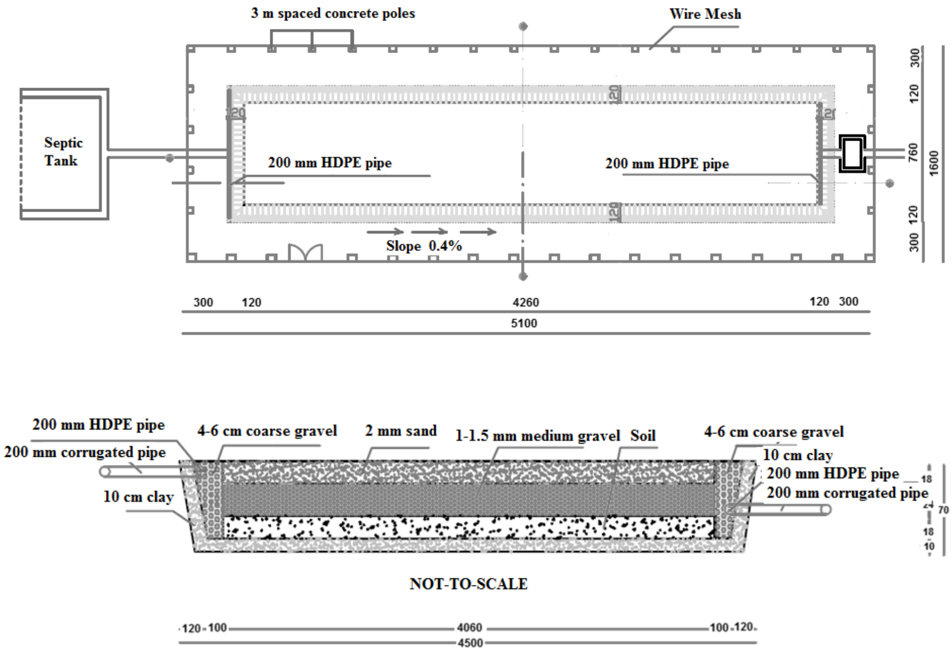

Fig. 4 A pilot project designed for a population of 500 people

4. CONCLUSIONS

Constructed wetlands, also called natural treatment systems, can reliably be implemented in sites with low land costs and limited labor force. They are getting common in rural parts of Turkey, especially in villages to treat domestic wastewater. Such implementations were also specified as the primary issue in rural development strategy document of State Planning Organization. Sub-surface horizontal flow constructed wetlands are common in practice. However, most of the already constructed systems are not either well-operating or not operating at all just because of errors and mistakes made in their design, operation and maintenance processes. Such errors must urgently be corrected to prevent the waste of investment made on these systems. Re-use of treated effluent for irrigation purposes is also a critical issue to be considered. Almost 70% of renewable water resources are allocated to irrigations and re-use of constructed wetland effluents may provide significant water savings in irrigated agriculture. But, irrigation water quality parameters must be taken into consideration before the re-use of treated effluents. As to conclude, constructed wetlands are the significant systems to prevent water resources pollution since the wastewater previously was being discharged into receiving bodies without any treatments. Now, treated effluents are discharged into water bodies with these systems and consequently both water quality and aquatic life are preserved against the toxic and hazardous impacts of untreated sewage.

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Scientific Review Paper

A REVIEW OF PASSIVE SYSTEMS IN AGRICULTURE STRUCTURES TOWARDS ENERGY CONSERVATION

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Abstract. *Agriculture is a continuously technologically developed sector. The increase of food and of any agricultural product demand results to an increase of the energy requirements, which, many times, has simultaneous odd effects on the environment. Moreover, several targets concerning environmental issues have been set by the EU and other organizations in order to prevent climatic change. For the above reasons, several methods and techniques have been investigated to rationalize the energy consumed in agriculture, among which some are based on passive energy systems. Passive systems have been used extensively in urban applications with significant results leading to great amounts of energy savings. In the present study a brief review of innovative agriculture structures towards this direction are presented. The theoretical background of these passive techniques will be analyzed (i.e heat transfer mechanisms) for the better evaluation of the system's energy efficiency. Some considerations on environmental and economical benefits will also be cited to estimate the contribution of those systems towards these directions, as well. Finally, the adaptability of those techniques on the European region and conditions are investigated taking into account climatic, economical and policy factors.*

Key words: *energy, agriculture, passive energy systems, innovative structures.*

1. INTRODUCTION

Agriculture spots a significant development during the last decades in terms of modernization of technologies and applications. As a consequence larger amounts of energy for agricultural applications are demanded. According to Eurostat in 2013 the EU 28 countries consumed 23898.2K toe (tones of oil equivalent) of energy in agriculture [9]. At the same time the agricultural sector is about to face a serious challenge until

2050. According to FAO (Food and Agriculture Organization of the United Nations), 70% more food should be produced as the earth's population is estimated to grow of 2.3 billion people. At the same time issues such as poverty and hunger, the efficient use of scarce natural resources and the adaption to the climate change should be encountered as well [10]. As a short conclusion agriculture should meet the needs for food demand by the most sustainable way including energy conservation and proper resource management. The amount of energy needs in the agricultural sector depends on some key factors according to the examined area. The most important of them are the rate in which the population is engaged in agriculture, the availability of arable land and the level of mechanization [19]. One category of energy consumption in agriculture is the building sector. Agricultural buildings play a important role in the development of agriculture as they are engaged with almost all the sub-sectors of agriculture such as livestock production, protected crop development, agricultural products storing and processing methods (drying tunnels, milk process etc). Table 1.1 illustrates the annual energy use per m^2 on some types of agricultural buildings.

Table 1 Energy use in typical buildings for agriculture purposes made by Williams et al., 2006 [32]

Building type	**Primary Energy use per m^2 per year (MJ)**
Steel clad, concrete floor, e.g. grain, potato store	26
Steel framed, fibre cement clad, concrete floor, *e.g.* grain, potato store	39
Steel roof, earth floor, *e.g.* machinery store	17
Broiler house, steel framed, wooden, earth floor	34
Steel framed, Timber sided building, concrete floor, *e.g.* dairy cattle	62
Pole barn, wood clad & steel roof	8.7
Pig house, slatted floor	87
Battery house	87
Perchery / stilt	28
Free range birds	24
Outdoor pigs	1
Low cost beef / sheep 1	10
Greenhouse	16

The energy consumption in buildings depends on the use of the building, the structure (materials used etc), the climatic conditions, the area and the overall design of the structure (orientation, shading etc). As it can be seen in table 1, there is a difference in energy consumption between stores, livestock buildings and greenhouse structures. This is due to the fact that stores and livestock buildings require certain amounts of energy for artificial heating, cooling, lighting and ventilation in order to retain specific conditions, while greenhouses requires specific indoor conditions but the solar energy is providing a big percentage of the heating needs. The above highlights the importance of passive technologies in energy conservation. Passive systems are widely used in urban buildings with positive results. These systems work without additional energy, and can be proven as an effective addition to a sustainable building. Passive designing exploits physical principles such as the movement of heat and air and manage to operate with the absence or limited mechanical assistance [27].

Urban buildings can achieve up to 90% energy savings by the use of such systems which also concentrates some additional advantages as low operational cost and environmental friendly operation [20]. Agricultural buildings require energy for heating, ventilation (livestock or storage buildings, greenhouses), hot water or hot air for various processes (drying, boiling, and pasteurization) and lighting. Most of those operations can be supported by passive systems. In this research work a review of passive systems which can be used in agricultural application is performed. Some systems already adapted to agricultural buildings and facilities are also presented in order to evaluate the possible benefits of those practices in actual case studies.

2. PASSIVE SYSTEMS DESCRIPTION AND DESIGN PRINCIPLES

Passive systems are operating with no assistance of any mechanical or technical mean. In some cases mechanisms that consume small amounts of energy are permitted such as automatic control systems etc. Usually hybrid and passive systems are identified incorrectly. Hybrid systems combine passive with active systems. As already mentioned systems with insufficient active systems can be considered as passive. In order to achieve the best possible results, the passive design approach should take into account the following factors.

a) The acceptable thermal comfort criteria of the examined case study should be defined.

b) A good data base and general analysis of the local climate conditions is also necessary.

c) The energy performance targets set should be clear, realistic and measurable [5].

The applications that can be supported by passive design are: space heating, water heating, ventilation, cooling, lighting, water management.

2.1. Space heating

Heating a building with the assistance of passive design is a practice which is used for many years with great results. The heating of indoor environment can be explained by basic heat transfer and thermodynamic principles. The techniques used are increasing the thermal insulation of the structure (heat conduction mechanisms), the natural movement of hot air (heat convection mechanism), the exploitation of solar radiation (heat radiation mechanism) and finally the capability of particular materials to store efficiently thermal energy (heat capacity principles) [27]. Passive design for space heating in buildings introduces techniques to harness solar radiation and at the same time capture the internal heat gains. That way free thermal energy is added to a building and the artificial heating is limited. In practice passive solar heating combines a well-insulated structure as well as other elements (special designed windows) that minimize energy losses and constructive elements which are able to store solar gains [5].

The capture of internal heat gains can be achieved by the use of insulation materials. The thermal resistance of a material depends on the thickness of the material and its thermal conductivity. Materials with high thermal conductivity lead to low thermal resistance values while at the same time the thicker the material the highest the thermal resistance. The adaption of materials with high insulation properties in walls and roofs of buildings limits heat losses. Proper insulation can reduce heating and cooling cost up to 20% [17].

Beyond insulation passive space heating is enforced by the implementation of constructive elements with high values of heat capacity. Thermal walls are typical cases of such elements. Some examples are the simple mass wall, the Trombe wall, and the water wall. Thermal walls are walls (usually with south orientation) made by materials with high values of heat capacity. At the outer side of the wall a glazing is placed in order to create a space between the wall and the glazing. That way the short wave solar radiation is trapped in the area between the two elements. The absorbed solar radiation is emitted to the indoor environment with some delay. So, thermal energy is absorbed during the day and “exploited” by the building during the night with conduction and radiation. A variation of the typical mass wall is the Trombe wall where openings at the wall allow the movement of the air from the space between the glass and the wall and the indoor environment. With this provision heat transfer with convection is performed as well. The water wall is differentiated from the two previous examples because water fills the space between the wall and the glazing in order to increase the heat capacity of the construction [21].

Another technique for enforcing the effort of passive heating is the proper selection and placing of windows. Windows have a double role at a building structure. They ensure proper lighting in the indoor environment and also are used for natural ventilation. From the thermal point of view windows are responsible for a big percentage of the total heat losses as they are characterized by lower thermal resistance compared to other construction elements. The minimization of heat losses can be achieved by the use of double glazing windows and good insulation of the glazing [5]. Proper placing of windows though can lead to sufficient amounts of heat gains from solar radiation. Windows on east, south, and west orientated walls will be exposed to more solar radiation during the winter. For this reason large window areas are chosen to be placed at these orientations. It should be mentioned that this practice is leading to satisfactory results in milder climates [5].

2.2 Water heating

Hot water is used in several applications in buildings (commercial, industrial, agricultural) for several reasons. The most common practice is via a solar collector. Solar collectors cannot be characterized as passive systems because the use of circulators, boilers and other supplementary energy demanding equipments are necessary. The preheating of water though can be considered as a passive technique and it can be considered as a supportive action in order to consume lesser energy for heating water with the use of conventional methods [15].

2.3 Ventilation

Natural ventilation is dedicated to forces caused by phenomena such as the air movement between indoor and outdoor environment or the temperature difference between two points inside a building. The driving of outdoor air inside a building can be performed by the overall design of the structure. Openings must be placed in specific points of the structure in order to create a path for the movement of air mass. Such kind of purpose interventions are building envelope openings, windows, doors, solar chimneys, wind towers and trickle ventilators. The effectiveness of buildings natural ventilation depends on the climate, the building design and the proper cooperation of the openings due to human behavior [3].

2.4 Cooling

Passive cooling techniques actually combine all the pre mentioned issues. To obtain proper conditions within a building during the summer, without any mechanical means, the structure and each surroundings should minimize the root of the problem which is the heat gains. The building structure itself must be well insulated in order to avoid the exchange of heat loads. Moving insulation layers used for nighttime during the winter can be used during daytime during the summer. The exploitation of earth's constant temperature in shallow depths can also be proven an important factor for the buildings insulation. Part buried buildings retain a constant temperature throughout the year. Natural ventilation is also part of the passive cooling strategies as it can reduce latent heat and also drops the temperature. The orientation and placing of the openings is crucial in this case in order to avoid the opposite results. The air movement is, also, directed by the landscape around the structure. An additional technique toward building cooling is the shading. The shading can be achieved by natural barriers for the solar radiation such as trees planted in chosen orientation or plants growing almost adjacent to the walls. Technical sunshades can also be placed to cut the solar radiation direct path. Finally, the option of evaporative cooling is also a reliable option. A common way of evaporative cooling is the supply of the outdoor air into the building through a moist filter or pad. The movement of the air is performed by the assistance of earth tubes and/or cool towers. The same principles are followed in convectional systems but passive design utilizes natural systems for air driving and distribution. Additional evaporation will occur in the case where underground intake pipes are made from porous materials and they are surrounded by well cooled and watered ground [1], [2], [3], [5], [32].

2.5 Lighting

Lighting is an important factor for all living organisms (humans, animals, plants). Natural light within a building structure (greenhouses are excluded) is obtained by the openings (mostly windows). Orientation of the windows and the whole structure plays a major role at the natural lighting of the building. Some of the most usual choices of passive lighting systems are solar tubes and skylights. Skylights are simpler to adapt but lead to heat losses during the winter and extreme heat gain during the summer. However, a selected placing of them in the structure can be proven effective. The solar tubes lighting option is based on the incorporation of reflectors placed in proper places in the structure so as to drive the solar light inside the building [5], [4].

