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The Third International Symposium on Agricultural Engineering

ISAE-2017

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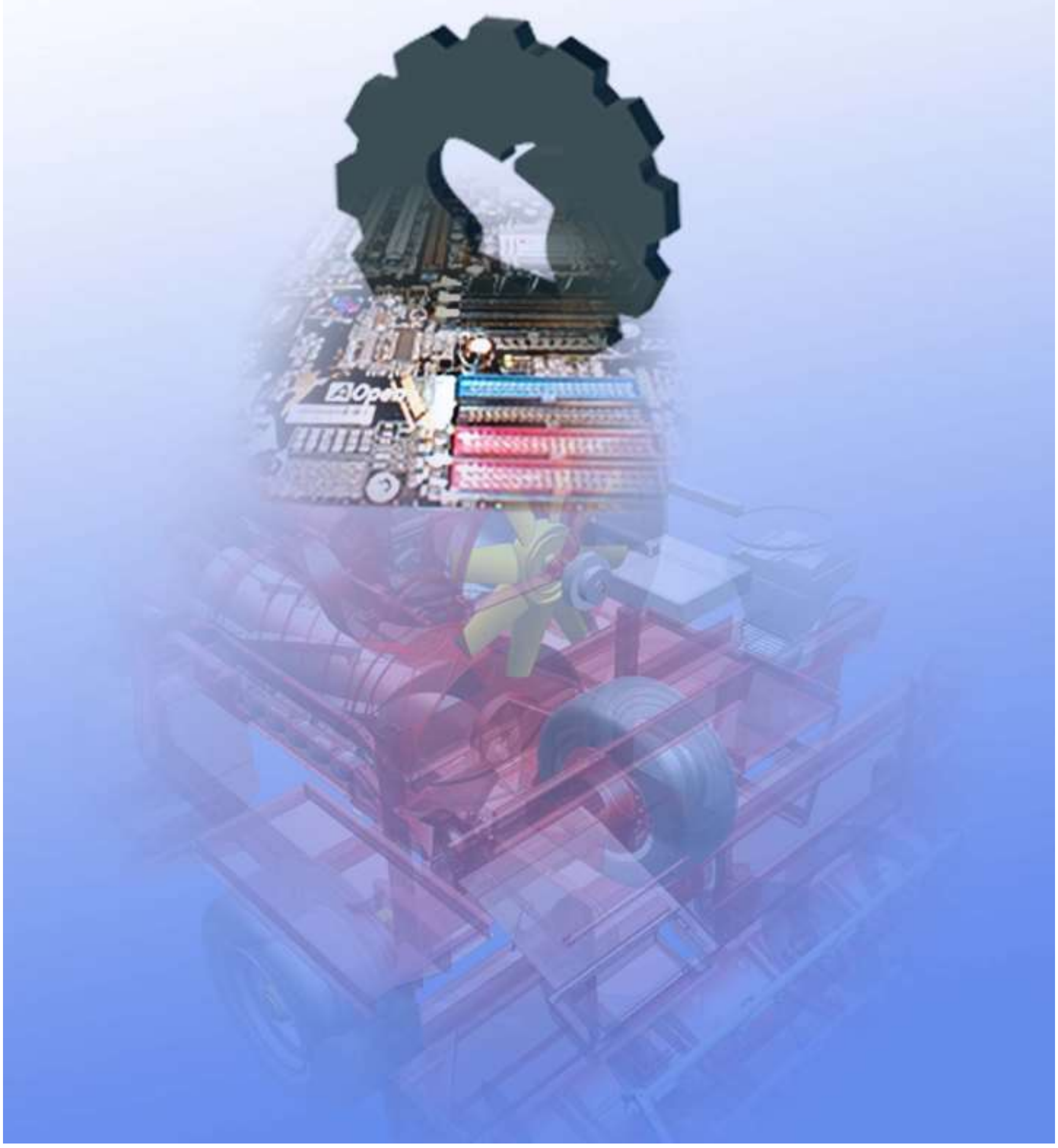

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PREFACE

After the successful First and Second International Symposium on Agricultural Engineering ISAE 2013 and ISAE 2015, that were held in Belgrade at the Faculty of Agriculture, thanks to our colleagues we are organizing The Third International Symposium on Agricultural Engineering – ISAE 2017. 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), Aristotle University of Thessaloniki Faculty of Agriculture, Thessaloniki (Greece), University of Belgrade, Faculty of Mechanical Engineering, Belgrade (Serbia), Vinča Institute for Nuclear Science, Belgrade, Serbia 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 34 papers that were submitted to the Scientific Committee of the ISAE 2017 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 2017 were reviewed by the members of the Scientific Committee and kind assistance of some members of other Conference bodies.

Book of Proceedings of the ISAE 2017 International Symposium has 324 pages and it is organized in eight thematic sections. Section I – Crop, Fruit and Vegetable Production Systems (13 papers); Section II – Livestock Farming Systems and Equipment (1 paper); Section III – Power and Machinery; Diagnostics and Maintenance of the Agricultural Machinery (4 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 (2 papers); Section VI – Soil and Water Use and Environment (1 paper); Section VII – Energy, biomass and bio recourses in Agriculture (2 papers); Section VIII – Agricultural Policies, Sustainable Agriculture, ergonomics and Safety in Agricultural Machinery Exploitation (5 papers).

We wish to thank to all the authors for their contribution to the ISAE 2017 Symposium and to the all the Institutions, Associations, Universities, Sponsors and Donors for the contribution in ISAE 2017 Symposium organization.

ISAE-2017 Proceedings

CONTENTS

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PRELIMINARY DESIGN AND THEORETICAL STUDY OF EARTH SHELTERED GREENHOUSES IN MOUNTAINOUS AREAS OF THE BALKAN
PART I: INITIAL CONSTRUCTION DESIGN- SOIL, WATER RUNOFF MANAGEMENT AND LEGISLATION

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Abstract: *Greenhouse horticulture is a common crop cultivation practice in areas where the climatic conditions are convenient. Most of the greenhouse structures are established in areas where the landscape is plain and the construction is feasible. However there are many mountainous areas in the Balkan region that lack of the aforementioned parameters. In this case a higher cost of vegetable and other agricultural products and an imminent risk of food dependence in the future are probable. In this study a preliminary holistic approach of the construction and operation of earth sheltered greenhouses in such areas is presented, focusing on the Balkan region in terms of legislation, climate and land morphology. Earth sheltered greenhouses are a common cultivation practice applied in the mountainous regions of various countries such as China and India, but never investigated systematically for commercial purposes. The study is divided into two parts. As far as the first part is concerned the construction design and the parameters that must be taken into account concerning the water runoff of inclined areas are presented. The relative legislation which regulates that type of installations in mountainous regions of several countries located in the Balkan is also presented. That way it will be examined whether the proposed plan is feasible and if it can work as a quarry rehabilitation method.*

Key words: *Earth Sheltered Greenhouse, Mountain Region, Soil, water runoff, legislation*

1. INTRODUCTION

Humanity has to face a number of challenges in the upcoming years. The population growth is considered as one of the major issues as it is expected to meet a significant increase [1]. In addition to the up mentioned fact there are other issues of great importance as the climate change, the energy issue, the proper management of resources etc that must be faced by modern societies. A very critical issue that combines all the previous is food availability. Population needs must be addressed without burdening the environment and at the same time by rational consumption of resources and energy. Among other factors, the ongoing unsustainable cultivation is one of the main reasons of desertification [2]. As a result more and more areas are no longer suitable for crop development while food needs increase. The available land for efficiently developing crops is highlighted at Figure 1. As it can be observed the most available area for crop development is located in Latin America and Sub-Saharan Africa. This fact raises some issues as not only the available area is concentrated at specific regions but there are also many restrictions (mostly environmental) that may further decrease this percentage. Taken into account the up mentioned statements The Food and Agriculture Organizations of the United Nations (FAO) concluded that the expected increase of the arable area by 2050 will be around 5%. This percentage will be mostly carried out at developing countries rather than developed where a decrease is expected [3].

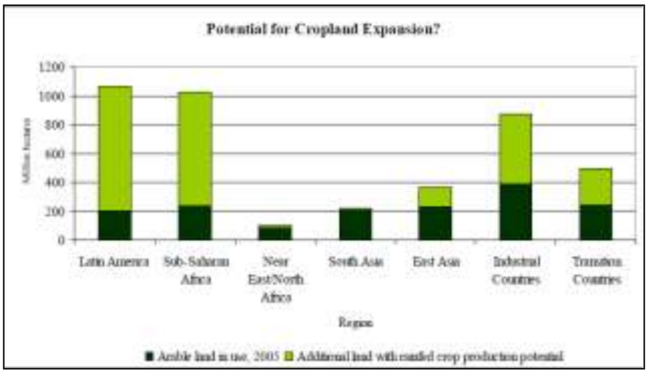

Fig.1 Cropland expansion potential by region [3]

The research around agriculture formation, in order to cover the food needs, is concentrating on two basic ideas. The one concerns the optimization of agriculture methods as a way to succeed more productive yields. The other idea is to develop crops in areas with no arable land by the exploitation of modern renewable energy systems and advanced greenhouse structures. Cultivation in deserted coastal areas by using solar energy for the energy systems and desalination systems for fresh water production could be a possible prospect [4]. The disadvantage of such an option is that production is concentrated at specific geographical regions and the final products are burdened with transportation costs. More than this food security issues may arise due to other reasons (political, social etc). A possible option could be the utilization of mountainous areas for agricultural purposes. Mountainous farming concentrates many disadvantages as the weather conditions are not proper as well as the soil characteristics, resulting to a shorter growing season [5]. In particular, FAO has estimated that around 45% of the world's mountain areas are not, or only marginally, suitable for growing crops [6]. Moreover the labor costs are usually higher and the use of conventional machinery difficult due to the morphology of the area [5]. In Europe, mountain farming holds 18% of agricultural enterprises including livestock. The agricultural land utilized is almost 15% of the total land while 15% of the agricultural workforce is also occupied in this activity.

As far as the productivity of these areas it concerned, it is approximately 28% lower in mountainous areas compared to other disadvantaged areas (such as coastal areas) and 40% lower than typical farming on the plains, due to geographical constraints. A rather interesting fact is that the usual crop in such areas is pastoral farming which holds a percentage of 60% [5]. Apart from the above mountain farming does have positive aspects. Due to the fact that it is characterized as a small-scale activity with necessary adjustment at local conditions it contributes to the diversification of crops. Also it doesn't enforce deforestation and the carbon footprint of such activities is low. Everything above mentioned leads to the conclusion that it is a rather sustainable form of agriculture currently in a traditional- large family scale [7]. One of the most crucial advantages of mountain farming though is that food insecurity is reduced for local communities. A secondary benefit is that the possible development of such areas could reduce migration trends which are very often in developing and developed countries [7]. For this reason means of cultivation in mountainous areas are of paramount importance. Building earth-sheltered greenhouses could be a potential by which agricultural economy could benefit from this unexploited 45 percent. This type of greenhouse is illustrated at the schematic diagram of Figure 2.

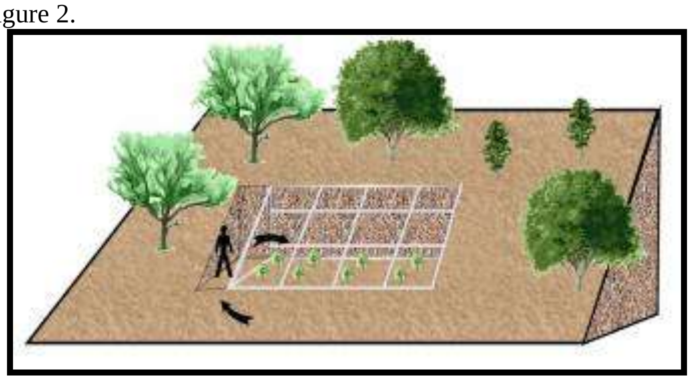

Fig.2 Schematic illustration of earth shelter greenhouses' rationale

Two decades ago, earth-sheltered greenhouses appeared from the first time as traditional farming methods in the cold regions of South America. The advantage of these structures was that they could provide a stable, warm and resilient environment regardless of the geographic and climatic conditions, using mainly natural resources. This method has been adopted in numerous countries for growing winter horticultural crops, such as China, Japan, Korea, Russia and the United States. Until now, there are mostly found in mountainous areas and are constructed by farmers based on their experience. The lack of space and the high transportation costs are the two most important factors which make their construction imperative. In cold regions, where bad weather conditions are prevailing, this type of subterranean greenhouse could be the obvious solution. According to the Benson Agriculture and Food Institute at Brigham Young University, the materials construction's cost of an 135 m^2 underground greenhouse (labor cost and additional equipment cost excluded) ranges between \$250 and \$300 [8],[9],[10]. This kind of investment could boost a series of other agricultural investments like livestock production and food-processing units leading to a strong local sufficient commercial network. Last but not least creating strong local economies in mountainous areas could lead to decentralizing population from large cities, a fact which is of outmost importance by all means. Up to now the construction of these greenhouses is based upon the experience of local communities and population. In this work an effort for standardizing the earth-sheltered greenhouses is performed. The aim of the work is to evaluate the possibility of the development of such structures in the future in a more systematic way. That way it will assist mountainous farming designers to create a more significant cultivation form capable to contribute at food production. The study is divided in two parts. In this part the construction study will be presented as it is considered of great importance. The study focused primarily on the static loads which the structure receives, as well as, the water runoff management. These two parameters must be studied thoroughly as the greenhouse must be statically stable and at the same time insusceptible to water flow issues due to meteorological phenomena. In order to study the feasibility of the proposed agriculture strategy, possible restrictions due to legislation must be examined at least in Greece and in most areas of Balkan regions.

2. Analysis of Current Potential, State of Legislation And Regulations in the Balkan Region

Up to now most cases of earth sheltered greenhouses are spotted in regions where no environmental issues exists or in private land by individuals. Building earth sheltered greenhouses can be part of quarry regeneration or an effort for increasing the area of cultivation land of regions with specific geographical characteristics. This process should be performed carefully in order to ensure that such a project is possible. For the quarry case study, inhibitory factors are few as there is an ongoing search for regeneration solutions. In fact the landscape and environment in this case is already degraded. On the other hand, the utilization of mountainous areas for cultivation processes is not an easy task as the areas should not be of environmental or historical interest. Apart from that, the soil composition should be taken into account in order to avoid corrosion or other relative issues. Before examining the type of legislation and possible barriers the potential of areas suitable for this use should be overviewed. In Table 1 the percentage of mountainous and hilly areas is highlighted for the Balkan region countries.