2.6 Water management

Water management refers to the use of water for human consumption (drinking, cooking etc), household uses (washing etc), industrial applications (evaporation, sterilization etc) and agricultural use (irrigation etc). Different water management should be performed for the water uses which have different characteristics in terms of quality. An issue of a great importance, today, is also the optimum or even the reduced use of water in term of quantity. Storm water and wastewater management are of great importance, too [27]. The systems for collecting water such as rainwater systems belong to the passive water treatment systems. These systems use no moving parts and can store the water in the soil or a tank. When rainwater is properly used no health risks arise. Usually filtering collectors or vortex filters are adapted to the facilities in order to remove pollutants and bacteria that may be included to the rainwater. Water treatment systems aim to reach the levels of modern technical water treatment systems without the use of chemicals. The most common systems are the septic systems following the waste cycle [27], [8].

3. PASSIVE HEATING, VENTILATION, COOLING AND WATER MANAGEMENT SYSTEMS USED FOR AGRICULTURAL PURPOSES

The options mentioned in paragraph 2 are adapted mostly in urban buildings. Some serious efforts are also mentioned in agriculture mostly for space heating and ventilation. Sustainable agricultural practices though should meet environmental protection, energy conservation and economic viability. Passive practices can assist the efforts toward this direction.

3.1 Passive space heating in agriculture

Agricultural buildings already use modern insulation materials in order to avoid heat losses. Modern livestock buildings are constructed by Polyurethane panels which are characterized as materials of high thermal resistance value. In this way, the proper comfort conditions for the animals can be easier maintained within the structure [16]. However, apart from the insulation some other innovative options are referred in the literature. The use of a mass wall in an experimental farrowing house was evaluated in Thessaloniki Greece (figure 1). The experimental building was heated by a hybrid solar system. Part of the system was a mass wall. The mass wall contributed to energy conservation in a significant way. In fact the contribution of the solar mass wall to the heating of the experimental structure ranges between 25% and 30%, and sometimes falls to 20% [30]. Several examples of greenhouse are also spotted in the literature. Hassanain et al. [12], studied the internal conditions of three different greenhouse prototypes (2011). In this study was found that the placing of a Trombe wall even in greenhouses can give higher indoor air temperature compared to a common greenhouse [12]. An interesting option for the greenhouse heating design or the retaining of standard conditions within the structure is the part-buried greenhouses. Such structures are met to several countries (figure 2) and are mostly non-professional experimental applications [31], [18]. The side which is buried in the ground provides high values of thermal resistance and actually undisturbed temperature. These structures are relatively cheap and can be built very easily [31]. The earth sheltered designed greenhouse by Mike Oehler is expected to expand the growing period up the three times [18].

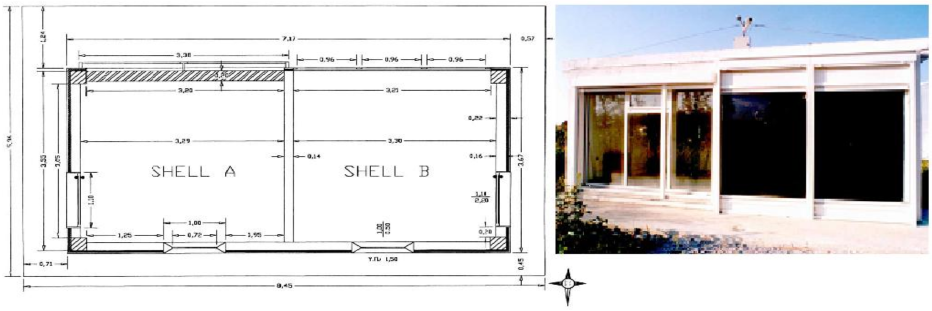

Fig. 1 Experimental farrowing house with mass wall (Left: Picture Right: schematic diagram) [29],[30]

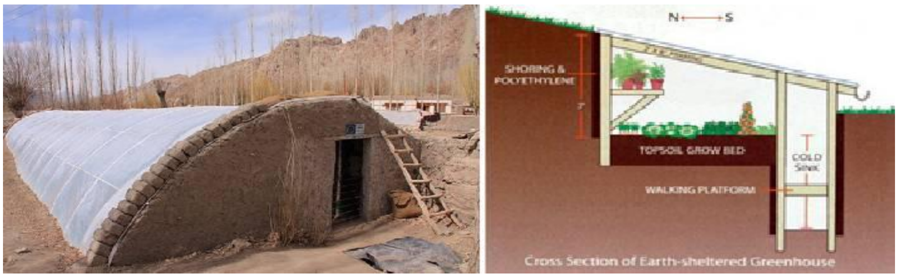

Fig. 2 Left: Passive solar greenhouse in Ladakh (India), Right: Mike Oehler's earth sheltered greenhouse design [31];[18]

Greenhouses are structures where passive design methods have been adapted for several years. Santamouris et al., presented the "solar greenhouse" back in 1994. The greenhouse had some passive constructive characteristics such as a 30cm mass wall at the north side of the structure. Also the greenhouse was not easily overheated during the summer and also achieved better resources management due to earth to air heat exchangers which was placed in low depths of the greenhouse's inner surface [25]. The results of this research work showed that this type of greenhouse maintains higher indoor temperatures compared to a typical structure.

3.2 Water heating in agriculture

Solar collectors demand the supportive operation of a circulator in order to exploit the water heated by solar radiation. As a result they cannot be considered as passive systems for water heating. The main application that can be used to produce domestic hot water is the solar collector heating systems but solar radiation can play a major role at passive water heating for some alternative applications. A solar stock tank for animal watering was designed and constructed at Montana USA. The tank's diagram and picture are illustrated at figure 3. Based on the measurements and actual use of the tanks lead to a saving of 3 U.S$ per day in electricity costs [22].

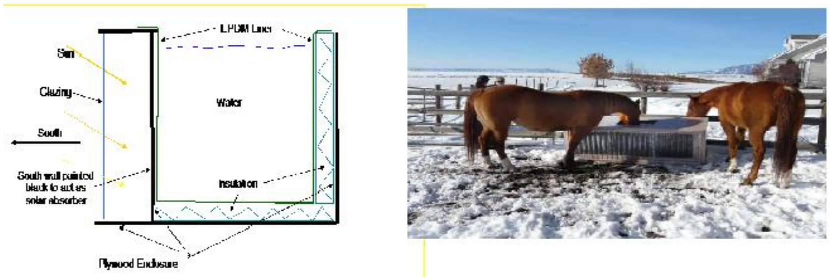

Fig 3 Solar Stock tank for animal watering [22];[39]

3.3 Natural Ventilation in agriculture

Ventilation is a fundamental application in agriculture. Both livestock buildings and greenhouse require air refreshment as animals and plants might be negatively affected by a low quality air environment. Natural ventilation can be easily succeeded by the proper placing of the windows or openings at the structure and have been a common practice to many agricultural buildings and structures. A bio hen house in Hungary was constructed by openings at the side walls and at the ridge (figure 4) in order to ensure natural ventilation of air [6].

Fig. 4 A bio hen house with proper placed openings for natural ventilation [6]

A combination of passive heating and natural air movement was investigated by Sallam et al. A solar mint dryer which had the option to utilize direct solar radiation was tested [24]. The ventilation in the dryer was made by natural air movement due to the constructions geometry (figure 5). This research shown that solar drying of mint was more intense by the use of forced ventilation but manages to have satisfactory results with the natural air movement as well [24].

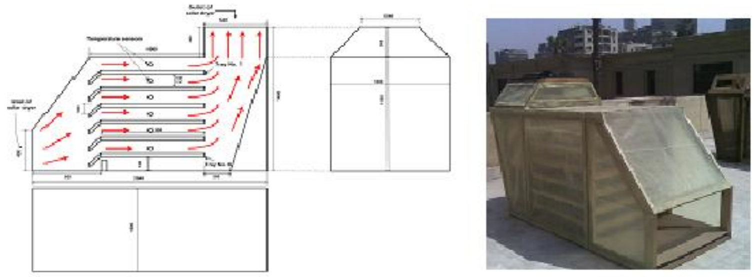

Fig. 5 Solar Mint wind dryer [24]

Almost all livestock buildings can be naturally ventilated. At grow-finish pig facilities this is a common application. In these buildings larger pigs are housed during the winter and are protected by outdoor conditions as they are housed in well insulated buildings. During the summer the ventilation provided must be high enough to remove moisture and refresh the indoor air. For that purpose large sidewall vents are optionally opened to keep the animals comfortable [14]

Natural ventilation is a common practice in greenhouse as well. The ventilation is performed by placing of windows in the roof and the side walls respectively so the air movement to be able to perform naturally. Natural ventilation is widely used in greenhouses and will not be extensively referred in this work.

3.4 Passive cooling in agriculture

Passive cooling in agriculture is mostly used in greenhouses. Some interesting applications are referred at the international literature. Goswami and Biseli [11] referred to the possibility of cooling (and heating) a greenhouse by the formation of underground tunnels beneath the greenhouse's surface area. The ground retains a steady temperature in low depths which is sufficiently lower than the temperature inside the greenhouse. That way and by the physical movement of the air from the hotter to the cooler environment a movement of the air is ensured and also a distribution of heat to the underground tunnel [11]. Sharma et al mentioned that shading can be a method for cooling the space inside a greenhouse. Shading can be done by various methods. Some of them are: the use of special paints, external shade cloths, or use of various colors nets (of various colors) [26]. Insulation and ventilation can also play a major role in cooling agricultural buildings as already mentioned in previous paragraphs.

3.5 Passive lighting in agriculture

Lighting is mostly achieved naturally by the windows almost in all building applications. Animals take all the necessary light by the sun as the covering material is transparent. Livestock buildings also get the lighting needed for animals by the windows which are by definition passive elements. There are some situations where the openings are placed in a way to ensure necessary lighting with the less heat losses and the proper ventilation (figure 6).

Fig. 6 Specially designed passive lighting and ventilation storage building [6]

3.6 Passive water management in agriculture

Typical actions for water management in agriculture include passive water harvesting and collection. The term water harvesting (mainly rainwater) aims to slow the water down and encourage it to soak into the ground. This can be achieved by simple land contouring that collect and direct stormwater for beneficially uses especially in agriculture (plant growth in landscapes while correcting erosion cuts) [7]. Simple rainwater collection can replace the need to irrigate with tap water. Rain water saving can be done in natural or technical ponds [13] as many areas with draining issues during the summer have excessive rainfall during the winter.

Fig.7 Rainwater collector in India for agricultural purposes [28]

Passive wastewater cleaning techniques are beyond the subject of this work as it concerns mostly human applications.

3. CONCLUSIONS

Passive design has serious advantages and it can support several building and construction applications in the direction of energy savings. Passive techniques have already been placed successfully in several agriculture applications. Most of the efforts though are experimental and haven't been commercially tested. Also some of the techniques haven't been adapted yet. The field of passive design in agriculture is still immature for some techniques and well developed in others. The main advantages of those systems are the zero operation cost, the protection of the environment and the disengagement of convectional systems. It can definitely consider as a research field of great importance in the future.

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Case Study

THE USE OF TELEHEATING FOR AGRICULTURAL PRODUCTION: A CASE STUDY IN PTOLEMAIDA, GREECE

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Abstract. *The use of teleheating in agriculture requires the existence of a heat and power production (CHP) plant, such one of those operating in the area of Ptolemaida and is already used for urban heating. The reason to undertake this case study was the will of the local authorities to exploit an abandoned industrial area for fertilizer production in agriculture. This area was 15.8 ha and the project should be used as a prototype for the exploitation of another 300 ha of available agricultural land in Ptolemaida and 45 ha in the nearby area of Kozani. Greenhouse heating was the main application of teleheating, but also its use for grain drying and livestock house heating was also considered. The expected conventional energy saving in greenhouses was calculated at 12000 GJ/ha per year, while the respective saving for maize drying was 657 GJ/10^{3}t per year and for cotton drying 488 GJ/10^{3}t. The cost cut of heating was about 65%, in all cases. Also, the final investment on this project is expected to create 184 new vacancies (employment). Finally, from environmental point of view, teleheating as a clear alternative energy source will not surcharge the already heavily polluted environment of Ptolemaida area.*

Key words: *Teleheating, Waste heat, Greenhouse, Energy saving*

1. INTRODUCTION

Teleheating is an application of heat distribution from a central heat production place to one or more distant users. The production of heat usually takes place in power plants burning conventional or renewable fuels and designed for combined heat and power production. The heat distributed in this way is used for space or/and water heating to cover residential (district heating), industrial or agricultural heating needs. Teleheating with the use of waste heat is much different from the conventional systems of heat production and consumption, which use the heat production installations in the place of the heat consumption.

Greece has district heating systems mainly in (a) the Provinces of Western Macedonia, and (b) the Province of Peloponnese (Megalopolis). The first small installation took place in Ptolemaida in 1960, offering heating to a suburb of Eordea using the Thermal Power Station (TPS) of Ptolemaida. Today, the largest district heating system is in the city of Ptolemaida, where five power plants (Thermal Power Stations) are in operation, providing heat to the majority of the largest towns and cities of the area and some villages. Also, other district heating installations are also available in the town of Kozani, today.

The contribution of the waste heat consumed to the overall energy consumption, used solely for district heating in Greece, is only 0.20% (table 1), while its proportion to the total alternative energy consumption is 3.80% (table 2) [6].

A major advantage of the combined heat and power (CHP) production, with the waste heat exploitation, compared with the separate heat and power production is the higher coefficient of performance (COP). The following example shows 26% COP difference in favor of CHP.