Table 1. Percentage of mountainous areas for the countries of the Balkan region [11],[12],[13],[14],[15],[16],[17],[18],[19],[20]

Country	**0**	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1000**	**1200**	**>1200**	**[m]**
Greece	**29%**		**29%**				**42%**							
Albania	**30%**			**60%**							**10%**			
Bulgaria	**32%**		**53%**								**14%**			
Fyrom	**20%**						**80%**							
Serbia	**57%**					**30%**					**13%**			
Bosnia & Herzegovina	**12,5%**			**28%**				**60%**						
Croatia	**53,42%**		**42,72%**								**3,86%**			
Montenegro	**10 %**		**35%**								**55%**			
Slovenia	**29,8%**							**70,2%**						
Romania	**36%**		**33%**								**31%**			

The data available didn't allow the detailed analysis for all the countries, but each country's topography situation can be realized. As it can be seen in Table 1, the mountainous areas of the Balkan countries occupy a high percentage of their territory in most cases. Except for Albania, Bulgaria and Serbia the other countries' mountainous areas occupy usually over 30% of land, while at the same time the areas with low to medium heights (200m-600m) are also covering a large territory of each country. So it could be said that the potential for the proposed greenhouse structures is relatively high. The question is if it is also necessary to include such a practice in agricultural production. The answer can be found at the percentage of the land that is characterized as arable in each country. In accordance with Table 1 it will be useful to examine the data concerning the established situation in each country as far as the land utilized for cultivation purposes is concerned. According to the data of the World Bank development indicators (graph of Figure 6 and Table 2), each country utilizes agricultural land in a different rate. The data presented exhibit a potential for considerable expansion of arable areas in the region [21], [22], [23], [24], [25], [26], [27], [28], [29], [30].

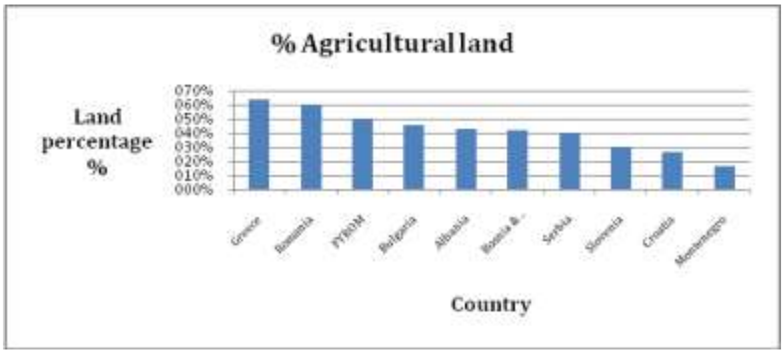

Fig.6 Percentage of each Balkan country's agricultural land

Table 2. Utilization rate of agricultural land for cultivation purposes

Country	Agricultural land % utilization for cultivation
Bulgaria	70.11%
Serbia	69.32%
Romania	63.47%
Croatia	53.89%
Albania	52.26%
Bosnia & Herzegovina	46.67%
FYROM	32.79%
Greece	31.80%
Slovenia	29.96%
Montenegro	3.80%

The percentage of agricultural land which is used for non-cultivation processes ranges, at worst around 30% (Bulgaria, Serbia, Romania) while for the rest countries this percentage ranges from 45%-70%. The country with the lowest percentage of agricultural land utilization for cultivation purposes is Montenegro by 4%. This can be partially explained by the fact that the plains of the country are only 10% of its territory. The interesting point of this comparative examination is that for most of the countries the arable land is close to the percentage of territories with height beneath 200m. That doesn't mean that those areas are the only ones cultivated but it shows a connection between the topography of each country and the final available land for typical agricultural development. Except for each country's potential, for the proposed greenhouse development technique, the legal restrictions that might appear for such an attempt should be examined. It is obvious that the land characterized as agricultural probably won't have any restrictions for such a use as it is currently used for livestock or according to OECD, permanent crop (land that produces crops from woody vegetation, orchardland, vineyards, coffee plantations, rubber plantations, and nut trees) meadows and pastures (land used as pasture and grazed range, natural grasslands, sedge meadows) [31]. So the use of the agricultural land, not characterized arable, is naturally under no restriction and the use for earth sheltered greenhouses relays only at the suitability of the topography of these areas. However earth sheltered greenhouses should be examined as a solution for "creating" agricultural land where previously was impossible. The two cases that must be included in this study are the mountainous areas not characterized as agricultural and the quarries. About the mountainous or hilly areas, that are not currently agricultural, the environmental effect of such activities must be examined A careful examination of each country's legislation about a number of factors affecting the natural environment should be performed- as they might be differences from country to country. In this point, it must be noticed that all the countries which are members of the EU are obliged to follow all the directions indicated at the CAP and all the relevant regulations concerning the environmental protection. The laws, programs and directions included in national laws usually originate by the Union's laws or have included the common directions at the national laws. The national legislation usually includes criteria for de-characterization of forest areas in order to be used for agricultural and other purposes.

Other important laws are the ones including, environmental criteria and terms for any type of activity in order to ensure that the natural environment is protected. The definition concerning which type of land is characterized as agricultural land is also of crucial importance for the realization of the project. Last but not least, laws and regulations defining the protected areas which are of natural, historical or other type of high significance should be taken into account. Those areas should not be considered as possible sites for the implementation of the earth sheltered greenhouse project (National Parks, Nature Reserves, Natural Monuments, Natural parks etc).

3. STATIC STUDY

One of the basic problems to be solved is the stability of the proposed structure. The only issue to be solved compared to a typical greenhouse structure is the stability of the soil at the back wall of the greenhouse (Fig.7). Taking into account that most of the water runoff issues will be solved (details at the next paragraph), the pressure that the soil itself will exercise at the greenhouse's back wall should be calculated (Equation 1) [32].

$$Pa = Ka \times \gamma_{soil} \times h \tag{1}$$

Ka: Active pressure coefficient

γ_{soil}: Soil density (kg/m^3)
h: height of retaining wall (m)

For the determination of the active pressure coefficient the most suitable equation is the Rankine equation. The equation originates from the Coulomb equation. Those two equations are intended for calculation of the lateral earth pressure of retaining walls. Their basic difference are that the Coulomb equation is taking into account more parameters such as the angle of friction between the wall and soil and also the wall slope angle from horizontal level. The Rankine equation is more simplified and it includes only the angle of backfill slope and the angle of the internal friction of the soil [33]. These two parameters are illustrated at Fig.(??? 7). The mathematic form of the equation is shown in Equation 2.

$$Ka=\cos\beta\frac{\cos\beta-\sqrt{\cos^2\beta-\cos^2\varphi}}{\cos\beta+\sqrt{\cos^2\beta-\cos^2\varphi}} \tag{2}$$

β: Angle of backfill slope (^{o})
φ: Angle of internal friction of the backfill soil (^{o})

The angle of friction φ as well as density ρ depends on the soil characteristics. In Table 3 all the required quantities are illustrated for the pressure applied at the wall.

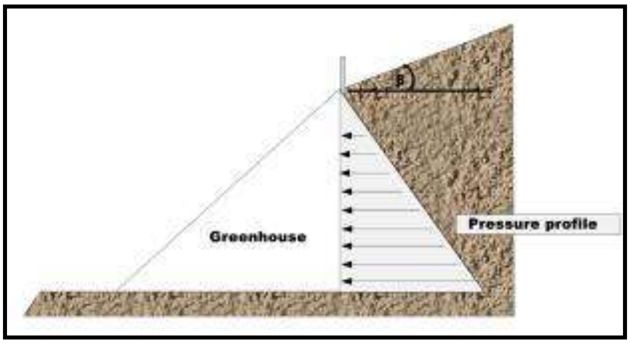

Fig.7 Pressure profile at the back wall of the greenhouse

This seems to be the only crucial point of the structure in terms of static load compression. Quarry case studies will be easy to handle as no motion of the soil is observed when the material is marble or stone. In mountainous or hilly areas though some types of soil are possible to be set in motion, but as far as the back side of the greenhouse is concerned, overlying soil layers' mass-pressure enhance the underlying layers' stability and soil movements might not be intense. However many factors could cause soil instability at the back side of the greenhouse and precaution measures are to be taken. A typical wall construction is observed in most earth sheltered greenhouses. A stone wall might be the most suitable solution. This option could be proved useful for the energy saving of the structure as well. In Table 3 the pressure for a case study which was chosen for this study can be also observed. The height of the back wall was set 3m and an angle β of 10^o was chosen. Of course this can be calculated easily for any given scenario. The reinforcement of the back wall depends on the condition of the hilly mountain or area. If there is motion of the subsoil levels, corresponding support must be applied. Usually in premade structures such actions are not observed.

Table 3 Values of φ and ρ for various types of soil and pressure occurred at the retaining wall [34],[35],[36],[37]

Soil Type	**φ (^{o})**	**ρ (kg/m^3)**	**Pressure (Pa)**
Well graded gravel, sandy gravel	33-40	2250.5	5394.988
Poorly graded gravel, sandy gravel	32-44	2250.5	5344.814
Silty gravels, silty sandy gravels	30-40	1962.5	4753.832
Clayey gravels, clayey sandy gravels	28-35	2131	5283.02
Well graded sands, gravelly sands	33-43	1874.5	4450.477
Poorly graded sands, gravelly sands	30-39	1962.5	4769.126
Soil Type	**φ (^{o})**	**ρ (kg/m^3)**	**Pressure (Pa)**
Medium sand	30-36	1762.5	4324.989
Dense sand	36-41	1762.5	4168.518
Clayey sands	30-40	1762.5	4269.365
Inorganic clays, silty clays, sandy clays of low plasticity	27-41	1818	4436.858
Inorganic clays of high plasticity	17-31	1818	4757.163
Loam	28-32	1280	3204.791
Clay	18-28	1600	4210.703
Peat and other highly organic soils	0-10	400	599.6956
Organic clays of high plasticity	17-35	1649.5	4261.85
Inorganic silts of high plasticity	23-33	1738	4415.129

4. WATER RUNOFF PROBLEM AND POSSIBLE SOLUTIONS

Water runoff control is essential for this case study because it affects structural stability. High precipitation is common in mountainous areas. If water runoff is not controlled by designing a drainage system at the rear side of the greenhouse, the structural stability is jeopardized. Precise estimation and design of a drainage system is complex because many factors are involved in the process. Parameters which define the design of a drainage system are replenishment, soil inclination, soil hydraulic conductivity, number and depth of soil layers and finally the depth of impermeable layers. This complex problem could be reduced in a simple drainage problem of stable flow, which could be solved by the Hooghoudt or the Ernst method. For this study a drawing figure of a suggested drainage system is to be presented along with hints for its application. PVC drainage tubes are to be installed into the rear ground by 2m depth, at the rear side of the greenhouse. In this study 4 drainage tubes of big diameter were chosen (5m spacing in between). In case better drainage is desirable and the replenishment of the area is high, more tubes or even coating materials like coconut fibers could be used. The installation depth is determined according to the depth of the impermeable soil layer or the borderline of soil layers. Drainage tubes are to be installed on top of the layer. Soil profile will be visible when installing the drainage tubes, so it will be easy to distinguish the layers. In case we deal with a sandy soil, drainage tubes are to be put closer to each other in contrast with clay soils or limestone. At the outlet point of the drainage tubes, inlet tubes are to be installed which will receive drainage water and transfer it through a tube sequence under the greenhouse until it reaches outlet point. Drainage tube blocking might be imminent in the long term, so it is suggested that a cap could be adjusted at the inlet tube point through which sufficient water quantity could be applied under pressure to clean the drainage tubes. In order to reduce the drainage system's degree of failure, drainage ditches filled with gravel can be formed underneath the greenhouse (5m spacing in between). The ditches could be formed 10cm under the ground with 20cm width and 10cm height. Outlet point of the ditches could be the same with the outlet tubes. With regard to lowering even more drainage system's degree of failure, a double or triple layer of covering material could be used at the rear side of the greenhouse when constructed and protective metal sheets (approximately 0,5m height aboveground) could be fitted into the upper soil ground to prevent material transfer or surface water runoff.

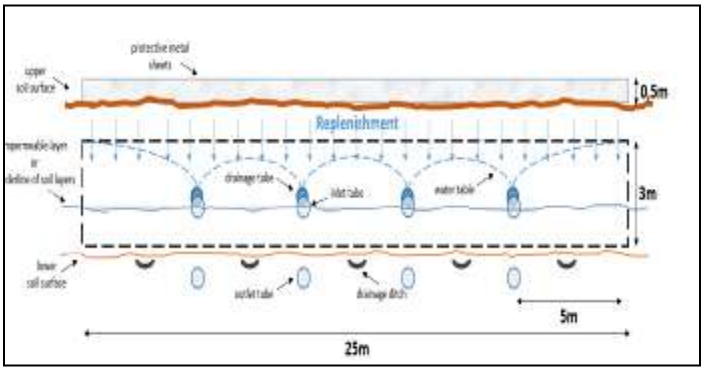

Fig. 8 Front view of the drainage system

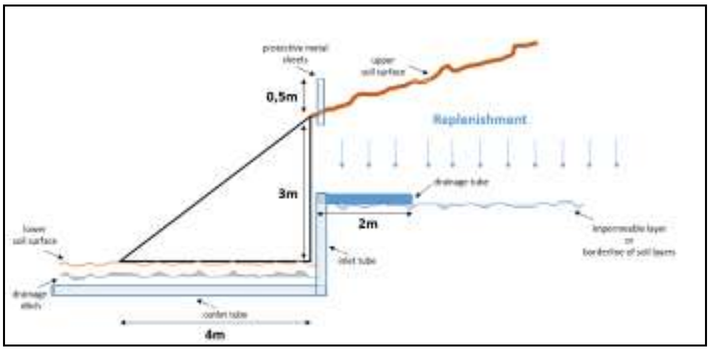

Fig. 9 Side view of the drainage system

4. RESULTS AND CONCLUSIONS

As it seems, food demand will grow the upcoming years. This will lead humanity to find new ways for satisfying this demand. In this first part some crucial points for the realization of such a project were examined. The topography of the Balkan region was found to have a sufficient potential for the application of such projects. It is interesting that this project could be adopted mostly in countries with not much arable land. The selection of the available land for the realization of such a project should be done according to topographical criteria and possible legal restrictions. In the evaluation process for available land, these restrictions (environmental, historical or other) should be taken into account. For the static study, the back wall of the structure is receiving the highest pressure load. In order to evaluate this load and decide whether support is needed the pressure must be calculated. The pressure equation is leading to the most reliable results. In most greenhouses already constructed under this rationale no special support is used and the retaining wall is reinforced with stones. A major problem for such a structure might occur by the water runoff that takes place at mountains or hills due to meteorological phenomena. A smart tube network is proposed in order to lead water runoff loading beneath the greenhouse. That way, two major problems are solved one of them concerning the extra pressure that might be exercised to the back wall because of the weight the water is adding and another one concerning any water entering the internal area of the greenhouse. So if the project is initially planned as presented above, its realization is possible to any country of the Balkan region. It must be noticed that a most thorough analysis of region legislation, soil and climatic conditions is necessary for the successful implementation of the project.

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CONDITION OF THE HORIZONTAL BOOM SPRAYERS IN PART OF THE MEDITERRANEAN REGION IN THE REPUBLIC OF MACEDONIA

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Abstract. *The Directive 2009/128/EC of the European Parliament establishes a framework for the implementation of National Action Plan referring to the sustainable use of pesticides in every member country. One of the areas covered by the Directive relates directly to the introduction of mandatory monitoring and inspection of pesticide application equipment. Considering that the Republic of Macedonia does not have a compulsory inspection, and as an EU candidate member country, is bound to harmonize its regulations, the basic aim of this research is to determine the current condition of the horizontal boom sprayers. The survey was conducted in a part of the Mediterranean region in the Republic of Macedonia, i.e. the municipality of Sveti Nikole and Stip. In this research 43 machines were visually and operationally checked. The results of this research will be a good basis for further research and implementation of mandatory inspection of these machines in the Republic of Macedonia.*

Key words: *plant protection, pesticides, inspection, visual flows, sprayers*

1. INTRODUCTION

The overuse and misuse of pesticides pose a threat to the environment and health hazards for the farmers in the agricultural production. Pesticide residues in food affect directly the health of consumers and the increasing number of people suffering from pesticide contamination. In addition, exporters of food must comply with the standards on the minimum allowed presence of residues in processed foods, fresh fruits and vegetables. The non-compliance with these standards can have catastrophic effect on the increasing of export, which is one of the primary economic objectives of our country.

With the new law on plant protection, the agricultural policy of our country pays special attention to the protection of agricultural land from pollution and to the principles of environmental protection. The law deals with the economic, health, environmental and social role of agriculture and establishes the principle of agricultural policy measures that are to be aimed at encouraging sustainable agricultural activities. The measures are aimed at maintaining the diversity of animal and plant species, conservation of soil and of its fertility and protection of natural conditions necessary for life in soil, water and air.

However, the outdated machines in Macedonia [5], worn and poorly maintained machinery and pesticide application equipment cause directly the increased number of treatments, poor protection and uncontrolled spread of diseases and pests in the agricultural production.

One of the areas covered by the *Directive 2009/128/EC* relates directly to the introduction of mandatory monitoring and inspection of pesticide application equipment [2], [5], [6], [7], [8], [9]. Considering that in the Republic of Macedonia the inspection is not mandatory, and as a country candidate it is bound to harmonize its regulations, the main goal of this research is to determine the current condition of the pesticide application equipment. The results are a good basis for further research and an opportunity to apply standardized procedures for mandatory inspection of machinery for pesticide application.

In the Republic of Macedonia at the end of 2014 began a process of harmonization of the old law for plants protection with new rules and regulations required by the European Commission. The new rules and regulations, inter alia, pay special attention to the pesticides application equipment and to their mandatory inspection at specific time intervals.

Because of that, within the Phytosanitary Administration are established committees whose objective is to work on alignment of the law and on collecting experiences from other member states of the European Union that have undergone this process or are at an advanced stage. This year in collaboration with the Phytosanitary Administration were organized several meetings with farmers, with the distributors of pesticides as well as with economic operators who sell machines for pesticide application. The goal is to consider all aspects for optimizing the new laws and regulations, and in terms of machinery for pesticide application, establishment of monitoring and rapid onset of inspections.

2. MATERIAL AND METHODS

The research was conducted in the eastern part of the Mediterranean region of the Republic of Macedonia embracing the several villages of the municipalities Sveti Nikole and Stip. The instrument used during the field research was the questionnaire including data divided into three groups:

a) General information about the owner,

b) General information on the (*PAE*) pesticide application equipment,

c) Visual and operational flaws of the horizontal boom sprayers.

3. RESULTS AND DISCUSSION

Mediterranean region in Macedonia is one of the major agricultural regions in the Republic of Macedonia, where crops, vine crops, fruits and vegetable are grown. In the several villages of the municipalities Sveti Nikole and Štip, where the research was conducted crops are prevalent and recently, new vineyards and orchards are renewed and raised.

The objective of this research is to determine the current condition of the horizontal boom sprayers and to learn how many of them correspond to the requirements of the *European Standard EN 13790* and the new *EN ISO 16122*, which relate directly to the inspection of machinery and equipment for application of pesticides.

Table 1 provides general information about farmers who own equipment for application of pesticides. According to the data in the table it can be concluded that most of the farmers 25 (44.64%) are not registered and most farmers have secondary education (69.64%).

The fact that all surveyed farmers have not attended any training on quality and on handling PAE (pesticide application equipment) is worrying. This means that these machines are used according to their personal experience or according to the experience of their relatives and friends which is often misleading and unsafe. In this part of the municipality, the most common are field crops.

Tab. 1. General data on farmers and agricultural surfaces

Total number of interviewed person	Registered farmers			Education of the farmer/manager			Attendance on trainings for PAE	
	Yes	No	Enterprise	Primary	Secondary	High	Yes	No
56	22	**25**	13	9	**39**	8	/	**56**
%	**39,29**	**44,64**	**23,21**	**16,07**	**69,64**	**14,29**	**0**	**100**

Tab. 2 shows machines for application of pesticides that are most common in the eastern Mediterranean region. According to the data we can conclude that *Aromehanika Kranj* 36 (42.86%) is the most common brand of machines for application of pesticides. The fact that these machines are old, frequently between 10-20 years (15 or 17.86%) and 24 over 20 years (28.57%) is worrying. If these machines are not properly maintained and used, they can be major contributors to increased pollution of the environment. As a result of the aid and subsidies that farmers receive for the purchase of new machinery in the last 7-8 years we have notices an increased number of new machinery for pesticide application - 28 machines (33.33%).

Tab. 2. General information on PAE in part of the Mediterranean region

Pesticide application equipment								
	Brand	Number of machines	Age				Functioning properly	Malfunctioning
			0 -5	5 -10	10 -20	> 20		
1.	Morava	20	2	3	3	12	16	4
2.	Agromehanika Kranj	**36**	15	10	6	5	36	/
3.	Mitterer	4	/	/	1	3	4	/
4.	Metalbraneks prokuplje	2	1	1	/	/	2	/
5.	Sprayer	1	1	/	/	/	1	/
6.	Sampo 20	1	/	/	1	/	1	/
7.	Leško	4	1	1	2	/	4	/
8.	SVL aseta	1	/	/	/	1	1	/
9	Agrin	1	1	/	/	/	1	/
10	Agrimir Vistula	1	/	/	/	1	1	/
11	Agroproizvodzac	1	/	/	1	/	1	/
12	TCM	1	/	/	/	1	1	/
13	Evrotech	1	/	/	1	/	1	/
14	Agron Nis	7	7	/	/	/	7	/
15	Fisher	1	/	/	/	1	1	/
16	Vrecek Kranj	1	/	1	/	/	1	/
17	Atomizatori	1	/	/	/	1	1	/
Total		**84**	**28**	**16**	**15**	**24**	**80**	**4**
%		100	33,33	19,05	17,86	28,57	95,24	4,76

Table 3 shows only the number of the horizontal boom sprayers by way of hitching to the tractor. According to the table the most common are carried horizontal boom sprayers for application of pesticides for agricultural crops - 41 (95,35%).

The survey of the pesticide application equipment included the determination of visual and operational flaws of the machines. The flaws of the machines were determined and are presented in Tables 4 and 5.

Tab. 3. Data on PAE in part of the Mediterranean region

Way of hitching	Carried	Trailered
Types of PAE	Horizontal boom sprayers	Horizontal boom sprayers
Total (84)	**41**	**2**
%	**95,35**	**4,65**

According to the data in the table 4 it can be noted that upon the visual inspection of the machines most defects and modifications are present in the machine's hoses. The hoses were often changed with not original parts.

Tab. 4. Visual flaws of horizontal boom sprayers in part of the Mediterranean region

Parts of the machine	Horizontal boom sprayers		Total
	No parts	Modifications	
Chassis	/	7	7
Hitching device	/	1	1
Power take-off	/	0	0
Wheels / pneumatic tires	1	/	1
Tank	1	8	8
Agitator	/	/	0
Pump	/	2	2
Filters	4	/	4
Command valve	/	7	7
Pressure gauge	3	/	3
Hoses	/	12	12
Sprayer boom	/	5	**5**
Nozzles	1	2	3
Total number of visual flaws	**10**	**44**	**54**
%	18,18	81,82	**100**

Tab.5. Operating flaws of horizontal boom sprayers in part of the Mediterranean region

Parts of the machine	Current state of the parts of the machines				
	Functioning properly	Malfunctioning	Functioning properly with modification /leaking	No parts	Total number of machines with operating flaws
Chassis	36	0	7	0	7
Hitching device	42	0	1	0	1
Power take off	43	0	0	0	0
Wheels/ Tires	1	0	0	1	1
Tank	36	0	6	1	7
Agitator	43	0	0	0	0
Pump	37	1	5	0	6
Filters	39	0	0	4	4
Command valve	36	0	7	0	7
Pressure gauge	32	8	0	3	11
Hoses	31	4	8	0	12
Sprayer boom	35	1	7	0	8
Nozzles	33	2	7	1	10

Analyzing the current state of horizontal boom sprayers it can be concluded that the most common malfunction in machines is determined in the hoses – 12 machines. The great pressure and the quality of hoses affect directly the length of their use and the need for replacement. The second common malfunction was pressure gauge – 11 machines, and three machines did not have any pressure gauge at all (Table 5). It should be noted that this instrument directly shows the operating pressure in the system and is one of the main control tools for proper and quality application of pesticides

During the conversation with the farmers about their experience the most common defects and problems encountered when using these machines were discussed. According to the results of the research it can be concluded that most defects occur in the hoses 18 (33, 33%) and pump 15 (27, 78%) of the pesticide application equipment from the total number of defects (54). A smaller number of defects are observed on nozzles (7), and on sprayer boom and filters (4).

4.CONCLUSIONS

Unfortunately, according to the first results, we can conclude that a large number of controlled machines can not meet the requirements of *European Standard EN 13790* and the new *EN ISO 16122*. All surveyed machines have only one tank and many of them have modifications that are not in accordance with the above mentioned standards.

According to the survey results it can be concluded that the number of registered and non-registered farmers is almost the same and most of the farmers have secondary education. The fact that all surveyed farmers have not attended any training on quality and safe handling of these machines is worrying.

The most represented brand of pesticide application machine is *Agromehanika Kranj*. Many of these machines are 15-20 years old and even more than 20 years old. If they are not properly maintained and used, they can be major contributors for the increased pollution of the environment.

The visual inspection of the machines showed that most common malfunction in machines is determined in the hoses. The great pressure and the quality of hoses affect directly the length of their use and the need for replacement. The second common malfunction was pressure gauge – 11 machines, and three machines did not have any pressure gauge at all.

Analyzing the current state of the functioning of the pesticide application equipment, it can be concluded that the most common malfunction in machines is in the hoses and pressure gauge. The great pressure and the quality of hoses affect directly the length of their life and the need for replacement.

During the conversation with the farmers they declared that from their extensive experience most failures occur in the hoses and pumps of pesticide application equipment. All farmers, owners of these machines have said that they would like to expand their knowledge by attending training for proper and safe exploitation.

In the Republic of Macedonia there is no compulsory inspection of pesticide application equipment. But as a candidate country, Macedonia is bound to apply and harmonize its laws and standards with the European Union laws and standards. The introduction of mandatory inspection, as well as other laws regarding the proper use and handling of waste pesticides affect directly the protection of the environment and human health.

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PHYTOECOLOGICAL CONDITIONS OF „БАЖБАН“ AND „КЫРГАН“ SAND MASSIFS OF WEST-KAZAKHSTAN AREA

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Abstrct: *The work shows results of phytoecological assessment of degraded pastures in the West-Kazakhstan region, assessed via method of satellite recording and terrain studies decoding. Research and mapping of sand massifs has been conducted based on the comparative analysis of satellite recordings and terrestrial terrain recordings of landscape-ecological profiles. Developed landscape-ecological maps and profiles will enable better organisation of pasture rotation on the degraded areas, and the same can be used for environmental protection and preservation of pastures, by providing information to small households in what way to use the pastures the most effectively, in order not to endanger the ecosystem.*

Key words: *sand massif, satellite recording, decoding, pasture, landscape-ecological profile.*

1. INTRODUCTION

In comparison to the other regions of the Republic of Kazakhstan, West-Kazakhstan area (WKA) has the most developed agricultural production, i.e. forage production from the pastures. WKA presents the vast area of 151.2 thousand km^2, out of which the major part is used for the pastures, and 20.8 thousand km^2 out of it pertains to the Jangal district.

The Jangal district is situated in the southern part of the region and it is mostly used for livestock pasturing [1]. Sand massifs “Бажбан” and " Кырган" are situated within this WK area, 3-4 km south from the village Saralzhin. These present wavy planes with the old and new centres of deflation-depression in concentric shape. Characteristic parameters of these sand massifs have been significantly supplemented at the end of XX century and have been directly connected to the research work of the academic Kulik [4]. Kulik ascribes the concentric form of depression centres in the north-eastern part of Volga-Urals sand pits to the effect of winds being constant ones in that area.

Numerous environmental problems have appeared in this territory in the past 30 years, amongst which land degradation has become the most important one. In many regional areas, ecosystem state has grown into an ecological catastrophe, so in certain villages the roads, cattle-keeping objects and even houses have been covered with sand. Pasture vegetation is becoming extremely deficient on annual basis; biodiversity has been reduced, as well as biomass yield. Therefore, there is a need to create the conditions for revitalisation and preservation of natural grasslands and to prevent further degrading of the pastures in the region. Pasture rotation is a possible solution for stated problems.

2. MATERIAL AND METHODS

In the wide world practice term "remote sensing" has spread, meaning the noncontact study of Earth, its surface and bowels of the earth, separate objects and phenomena, by registration and analysis of their own or by them reflected electromagnetic radiation. Among the variety of the distance controlled methods, the special place occupies the space pictures [10]. Currently, space pictures are used for the decision on many questions related to the phytoecological estimation of territories. Giving the description of territories, space pictures are decoded by certain signs, such as tone, color, size, texture, picture, shade, location, connection with other elements [9].

Sand pit surveys have always had the goal to define landscape components and determine pasture ecosystem degradation stadium. Landscape-ecological profiles have been preserved in the sand pits. Decoding was conducted on the space picture of Quick Bird 2013 year of 1: 50 000 scale. Application of space picture allowed defining the hearths of deflation. This is one of the main methods of Polish surveys where research results of the land terrain mapping are converted into maps which assess pasture profiles [3. 4, 5, 11]. Complex profile presents a spatial relation of all landscape components, expressed in both vertical and horizontal planes, with their characteristics included. Depending on the landscape complexity, one or two profiles are opened. Profile lines are marked in advance on the satellite recordings, and then these are being adjusted on the field, by comparison with the maps [5].

Profile dimensions depend on the scales of measurement and mapping subject. It is important that the profile characterises every natural complex in its specific typical manifestation [5, 6].