1. Total COP of separate heat and electricity production:
   a. 100 MWh_{fuel} → Heat production → 80 MWh_{heat}
   b. 100 MWh_{fuel} → Power production → 38 MWh_{el}

$$TotalCOP = \frac{80+38}{200} = 59\%$$

2. Total COP of combined heat and power (CHP) production:
   100 MWh_{fuel} → Co-production → 85 MWh_{CHP}

$$TotalCOP = \frac{85}{100} = 85\%$$

Table 1 Overall energy consumption in Greece

Energy products / Energy flow	Solid Fuels	Liquid Fuels	Gas Fuels	Renewable Energy	Heat	Electricity	Fuels, totals
Industry	540	2567	454	265		1318	5144
Transport		8533	21	67		22	8576
Commerce	1	398	128	4		1615	2146
Households	7	2540	208	783	44	1544	5126
Agriculture		804		24		248	1076
Total Energy Consumption	**548**	**14842**	**811**	**1143**	**44**	**4746**	**22068**

From environmental point of view, the combined heat and power production used in teleheating is considered as an environmentally friendly heating system, since its application avoids the use of conventional fuels, which have as an odd consequence enormous quantities of greenhouse gas emission. The CO_2 emitted by several heating systems and different conventional fuels is shown in figure 1 [5]. The total efficiency, the power to heat ratio and the CO_2 emission rate in g CO_2 per MJ of fuel for various fuels and technologies used for combined heat and power production are shown in table 3 [7].

The European Union of 27 perspectives for the increase of district heating application in household and services, for the first half of the 21st century, are presented in table 4

[1]. The advantages of CHPs can also be considered, apart from the urban district heating, for similar applications, as it is the rural district heating in regions and areas with intense agricultural activities, such as the greenhouse cultivations (fig. 2).

Table 2 Alternative energy consumption in Greece

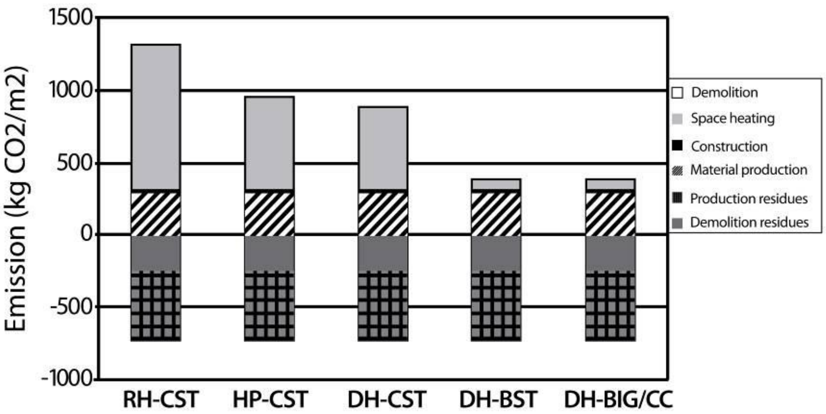
Energy products / Energy flow	Solar Energy	Geothermal Energy	Biomass	Biodiesel	Heat	Total Energys
Industry			265			265
Transport				67		67
Commerce	4					4
Households	157	8	618		44	783
Agriculture		9	15			24
Total Energy Consumption	**161**	**17**	**898**	**67**	**44**	**1143**

Table 3 The total efficiency (η_{tot}), power-to-heat ratio (α) used and the CO_2 emission factors

Fuel / Technology	**Total efficiency, η_{tot}**	**Power-to-heat ratio, (α)**	**CO_2-emission factor (EF),**
	(based on lower calorific value)		**CO_2(g/MJfuel)**
Waste CHP/HOB	0.85/0.85	0.25/0.00	32.7
Peat CHP/HOB	0.85/0.85	0.40/0.00	107.3
Coal CHP/HOB	0.85/0.85	0.40/0.00	90.7
Co-fired coal/wood fuel CHP	0.85	0.4	90.7/0.0
Wood fuels CHP/HOB	1.05/1.05	0.40/0.00	0
Tal oil pitch CHP/HOB	0.90/0.90	0.50/0.00	0
Oil CHP/HOB	0.90/0.90	0.50/0.00	76.2
Bio gas CHP/HOB	0.90/0.90	0.50/0.00	0
LPG CHP/HOB	0.90/0.90	0.50/0.00	65.1 (a)
Natural gas CHPCcgt/CHPConv/HOB	0.90/0.90/0.90	1.10/0.50/0.00	56.5
(a): Emission coefficient for propane used			

The existence of power stations such as those operating in the area of Ptolemaida is taken as a prerequisite for the use of a rural district heating system for heating greenhouses, for heating livestock buildings and for green crop and grain drying.

The exploitation of the district heating in the agricultural (ADH) sector was one of the first innovative proposals deployed by Mr. Grigorios Tsioumaris, the former mayor of the town of Ptolemaida. A twofold benefit was expected by this action; (a) to make the maximum exploitation of the available heat from the nearby power plants, which already is used for urban heating, and (b) to exploit a bare land of 15.8 ha, abandoned by a withdrawn nitrogen fertilizer industry, very close to the town.



Resistance Heaters (RH), Heat Pump (HP) and District Heating (DH), combined with Coal-based Steam Turbines (CST), Biomass-based Steam Turbines (BST) and Biomass-based Integrated Gasification Combined-cycle Systems (BIG/CC)

Fig. 1 CO_2 emissions from various heat production systems and fuels

Table 4 Annually delivered district heating volumes to residential and service sectors in EU27 for the current situation (2010), 2030, and 2050, by strategic heat supply sources, as modeled in the energy system analysis, and the resource potential assessed in the GIS mapping.

Main strategic heat sources	**Potential Map (a) (PJ/a)**	**2010 (13% DH) EM (PJ/a)**	**2030 (30% DH) EM (PJ/a)**	**2050 (50% DH) EM (PJ/a)**
Fossil fuel power generation excess heat and heat from boilers	7075	1120	2410	1540
Waste-to-Energy incineration excess heat	500	50 (b)	330	585
Industrial excess heat	2710	25	205	385
Biomass heat	n/a	250	325	810
Geothermal heat	430	7	190	370
Solar thermal heat	1260	0	180	355
Large-scale heat pumps	n/a	0	1290	1875
Total district heating in the modeling	11975	1460	4930	5920
Main strategic heat sources	Potential Map (a)	2010	2030	2050

(a): This is the potential identified from the GIS mapping.
(b): Total heat delivered from waste in 2010 was 170 PJ. However, only 50 PJ/year is assumed to go to the residential and services sectors due to the assumptions used to remove industry from the *Energy Roadmap 2050* projections.

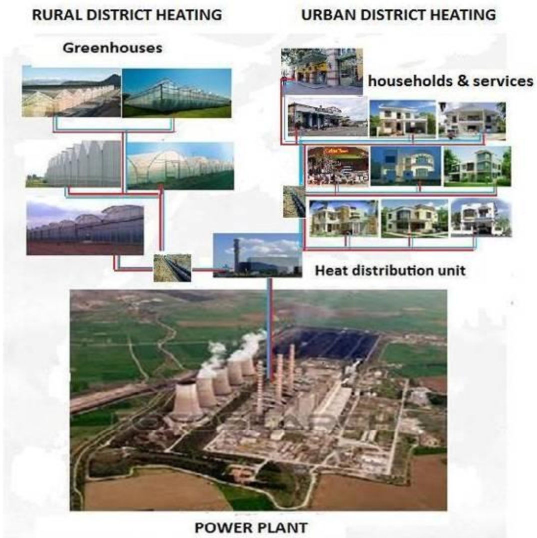


Fig. 2 Rural and urban district heating from a CHP system of a power plant

2. DESCRIPTION OF THE PROJECT

2.1 The District Heating Municipal Company of Ptolemaida (DHCP)

The project is designed to operate in the area of Ptolemaida town located in Kozani County, West Macedonia, Greece. Ptolemaida with its surrounding communities has a total population of 60000. Ptolemaida and its communities cover an area of 218 km^2, which is located in the center of Kozani's county energy valley. Five power plants with in total fourteen steamelectric units, based on the local lignite fuel, operate in Kozani energy valley. The total installed electric power of the above plants is 4050 MW_{el} and equates to the 45% of Greece's electric needs.

The urban district heating was installed in Ptolemaida at 1991-93 and it is administrated by the District Heating Municipal Company of Ptolemaida (DHCP) since 1994.

The total heat power of the four CHP steamelectric units of the three nearby power plants (Ptolemaida plant, LiPtol plant and Kardia plant) is 175 MW_{th}.

The heat consumed every year from the system by the local households and services is around 195000 MWh_{th}.

The improvement of the town's environmental conditions after the use of the urban district heating, due to the reduction of the greenhouse gas emissions is very obvious [2] ranging between 35% to 37% in terms of the emitted CO_2 (table 5).

A substantial economic benefit of about 70% arises from the use of district heating for the consumers, comparing with those using oil for heating. This is due to the tariff policy exercised by the DHCP, which offers the heat for 37.74 €/MWh_{th} (heating oil price at 2013/14: 1.29 €/l of oil).

Table 5 Total CO_2 emissions before dh operation [tn]

Year	2007-08	2008-09	2009-10	2010-11
Total CO_2 emissions before dh operation [tn]	132.807	133.39	117.258	137.102
Total CO_2 emissions after dh operation [tn]	85.56	83.791	75.845	87.993
Total reduction of CO_2 emissions after dh operation [tn]	47.247	49.599	41.414	49.109
TotaL reduction of CO_2 emissions after dh operation %	-36%	-37%	-35%	-36%

2.2 The Zone of Greenhouse Installation - ZGI

The application of this project, which is apart from the current ordinary use of urban district heating, stimulates the broadening of the DHCP activities to other productive sectors.

The beginning of this collaboration between the municipality of Ptolemaida (now Eordea) and the laboratory of Alternative Energy Sources in Agriculture of AUTH was realized at the end of the year 2008. The aim of the collaboration was the rendering of technical and scientific services on behalf of AUTH for the realization of rural district heating system for heating greenhouses.

Fig. 3 The map of the Zone of Greenhouse Installations (ZGI: within the red frame)

Initially, the project was designed to begin with 15.8 ha, which is a part of a total municipal area of 170 ha owned before by the former (abandoned) factory of AEVAL (a nitrogen fertilizer industry) in the industrial zone of Ptolemaida, 1 km away from the main road connection between Ptolemaida and Kozani (fig. 3). This area of the 15.8 ha was proposed to be used as a pioneer area for the exploitation of the local teleheating system in agriculture and more precisely in heating greenhouses. For this reason the area is also known as "Zone of Greenhouse Installations" (ZGI). However, since an impressed interest was expressed (2009-2010) for investment in teleheated greenhouses, at that time, the municipality of Ptolemaida applied for another 300 ha to the Ministry of Agricultural Development and Food to be allocated for such applications with the extension of the Agricultural District Heating (ADH) system.

The zone has been divided in 21 plots with a size between 0.5 ha to 1.0 ha, but two or more neighboring plots can be unified in larger plots (fig. 4). All plots have access to the road network. A separate sufficient building in the AEVAL area is suggested to be used for the sorting out, standardization, packing up and storage of the greenhouse products.

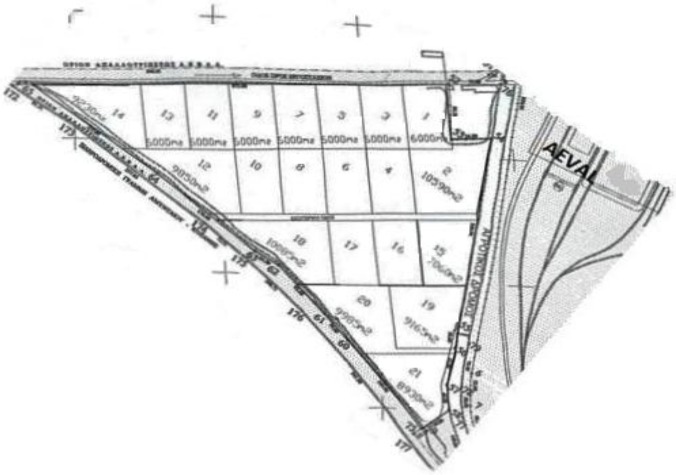


Fig. 4 A proposed survey of the plots for the zone of greenhouse installations (ZGI)

2.3 Economical Aspects of Teleheating for Agricultural Use in Ptolemaida

The tariff of teleheating proposed by the DHCP is 46.42 €/MWh_{th} including 23% VAT. Since the ZGI project is considered as a pilot one, the district heating company has been suggested to introduce no fee for the connection to urban district heating system, as a measure to attract the first investors. For the same reason, on top of this offer, the DHCP decided to propose a 30 % discount for the night tariff.

Other costs related with the connection to the heating grid include the expenses for materials (pipes, valves, heat meters etc) and labor.

The new vacancies (new labor force) expected to be derived after the realization of the project are estimated to be covered by 184 persons taking into account that 84 (21x4) will be created within the zone and about a 100 will be dealt out in seasonal activities, transportation, technical assistance, scientific consultancy etc.

The cost reduction expected by the use of teleheating in the suggested agricultural investments is calculated about 65%, as is shown below.

2.3.1 Cost of teleheating greenhouses

The Thermal power requirement of a 1ha typical greenhouse is 1500 kW/ha and the yearly heat consumption is 12000 GJ/ha. The fuel (oil) consumption (boiler performance: 80%) to cover these heating needs is 340 m^3/ha. Taking into account that the oil price at 2009/2010 in Greece was 1.29 €/l of oil, the cost of conventional heating is 43860 €/ha.

The teleheating cost is (1200/3.6) MWh x 46.42 €/MWh = 15473 €/ha. So, the profit from the replacement of oil with the local ADH system will be 64.72%.

2.3.2 Cost of heating the farrowing house of a 200 sows pig farm

The energy consumption for heating a farrowing house per year is 250 W* x 24 h x 28 d x 200 sows x 2.2 births/year =74000 kWh_{el} for heating newborn piglets, with one 250 W infra-red lamp/crate. The cost of the conventional heating is 9990 €/year. The cost of teleheating is: 74 x 46.42 = 3435 €/year. Therefore the profit is 65.6%.