The profile presents a straight line, which curvature shall not exceed 15^0. Points of complex surveillances and contour borders have been marked on the satellite recording. All the characteristic forms of micro and mesorelief, soil borders and geobotanical contours have been marked with points and zones.

Geobotanical contours differ in the process of making landscape-ecological profiles [8, 5]. The base for contour isolation is homogeneity of the following features:

- ecological conditions (relief, soil, humidity);

- vegetation composition, considering dominant vegetation species.

Geobotanical contours are split into homogenous and complex one. Homogenous contour is of the same type, while the complex one combines several types. Vegetation description is carried out at the location of 100 m^2 surface area.

The following actions are being performed on geobotanical locations [14]:

- short vegetation description indicating the dominant vegetation, as well as the description of sort of economic importance;

- the definition of generally projected pasture coverage via geobotanical network;

- the analysis of biomass characteristics due to determination of pasture productivity.

Dominant congregations are determined during work on the landscape-ecological profile on the projected points, as well as the number of dominant and subdominant species, total projected coverage, yield of the dry mass and degradation level of the vegetation cover.

Quantitative relation of species has been described with “Drude“ scale, having 6 gradations: Soc. – plants are growing in continuity (soil coverage is continuous), closing their over-ground parts; Sor.3 – plants can be found in vast number; Sor.2 - plants can be found in severe number; Sor.1 - plants can be found in significant number; Sp. –species rich in varieties, but soil coverage is not continuous; Sol. – the species grows sporadically-scattered (soil coverage is very low); Un. – the species can be found only as individual specimen [14]. The scale of Drude determines a quantity and project coverage of vegetation by means of visual inspection in points with the use of approximate size of project coverage in percents. In our researches the scale of Drude helps in defining the change of project coverage from the remoteness of stock-raising points.

3. Results and discussion

During this research work, the following landscape-ecological map of sand massifs has been created, with the massifs being split - classified per level of vegetation coverage over non-covered, and slightly and middle covered parts (Figure 1).

Landscape-ecological AB profile has been set on the southern edge of «Бажбан» tract, in the length of 1.8 km (Figure 2). Geobotanical description of AB profile has been presented in the Table 1.

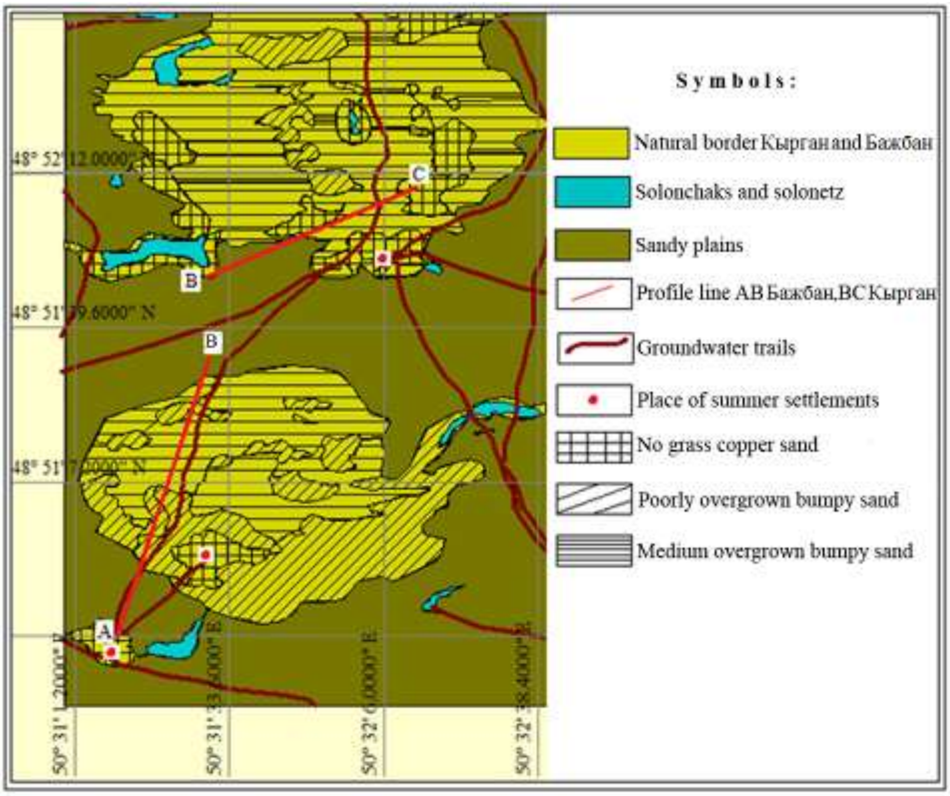
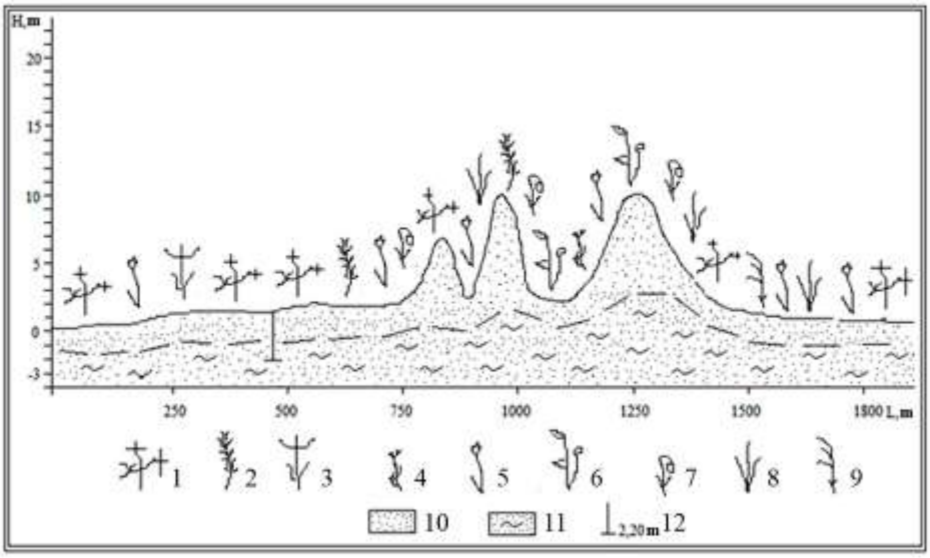


Fig.1. Landscape-ecological map of «Бажбан» and «Кырган» sand pits

(1:100000 scale range)

The profile starts in an uninhabited zone with coordinates 48°50′34″ N and 50°31′10.5″ E. At 220 m from the profile beginning, an uncovered sandy surface without grass starts, where the underground water is at the depth of 2.2 m. Vegetation congregation comprises wheatgrass *(Agropyron)* and absinthe wormwood *(Artemisia incana)* in the zone of up to 1.5 km from the profile beginning, and then congregations of common wormwood (*Artemisia)* and camelthorn *(Alhagi pseudalhagi)* become mostly predominant. Vegetative sand pit coverage goes up to 50%. In the selected zones, sporadic appearances of astragal *(Astragalus)*, periwig *(Anisantha)*, alyssum *(Alyssum)*, wheatgrass *(Agropyron)*, saltbush *(Atriplex)*, Prangos odontalgica (*Prangos odontalgica)*, ceratokarpus (*Ceratocarpus)* and strawflower (*Helichrysum arenarium*) can be noticed. Besides mentioned, mammoth wild rye *(Leymus racemosus)* is significantly present on the elevations and depressions. Slope is present as the profile beginning, and yield of the dry mass in this area is 1350 kg/ha.



1 - Artemisia
2 - Leymus racemosus
3 – Euphorbiaceae
4 – Anisantha
5 – Agropyron
6 – Astragalus
7 – Ceratocarpus
8 - Poabulbosa L
9 - Festúca valesiáca
10 - Sand
11 - Sandy loam
12 - Depth of groundwater

Fig. 2. Landscape-ecological profile (AB) of the representative «Бажбан» massif part

Soil profile of the representative «Бажбан» massif part is presented on the figure 3. Profile coordinates are 48°50′34″ N and 50°31′10.5″ S; relief is the plane. Vegetation mass comprises: absinthe wormwood *(Artemisia incana)*, couch grass *(Agropyron)* and sedge *(Carex)*. Soil is of light chestnut brown colour, incompletely formed, sub-sandy (Sandy loam).

Morphological description

Horizon A is from 0 to 3 cm, of light chestnut brown colour, sub-sandy, dry, lax; transfer edge towards horizon C is relatively even; it is pervaded with plant roots and humus content is 0.27 %.

Horizon C is from 5 cm and deeper; sand is cohesive; pervaded with plant roots up to 35 cm and humus content is 0.20 %.

Fig. 3. Soil profile of the representative «Бажбан» massif part

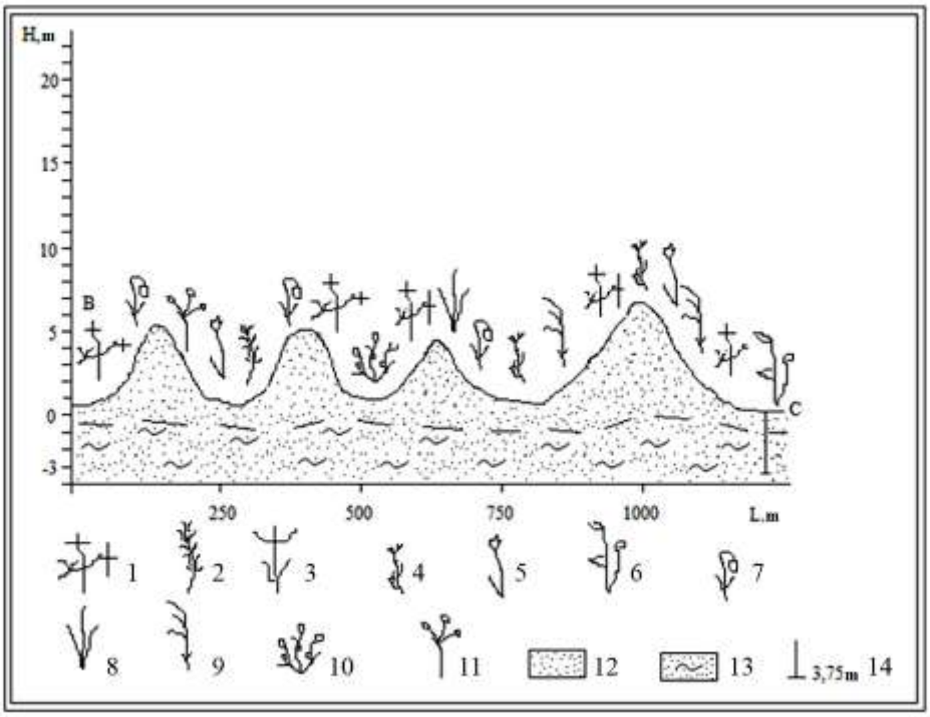
(photo of Есмагулова Б. Ж., June 2015)

Table 1. Geobotanical description of «Бажбан» AB profile

Sample No	1	2	3	4	5	6	7	8	9	10	11	12
Projected coverage %	20	20	10	20	25	15	20	50	50	10	20	20
No of species	7	5	7	6	6	4	3	6	4	7	6	4
Sort	Concentration according to the "Drude" scale											
Astragalus			Un.		Un.				Un.			
Anisantha tectorum				Un.								
Alyssum desertorum	Un.								Un.	Un.		
Agropyron	Sp.		Un.	Un.	Un.	Un.			Un.		Un.	Un.
Atriplex	Un.											
Poa bulbosa	Un.	Un.	Un.	Un.		Un.	Sol.			Un.	Un.	Un
Euphorbia agraria	Un.	Sp.								Un.		
Leymus racemosus			Sol.	Sol.	Sol.				Un.			
Artemisia austriaca							Sol.					Sp.
Artemisia incana	Sp.	Sp.	Sol.	Sp.	Sp.	Sol.	Sp.			Sp.	Sp.	Sp.
Artemisia arenaria								Sol.			Un.	
Festúca valesiáca										Un.	Sol.	
Achillea millefolium										Un.	Un.	
Anisantha tectorum												
Prangos odontalgica	Un.	Un.	Un.	Un.	Un.							
Ceratocarpus arenarius						Un.				Sol.		
Helichrysum arenarium		Un.										

The following BC profile starts from the „Кырган“ tract (natural border) and from the point with coordinates being 48°50′49.5″ N and 50°31′28″ E. (Figure 4).

Geobotanical profile description is given in the Table 2.



1 - Artemisia
2 - Leymus racemosus
3 – Euphorbiaceae
4 – Anisantha
5 - Agropyron
6 - Astragalus
7 - Ceratocarpus
8 - Poabulbosa L
9 - Festúca valesiáca
10 -Tamarix
11 - Elytrigia- Agropyron
12 - Sand
13 - Sandy loam
14 - Depth of groundwater

Fig. 4. Landscape-ecological profile (BC) of the representative «Кырган» massif part

Congregation of absinthe wormwood *(Artemisia incana)* mostly predominates at the major part of this profile’s surface. Individual species which can be found here are periwig *(Anisantha),* bulbous meadow-grass (*Poa bulbosa*), spurge *(Euphorbia),* sedge *(Carex)* and *Ceratocarpus.* At the profile beginning, *Halocnemum strobilaceum* can be also found. In the southern part of the sand massif, small-flower tamarisk population can be seen *(Tamarix parviflora*). Vegetation coverage of the sand plane is up to 50 %. Minimally projected vegetation mass coverage is in the zone of summer settlements and wells, where underground water is at the depth of 3.75 m.

Table 2. Geobotanical description of «Кырган» BC profile

Sample No	1	2	3	4	5	6	7	8	9	10
Projected coverage %	40	35	35	50	25	20	20	7	7	5
No of species	5	5	5	5	3	6	4	3	3	7
Sort	Concentration according to the “Drude“ scale									
Anisantha tectorum							Un.			Un.
Alýssum desertórum	Un.	Sol.		Un.		Un.				Un.
Calligonum aphyllum						Un.				
Agropyron	Sol.		Un.	Un.	Un.	Un.		Un.	Un.	Un.
Atriplex	Un.			Un.		Un.				
Poa bulbosa			Un.							Un.
Euphorbia agraria			Un.							Un.
Cárex			Un.							
Artemisia incana	Sp.	Sp.	Sp.	Sp.	Sp.	Sp.	Sp.	Sol.	Sol.	Sol.
Agropyron répens		Sol.								
ceum		Un.								
Festúca valesiáca							Sol.	Un.	Un.	Un.
Achilléa millefólium							Un.			
Ceratocarpus arenarius	Sol.	Sol.		Sol.	Un.	Un.				

According to the results of realised surveys, projected coverage of the sand plane is in the interval from 25 to 50 %.

Thus, equation (1) of project coverage dependence from distance to summer settlements on the key area of "Кырган" looks like :

$$OPP = 0{,}006 \times L^{1{,}1} \qquad (1)$$

$$R^2=0{,}84; \quad 200<L<1500,$$

where OPP is common project coverage, %;

L - is distance from cattle-keeping objects, m;

R^2 - is a coefficient of determination.

The analysis of change of project coverage regarding the distance from summer settlements on the key area of Кырган (tab. 2) showed that some "critical" distance is - an about 1.5 kilometer from a cattle-keeping objects where project coverage arrives at 20 to 50%. On the whole, territory, in the area close to the summer settlements (to 200 m) the productivity is 3.5-10.0 times below to the area that is 1.5 kilometer further away. And in the key area of Бажбан such sharp change in project coverage is not observed, because summer settlements being in a key area are not used in an economy.

Having regard to that, proper pasture exploitation is of utter importance. Following research studies of Larin and Harin [7, 12], adequate exploitation of pastures improves fodder base and yield increase of the grass mass.

In order to preserve the pastures in the good natural state on the «Бажбан» and «Кырган» sand pits and following the surveys [8, 13], recommendation is to subdue 438 ha to the rotation, so that spring exploitation season is to be exchanged with a winter one and summer season with an autumn one (Table 3).

Table 3. Recommendation of pasture rotation in «Кырган» and «Бажбан» sand pits

Exploitation year	Pasture parts			
	1	2	3	4
1	Spring	Winter	Summer	Autumn
2	Spring	Winter	Summer	Autumn
3	Winter	Spring	Autumn	Summer
4	Winter	Spring	Autumn	Summer

The most appropriate pasture exploitation system in terms of organisation and management, presents the use of one part of the pasture in the spring-winter season and the other part during summer and autumn, and to make rotation after 2 to 3 years. According to this exploitation system, shelters and barns would be built solely on spring and winter pastures, since these infrastructures are quite the expensive ones. Spring shelters would be used for lambing season and for keeping cattle away from low temperatures in the winter. There is no need for expensive and permanent objects in the summer and only cheap prefabricated objects are needed in the autumn for cattle insemination. Such a system of pasture rotation will help in natural vegetation preservation, productivity increase and pasture degradation prevention. Mentioned pasture exploitation increases the amount of consumed grass mass and records the most efficient grass growth, which increases productivity of pastures in question by 15-20% and more [4].

4. CONCLUSIONS

Ecological landscape map and geobotanical sand pit profile has been made on the basis of satellite photos and terrain studies. By the implementation of survey results, ecological conditions of degraded pastures may be improved and rotation of pastures is recommended for this, as a kind of an exploitation. Suggested technology has given good results from the very beginning and the additional improvements are expected in the longer perspective, mostly in terms of grass mass yield and soil preservation.

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THEORETICAL CALCULATION AND DESIGN OF A WATER ASSISTED EARTH TO AIR HEAT EXCHANGER FOR GREENHOUSE COOLING

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Abstract: *Greenhouse internal conditions must remain on certain levels in order to ensure that the crop will be developed properly. For this purpose several commercial systems are used for heating and cooling purposes. The most common cooling system used is the fan and pad system which is based on evaporation cooling. This method has relatively good results but in extreme hot conditions it might increase the humidity ratio within the structure in levels that might harm the crop. In this study an improved version of the earth to air heat exchanger is presented. In particular the system which has been studied for urban buildings and applications is adjusted to greenhouses. In order to enhance the cooling capacity of the system a second heat exchange process is taking place between the circulated air and drilling water. The methods of defining all the parameters that affect the internal climate such as temperature, humidity, air velocity etc are presented in this study, as well as, the technical elements required to do so. Also the system is illustrated in detailed drawings. For the scope of the study, the system's theoretical performance is compared with other systems' performance.*

Key words: *greenhouse, cooling, heat exchanger, resource management*

1. INTRODUCTION

Greenhouse crop development demands specific environmental conditions. In particular temperature, humidity, light and air quality should remain at certain levels in order to achieve the optimum production rates. Greenhouse crops in the Mediterranean are relatively easy to be developed. In countries like Greece, Italy, Spain, and Turkey or in regions like Northern Africa or the Adriatic coast,climatic conditions during the winter are allowing greenhouse crop development without high energy costs for heating. However, greenhouse producers in these regions are facing the issue of extensive periods with high temperatures during the summer when greenhouse crop isn't possible to develop [1]. In Greece for example, the mean cultivation period is estimated between 5-6 months [2]. The same situation is also reported in Morocco where the cultivation period usually lasts from October to March [3]. In Almeria- Spain it is reported that in greenhouses with modern climate systems the cultivation period can be divided in two periods- one between October and the end of winter (5 months) and one, shorter, from April to June (2-3 months). Still during the summer the greenhouses are not operating and in structures which stand in a lower technological level the cultivation period isn't that long. That way the profit loss might be sufficient and the investment in a greenhouse crop not feasible. So a major concern for producers and greenhouse designers is how to extend the cultivation periods in the more feasible way. That can be assisted by the use of cooling methods and systems.

The most common greenhouse cooling techniques which operate with relative efficiency are natural ventilation, evaporative cooling and shading. These methods are already fully developed commercially and have advantages and disadvantages. Natural ventilation occurs due to some basic principles, the pressure difference which is created by wind and temperature gradient formed between the internal and external greenhouse environment and the buoyancy effect [4]. The buoyancy effect (warm, moist air rising) is leading to better results during the winter when the temperature difference between the external and internal environment is sufficient. In the contrary, when the temperature difference is close to 5-10^{o}C the buoyancy effect is insignificant [4]. As a consequence, such methods are more suitable during colder months when cooling needs are not that high. Natural ventilation may not be suitable for very intense climatic conditions but has the advantage of the construction simplicity and the low operation costs and it also serves the ventilation needs of the structure (humidity and air quality control). On the other hand there is evaporation cooling which is basically realized with the assistance of a fan and pad system or a fog system. The fan and pad system is consisted of exhaust fans which are used to pull air through cooling pads in which water is circulating. This technique is based on the evaporation phenomenon which leads to cooling of the air in the corresponding environment [5]. These systems can lead to a temperature even 15^{o}C lower than the external air temperature during their operation. However, this temperature drop is accompanied with an increase on the relative humidity in the internal greenhouse environment. As relative humidity is increasing the cooling potential is lowering. Moreover these systems are requiring energy and water consumption to operate. Last but not least, shading is a passive method for greenhouse cooling. The shading of a greenhouse is aiming to reduce the solar radiation entering the greenhouse in order to minimize the heat gains. This can be succeeded by special manufactured nets placed on the sides of the greenhouses that are mostly exposed to solar radiation. Another technique is by painting the greenhouse covering with colors that faint after a period of time (usually they last as long as the warm periods or they are washable). Shading is an effective method to prevent a percentage of the solar radiation entering the structure but it cannot stand alone as a cooling technique. More than this- it prevents useful solar light to enter the structure. That way the plant development is affected negatively. Many recent research works have been conducted in the up mentioned concepts in order to optimize their operation or minimize some disadvantages they appear, as energy consumption, water consumption etc [6], [7], [8], [9]. Except those techniques some active systems already used in urban applications are also tried as solutions in greenhouses such as heat pumps [10], [11], [12]. Heat pumps can lead to significant temperature drop but the issues that has to be challenged are the cooling distribution (chilled air is not good for plants, as well as high distribution speeds), the high initial cost and the higher energy consumption compared to the pre mentioned systems (even as for urban application is considered a low operation cost system for agricultural purposes the cost is considerable). Part of the research today is focusing on the development of new systems and techniques to support the already developed ones or eliminate the disadvantages they appear. One system already studied is the earth to air heat exchanger. This system is based on the idea of sending hot outdoor into buried pipes or tube in the ground. Heat transfer is taking place between the air and the ground when flowing into the pipes. This way the temperature of the air drops after it has flown through the pipe or tube (Fig.1).

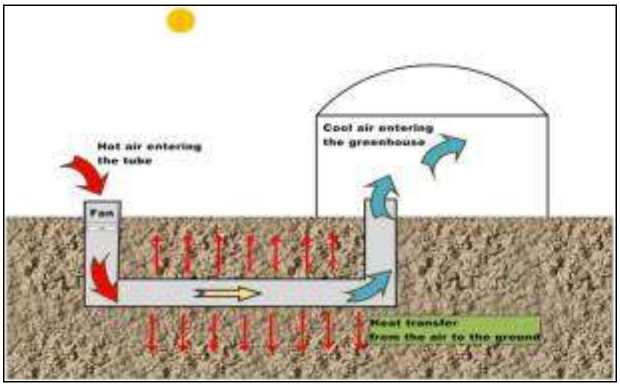

Fig1. Earth to air heat exchanger schematic design

In the study of M.K. Ghosal et al., (2004), an earth to air heat exchanger system was evaluated via modeling study. It was found that for the climatic conditions of New Delhi India, a drop of temperature about 3-4^{o}C can be achieved by the integration of such a system at a Greenhouse [13]. The heat exchanger had a length of 39 m and diameter 6 cm while the blower's capacity was 372.5W and a flow rate 100000 m^3/ h. In an experimental study in Thailand by S. Mongkon et al., (2013) an earth to air heat exchanger was installed in 1 m depth of the ground surface. The air was distributed inside the greenhouse via a centrifugal blower inside the greenhouse. During the afternoon hours of summer period, when the climatic conditions are the roughest possible, the system could drop the temperature in the worst case scenario about 1-7^{o}C [14]. In that study the earth to air heat exchanger had a 38.5 m length and buried in 1m depth. The blower was operating in a supply of 216000m^3/h. In a study by Ozgener et al., (2011) the thermal resistance of the earth tube buried in the ground was predicted experimentally. The system was indented to be used for greenhouse cooling. For the scope of this study the pipe with a diameter of 56 cm and a length of 47 m was buried at 3 m depth. For the movement of the air a blower with 736 W power capacity and 5300m^3/h volumetric flow rate was adjusted to the pipeline. Some interesting results came out of this research as the fact that a temperature difference of 1-5^{o}C between the inlet an outlet air of the tube could be almost achieved, as well as, that the mean thermal resistance of the tube in steady state conditions was estimated around 0.021 K m/W [15]. All the above studies have exploited the lower ground temperature in order to succeed heat transfer from the air to the ground. In the present study it is going to be examined if the adjustment of a second tube inside the ground heat exchanger could enhance the air cooling process and what are the characteristics that should concentrate in order to do so. In this second internal tube, water from a drill will be circulating. As a result it is expected to provide further cooling to the external air entering the greenhouse structure. It is the first time that such an approach is evaluated and it is considered of great interest as it easy to be installed and it can contribute to the cooling issue in an economic and environmental friendly way.

2. INITIAL DESIGN AND ASSUMPTIONS

The case scenario that will be examined will be a greenhouse area of $70m^2$. The method that will be used in order to calculate the parameters of the system will be the following.

1. The system will operate as a simple earth to air heat exchanger at the first phase for a specific period of time. It will assumed that after a period of time the air temperature difference between the inlet and outlet of the tube will be constant in levels of previous research works

2. When this temperature difference is formed the water circulation will begin.

3. The heat that will be absorbed by the water will be determined by the extra temperature difference that must be realized in the air tube. That way the heat absorbed by the water pipe via convection will be defined.

4. Taken the heat amount that the water is absorbing as granted, the parameters of the heat convection problem can be defined. In particular, as the water specific heat (cp) and water inlet (Ti) are defined, the parameters that will be examined as variables are the length of the pipe, the diameter of the pipe, the material of the pipe and the water flow. Water outlet temperature will be assumed in various values.

5. For the scope of the study the parallel flow heat exchangers will be used, as well as, the internal flow heat transfer with convection

6. The more realistic approach will be proposed

In Fig 2 and 3 the parts of the system are schematically illustrated. The final geometrical features of the tube, as well as, the operational parameters (flow rate etc) will be chosen after the calculations and a try and error procedure. This approach will lead to the optimum design of the system as a solution for cooling a greenhouse structure. In Fig.2 the basic idea of the proposed technique can be seen. The water tube is placed within the earth to air heat exchanger. In Fig. 3 the other side intersection of the system can be highlighted. The elements and parts of the system, as well as, the ones already numbered in Fig. 2 are presented in Table 1. A technical issue that must be taken into account is the water pipeline support method. The methods to manufacture a modified tube, as the one shown in Fig. 2, are fully developed technologically. Another option could be to place the water pipeline at the bottom of the air tube. That way the support issue will be easily solved but part of the heat transfer from the water to the air would be lost and absorbed by the ground. This issue is under consideration for further research. Also the existence of a drill is necessary for this system. It must be noticed that in order to have a positive result, the water temperature must be lower than the ground temperature. If that doesn’t happen, there will be no heat absorbed by the water, as the heat transfer mechanism via conduction is more effective than the heat transfer via convection. Moreover, in the examined case the ground is acting like a very large cooling sink and its mass is much more than the water's mass flowing through the pipe. So the heat transfer, if the water isn't in a low temperature, won't be sufficient. In most of the systems already studied by previous researchers the air tube isn't placed in depths more than 1 m. So the ground temperature can be assumed to be higher than 12-15^{o}C as it is affected by the environmental temperature. The water temperature value will be chosen as it is in most agricultural applications drills.