2.3.3 Cost of green crop and grain drying

For 1000t maize drying the yearly heat consumption is 657 GJ/ 10^3t, which equates to18.8 m^3 of fuel (oil). Thus the conventional heating cost is 24252 €. The respective cost for teleheating is (657/3.6) MWh x 46.42 €/MWh = 8471.65 €. Therefore the profit is 65.1%.

For 10000t of cotton drying the yearly heat consumption is 4879 GJ/ 10^4t of cotton, which equates to 140 m^3 of fuel (oil). Thus the conventional heating cost for drying 10^4t cotton is 179955 €. The respective cost for teleheating is (4879/3.6) MWh x 46.42 €/MWh = 62912 €. Therefore the profit is 65.0%.

3. DISCUSSION

The project was designed for the exploitation, mainly, of the available piece of land of 15.8 ha with the use of greenhouse but, also, other heat demanding agricultural investments should be taken into consideration.

Among the main actions taken by the University team in collaboration with the local authorities of Ptolemaida until November 2010 are:

- the promotion and the dissemination of the project through the local means (TV and press).
- the participation in the yearly local flower fair, where a prototype greenhouse was used as the information center for the ZGI.
- the composition and announcement of a call for expression of interest
- the co-organization with the Kozanis' agronomist society of a seminar to promote the ZGI project, in 2009.
- the design of the managerial plan for the agricultural enterprises of ZGI.
- preliminary work for a further growth of ZGI (2nd phase) , which includes the incorporation of new bare land into the ADH system and the creation of supporting infrastructures such as collection, storage, standardization, certification and transportation of the products.

The minimum profits expected to be drawn from the complete and successful application of this job are the following:

- ✓ In terms of energy saving: The total area to be covered by greenhouses in the ZGI is estimated at 11 ha and the energy to be replaced by the local district heating system 132000 GJ, which corresponds to 3740 m^3 of oil per year.
- ✓ In terms of cost saving: The oil required to heat 11ha greenhouses is 3740 m^3 and the total cost for heating is accounted at 4824600 €. Taking into consideration that the

financial profit arising from the use of ADH system in the ZGI is 65% the financial saving comes up to 3136000 €/year.

- ✓ In terms of environmental improvement: The oil required to heat the 11 ha of greenhouses in Ptolemaida is calculated to be 3740 m^3. According to Greenpeace [4] the oil used for heating emits 74 kg CO_2/kg of oil (tab. 6) and the specific weight of oil ρ=835 kg / m^3. So, the total CO_2 expected to be emitted, in the case of oil heated greenhouses should be 3740x835x74=231095 t CO_2 each year.
- ✓ In terms of social benefits: The new vacancies (labor force) expected to be created after the full operation of the project offer an additional attractive reason to the local community for the implementation of the project.

Table 6 CO_2 emissions from several heating sources

Fuel	**CO_2 emissions** (kg CO_2/kg of fuel)
Oil	74
Natural Gas	56
Electricity* (for heating)	278
Biomass	0

* Based on energy (fuel) mixture used in Greece

The study of this project was initiated in November 2008 and remains under a "hypnosis" from November 2010 because, after the last local elections, the change of the local authorities resulted to the change of their action priorities. On top of that, the financial recession appeared from the mid of 2010 till nowadays in Greece, caused a decline interest of the possible investors in ZGI project. However, the results of this project remains on the availability of the new authorities whenever they decide to exploit the abandoned and bare agricultural land for the benefit of the local community, the wider environment and the local and national economy.

4. CONCLUSIONS

The heating demand in the agricultural sector, apart from the residential and service sectors should be considered of importance in places like Ptolemaida due to the odd climatic conditions prevailing during the long lasting cold period of the year.

The extension and the application of the DH of Ptolemaida into the agricultural sector have been thoroughly examined and the deriving general benefits from this application in the industrial, residential, service and agricultural sectors are summarized, according to DHCP [2], as follows:

- Higher energy efficiency (energy saving above 30%) due to the heat and power co-production
- Substantial Reduction CO_2 emissions minimizes the city pollution due to the use of the waste heat from the nearby power plants instead of oil.
- Cheaper Space Heating and water, (more than 50%-60% savings than heating with Oil) 30% cost reduction is contractual commitment of DHCP to DH consumers
- Upgrading of life quality for the citizens.

- Increase of labor with the creation of new, stable, specified positions for DH employees, as well as new jobs for private constructors, suppliers, designers, project managers, agronomists, etc.
- Independency from imported fuels (oil, natural gas) because of domestic lignite production and use.
- Novel opportunities for sustainable regional development.
- Increase of public awareness on this clean, sustainable and environmentally friendly alternative energy source

Moreover, since the aforementioned systems are of highly capital-intensive nature, the extension of the Ptolemaida DH system to a District Heating and Cooling (DHC) system will support an additional action of the local authorities in providing services with the corresponding financial incomes. The DHC system may be owned by the DHCP, but it will be financed by public or/and municipal funds. District Heating and Cooling plays a significant role in the supply of low-carbon heating and cooling, replacing the conventional electricity or fuel-driven air conditioning systems. The DHC systems reach efficiencies that are between 5 and 10 times higher than with traditional electricity driven equipment [3]. The application of the DHC system has the additional advantages of making a good use of the waste energy from the power plants, offers cost saving for cooling and contributes to avoid electricity peak loads during the warm period of the year.

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Popular Paper

PRODUCTION TECHNOLOGY AND OPPORTUNITIES OF USING BIOGAS OBTAINED FROM ORGANIC AGRICULTURAL WASTE

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Abstract: *The world is increasingly focused on the development and application of biofuels produced from renewable primary and secondary agricultural raw materials. Today, the production of biofuels is mainly based on the production of methanol, biomethanol, ethanol, biodiesel, natural gas, hydrogen, that are obtained from primary agricultural production such as: sugar cane and sugar beet, sorghum corn, maize, wheat, rapeseed, sunflowers, potatoes, barley, olive, palm. One part of the biofuels, has its base in forest mass, wood, pulp, paper, black liquor etc. However, today increasing attention is paid to the development and procedures for the collection and production of biogas from various forms of waste, such as municipal waste and secondary, wastes from livestock production, cereal production and food and other forms of waste. The paper gives a short overview of the possibilities of biogas production from organic waste as an alternative fuel powertrains and industrial plants, and at the same time as a solution for reducing the waste disposal.*

Key words*: biogas, agriculture, waste, biomass, production, potential*

1. INTRODUCTION

From an environmental point of view, the village is much closer to the natural environment than the city, which is an artificial environment is often juxtaposed to nature, which does not mean that the environmental benefits of the village can neutralize all the advantages of the city. Demographically speaking, cities are densely populated with a large population and many professions. The villages have small population of the represented professions such as farmers, craftsmen, teachers, priesthood and others.

However, in the villages smaller industrial companies are present, which periodically or continuously employ locals. Therefore, it changes the professional structure of the village which is increasingly dissipateing. Though this phenomenon carries many positive effects (reserves villagers in the village, reduces the excessive concentration of population in cities and regulates regional development), but also negative consequences, primarily environmental (air pollution, increase of secondary raw materials, noise and other consequences).

The store is usually done on an individual level, but it is very important for the supply of the population, boosting commodity-money exchange and consumption structure, increasing employment and living standards, and the state collect some profits.

Serbia, with its land resources, favourable climate and natural conditions, population, ecosystems, clean air, healthy food, spectacular flora and fauna and other benefits, has very good opportunities for the development of rural tourism. Considering that in the world, nature nowadays attaches great importance, and thus the goal of Serbia should be the development of ecotourism, conservation of the rural environment and nature and the creation of conditions for reducing the migration of population from these rural areas, and even the creation of conditions for return of people from the cities to the villages.

Resources for the development of ecotourism in Serbia certainly exist, but they are few or underutilized. Rural tourism is not only the stay of tourists in rural households, but also includes trips into the surrounding areas, visiting natural attractions and cultural and historical attractions, traditional, folk and tourist events, sports and recreational activities in nature, craft and sell handicrafts and souvenirs, homemade food and drink.

In rural areas more than 60% of households own a farm where the production of crops, vegetable and fruit, and primarily livestock production is the main activity.

Animal husbandry as an important aspect of animal food production, brings another clear advantage that is increasingly used in the world. For example, utilization of various types of manure to produce biogas.

Estimations are that in Serbia over one million tonnes of manure is produced, which can, with other types of organic waste be used for the production of biogas as an alternative energy source. Organic waste from agriculture in Serbia is rather disorganized (Fig. 1a). Organic waste prepared for the production of biogas is stored in box silos (Fig.1b) [4, 7, 10].

a) b)

Fig.1 The appearance of a disordered dump manure in rural area (a) and decorated (b)

2. THE GENERAL TREND OF THE ENERGY USE AND EMISSIONS IN THE EUROPEAN UNION

Fossil fuels are for many decades dominating as the power source for the internal combustion engines. However, it is unrealistic to expect that this trend will last forever, primarily due to the more pessimistic estimations of the reserves of crude oil. Initiatives in the world in terms of development and production of alternative fuels are dating many decades back.

The European Union has, in 2003., in order to promote the use of biofuels and other alternative fuels, primarily for road transport, in which fuel is estimated by the contributes more than 85%, adopted two directives:

- Directive 2003/30 / EC, requires from the Member States to produce and provide the market a minimum amount of biofuels that would meet the goals and that by the end of 2003., reduce the consumption of fossil fuels by 0.2%, which corresponds to around 460,000 tons alternative fuel-ethanol, and by the end of 2005., provide a replacement of 2%, which is about 3.7 million tons, fossil fuels, and by the end of 2010., 5.75%, which is about 10.7 million tons, fossil fuels.

-Directive 2003/96/EC, allows EU member states to apply different fees for biofuels in order to encourage their development.

The main objectives of European directives are to start initiating reduced imports of fossil fuel, which is now about 50% of total energy, which according to some estimates, if this trend of consumption continues, can reach about 70% up to 2030. A significant contribution is given to achieving the objectives of the Kyoto Protocol in 1997., which refers to the reduction of emissions and the greenhouse effect, with the greatest attention is paid to emissions of carbon dioxide CO_2 (methane CH_4, nitrogen oxide N_2O, HFCs, PFCs and SF69). It was therefore necessary to reduce in the period of 2008-2012., CO_2 emissions by 5.2%, compared to the situation in 1990.

One of the most important goals is the achievement of replacing 20% of fossil fuels road transport by 2020. Transport is an important sector of energy consumption and is completely dependent on the supply of petroleum products, and is based with 98% and consumes around 67% of total EU oil products. Transportation is the key generator of CO_2 and emits about 28% of total emissions in the EU [8, 18, 22].

All legal provisions are forcing the EU member states, and those that are not all actively doing research in terms of opportunities for development and implementation of alternative fuels. In addition to the various possibilities of producing alternative fuels, a significant contribution to this study, may have a secondary waste and other organic origin of agricultural production. Utilization of such waste has multiple benefits to a country, primarily the release of the deposited waste while obtaining clean fuels whose combustion slight or negligible influence on environmental pollution.

Unfortunately, the amount of fuel obtained from these substances is not high, but the waste materials free of charge, and their processing and disposal of secondary raw materials significantly reduces environmental pollution. In World the number of such facilities is increasing, while in Serbia they almost do not exist, primarily because of the lack of adequate projects and weak material basis [1, 2, 14, 15, 16].

3. Main characteristics biogas

Biogas typically refers to a gas with a large amount of methane in itself, produced by fermentation of organic substances like manure, sludge from wastewater treatment, municipal solid waste or any other biodegradable matter in anaerobic conditions. Names such as marsh gas, landfill gas, swamp gas and the like are often used for biogas. Each variant has different levels of methane and carbon dioxide in it, along with a smaller share of other gases.

Biogas is produced by microbiological process of anaerobic digesters and in controlled conditions (absence of oxygen). Anaerobic bacteria break down organic matter, and as a product of this process biogas is created, and the rest of the heat of fermentation.

Biogas is a mixture of gases whose volume accounts for about two-thirds of methane (CH_4) and one-third of carbon dioxide (CO_2). In addition to methane and carbon dioxide, the volume of biogas and other gases have a much smaller share, as shown in Table 1. The volume shares are presented in volume, and depend on the raw material (substrate) and the conditions in which biogas is generated [3, 6, 9].

Table 1 The basic composition of biogas [8]

Ingredient	**Chemical symbol**	**Volume fraction (%)**
Methane	CH_4	50-75
Carbon dioxide	CO_2	25-45
Water vapour	H_2O	2-7
Oxygen	O_2	< 2
Nitrogen	N_2	< 2
Ammonia	NH_3	< 1
Hydrogen	H_2	< 1
Hydrogen sulphide	H_2S	20-20.000*

The process for treating organic waste is becoming more popular because it allows a convenient way of turning waste into energy, thereby reducing the amount of waste, as well as the number of pathogenic substances contained in waste, also reducing the amount of carbon dioxide in the atmosphere.

Processing of biodegradable substances takes place in an anaerobic digester, which must be sturdy enough to withstand the increased pressure, as well as to provide anaerobic conditions for the bacteria inside. Digesters are usually built near sources of organic inputs, usually several to one another, in order to ensure continuous production of biogas.

In recent years, there is increasing use of biogas obtained from landfills and wastewater. Even when not used for heat and/or electricity, landfill gas must be properly disposed and purified, because it contains dangerous flammable materials, many of which generate smog. Biogas digesters using biodegradable materials, all of which are made of two useful products: biogas and fermented biowaste of superior quality.

Biogas purified to a level of purity for the gas pipeline is called renewable natural gas and can be used in any application where natural gas is normally used with. This includes the distribution of this gas through a pipeline, the production of electricity, heating, water heating and use in various technological processes. Compressed, biogas can be used as fuel for vehicles [19, 20, 21].

4. TECHNOLOGICAL PROCESS OF BIOGAS PRODUCTION

Biogas combustion leads to the formation of very small amounts of carbon dioxide (CO_2), the presence of carbon in plant weight, absorbed from atmospheric carbon dioxide. It is therefore considered that the use of biogas does not increase the amount of greenhouse gases, leading to the conclusion that any replacement of fossil fuels, biogas reduces emissions of CO_2.

Plants absorb CO_2 from the atmosphere during its entire development, and after the end of its development, the same carbon returns to the atmosphere as a mixture of carbon dioxide and methane.

In the atmosphere, methane is converted into carbon dioxide, thereby completing the circulation. Combustion, directly or indirectly, biomass and biogas as fuels, also returns CO_2 to the atmosphere. Of course, and this is part of the CO_2 in the atmosphere of carbon cycle, as shown in Fig. 2.

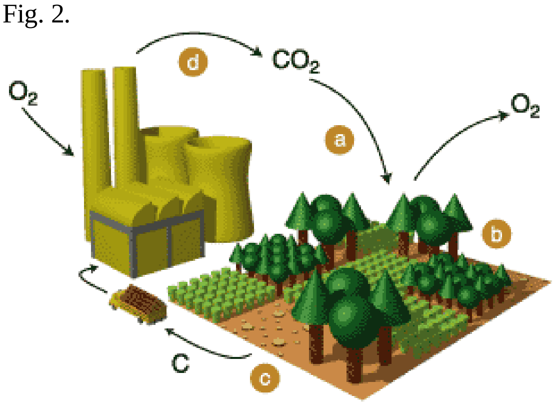

Fig. 2 Circulation of CO_2 in the atmosphere [19]

As stated before, biogas is a metabolic product of bacteria in controlled conditions, primarily the absence of oxygen, constant temperature, pH of 6.5 to 7.5, and other conditions. Decomposition is most effective at a temperature of 15°C (psychrophilic bacteria), 35°C (mesophilic) and 55°C (thermophilic). Practice has shown that the retention of about 10 days the most effective for thermophilic bacteria, 25 to 30 for mesophilic and 90 to 120 for psihrofilne. Most plants in operation today, working in the mesophilic temperature range.

Since the biogas produced, where the organic material decomposes without air, there is a wide range of organic substances which are suitable for anaerobic digestion. Some of these substances are: solid and liquid manure, particularly biologically waste collected from residential parts, renewable materials such as corn silage, seeds that are not used for food, sewer sludge and grease, used lubricants, grass, biological waste from slaughterhouses, breweries, distilleries, fruit processing and wine production, dairies, pulp, sugar refineries etc.

Wood is not suitable for the production of biogas because bacteria that produce methane can not digest lignin, which has in the tree. Also, pesticides, disinfection and antibiotics have an adverse effect on bacteria [1, 2, 20, 24]. The basic process of biogas production usually consists of three parts: the biological inputs, destruction and treatment of residues.

As shown in Fig. 3, the organic material is collected in a tank for collection and pre-mixing (Fig. 3, position 2). This tank is used for mixing and homogenization of different fermentable substances. After cleaning at 70°C, where the negative kills all bacteria on the fermentation process (pos. 3), material is transferred to an anaerobic digester (pos. 4). In the case of plants closing (for example regular service), as well as in the case of higher gas production it is necessary to have a gas torch, that burns the excess (pos.5). The purified biomass is the beginning of anaerobic decomposition.

In order to ensure a steady stream of gas, regardless of the flow of inputs, biogas produced is collected in the gas tank (pos.7), where it is forwarded to the gas engine (pos.8). The heat generated during engine operation, can be effectively utilized through the heat exchanger (pos.9). In the total it is possible to use about 50% of inputs for thermal energy to consumers, through the heat exchanger from a gas mixture, oil, cooling water and exhaust gas.

Thanks to good fuel characteristics and optimal biogas combustion technologies, the required emission limits can be achieved. Biogas as a renewable energy, source produces exhaust gases which are free to return to the natural cycle. Using generators, mechanical energy of the gas engine is converted to electrical energy (pos.11). The substrate can be used as agricultural fertilizer (pos.12) [19, 20].

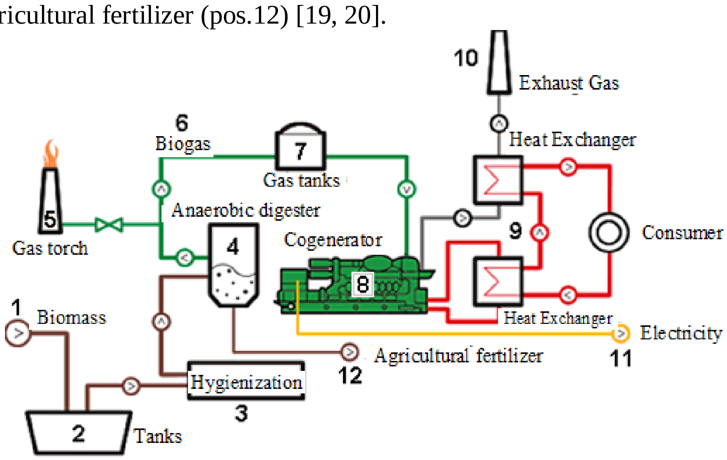

Fig. 3 Schematic display of the installation for the biogas production [19]

Biogas as a gas mixture, containing various volume ratios of individual gasses consisting of 60-70% methane (CH_4) and 30-40% of carbon dioxide (CO_2). With a caloric value of 6.5 kWh/Nm^3, one cubic meter of biogas contains about the same amount of energy as 0.6 litters of heating oil, or 0.65 Nm^3 natural gas (Fig. 3, position 6).

Key parameters (volume of biogas in Nm^3/t of liquid material) for the production are: Biological waste:100-200, Food waste:120-150, Fats from collectors:80-150, Used Oil, grease:1,000 Distillery:20, lactic curd:25, Slaughterhouse waste:100, Liquid waste, dung/manure:20-70. Seen from another angle, the operation of CHP plants, electric power of 500 kW is necessary to manure from about 2,500 cows, 30,000 pigs or 300,000 chickens [4, 5].

The decomposition of the organic part of solid waste in gases with methane is implemented through anaerobic decomposition or anaerobic fermentation in the digester, whose scheme is shown in Fig. 4, and one type of digester in Fig. 5.

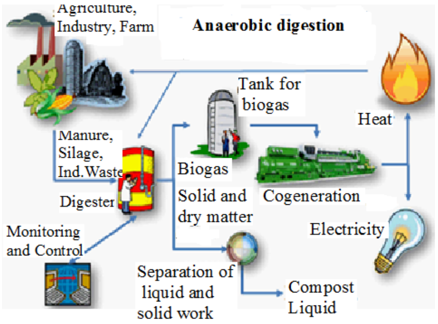

Fig. 4 Diagram of anaerobic digestion [19]

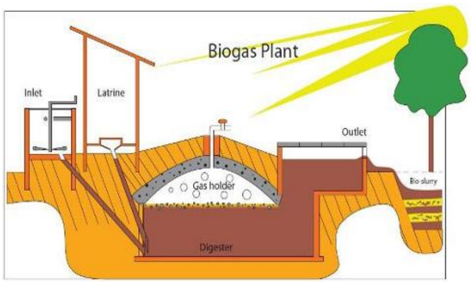

Fig. 5 One type of digester [20]

Despite significant limitations, biological methods for the processing of solid and hazardous wastes constantly attract attention because various types of microorganisms can be removed and converted some organic matter into harmless, even useful by-products such as methane. The solid waste from towns and sludge from sewage treatment, processed in special tubs where relatively quickly comes to anaerobic microbial decomposition from which arises a useful gas, methane. Anaerobic digestion can be compared with the situation in the marshes and other similar water areas where methane is formed. Methane is collected and used as an energy source, in all techniques controlled fermentation waste final product that is emitted into the atmosphere as CO_2. After the fermentation of organic waste separated at source, the fermentation residue is normally treated through aerobic composting. In this way, the final result of the fermentation of waste in the majority of cases similar to the aerobic composting.

The process of decomposition of the organic fraction is converted into biogas, compost, and water. Biogas production is 130-150m^3 per ton of waste, depending on the composition of organic matter [5].

5. BIOGAS FROM AGRICULTURE

The energy potential of biomass in farms is determined according to the number livestock. Conditionally livestock (CL), represents an animal (or more), weighing 500 kg live weight, Organic Dry Matter (ODM), Chemical Oxygen Demand (COD)

Indicative energy potential returns from manure and volume fraction of methane in it, is shown in Table 2.

When considering potential substrates for biogas production, it is essential to analyze their characteristics which determine their potential. It is important for each investor to consider the size of the potential of biogas plants, or just to determine the amount of substrate that has or can be provided. Potential biogas yields are expressed per tonne fresh, dry or organic dry mass of the considered substrate, so it is important to know the dry and organic dry mass.

Table 2 Potential biogas yields and volume fraction of methane from manure [6]

Substrate	**Biogas yield**		**Share CH_4 % (v/v)**
	Stm^3/tDW	Stm^3/tDW	
Beef liquid manure	20-30	200-500	60
Pig liquid manure	20-35	300-700	60-70
Solid manure of cattle	40-50	210-300	60
Solid pig manure	55-65	270-450	60
Solid manure Poultry	70-90	210-300	60

When speaking of the biogas yield of substrates, it is considered that the possibilities are great, but how much they amount depends on many conditions and process stability. From this point of view, the most favourable substrate is manure, solid or liquid, because the most widely used from its own farm and is free of charge. Exceptionally, when rendering farm on the other, there should be transportation costs.

In case that is not used as a substrate for the production of biogas, manure must be aged for sometime before the disposition on the fields, which leads to stabilization of active organic matter, destruction of pathogenic organisms and transformation of harmful substances in those who are not.

Ageing of manure is a process that takes time, and on modern farming equipment, work and storage space. Since the biogas production takes place in a process similar to the one in which there is a spreader of maturation, the fermentation residue can be distributed by the agricultural areas.

From the standpoint of environmental protection, fermentation of manure has significant positive effects, because it prevents direct emissions of methane into the atmosphere, and reduces odours. There is a difference in liquid and solid manure. Liquid consists of animal excrement and it is distributed by pumps and pipelines.

The dry matter content of liquid manure is up to 10%. Extending maturity manure time, a solid manure is obtained, which may have a dry matter content to 40%. Data on potential yields of biogas from different types of manure are shown in Table 3 [6, 23, 25].

Table 3 Potential yields of biogas and volume fraction of methane [6]

Substrate	DW %	ODW %	ND	NH_4 % DW	P_2O_5	K_2O	Mg
Beef liquid manure	8-11	75-82	2.6-6.7	1-4	0.5-3.3	5.5-10	0.3-0.7
Pig liquid manure	ca. 7	75-86	6-18	3-17	2-10	3-7.5	0.6-1.5
Solid manure of cattle	ca. 25	68-76	1,1-3.4	0,22-2	1-1.5	2-5	1,3
Solid pig manure	20-25	75-80	2.6-5.2	0.9-1.8	2.3-2.8	2.5-3	ND
Solid manure poultry	ca. 32	63-80	5.4	0.39	ND	ND	ND

DW- Dry Weight; ODW- Organic Dry Weight; ND-No Data.

The water content in manure is very high (68 to 93%), which is convenient when manure is combined with other co- substrates with higher shares of dry weight, for example, corn silage. After fermentation, the rest of the process, except for part of the nitrogen, there are also other nutrients, and such a compound can be used as a fertilizer in the plots in the cultivation of many agricultural crops.

Of course, the amount of the nutrients depends on numerous parameters which influence the fermentation process. However, looking at the energy aspect, animal manure is not suitable for these purposes because of the presence of a high percentage of moisture or an energy potential is very low.

It is considered that the in comparison with corn silage, manure can have up to ten times less utilization of the quantity of biogas, which means that for the same biogas production requires ten times the amount of manure but silage corn.

One, 500 kg, provides only 0.11 to 0.15 kWe installed capacity. So, for the plant with a nominal electrical power of 150 kW, it would need at least 1,000 livestock units.

The number of large farms that have so many livestock units in Serbia, is small.

Some economic analyzes that have been done in competencies in institutions show that the cost-effective construction and use of major installations with a nominal electrical power rating of 500 to 1,000 kW [13, 17].

This is the reason that modern biogas plants use a mixture of manure and other substrates. Substrate is referred to as one of raw materials to be used in small part to the production of biogas

For example, if the substrate manure and from it 70% of biogas is produced in a facility, the remaining amount of biogas produced from substrate such as silage corn. Under other substrates for biogas production, it is understood biomass from agriculture more plant species [6, 11, 12].

6. LANDFILLS - SOURCE OF ENERGY

In industrial countries 300-400 kg of waste per year per person is produced yearly. This waste is collected and disposed of in a safe and sanitary landfills, which include the protection of ground water and air protection from dirty and hazardous landfill gas.

Based on the above composition of landfill gas, it can be seen that he is very dangerous for the environment, for the health of living organisms as well as the infrastructure facilities in the vicinity of landfills, since methane is in certain circumstances very explosive. Methane is 20 times more harmful to the climate and the ozone layer than carbon dioxide, which means that 1t of methane damages the ozone layer (greenhouse effect) as 21t of carbon dioxide. To eliminate the negative effects of the uncontrolled spread of landfill gas, a planned collection and forcibly directing gas to the city of combustion is carried out.

The legal obligation of collecting and burning landfill gas imposes a real solution: combustion gas for energy purposes in addition to creating economic profit.

7. CONCLUSION

Secondary waste of organic origin, produced today, emerging in the past, always will arise. This waste will always be a problem and a burden for the environment, if who do not find an appropriate solution for its utilization. At the present time, when the amount of organic waste from agriculture and other areas, is rapidly growing, one needs to understand that the same waste at the same time is an inexhaustible source of energy.