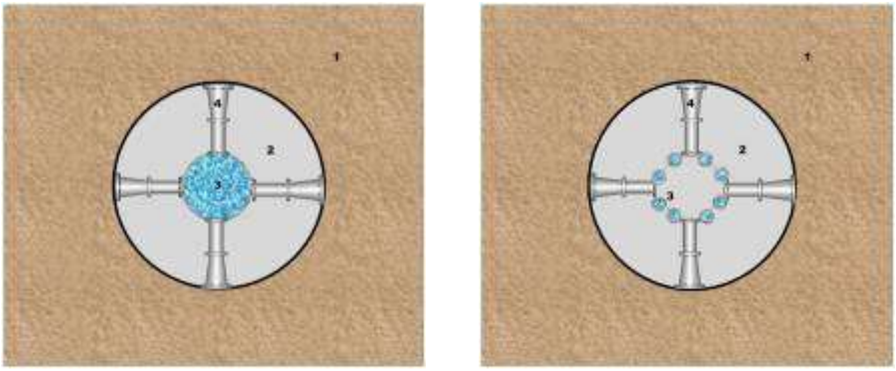

Fig 2 Water assisted earth to air heat exchanger system variations side intersection

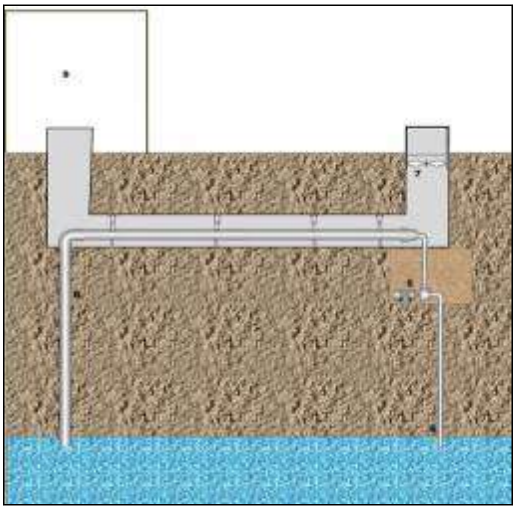

Fig 3 Water assisted earth to air heat exchanger system overview side intersection

Table 1 System parts and elements as illustrated in Fig 2 and Fig 3

1	Ground (the depth determines the stability of the temperature)
2	Air tube
3	Water pipe or tube
4	Supports for the water pipeline (initially welded or screwed on the outer air tube)
5	Pump
6	Water supply pipeline
7	Air fan
8	Water return pipeline
9	Greenhouse

3. THEORETICAL CALCULATIONS AND CASE STUDIES EXAMINED

In this paragraph the equations that will be used are presented. For the heat transfer taking place between the air tube and the water pipe the energy balance equations will be used (Eq. 1 and Eq.2). The heat transfer exchange area between the two tubes can be calculated by the kinetic equation from the heat exchange design theory will be used (Eq.3) [16].

$$\dot{Q}=\dot{m}_h \times c_p \times (Th_i\text{-}Th_o) \tag{1}$$

$$\dot{Q}=\dot{m}_c \times c_p \times (Tc_o\text{-}Tc_i) \tag{2}$$

$$\dot{Q}=k \times A \times \Delta\theta_m \tag{3}$$

The heat transfer equations for the heat transfer convection mechanism taking place during the water circulation inside the water pipe are the following

$$\alpha=\frac{Nu_x \times \lambda}{L} \tag{4}$$

$$Re_L=\frac{u_\infty \times L}{\nu} \tag{5}$$

$$Pr=\frac{\nu}{a} \tag{6}$$

If Re<2300 the flow inside the pipe is considered laminar and the Nusselt number is calculated by equation (8), while when Re>10000 the flow inside the pipe is considered turbulent the equation used for the Nusselt number is (9). When the Re number is 2300<Re<100000 than the Nusselt number is calculated by linear interpolation [16].

$$Nu_d=\left[3{,}66^3+\left[1{,}62+\sqrt{\frac{2Gz_d}{1+22Pr}}\right]\times Gz_d\right]^{1/3} \tag{7}$$

$$Nu_d=\frac{\left(\frac{\xi}{8}\right)\times Re_d \times Pr}{1+12{,}7\times\sqrt{\xi/8}\times(Pr^{2/3}-1)}\left[1+\left(\frac{d_{\varepsilon\sigma}}{L}\right)^{2/3}\right] \tag{8}$$

$$\xi=(1{,}8\times\log(Re_d)-1{,}5)^{-2},\ Re>10^4,\ 0{,}5<Pr<10^4,\ d<L \tag{9}$$

$$\frac{1}{U}=\frac{1}{\alpha_i}+\frac{l_i}{k_i}+.......+\frac{l_n}{k_n}+\frac{1}{\alpha_o} \tag{10}$$

In Table 2 all the values of the above equations are described.

Table 2 Units used in equations 1-10

Symbol	Name	Units	Symbol	Name	Units
$\dot{m}_h$	Air Mass flow	(kg/sec)	α	Convection coefficient	W/m^2K
$\dot{m}_c$	Mass flow	(kg/sec)	Nu_x	Nusselt number	-
$\dot{Q}$	Heat flow	(kW)	L	Characteristic length of body	m
c_p	Specific heat	(kJ/kg K)	Re	Reynolds number	-
Th_i	Air inlet temperature	^oC	ν	Kinematic viscosity	Ns/m^2
Th_o	Air outlet temperature	^oC	u_∞	Velocity of the fluid	m/sec
Tc_i	Water inlet temperature	^oC	Pr	Prandtl number	-
Tc_o	Water outlet temperature	^oC	a	Thermal diffusity	m^2/sec
K or λ	Thermal conductivity	W/mK	Gzd	Graetz number	-
A	Heat exchange area	m^2	dεσ	Internal diameter of water tube	m
Δθm	Logarithmic Temperature difference	^oC	ξ	Pressure loss coefficient	-
l	Thickness	m	U	Total heat transfer coefficient	W/m^2K

For the case study examined it will be assumed that the air tube is operating in three different air supplies close to the ones already studied in previous research works (5000m^3/h, 100000m^3/h and 200000m^3/h). The assumed diameters will be two (50cm and 60cm). The air temperature drop that will be demanded is 2^{o}C, after the air tube has an air temperature drop from 37^{o}C to 33^{o}C. That means that the total air drop will be 6^{o}C. The length of the air tube and as a consequence the water tube will occur by the calculations. The water supply will be given by three types of pumps according to the water temperature difference that will be assumed for the tube. In Table 3 the data used and the results by this approach are presented as far as it concerns the heat that must be absorbed by the water for the three possible cases. In this approach only the Equations (1), (2) and (3) was used.

Table 3 Heat exchange amount between an air tube and the water tube [16], [17], [18]

	Thi	Tho	$\dot{m}$air	cpair	Q
	^oC	^oC	kg/s	kJ/kg K	kW
Air tube 1	31	29	1,388	1,002	2,77
Air tube 2	31	29	27,77	1,002	55,55
Air tube 3	31	29	55,55	1,002	111,11

The water supply for the water tube, for each of the above case studies, is presented in Table 4 for three different water temperature differences (1^{o}C, 2^{o}C and 3^{o}C). In table 4 it can be observed that the water supply depends on the water temperature drop that is assumed for the water. The next step is to calculate the length of the tube for the possible air tube diameters.

Table 4 Necessary water supplies for each possible tube combination [17]

	Water ΔT	cp	Air tube 1	Air tube 2	Air tube 3
			ṁ water	ṁ water	ṁ water
	ºC	kJ/kg K	m3/h	m^3/h	m^3/h
Water tube 1	1	4,198	31,761	47,641	95,283
Water tube 2	2	4,198	15,880	23,820	47,641
Water tube 3	3	4,198	0,794	1,190	2,3823

As the diameters were chosen 0.6m and 0.5m, the possible water tube diameters will be approximately 0.4m and 0.3m and the possibility of cooling with an array of pipes with internal diameter 0,03m. By the use of Equation (3) the heat exchange surface between the air tube and water tube can be calculated. In this point the material of the water tube must be chosen. The options that will be studied are one with a copper tube, a second one with a stainless steel tube (AISI 304) and a third one manufactured by iron. In Table 5 the data of the water tube calculation are presented.

Table 5 Water data and water tube characteristics [16], [17], [18]

	Water ΔT	ṁ water (1)	ṁ water (2)	ṁ water (3)	Copper k	Stainless steel k	Iron k
	oC	m^3/h	m^3/h	m^3/h	W/mK	W/mK	W/mK
Water tube 1	1	31,761	47,641	95,283	403	14	83,5
Water tube 2	2	15,880	23,820	47,641	403	14	83,5
Water tube 3	3	0,794	1,190	2,3823	403	14	83,5

In order to calculate the total k that is contributing to the heat exchange the internal and external flow convection coefficients must be calculated. As we assumed the air flow will be fully developed before the beginning of the water flow so the two cases (air tube flow and water flow) will be examined as two independnet systems. Actually the k coefficient appeared in Equation (3) refers to the total heat transfer coefficient when calculating multilayer surfaces heat transfer. In this case the external air boundary layer, the tube wall, and the internal water boundary layer are forming a structure (Fig.4) with total k value calculated as U in Eq.10. For the calculation of the convection coefficient Equations (4)-(9) are necessary. The results of the calculations are highlighted in Table 6.

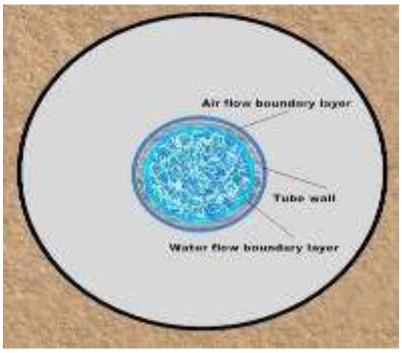

Fig 4 Flow boundary layers schematic illustration

Table 6 Convection heat transfer coefficients for each case study examined

Case	Air tube diameter	Air flow	Re	Flow	Nu	α
	m	kg/sec	-		-	W/m^2K
A1	0.6	1.388	139520	Turb	323.8	64.7
A2	0.6	27.77	2807602	Turb	3575.5	715.1
A3	0.6	55.55	5616216	Turb	6226.2	1245.2
A4	0.5	1.388	116267	Turb	279.9	55.9
A5	0.5	27.77	2339669	Turb	3090.2	618.0
A6	0.5	55.55	4680180	Turb	5381.1	1076.2
Case study		Water flow	Re	Flow	Nu	α
		kg/sec	-		-	W/m^2K
A11	Water flow (0,4m tube/DT 1) combined with air flow A1/4	0.66	1.71	lam	3.7	5.45
A12	Water flow (0,4m tube/DT 2) combined with air flow A1/4	0.33	0.85	lam	3.68	5.43
A13	Water flow (0,4m tube/DT 3) combined with air flow A1/4	0.22	0.57	lam	3.67	5.42
A14	Water flow (0,3m tube/DT 1) combined with air flow A1/4	0.66	1.28	lam	3.69	7.25
A15	Water flow (0,3m tube/DT 2) combined with air flow A1/4	0.33	0.64	lam	3.67	7.23
A16	Water flow (0,3m tube/DT 3) combined with air flow A1/4	0.22	0.42	lam	3.67	7.22
A17	Water flow (0,03m tube/DT 1) combined with air flow A1/4	0.66	0.12	lam	3.66	72.04
A18	Water flow (0,03m tube/DT 2) combined with air flow A1/4	0.33	0.06	lam	3.66	72.01
A19	Water flow (0,03m tube/DT 3) combined with air flow A1/4	0.22	0.04	lam	3.66	72
A20	Water flow (0,4m tube/DT 1) combined with air flow A2/5	13.23	34.39	lam	4.22	6.22
A21	Water flow (0,4m tube/DT 2) combined with air flow A2/5	6.61	17.18	lam	3.97	5.86
A22	Water flow (0,4m tube/DT 3) combined with air flow A2/5	4.41	11.46	lam	3.88	5.72
A23	Water flow (0,3m tube/DT 1) combined with air flow A2/5	13.23	25.79	lam	4.1	8.07
A24	Water flow (0,3m tube/DT 2) combined with air flow A2/5	6.61	12.88	lam	3.91	7.68
A25	Water flow (0,3m tube/DT 3) combined with air flow A2/5	4.41	8.59	lam	3.83	7.53
A26	Water flow (0,03m tube/DT 1) combined with air flow A2/5	13.23	2.57	lam	3.72	73.08
A27	Water flow (0,03m tube/DT 2) combined with air flow A2/5	6.61	1.28	lam	3.69	72.55
A28	Water flow (0,03m tube/DT 3) combined with air flow A2/5	4.41	0.85	lam	3.68	72.36
A29	Water flow (0,4m tube/DT 1) combined with air flow A3/6	26.46	68.78	lam	4.6	6.79
A30	Water flow (0,4m tube/DT 2) combined with air flow A3/6	13.23	34.39	lam	4.22	6.22
A31	Water flow (0,4m tube/DT 3) combined with air flow A3/6	8.82	22.92	lam	4.06	5.99
A32	Water flow (0,3m tube/DT 1) combined with air flow A3/6	26.46	51.59	lam	4.42	8.7
A33	Water flow (0,3m tube/DT 2) combined with air flow A3/6	13.23	25.79	lam	4.1	8.07
A34	Water flow (0,3m tube/DT 3) combined with air flow A3/6	8.82	17.19	lam	3.97	7.82
A35	Water flow (0,03m tube/DT 1) combined with air flow A3/6	26.46	5.15	lam	3.77	74.09
A36	Water flow (0,03m tube/DT 2) combined with air flow A3/6	13.23	2.57	lam	3.72	73.08
A37	Water flow (0,03m tube/DT 3) combined with air flow A3/6	8.82	1.71	lam	3.7	72.73
A38	Water flow (0,4m tube/DT 1) combined with air flow A3/6	0.66	1.71	lam	3.7	5.45

For each combination of conditions (Water flow/ air flow and tube material) 81 case studies of U and finally length of tube are presented in Table 7. From those the one with the more realistic tube length will be suggested. It must be noticed that the flows chosen for water pumps and air blowers are supported by commercial products already in the market. For the water pumps though the capacity is relatively high as the heat transfer mostly occur by the mass flow than the low temperature differences.

Table **7** Calculated water tube length for each case study examined with (non acceptable) (acceptable) (recommended) (ideal)

Case study	Tube material	Water tube length (m)	Case study	Tube material	Water tube length (m)	Case study	Tube material	Water tube length (m)
A11	Copper	3.83	A11	Steel	70.69	A11	Iron	17.22
A12	Copper	1.92	A12	Steel	35.35	A12	Iron	8.61
A13	Copper	1.28	A13	Steel	23.57	A13	Iron	5.74
A14	Copper	6.8	A14	Steel	124.94	A14	Iron	30.57
A15	Copper	3.4	A15	Steel	62.48	A15	Iron	15.29
A16	Copper	2.27	A16	Steel	41.66	A16	Iron	10.19
A17	Copper	671.79	A17	Steel	10360.27	A17	Iron	2909.82
A18	Copper	335.9	A18	Steel	5180.54	A18	Iron	1454.94
A19	Copper	223.93	A19	Steel	3453.78	A19	Iron	969.97
A20	Copper	68.73	A20	Steel	1410.56	A20	Iron	344.22
A21	Copper	34.37	A21	Steel	706.09	A21	Iron	172.16
A22	Copper	22.92	A22	Steel	470.93	A22	Iron	114.79
A23	Copper	122.16	A23	Steel	2492.98	A23	Iron	611.06
A24	Copper	61.08	A24	Steel	1248.02	A24	Iron	305.63
A25	Copper	40.73	A25	Steel	832.4	A25	Iron	203.78
A26	Copper	12092.97	A26	Steel	206692.16	A26	Iron	58166.95
A27	Copper	6046.98	A27	Steel	103491.99	A27	Iron	29095.02
A28	Copper	4031.44	A28	Steel	69028.16	A28	Iron	19399.33
A29	Copper	126.99	A29	Steel	2816.02	A29	Iron	688.13
A30	Copper	63.5	A30	Steel	1410.57	A30	Iron	344.22
A31	Copper	42.34	A31	Steel	941.07	A31	Iron	229.52
A32	Copper	225.7	A32	Steel	4976.04	A32	Iron	1221.53
A33	Copper	112.86	A33	Steel	2493	A33	Iron	611.07
A34	Copper	75.25	A34	Steel	1663.32	A34	Iron	407.46
A35	Copper	22359.7	A35	Steel	412292.98	A35	Iron	116248.06
A36	Copper	11181.46	A36	Steel	206694.02	A36	Iron	58167.48
A37	Copper	7454.68	A37	Steel	137924.54	A37	Iron	38788.49

4. CONCLUSIONS

In the current research the possibility of enhancing the cooling of an earth to air tube for greenhouse cooling was examined. According to the calculations, the feasibility of such a project relays on the material chosen for the water tubes, as well as, the temperature difference that will occur between the water inlet and outlet. From the examined cases a 33% seems to be applicable. By using copper, the tube length wasn't big in the case of high air flow and a 0.4m or 0.3m internal tube (A20-A25, A29-A31, A33-A34)). Copper array pipes can support only the case of low air flow (A17-A19) where the total length can be divided in 4-8 pipes. Steel tubes of nominal diameter 0.4 m or 0.3 m can lead to a logical result in the case where the water temperature is supporting low energy exchanges with air. The usage of array pipes isn't possible in that case. Finally iron tubes can lead to a rational result in the medium value air flow (A21-A22) and in the low value air flow (A11-A16). In this point it must be notice that very small lengths as the ones appeared in A11-A16 in the case of copper and A12-A13 in the case of iron aren't possible to be installed in air tubes as the length is so small that the air won't have the potential to absorb the main amount of heat to the ground which is the main heat transfer mechanism. All the cases colored yellow have a length that could be applied under conditions (large greenhouses) but still lengths over 200 m is difficult to be accepted as applicable in a typical greenhouse due to the high digging work and material costs. Lengths colored red are not applicable as the length is too big for such an application. It could be said, that by using the proper materials the proposed heat exchanging system lead to the required extra temperature drop (2^{o}C) of air entering the greenhouse. Issues for further study are the cost analysis of the projects, as it must be examined whether such an application is economical feasible and the static and installation of the system from a technical point of view. The more analytic study of the study in terms of heat transfer mechanisms is assessed that will lead to more detailed and exact results as the assumptions made led to a preliminary result. Some of the basic assumptions must be further researched especially fact that the interaction between the two flows wasn't taken into account. Practically the length calculated in this study isn't expected to be much different and certainly not higher in a more thorough result as the main heat transfer mechanisms were included. As a final conclusion, it can be said that the proposed system can theoretically assist the operation of an earth to air tube for cooling purposes. The application in actual conditions though needs to be further studied taking into account the economical and technical feasibility of the project.