Organic waste everywhere and always acompanies man: it occurs in cities, on dumps, in waste water population and industry, on farms, in agricultural production of various types of plants, etc. The only real solution, which would enable sustainable development of human society, is the utilization of such waste and its biomass to produce biogas, which would be used for energy purposes.

The most preferred substrate for biogas production is manure, which is the raw material for the production of a renewable energy source with relatively clean combustion, and solid residues used as an agricultural fertilizer and others. For the presentation of this work can be concluded that the problem of organic waste generated during the agriculture production is evident, but it is solvable through the possible production of biogas and further use of the substrate, with the aim of sustainable development of ecology and production of renewable energy sources. Distribution residue after fermentation in agricultural areas contributes to the preservation and enhancement of soil fertility, given that it contains significant amounts of macro, but also organic matter. The residue of the fermentation, after separation and drying, may be further distributed in the form of briquettes or pellets, as a solid fuel.

Considering the difficult economic situation in Serbia, however, state involvement in the development of biogas technology and the construction of new plants is expected to increase.

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Professional (Expert) Paper

NEW EU TYPE-APPROVAL LEGISLATION FOR AGRICULTURAL AND FORESTRY VEHICLES

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Abstract. *In the Official Journal No. 167 from 2013 the new Regulation (EU) No 167/2013 of the European Parliament and of the Council of 5 February 2013 on the approval and market surveillance of agricultural and forestry vehicles has been published and the framework for the new legislation structure for agricultural and forestry vehicles has been set. Following the recommendations from the Competitive Automotive Regulatory System for the 21st century (CARS 21) report the European Commission prepared and in year 2015 published in the Official Journal all relevant legislation acts and with this prepared the complete new EU type-approval regulation for agriculture and forestry vehicles. This new system will start on 1 January 2016 when the existing framework Directive 2003/37/EC and their 23 separate Directives on will be repealed. This paper describes the content of all legislations acts followed by Regulation (EU) No 167/2013.*

Key words (bold): *EU legislation, agricultural vehicles, forestry vehicles, approval.*

1. INTRODUCTION

Until the end of this year and from the year 2013 the framework Directive for agricultural and forestry tractors is the “Directive 2003/37/EC of the European Parliament and of the Council of 26 May 2003 on type-approval of agricultural or forestry tractors, their trailers and interchangeable towed machinery, together with their systems, components and separate technical units and repealing Directive 74/150/EEC” [1]. Under this Directive there are 23 separate directives with several amendments and corrections that cover all relevant and important parts, elements and systems of agriculture and forestry tractors. Beside this agricultural and forestry vehicles are also regulated with several UNECE Regulations prepared in Geneva on World Forum for

Harmonization of Vehicle Regulations (WP.29) and some OECD Codes done in Paris that content very similar technical requirements and test procedures to above mentioned separate directives. So the type-approval system is very strictly regulated and therefore also very complicated for the vehicle producers and also for type-approval authorities and technical services. Every European Union Member State has to transpose all these directives in their national law and this is a huge work for technicians and layers.

In the Republic of Slovenia we transpose the framework Directive 2003/37/EC in the national legislation with the “Rules on approval of agricultural and forestry tractors” [2]. We prepared then also 23 technical specifications for vehicles that contain consolidated texts of 23 separate directives together with their amendments, modifications and corrections. They are not published in the Slovenian Official Journal but only the list of valid technical specifications is printed in it. As equivalent legislation we accept also type-approval based on UNECE Regulations and OECD Codes test reports. The complete legislation is available on the official website of the Ministry of Infrastructure and is regularly updated [11], [12].

In 2010 the European Commission started with the preparation of the complete new legislation in accordance with recommendations of “Competitive Automotive Regulatory System for the 21st century” (CARS 21) [3]. Final report of CARS 21 concluds that most of the legislation in force should be maintained for the protection of citizens and the environment, a simplification exercise should be undertaken so as to rationalise the regulatory framework and move towards international harmonisation of requirements. On 2 March 2013 the new Regulation (EU) No 167/2013 of the European Parliament and of the Council of 5 February 2013 on the approval and market surveillance of agricultural and forestry vehicles was published [4]. This is the so called “mother regulation” that regulate all technical requirements for agricultural and forestry vehicles before putting on the market and are harmonized in all European Union Member States. The Regulation entered into force the twentieth day after its publication, but it shall apply from 1 January 2016 [10]. And because this is a Regulation and not a Directive, which is automatically valid in all European Union Member States there is no work for the type-approval authorities in European Union Member States with the transposition to the national law.

Immediate after this publication European Commission started a work on delegated acts and involved in this process a lot of experts from all European Union member states and manufacturers of agriculture and forestry vehicles. European Commission organised several meetings and new acts has been developed and finished at the end of 2014. The work is now done and all new Commission Regulations have been published in the Official Journal of the European Union.

2. OVERVIEW OF ALL NEW ACTS

2.1. General information

All Commission Delegated Regulations cover all agriculture and forestry vehicles and not only agriculture and forestry tractors. Type-approval requirements are now prepared for agricultural or forestry tractors, their trailers and interchangeable towed machinery, together with their systems, components and separate technical units. Constructional and technical requirements are now joined in only four acts instead of 23. If there is European or international standard or UNECE Regulation for system, component or separate technical unit, the regulation uses only the reference to such document and therefore there is no duplication of legislation. With referring to UNECE Regulations these Commission Regulations follow the technical progress because ENECE Regulations are constantly amended. On the other side important modifications to update the technical progress or extending the scope to further vehicle categories or to increase the level of safety will be done by the modifications of the Commission Regulation [13], [14]. All administrative requirements are joined in one special act and therefore the “paper work” in simpler than the existing one. In all acts we have the consistency of the terminology used with the respect to the EU Whole vehicle type-approval (WVTA) process.

2.2. Vehicle construction and general requirements for the approval

Vehicle construction and general requirements for the approval are prescribed in Commission Delegated Regulation (EU) No 1322/2014 of 19 September 2014 supplementing and amending Regulation (EU) No 167/2013 of the European Parliament and of the Council with regard to vehicle construction and general requirements for the approval of agricultural and forestry vehicles [5]. This is the first big piece of legislation with more than 300 pages and with 30 Annexes. This Regulation prescribed test procedures and requirements for roll-over protection structures (static and dynamic testing), for falling object protection structures, protection against penetrating objects, protection against other mechanical hazards, protection against hazardous substances, passenger seats, driver’s exposure to noise level, driving seat, operating space and for access to the driving position, power take-offs, protection of driving components, seat-belt anchorages, safety belts, exhaust systems, operator’s manual, control devices, guards and protective devices, warnings, markings, materials, products and batteries. In Annex I we could find a list of UNECE Regulations that are directly applicable for the type-approval and on such way there is no duplication of legislation. OECD Codes are also recognised for type-approval procedures and this is prescribed in the Annex II. This Regulation introduced also the virtual testing that is new topic on this field. In the Regulation we could find also the requirements for conformity of production, about the access to repair and maintenance information and performance standards and assessment of technical services.

2.3. Vehicle braking requirements

Vehicle braking requirements are prescribed in Commission Delegated Regulation (EU) 2015/68 of 15 October 2014 supplementing Regulation (EU) No 167/2013 of the European Parliament and of the Council with regard to vehicle braking requirements for the approval of agricultural and forestry vehicles [6]. This Regulation updates and supplements in line with technical progress current type-approval requirements regarding the braking safety on agriculture and forestry vehicles. This act has in Annexes requirements from European (CEN/CENELEC) and international (ISO) standards as well as from UNECE Regulation 13 that prescribed provisions concerning the approval of vehicles of categories M (motor vehicles designed and constructed primarily for the carriage of persons and their luggage), N (motor vehicles designed and constructed primarily for the carriage of goods) and O (trailers) with regard to braking. Because of the technical progress it contains specific provisions for energy reservoirs, vehicles with hydrostatic drive, vehicles with inertia braking systems, vehicles with complex electronic control systems, anti-lock braking systems and electronically controlled braking systems. Anti-lock braking systems are not yet widely available for vehicles with a design speed between 40 km/h and 60 km/h and therefore for those vehicles the introduction of anti-lock braking systems should be confirmed after a final assessment by the Commission of the availability of such systems that has to be done at the latest by 31 December 2016. This Regulation also includes stricter requirements on brake control of towed vehicles and brake coupling between the tractor and towed vehicles than older Council Directive 76/432/EEC.

2.4. Environmental and propulsion unit performance requirements

Environmental and propulsion unit performance requirements are prescribed in Commission Delegated Regulation (EU) 2015/96 of 1 October 2014 supplementing Regulation (EU) No 167/2013 of the European Parliament and of the Council as regards environmental and propulsion unit performance requirements of agricultural and forestry vehicles [7]. This Regulation stipulates the detailed technical provisions and test procedures for vehicle manufacturers and other stakeholders to determine the propulsion unit performance of agricultural and forestry vehicles. With reference to Directive 97/68/EC on the approximation of the laws of the Member States relating to measures against the emission of gaseous and particulate matter pollutants from internal combustion engines to be installed in non-road mobile machinery this Regulation sets-out measurement requirements and emission limits for internal combustion engines used in agricultural and forestry vehicles. It covers the pollutant exhaust emissions and the external sound level. The limit values for external sound level are defined in the Regluation (EU) No 167/2013 (tractors with an unladen mass in running order of more than 1500 kg (89 dB(A)) and for those that the mass is not more than 1500 kg (85 dB(A)).

2.5. Vehicle functional safety requirements

Vehicle functional safety requirements are prescribed in Commission Delegated Regulation (EU) 2015/208 of 8 December 2014 supplementing Regulation (EU) No 167/2013 of the European Parliament and of the Council with regard to vehicle functional safety requirements for the approval of agricultural and forestry vehicles [8]. This is also a big piece of legislation with more than 170 pages and with 34 Annexes. To avoid the duplication of legislation this act is very much referring to European and international standards and UNECE Regulations. This Regulation prescribed test procedures and requirements for vehicle structure integrity, speed governors, speed-limitation devices, steering, speedometers, the field of vision, glazing, rear-view mirrors, lighting, light-signalling devices and their light sources, electromagnetic compatibility, heating systems, fuel tanks, towing devices, tyres, spray-suppression systems, reverse gear, tracks etc. This Regulation allows (with a few exemptions) national authorities also to grant national type-approval to a type of vehicle, system, component or separate technical unit.

2.6. Administrative requirements

Administrative requirements are prescribed in Commission Implementing Regulation (EU) 2015/504 of 11 March 2015 implementing Regulation (EU) No 167/2013 of the European Parliament and of the Council with regard to the administrative requirements for the approval and market surveillance of agricultural and forestry vehicles [9]. This Regulation sets out the detailed administrative requirements regarding the templates of documents, certificates, test reports, EU type-approval mark and statutory plate to harmonise all aspects related to the procedure of authorisation for placing on the market and entry into service. It prescribed also the template for the manufacturer's certificate on access to vehicle on-board diagnostics (OBD) and to vehicle repair and maintenance information. These requirements are new in the area of agricultural and forestry vehicles. In the Annex IX there is a list of parts or equipment which may pose a serious risk to the correct functioning of essential systems.

3. CONCLUSIONS

All this Regulations are now prepared and are waiting on manufacturers and also to approval authorities and technical services to start using them from 1 January 2016. Nobody knows how this new system will start but legislation is a "living thing". Already now the European Commission and some EU Member States prepared some corrections and supplements for above mentioned acts and we will discussed about this on next meetings of Working Group of Agriculture Tractors.

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VALORIZATION OF TRADITIONAL BUILDING MATERIAL FOR THE SUSTAINABLE DEVELOPMENT OF RURAL AREAS

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Abstract. *The recent increase in the sensitivity about the concept of sustainable development is stimulating the valorization of the locally available material for agricultural construction, both for housing purpose and for some single components. This traditional building technique has indeed interesting consequences on the rural landscape perception - since the color is similar to the countryside surroundings – as well as on the agricultural environment – this material being, at the end of its useful life, recyclable in the same context. Traditional material could be employed in other agricultural components, e.g. for food ageing, a technique used since Roman times, involving the use of earthenware amphorae, buried in the soil and used for storing wine and oil. In the present paper, the most diffused traditional building materials currently rediscovered are analyzed, focusing on their utilization opportunities. One of the most interesting traditional construction material is the sun-dried earth brick, made of raw clay soil (so-called, "adobe"), often improved by the addition of fibers to control cracking while drying in the sun. After a general overview about the diffusion of earthen construction within agriculture, the results of experimental tests on adobe bricks reinforced with a natural fibre – Spanish Broom (Spartium junceum L.) – are reported.*

Key words: *Rural areas, sustainable development, farm building, traditional material, Adobe brick, Spanish Broom*

1. INTRODUCTION

Farm buildings are one of the most intriguing examples of original technical and scientific design: conceived to host biological productions, there is no other comparable example in the wide epistemological sector of building construction [22]. The birth, growth and development of living vegetal or animal organisms contained *inside* these volumes raise architectural and technical issues that are radically different if compared to those of other building sectors. Aimed at producing optimal environmental conditions for plants and animals, while at the same time protecting the hygiene and health of workers involved in the daily operations for the care of living organisms at different stages of their development, the rural building constitutes a unique and unrepeatable technological model [8, 9, 23].

Indeed, the originality of what happens *inside* the farm building corresponds to what happens *outside*. The role that the buildings have historically played is strictly connected with the surrounding context, due to the need of the farmer to live in close contact with agricultural land and animal husbandry [6, 10, 11, 14, 15]. While the organization of human beings involved in the activities of the industrial or tertiary sector allowed aggregation in urban centres, the need to live in constant contact with the agricultural production developed a synergetic function of close proximity to the extra-urban land. This aspect led to the spread in rural areas of many examples of buildings that served for farming, storage and processing of agricultural products constituting, at the same time, housing for the farmer and his family. This form of settlement has been, and still is, a unique way by which humans have populated, in harmony with the natural elements, the agricultural land, joining the primary production needed for human nutrition with the control and care of rural land. So, the activities made by the Man have often strongly influenced the agricultural environment and the visual perception of its landscape [27, 28, 29, 30].

The growing interest towards the role that rural areas may play for a more balanced pattern of modern life, under the currently increasing sensitivity of large segments of the European population about the concept of sustainable development, is stimulating the valorization of the locally available material used in agriculture for the realization of constructions, both for housing purpose and for the realization of each single element within the farm. This choice, that was at the time one of the pillars at the base of the formation of rural landscape, has its roots in the tradition left by our forefathers, since they had no choice than realize farm buildings and ancillary elements using the local material. Indeed, even if traditionally based mostly on an economic reason, this has very interesting consequences on the current perception of the rural landscape - since the color of the building is similar to the surroundings - as well on the agricultural environment – this material being, at the end of its useful life, incorporated in the same context. In the present paper, the most diffused traditional building materials currently rediscovered are analyzed, focusing on their utilization opportunities for farm building as well as for the realization of other farm components.

1.1. Food maturing and storing

Today, a technique of ageing that is becoming increasingly popular, used since Roman times, involves the use of earthenware amphorae for storing wine and oil. This technique was most popular in Georgia, where large earthenware amphorae were buried and used to allow the first fermentation and then the ageing of wines, both red and white. The use of earthenware pots (*Kvevri* in the local language) provides a completely natural treatment and enhances the varietal characteristics. Amphorae, usually made of clay, are produced in different sizes and subjected to different types of treatment (cooking at high temperature, coatings, *etc.*). They can be buried in the ground, half buried or not buried at all, depending on the system of temperature control installed in the cellars.

Wine contains different chemical substances that influence the sensory characteristics of the final product. Amount and type of these components can be opportunely modified by managing viticultural practices, winemaking process, aging, and type of containers and closures. Phenolic compounds are important components of wine. They not only contribute to their sensory profiles, such as colour, flavour and astringency, but may also act as antioxidants, with mechanisms involving both free-radical scavenging and metal chelation. The composition and concentration of phenolic components in wine depends not only on grape variety and wine-making procedures, but also on the chemical reactions that happen during aging. A fundamental role in wine sensory profile and consumer preferences is also played by volatile compounds. The aromatic profile of wine is the result of important modifications deriving from esterification, hydrolysis, redox reactions, slow and continuous diffusion of oxygen, spontaneous clarification, and CO_2 elimination [3]. As a result of these physical and chemical changes, the volatile fraction is extremely complex, accounting for more than 1000 compounds, which belong to different chemical classes, and cover a wide range of polarities, solubility, and volatility values. Aging can be made in different containers, such as stainless steel tanks, oak barrels, clay vessels, with the aim of enhancing wine flavour. Stainless steel tanks are inert containers while wood and clay interact with wine. Aging in wood changes colour, structure, phenolic profile and aroma, since it is a material that enables to make a micro-oxygenation of wine and to release phenolic and aromatic substances while adsorbing other wine components. However, in the case of white wines, the aging in oak barrels is not always advantageous since both the oxygen could oxidize the wine and the wood deriving components completely mask its sensory characteristics.

The aim of in-amphorae ageing is to replicate the beneficial air exchange of wood containers, without the transferring of vanillin, tannins and toast flavours from the oak barrels to the wine. Therefore, the resulting wines are different, with a cleaner taste and more pronounced characteristics of minerality and freshness. Several French (in Corsica, southern Rhone Valley, and Beaujolais), Portuguese (in Alentejo), Croatian (in Istria), U.S. (in the Napa Valley), Slovenian (in Goriška Brda region), Austria (in the east-central Thermen region) and Italy (mostly, regions such as Friuli, Campania and Sicily) wine producers have experimented with fermentation and/or ageing in amphorae.

From an economic point of view, the production of in-amphora wines is becoming increasingly attractive to producers, especially to those belonging to the ‘natural wine’ movement. In fact, only a few hundred thousand bottles of such wine are produced annually; they are designed for consumers willing to pay medium–high prices. The in-amphora wines have received a lot of attention from wine magazines and wine lovers but there is a lack of scientific literature about the effects of this type of ageing and comparison with conventional processes [2].

1.2. Dry-stone construction

In many rural areas, rich in sound and easily worked limestone, dry-stone walling can be found as a vernacular and widespread form of construction. Dry-stone constructions depend on the skills of professional masons; they are built by fitting pieces of stone without or, in some cases, with a small quantity of mortar. A very large number of dry-stone edifices have been raised in the past, such as retaining walls or rural constructions in Europe, but in the early 1900s dry masonry was largely renewed because of modern techniques. Over the past few years, there has been a growing interest into dry-stone masonry, not only for the maintenance and assessment of existing heritage, but also to promote know-how and to complete new projects.

Dry stone constructions are spread all over many parts of the World. Mostly within the Mediterranean area, they were employed in agricultural areas for housing purposes, as well as for the materialization, through stone walls, of the delimitation of borders between neighbouring countryside estates, as in some Southern Italian regions, *e.g.* Apulia and Basilicata (fig. 1). These extraordinary examples of spontaneous architecture still constitute a visible witness about the role that the rural constructions have historically played in connection with the surrounding environment, joining the agricultural production needed for human nutrition with the control and care of extra-urban land [22].

Fig. 1 Dry-stone building and walls for the delimitation of borders between neighbouring countryside estates

1.3. Earthen building

Earthen construction has been one of the most largely used construction techniques in different historic ages. Man began to use earthen construction at least 5000 years ago in Mesopotamia and Turkmenistan and it has been largely used by different civilizations all around the world [1, 2]. Nowadays it is estimated that between 30% and 50% of world population lives in earthen structures, mainly in some regions of Africa, Asia and Latin America, where earthen construction techniques are still largely used for new dwellings. Even in Europe, new earthen structures are built as a niche product of construction industry, mainly to ensure comfort to occupants and architectural compatibility with historical built environments. In fact, 10% of the UNESCO World Heritage properties includes earthen structures. In Europe, the historic centres of Matera, Cordoba, Oporto, Lyon, Guimarães are some of the UNESCO sites where earthen structures are largely present [12, 20, 21, 26].

One of the most interesting element of earthen construction is the use of sun-dried earth bricks - made of raw clay soil mixed with barley or wheat straw (so-called, "*adobe*") - as a walling material (fig. 2). The main applied raw materials are coarse sand, argillaceous earth and lime. The natural earth mixtures are often corrected by the addition of fibers, to control cracking while adobes are drying in the sun. The adobe masonry is an assemblage of adobe bricks and mud mortar. On the other hand, *pisé* or rammed earth is produced by ramming and compacting earth in a formwork [18, 34].

Fig. 2 Earthen rural constructions realized with *adobe* bricks

Adobe is a construction material that presents several attractive characteristics. It is low cost, locally available, recyclable, adapted to a large variety of soils, presents good thermal and acoustic properties, and it is associated to simple constructive methods that require reduced energy consumption [19, 21, 32, 33]. Adobe bricks are usually obtained by pressing the mixture of soil, water and fibers into a prismatic formwork, and then drying each brick through the combined action of air and sunshine. In some countries, several additives are also currently added to the soil mixture. In some cases, the mixture of adobe bricks was typically also stabilized in the past with dung and urine. Nowadays, cement is sometimes added to the mix of modern adobe bricks in order to increase strength and reduce erodibility, as it also happens by adding lime [20].

Due to the re-discover of this traditional construction material, material scientists and civil engineers are currently largely interested in earthen construction and many scholars are working on this topic [4, 5, 17, 26, 31]. The interest in this kind of structures is motivated not only by their large spread all over the world, but also by their poor mechanical properties resulting in high structural vulnerability against natural hazards (*e.g.* earthquakes, floods). Even though many scientific works on different types of earthen materials and structures are available in literature, detailed studies are needed to assess material properties and structural behaviour, since earthen structures are strongly site-specific, depending on the techniques used for material production and on-site construction of the building [13, 16].

To improve the mechanical strength, impermeability and the durability of locally produced adobe, in general, small amounts of hydrated lime or natural fibers are added to the soil matrix. The use of local natural fibers, especially in developing countries, is more beneficial for the population, as fibers are locally available in abundance, and their productions are of low cost and low consuming energy besides are not polluting. In the available international scientific literature, several experimental investigations have established the positive effects on the physical and mechanical properties of soil composite blocks from the addition of vegetable fibers such as: jute, sisal, straw, rice-husk, sugarcane bagasse, chopped barley straw, processed waste tea, vegetal, oil palm empty fruit bunches, lechuguilla, pineapple leaves, cassava peel, *Hibiscus cannabinus*, *Pinus roxburghii* and *Grewia optivia* [24].

The effect of synthetic fibers on soil composites have been studied theoretically with the objective of producing specific analytical models for soil composites. The main parameters that strongly influence the physical, mechanical and the durability behaviour of soil composites are: the type, tensile strength and durability of fibers, besides the fibers' length and their volume fraction in the composite mix. The type of fiber has an important influence on the impermeability of the composites depending on the percentage of the lignin in the fiber. The higher the percentage of lignin in the vegetable fiber, the higher is the impermeability. Depending on the mixture of soil, its differential shrinkage during the drying process could be high. To prevent the shrinkage cracks of the soil matrix, fibers are added. The higher the resistance of fibers with high bonds, less shrinkage cracks in the brick. The optimum volume fractions and length for most vegetable fibers have been found to be between 0.3% and 0.8% in weight with 30–80 mm length respectively [19]. Fibers tensile strength directly determines the crack resistance of fiber-reinforced soil. Even if the long-term stability of this feature was not adequately studied so far, existing buildings where fibers did not decompose in the soil validate the durability of soil composite reinforced with vegetable fibers. The fiber length determines the pull-out resistance of the embedded fiber in the soil matrix and therefore directly determines the reinforcement force, which is less than or equal to the fiber tensile strength. The amount of fiber determines the intensity of the reinforcement: for small amounts (<0.2 wt.%), the strength of the reinforcement increases with the number of fibers. However, at a higher fiber mass fraction over a certain threshold, the fibers are so numerous that they weaken the soil matrix and thus lead to a lower resistance of the reinforced soil composites.

With the aim to examine the mechanical properties of adobe bricks realized with natural material locally available in Southern Italy, in the present paper the results of mechanical tests on adobe bricks suitably prepared are presented. These bricks were tested with different kinds of reinforcement fibers: straw as well as one of the most interesting natural fiber diffused all over the Mediterranean area, where it spontaneously grows, *i.e.*: Spanish Broom *(Spartium junceum L.)*.

2. MATERIALS AND METHODS

Since no studies regarding the use of Spanish Broom fibers for the enhancement of the mechanical properties of adobe bricks appear to be conducted so far, in the present paper experimental tests on adobe bricks reinforced with natural fibers - *i.e.*: wheat straw, considered as a reference, and Spanish Broom - as well as on the fibers of this latter, are reported [16, 17, 25]. All these mechanical tests were performed at the Laboratories for

Testing Materials of the SAFE School of the University of Basilicata (Potenza – Italy) by using a Galdabini PMA 10 (Galdabini S.p.A., Italy) universal testing machine.

2.1. Compression test on adobe bricks

Adobe bricks of cubic shape (150 mm edge) were produced, according to local traditional practice in Basilicata Region, by taking soil having the following composition: 49.3% clay, 36.9% silt and 13.8% sand. The Atterberg values of this mixture were: Liquid Limit LL = 38.7%, Plastic Limit PL = 21.0 %, Plastic Index PI = 17.7%.

Natural fibers were added to the soil-water mixture, at a 33% volume rate [31], ensuring a distribution of fiber reinforcement within the brick volume and their stabilization, in terms of lack of shrinkage cracking. N.4 different typologies of adobe bricks were produced (fig. 3/a), by adding to the soil the following reinforcing fibers:

ASr – Adobe brick reinforced with wheat straw, randomly disposed within the brick.
ASo - Adobe brick reinforced with wheat straw, disposed orthogonal to the compression load.
AGr - Adobe brick reinforced with Spanish Broom, randomly disposed within the brick.
AGo - Adobe brick reinforced with Spanish Broom, disposed orthogonal to the compression load.

For each typology, n.10 specimens were produced. After drying at the sun, the mechanical behaviour of the adobe bricks was measured by placing them between the rigid steel plates of the testing machine and testing them in terms of unconfined compression strength through displacement-controlled uniaxial tests (fig. 3/b). A uniform load was applied without shock and increased continuously until failure, with the moving head of the testing machine travelling at a rate of 1 mm/min.

Fig. 3 Adobe bricks reinforced with natural fibers (a–left) and compression test (b–right)

2.2. Tensile test on Spanish Broom

Spanish Broom (*Spartium junceum L.*), a member of the Leguminosae family, is a perennial shrub growing in hot and dry climate throughout the Mediterranean area, where it naturally occurs in hilly soils, contributing to lower erosion and risks of nutrient leaching. This plant is somewhat adapted to alkaline and salty soils. In comparison with flax and hemp, Spanish Broom grows in the most unfavourable limestone soil and once planted it can be used during a period of up to twenty years, whilst hemp and flax demand high quality soil each year [7]. The name *Spartium* is from the Greek word denoting "cordage," in allusion to the use of the plant. The stem fibers have been used since ancient time as hemp substitute, being used mainly for coarse fabrics and cordage. Spanish Broom cortical fibers are multiple elementary fibers (*ultimates*) arranged in bundles. The elementary fibers are bound together by lignin. A thick secondary cell wall indicates a high cellulose content. The diameter of *ultimates* varies from 5 to 10 μm while the diameter of the whole bundle is about 50 μm [1]. Spanish Broom has been considered a potential interesting source of natural, sustainable, and renewable fiber for textile and technical applications. These fibers derived from the plant branchlets (known as *vermenes*) show extraordinary tensile resistance and flexibility and are able to produce materials in combination with biodegradable and plastic matrices.