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PREMLIMINARY DESIGN AND THEORETICAL STUDY OF EARTH SHELTERED GREENHOUSES IN MOUNTAINOUS AREAS OF THE BALKAN/PART II: ENERGY MANAGEMENT, VENTILATION AND CROP DESIGN

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Abstract: *Greenhouse development is a common crop development practice in areas where the climatic conditions are proper. Most of the greenhouse structures are mentioned in areas where the landscape is plain and the construction is easy. However there are many mountainous areas in the Balkan region that lack the presence of the up mentioned parameters. That results to higher cost of vegetable and other agricultural products and the risk of food dependence in the future. In this study a preliminary holistic study for the construction and operation of earth sheltered greenhouses in such areas is presented, focus on the Balkan region in terms of legislation, climate and land morphology. Earth sheltered greenhouses are a traditional cultivation practice applied in mountainous regions in China, India etc but it was never studied systematically for commercial use. The study is divided in two parts. In this second part the energy study of the greenhouse operation is presented in terms of heating and cooling needs and operation requirements. Additionally the ventilation options are studied and presented in order to make the operation of the greenhouse effective. Finally the way that the crop will be developed inside the structure is also studied as the special characteristics of the structure require specific crop design installation in order to maximize the production rates. The study of such greenhouse structures can be proven very useful as it will give a design approach for greenhouse crop development in mountainous areas which have never been performed before.*

Key words: *Earth Sheltered Greenhouse, Mountain Region, Soil, water runoff, legislation*

1. INTRODUCTION

As it was already presented at the first part of this research project, the installation and operation of earth sheltered greenhouse can prove to be a useful agriculture cultivation method where arable land is not available. If designed properly, earth sheltered greenhouses can be proven energy efficient and have a quite satisfying ventilation. These two parameters affect the crop positively and they can lead to a sufficient production rate which is very crucial for the proposed cultivation method.

The energy issue in greenhouses' climate formation is very critical. Especially in mountainous areas where the climate conditions are rougher during the winter the heating cost is relatively high. According to Sandford the energy needs in greenhouses is the third highest cost after labor and plant management. A more detailed analysis depicts that heating needs represent almost 70-80% of the total energy consumption, while the rest 10-15% are electricity and the rest mostly transportation [1]. In northern Greece according to data of local producers the tomato production cost per kg can reach 0.42€. From this cost, the 0.25€ are heating costs. So the percentage on the total cost is around 60% [2]. Other relevant research efforts and data in the Balkan region present a similar situation as far as the heating costs of greenhouses are concerned. In a research work by M. Djevic and A. Dimitrijevic [3] it was found that in the Serbia region the heating needs for a greenhouse can be almost 50% of the total energy consumption. In an actual greenhouse case study in Romania at the region of Copaceni (IIfov)- for a 5000m2 greenhouse area the installed heating system has a capacity of 581kW [site]. For the area of Banja Luka in Bosnia & Herzegovina it is estimated that the heating costs are around 60-70% of the annual costs in a greenhouse [4]. In a study conducted by Tomislav Kurevija and Renata Kos [5] for a case study of a 675m2 greenhouse area in the region of town Bjelovar it was calculated that for a double layer greenhouse operation the installed heating system should cover up to 175kW, while for a glass greenhouse this need is almost doubled up to 350kW. From the up mentioned data it is obvious that typical greenhouse structures in the Balkan region (especially in the non coastal areas) are difficult to be developed due to the high energy heating demands. On the other hand transportation of agricultural products in those areas from long distanced production sites leads to high price formation in fruits and vegetables. According to a study conducted by J.L Guash and the World Bank [6] the transportation related cost of agricultural products holds the 36% of the final price. Especially in periods when the fossil fuels prices are rising, distance regions are more vulnerable to higher price formation as the transportation costs are increased. According to the Trade and Marketing Division of FAO, transportation costs are highly responsible, in a high percentage, for the agricultural products' price fluctuation observed through the years. Actually the fluctuation of fossil fuel prices is the major factor that affects the final price of the products [7]. According to the United States Agency for International Development fuel costs represent almost 50 to 60% of total ship operating costs. In the period 2007-2008 shipping food cost increased almost by 30% due to the increase of the fuel prices [8]. As mentioned at the first part of this research work local production can create great possibilities for the involved communities. One great benefit for such a venture is the reduction of the food cost and product independence. Earth sheltered greenhouses could assist towards this direction as they exploit land which previously was not arable and apart from that they are passive energy systems with high insulation. Two more barriers to overcome are the ventilation of such a structure and the crop design. Up to now any effort of earth sheltered greenhouses mentioned in the literature are supported with on earth crop development [9], [10], [11] . A case study of such an effort can be seen in Fig.1. The reason of this approach was that this cultivation method was usually adopted by individuals for personal use. This method leads to low amounts of productions and it cannot be considered as a systematic cultivation method. In this work a more effective crop design will be presented in order to maximize the production in a given greenhouse area. As far as, the ventilation system of these structures is concerned, some methods are already presented in the literature

Figure 1 Internal of an earth sheltered greenhouse **[**10**]**

The ventilation issue for these greenhouses might be more complex than the typical structures but it is not difficult to accomplish a satisfying result. In most studies which have already been conducted the ventilation is performed naturally or by the assistance of a vent. Benson Agriculture and Food Institute present four possible options for performing ventilation in an earth sheltered greenhouse [12]. The proposed techniques include two doors- openings at the opposite walls (side walls of the greenhouse) in order to ventilate the greenhouse naturally or by the support of a vent in order to give more dynamic characteristics to the operation. The third option is to support ventilation with a roof window, or by a chimney which will be equipped with a vent. These four options seem to cover most of the cases. However in the case of earth sheltered greenhouses adjusted at the inclined side of a mountain or a hill some details and parameters should be taken into account. In this research work the holistic design of earth sheltered greenhouses in the Balkan region will be completed. For the first time data are given for the energy needs of such a project in the Balkan region. That way it will be estimated if it is possible to proceed in such a project more systematically. Additionally a crop design suggestion is presented, as well as, the ventilation issues that should be taken into account for the successful realization of the project. By combing the results and observation of the first part of the research (potential of the Balkan region countries on agricultural but non arable land, and the static issues, water runoff management) and the energy management, ventilation design and crop design presented at the current one, some first results can occur for the feasibility of such a project. This preliminary study will give the basic directions for the further and more detailed study of the earth sheltered greenhouse project as a part of future perspective for crop land expansion in the region. The outcome of this study is aiming to set the scene for a more systematic approach of the project in the future as part of alternative development for local communities.

2. ENERGY ANALYSIS OF THE EARTH SHELTERED GREENHOUSE IN THE BALKAN REGION

In this paragraph the energy needs for the proposed project are presented for each country in the Balkan region. For the purpose of this study it was assumed that a 25×4 m fundamental structure will be installed in a hill or mountain with 36^o inclination. The height of the back wall of the structure was chosen 3m. In Figure 2 a sketch of the sides of the greenhouse is illustrated. In order to evaluate the heating needs of the greenhouse the worst case scenario will be examined. That occurs during winter nights in the absence of sunlight with no ventilation. So the only heat transfer mechanism is via conduction and convection and it is best described by the total heat transfer coefficient U (W m^{-1} K^{-1}). The equation used for this calculation is described below (Equation 1) [13]

$$Q=U\times A\times(\Theta i-\Theta o) \qquad [1]$$

Q: Heating losses (W)
U: Heat transfer coefficient (W m^{-2} K^{-1})
A: Surface exposed to the environment (m^2)
Θi: Internal temperature (^oC)
Θo:External temperature (^oC)

The possibility of applying this method in the Balkan region will be examined by choosing the climatic data of two areas per country (except Montenegro) (Table 1). Also, the crop chosen was lettuce which can be developed during the winter. The optimum temperature for lettuce growth in a greenhouse is 24^oC during the day and 19^oC during the night [14]. However the range in which the plant can develop without serious problems is between 15-22^oC [15]. These two case studies will be examined separately, and the temperature differences which occur are presented in Table 1. The area, exposed to the environment, can be calculated by the geometry of the structure as it is shown in Figure 2. The heat transfer coefficient U depends on the thermal resistance of the covering materials and, in the examined case, by the soil which surrounds the structure. For the scope of the study several soil types were examined, as well as, different covering materials. For the exact calculation of the heat transfer coefficient for each material two factors are necessary, the material's thermal conductivity and thickness. The covering materials' dimensions are the ones used in commercial applications for greenhouses. At this point it must be noticed that the heat losses to the sides which are in contact with the soil hold the least percentage. In many cases these losses can be assumed to be neglected. However in this study this parameter was taken into account in order to highlight the different ability of various types of soil to act as heat insulating factors. In order to quantify the heat loss or gain via the ground it was assumed that heat transfer is taking place until 3m depth where the temperature is stabilized around 15-25^oC and is no more affected by the external environment fluctuations [16]. So there are two temperature differences- the one between the internal environment and the external environment and the other between the internal environment and the soil which will be chosen as 15^oC. The corresponding surface area and heat transfer coefficient which participates in each heat exchange are illustrated in Table 4, for each country case study. In Figure 2 the sides of the greenhouse that are buried in the ground are highlighted. Sides A and E are exposed to the external environment while sides B, C, D are buried in the ground.

Table.1 Climatic data for chosen Balkan region countries and temperature differences for the heat loss calculation [17]

Country	City	Lowest Mean Daily Temp (◦C)	ΔΘ1 Internal-External Environment (Crop Temp design 19°C)	ΔΘ2 Internal-External Environment (Crop Temp design 15°C)	ΔΘ3 Internal Environment with soil temperature (Crop Temp design 19°C)	ΔΘ4 Internal Environment with soil temperature (Crop Temp design 15°C)
Greece	Herakleion	9.0	10.00	6.00	4	0
	Thessaloniki	1.2	17.80	13.80	4	0
Bulgaria	Varna	-1.1	20.10	16.10	4	0
	Sofia	-4.9	23.90	19.90	4	0
Fyrom	Skopje	-3.4	22.40	18.40	4	0
	Bitola	-4.5	23.50	19.50	4	0
Bosnia and Herzegovina	Sarajevo	-4.4	23.40	19.40	4	0
	Tuzla	-4.5	23.50	19.50	4	0
Croatia	Zagreb	-4.0	23.00	19.00	4	0
	Osijek-Donji Grad	-4.2	23.20	19.20	4	0
Romania	Bucharest	-4.8	23.80	19.80	4	0
	Cluj-Napoca	-5.7	24.70	20.70	4	0
Serbia	Belgrade	-2.3	21.30	17.30	4	0
	Novi Sad	-6.0	25.00	21.00	4	0
Slovenia	Ljublijana	-2.7	21.70	17.70	4	0
	Maribor	-3.6	22.60	18.60	4	0
Montenegro	Podgorica	1.4	17.60	13.60	4	0
Albania	Tirana	1.8	17.20	13.20	4	0
	Korce	-3.5	22.50	18.50	4	0

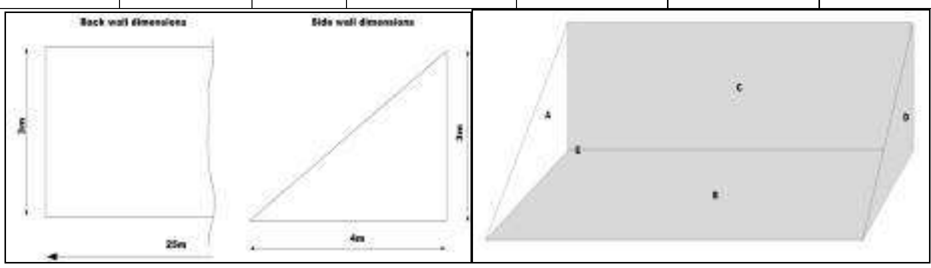

Figure.2 Greenhouse sides dimensions and overview

The temperature differences presented in Table 1, create different scenarios to be examined. Actually there must be examined the cases when the internal temperature is chosen to be 15^{o}C and the one which is chosen to be 19^{o}C. These two scenarios lead to different temperature differences between the internal- external environment and the internal environment- soil. So there are 4 different combinations of ΔΘ. Apart from that different covering materials and soil type are forming different case studies which are encoded in Table 2.