Within the present experimental tests, both fibers of Spanish Broom as a natural sprig (fig. 4/a), as well as pieces of twine drawn from a rope ball (fig. 4/b), were examined by tensile tests.

Fig. 4 Tensile test on a Spanish Broom natural sprig (a - left) and rope (b - right).

The diameter of the rope was equal to 0.9 mm, while the diameter of each natural sprig specimen, assumed circular in shape, was measured using a micrometer with a precision of 0.01 mm. The test samples were fixed to the grips of the machine, removing the slack without stretching the sample; making certain that the specimen was well aligned and straight within the grips and in the line along the applied load to the fiber, since any misalignment could produce the transverse movement of the clamps and hence introducing errors in the measurement of elongation and contributing to the premature failure of the fiber.

3. RESULTS AND DISCUSSION

3.1. Adobe bricks

In table 1 the results of compression tests on the four different types of adobe bricks are reported. From these results it can be concluded that the mechanical strength of the adobe bricks appear to be similar to those with no natural fiber added [17], and in general agreement with the results reported within the scientific international literature [20, 24, 31], the addition of fibers having apparently not led to a significant increase in compressive strength of soil.

Table 1 Compressive strength of the different adobe bricks experimentally tested.

Adobe brick	**Compressive strength** σ_m [N/mm^2]
ASr	0.92
ASo	1.43
AGr	1.10
AGo	0.97

Figure 5 reports a diagram stroke/load for one of the tested adobe bricks. It can be noticed that the behaviour of this material is almost elastic in the first phase, followed by a very limited plastic phase, that quickly precedes the definitive failure of the cubic specimen.

From the results obtained through the present experimental tests it can be concluded that further analysis should be performed, aimed to the definition of optimal mixture of soil with natural fibers. The presence of fibers, together with their length, plays in fact a significant role in the compressive strength improvement of soil [24], giving a general increase of the mechanical strength, since fibres, even due to their increased aspect ratio (length/diameter) compared to non fibrous filler, usually improve the mechanical properties of composite materials.

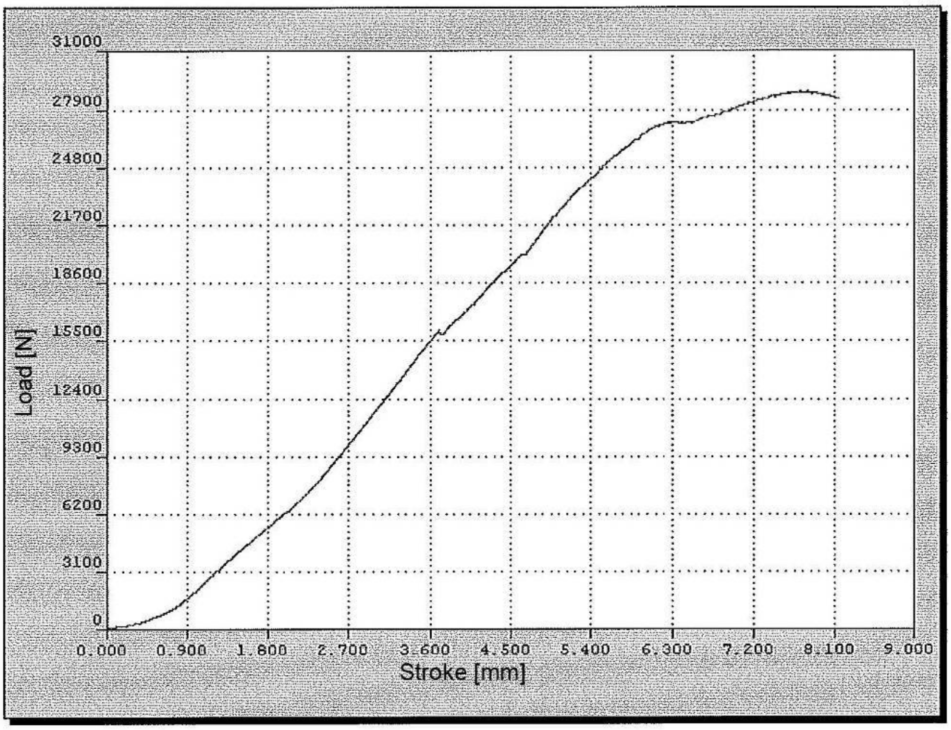

Fig. 5 Stroke/load diagram for the compression test on a cubic-shape adobe brick

Moreover, in addition to possessing greater compressive strength, the adobe bricks prepared with higher percentage in straw could underwent less shrinkage. This characteristic, together with an average density usually lower than that of the other mix ratio, represents an advantage in its use as a construction material, as less shrinkage implies a reduced possibility of cracks appearing, and lower density results in a lighter material.

Another important aspect that was observed by some Authors [31] is that the adobe bricks demonstrate greater strength when loads are applied perpendicularly to the upper face of the brick, which coincides with the direction in which they were manually pressed during preparation. It would therefore be important to ensure that during construction, they are positioned in such a way that this is the direction in which they receive loads, which is also the same position in which they are laid out to dry once prepared.

3.2. Spanish Broom fibers

The Spanish Broom fibers showed the tensile properties reported in table 2.

Table 2 Tensile strength of the Spanish Broom fibers experimentally tested.

Spanish Broom fiber	**Tensile strength** σ_t [N/mm^2]	**Strain** [%]
Natural sprig	41.53	2.72
Rope	36.32	20.72

In figures 6 and 7 the diagrams elongation/load respectively for one of the tested Spanish Broom natural sprig and rope are reported.

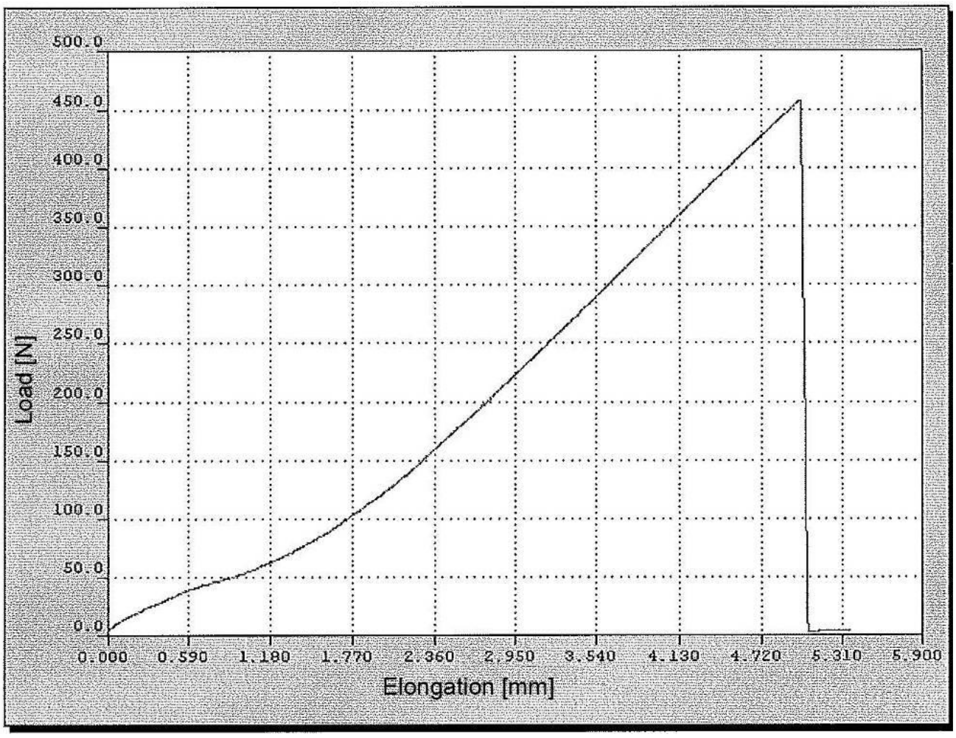

Fig. 6 Elongation/load diagram for the tensile test on a Spanish Broom natural sprig

The mechanical behaviour of Spanish Broom appears very interesting, mostly because its tensile strength is considerably high, if compared with other different natural fibers.

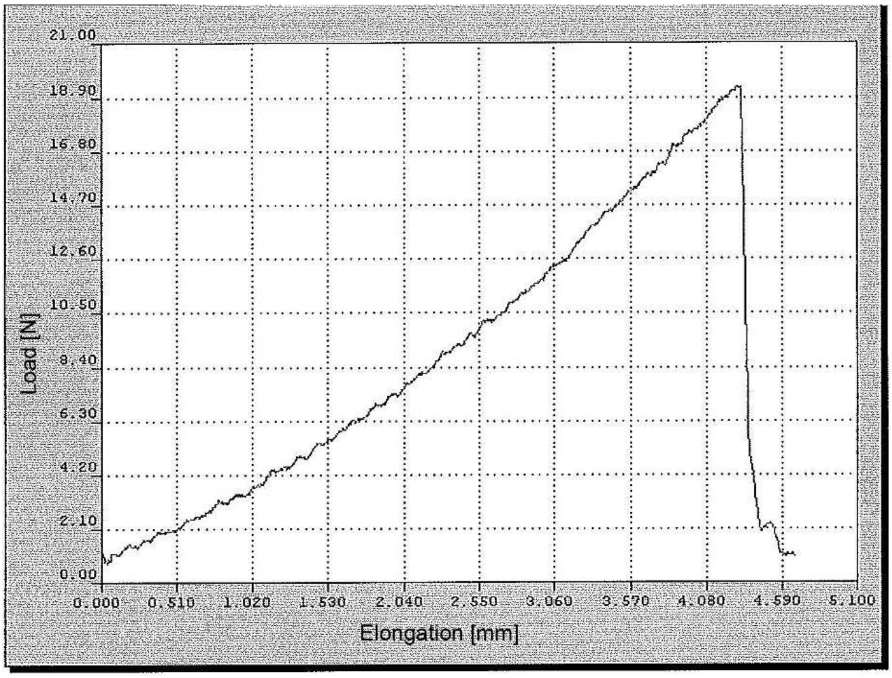

Fig. 7 Elongation/load diagram for the tensile test on a Spanish Broom rope

Many other different natural fibers have, in fact, showed lower tensile strength and strain properties even if, in some cases, much higher results were obtained, as in the case of *Grewia optivia* [24] and specially *Hibiscus cannabinus*. In this last case, from the laboratory tests, an experimental mean value of the tensile strength equal to about 1,000 MPa was detected indeed [19], with a high standard deviation depending on the natural variability of the fibers. This tensile stress is even approximately twice higher than steel, with a stiffness twice smaller, which means that this material is 4 times more deformable than steel. This deformability is favourable to reinforce Pressed Adobe Bricks (PABs), which is a material with a low stiffness.

Again in this case [19], anyway, it was noticed that longer fibers and their high contents had a negative effect on the compressive strength of the adobe bricks, since the increase of the mechanical properties is linked to the non-propagation of cracks due to the presence of fibers in the clay matrix. The impact of these fibers on the flexural strength was positive because of the high tensile strength of the fibers and their adhesion to the clay matrix.

4. CONCLUSIONS

Farm buildings play a central role in the environmental characteristics of agricultural land. Over the centuries they have accompanied the development of the agricultural activities of man who has thereby been able to breed cattle, to grow and yield crops, and to store, transform and process agricultural products in a more and more functional and efficient way, working in intensive conditions unaffected by the external climate. On the other hand, constructions built by farmers marked the rural territories, influencing and steering the spontaneous development of nature while leading to production that enabled to get food.

Within the general current re-discover of agricultural heritage and genuine food techniques, the valorisation of traditional construction material both for building purpose and for the realization of some components directly connected with agro-food production may contribute to the improvement of agricultural production within the concept of sustainable development. Rural tourism seems to be among the most currently intriguing activities aimed to the sustainable growth of the agricultural sector joined with new ways for a sound valorisation of the agricultural land, that can be enjoyed in close contact with naturally untouched landscapes, often coupled with the unique opportunity to personally look at the preparation of traditional genuine food products and to taste and buy them. The recent growing research of new ways for widening sustainable tourism opportunities leaded, in many European countries, to the valorisation of some farmyards, together with the working activities usually conducted there. In this framework, a suitable restoration and functional requalification of the farm building plays a central role, in which a suitable use of traditional building material may contribute to a significantly positive effect.

Popularly employed forms of earth in building construction involve use of rammed earth, cob or earth in combination with wood and stone, and adobe bricks. Adobe is a construction material that presents several attractive characteristics. It is low cost, locally available, recyclable, adapted to a large variety of soils, presents good thermal and acoustic properties, and is associated to simple constructive methods that require reduced energy consumption. Adobe construction, however, if not properly designed and strengthened, may present a deficient response when subjected to severe mechanical actions. Owing to increasing popularity of use of earth, many countries have framed appropriate legal guidelines as codal provisions. These regulations specify the usage process of earth in various forms as per geographical location. Not only these regulations are guides for better construction process and are helpful in seismic activity prone areas, but they also help to enhance indoor thermal comfort of buildings at negligible cost.

Future analysis appears anyway necessary, mainly focused on the role that natural fibers could perform when mixed into the earthen mixture of adobe bricks, that could be better explored through the study at microscopic level of the adhesion of the fibers to the clay matrix and the consequent effects on the general mechanical properties of the reinforced earth construction.

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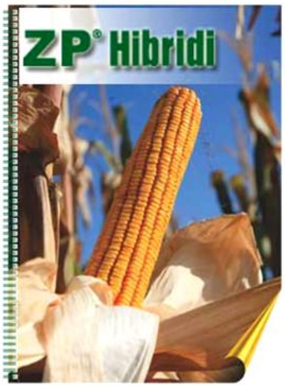

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