Table 2 Scenarios evaluated classification and encoding

Basic Scenario Number	Description (Covering material/ Soil Type)	Internal temperature 15^{o}C	Internal temperature 19^{o}C
1	Glass/ Limestone	A	B
2	Glass/ Siltstone		
3	Glass/ Clay		
4	Polyethylene/ Limestone		
5	Polyethylene/ Siltstone		
6	Polyethylene/Clay		

Table 3 Heat losses calculation for scenario A for several regions of the Balkan area [15],[18]

Scenario A		Internal Greenhouse temperature at 15^{o}C (kW)					
Country	City/Region	**1A**	**2A**	**3A**	**4A**	**5A**	**6A**
GR	Herakleion	4.422	4.422	4.422	5.234	5.234	5.234
	Thessaloniki	10.171	10.171	10.171	12.039	12.039	12.039
BG	Varna	11.867	11.867	11.867	14.045	14.045	14.045
	Sofia	14.668	14.668	14.668	17.360	17.360	17.360
FYROM	Skopje	13.562	13.562	13.562	16.052	16.052	16.052
	Bitola	14.373	14.373	14.373	17.011	17.011	17.011
B-H	Sarajevo	14.299	14.299	14.299	16.924	16.924	16.924
	Tuzla	14.373	14.373	14.373	17.011	17.011	17.011
CRO	Zagreb	14.004	14.004	14.004	16.575	16.575	16.575
	Osijek-Donji Grad	14.152	14.152	14.152	16.750	16.750	16.750
ROM	Bucharest	14.594	14.594	14.594	17.273	17.273	17.273
	Cluj-Napoca	15.257	15.257	15.257	18.058	18.058	18.058
SERB	Belgrade	12.751	12.751	12.751	15.092	15.092	15.092
	Novi Sad	15.479	15.479	15.479	18.320	18.320	18.320
SLOV	Ljublijana	13.0466	13.046	13.046	15.441	15.441	15.441
	Maribor	13.710	13.710	13.710	16.226	16.226	16.226
MNG	Podgorica	10.024	10.024	10.024	11.864	11.864	11.864
ALB	Tirana	9.729	9.729	9.729	11.515	11.515	11.515
	Korce	13.636	13.636	13.636	16.139	16.139	16.139

Table 4 Heat losses calculation for scenario B for several regions of the Balkan area

Scenario B		Internal Greenhouse temperature at 19°C (kW)					
Country	City/Region	**1B**	**2B**	**3B**	**4B**	**5B**	**6B**
GR	Herakleion	8.081	7.870	7.820	9.450	9.232	9.188
	Thessaloniki	13.830	13.619	13.569	16.255	16.036	15.992
BG	Varna	15.526	15.315	15.264	18.262	18.043	17.999
	Sofia	18.327	18.116	18.065	21.577	21.358	21.314
FYROM	Skopje	17.221	17.010	16.960	20.268	20.049	20.005
	Bitola	18.032	17.821	17.771	21.228	21.009	20.965
B-H	Sarajevo	17.958	17.747	17.697	21.140	20.922	20.878
	Tuzla	18.032	17.821	17.771	21.228	21.009	20.965
CRO	Zagreb	17.663	17.452	17.402	20.792	20.573	20.529
	Osijek-Donji Grad	17.811	17.600	17.549	20.966	20.747	20.703
ROM	Bucharest	18.253	18.042	17.992	21.489	21.271	21.227
	Cluj-Napoca	18.916	18.705	18.655	22.275	22.056	22.012
SERB	Belgrade	16.410	16.199	16.149	19.308	19.090	19.046
	Novi Sad	19.137	18.927	18.876	22.536	22.318	22.274
SLOV	Ljublijana	16.705	16.494	16.444	19.657	19.439	19.395
	Maribor	17.368	17.158	17.107	20.443	20.224	20.180
MNG	Podgorica	13.683	13.472	13.422	16.081	15.862	15.818
ALB	Tirana	13.388	13.177	13.127	15.732	15.513	15.469
	Korce	17.295	17.084	17.033	20.355	20.137	20.093

As it can be seen in Tables 3 and 4, when trying to maintain 19°C inside the greenhouse the heat losses occurred are much higher. Even in the case of 15°C the losses are quite high. It is easy though to install a thermal curtain in the inclined side of the greenhouse which will close during the night as it can be seen in Figure 3. That way the heat losses from the inclined side will be reduced around 59% when the curtain is made by aluminum foil or clear vinyl film laminate or by 38% when a cheaper and simpler solution will be uses as a double layer spun bonded polyester [18], [19], [20]. In that case, taken into account the optimum case scenario from Tables 3 and 4 for each covering material- the heat losses occurred can be seen in Table 5. The insulation thermal curtain that is suggested is the one with the higher thermal resistance. The operation of such a system is easy to be achieved by a simple automatic system which will operate by a temperature sensor or a light sensor in order to operate during the night hours when the sunlight is not present.

Table 5 Heat losses after the application of a thermal blanket

Heat losses after the improvement of the greenhouse insulation by the application of a thermal curtain at the inclined side of the structure					
		Glass with Clay soil		**Polyethylene with Clay soil**	
Country	City/Region	**3A**	**3B**	**6A**	**6B**
GR	Herakleion	1.813	3.206	2.146	3.767
	Thessaloniki	4.170	5.563	4.936	6.557
BG	Varna	4.865	6.258	5.758	7.379
	Sofia	6.013	7.407	7.117	8.738
FYROM	Skopje	5.560	6.953	6.581	8.202
	Bitola	5.893	7.286	6.974	8.595
B-H	Sarajevo	5.862	7.255	6.939	8.560
	Tuzla	5.893	7.286	6.974	8.595
CRO	Zagreb	5.742	7.135	6.795	8.416
	Osijek-Donji Grad	5.802	7.195	6.867	8.488
ROM	Bucharest	5.983	7.376	7.082	8.703
	Cluj-Napoca	6.255	7.648	7.404	9.025
SERB	Belgrade	5.228	6.621	6.187	7.808
	Novi Sad	6.346	7.739	7.511	9.132
SLOV	Ljublijana	5.349	6.742	6.331	7.951
	Maribor	5.621	7.014	6.652	8.273
MNG	Podgorica	4.110	5.503	4.864	6.485
ALB	Tirana	3.989	5.382	4.721	6.342
	Korce	5.590	6.983	6.617	8.238

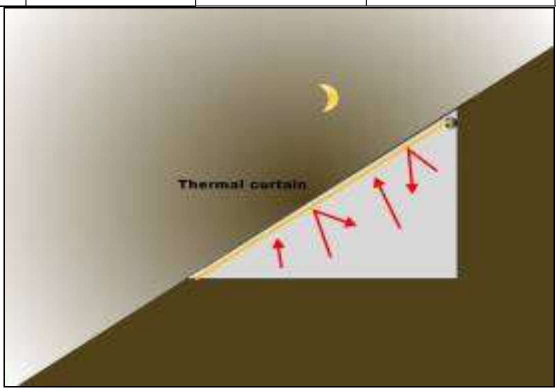

Figure 3 Schematic description of thermal curtain system

3. CROP DESIGN

Decision-making : Crop design is based on mountainous environmental conditions, greenhouse's spatial potentiality and investment plan. A NFT (Nutrient Film Technique) hydroponic cultivation system was chosen for the purpose of this study. To begin with, the suggested hydroponic system fits best the spatial potentiality of the greenhouse. In addition, the idea of building greenhouses in mountainous area was based also on the fact that 45% of mountainous soils are unsuitable for cultivation (FAO, 2015) [21], so cultivating on soil is not desirable. The greenhouse's energy demand which is high and crucial for the greenhouse's systems to function is to be discussed in the energy management section. Establishing a hydroponic system might be much more expensive than cultivating on soil, but it seems that it is a worthwhile investment for this case study.
A-frame hydroponic system for lettuce: Hydroponic lettuce (Lactuca satuva) was chosen as a cultivar. Barbosa et al., 2015 [22] reported that hydroponic growing of lettuce uses land and water more effectively than conventional farming. We suggested that hydroponic lettuce is to be grown in the greenhouse on an A-frame hydroponic system (continuous flow-active) which resides in the NFT technique (Nutrient Film Technique). By an A-frame hydroponic growing system we can exploit greenhouse's cultivation space to the maximum. In specific, hydroponic lettuces can be grown soilless, not in substrates (rock wool, sand, perlite), but in PVC tubes, through which nutrient solution will flow (Sonneveld and Voogt, 2009) [23]. This is not a new cultivation practice as it has already been applied in various cases all over the world the last years. Given the shape and size of our greenhouse-case we introduce the following adjusted to the needs A-frame hydroponic system. Plants will be placed through holes along a PVC pipe. Nutrient solution will flow continuously through the pipes, in which plant roots will expand and absorb nutrients. Pipes will have a slight inclination, so that nutrient solution flows with gravity. Harvest and monitoring must be feasible, for this reason the triangle set-up should have a height of 2.1m at most and the base of the triangle should be approximately 1.7m (see Fig. 4). Plant distance could be 0.2m, pipe distance 0.4m and pipe length 20m approximately, leaving a free space of 2.5m at each side (see Fig. 5). Usually two solution tanks provide the solution, after mixing, to the pipes. By doing a simple calculation we estimate that each greenhouse-unit can produce 600 heads of lettuce in each growing season.
Monitoring parameters: Hydroponic lettuce demands 25℃ air temperature, water temperature no more than 25℃, relative humidity between 50-70%, 1500ppm of carbon dioxide provision, 17mol m-2 d-1 of light, 7ppm of dissolved oxygen and not less than 3ppm, and finally solution pH's value must be between 5.6-6 (Cornell University CEA Program) [24]. Water quality is a key factor in hydroponics. We do not know whether a natural water source could be at hand and whether the quality of water would allow hydroponic growing (pH, electrical conductivity). For this reason we decided to ensure water supply by a tank which will be filled with good quality water. In addition, pest and disease control should be exercised thoroughly through environment control. It is essential that the aforementioned parameters are continuously monitored by sensors (fitting hardware) and experienced growers, as losing control of one of them could terminate production.

Meeting the market's needs: It is obvious that an investment plan (start-up cost, energy supply cost, labor cost, harvest and storage, market's needs and promotion, expected profits and future potentials) is crucial for this case study if it is to be realized (Kaiser and Ernst, 2012) [25]. The variety of lettuce (romaine, looseleaf, butterhead) should be chosen according to target-population preferences and demand.

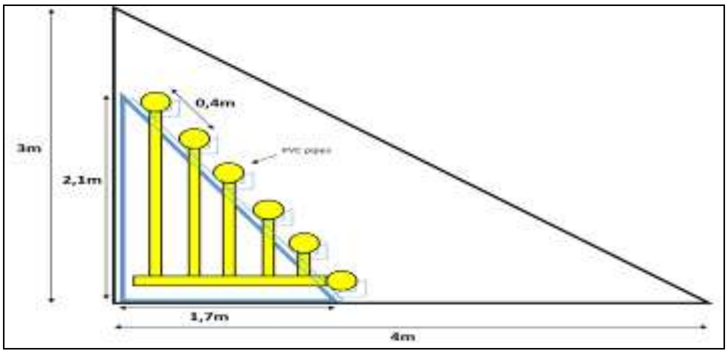

Figure 4 Side view of the A-Frame NFT hydroponic system

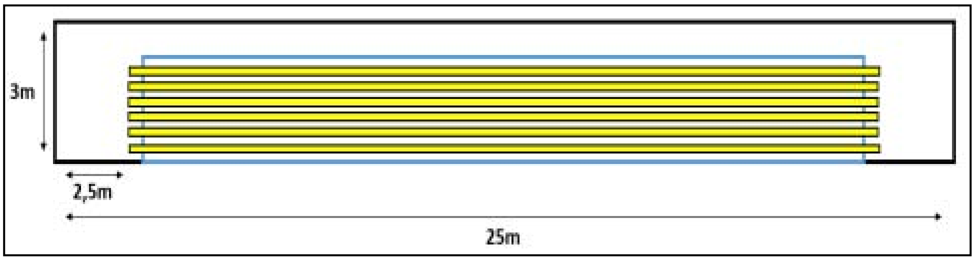

Figure 5 Front view of the A-Frame NFT hydroponic system

4. VENTILATION OPERATION DESIGN AND SUGGESTIONS

Ventilation is needed to prevent overheating and air renewal for air quality reasons and humidity control. The most suitable approach of the ones mentioned already in the literature is the one suggested by Benson Agriculture and Food Institute and includes a simple chimney and a fan as sketched in Figure 6 [19]. In order to size the ventilation system the necessary air renewals must be determined. The volume of the greenhouse structure is 600m^3. According to the US Center for Agriculture Food and the Environment the fan size should be chosen in order to perform an exchange of air per minute [26]. That means that the fan size must have a capacity of 36000m^3/hr. Two commercial axial fans of 18000m^3/ hr could operate to succeed this ventilation rate with power from 0.5 HP each [27]. The ventilation system in the case examined won't play the role of the cooling factor in the greenhouse, so possibly the operation of both fans according to the theory might not be necessary. An opening at the side walls for natural ventilation is also suggested when the prevailing winds allow such an operation.

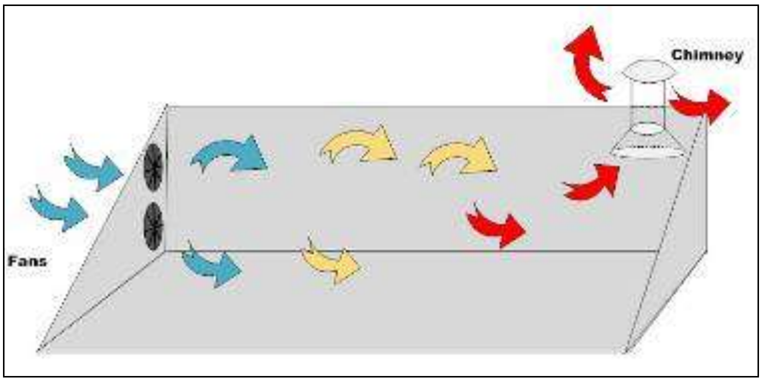

Figure 6 Ventilation rationale schematic illustration

5. Conclusions

In the second part of this study the energy design, crop design and ventilation design was presented. In the Balkan region heating of greenhouses is necessary for optimum crop development. Based on the calculations made for several scenarios it was found that earth sheltered greenhouses can be proven low energy consumtion structures for crop development in the Balkan climatic conditions when a thermal curtain is adjusted to the inclined side of the greenhouse. Glass structures seem to have better thermal behaviour in terms of heat loss. On the other hand polyethylene covered greenhouses may have a higher heat transfer coefficient but in reality they prevent more efficiently the air pass through the structure constructive elements. Furthermore glass structures might be proven more vulnerable to damages in such an environment. Even with the adjustment of the thermal curtain, heat losses couldn't be totally eliminated. Therefore a heating system might be needed to support such a project. In this case small biomass burners might be efficient even to the worst cases as in regions such as Cluz (Romania), Maribor (Slovenia), Sofia (Bulgaria) etc where the heating needs are 8-9.5kW. One technique that might also help the stability of the back wall could be the adjustment of special materials (usually rocks) which can trap heat and attribute it with a delay [28]. The heat losses to the ground are practically zero. In the detailed calculation occurred that the heat losses to the ground ranges from 2-5% of the total heat loss in the case where the greenhouse operates at 19^oC and 0% in th ecase where it operates at 15^oC. As for the crop design- the more systematic approach will be a hydroponic system. That way the area and volume of the greenhouse will be better exploited. Finally ventilation is easy to be achieved via common techniques already used in greenhouses. In this study it was found that earth shelterd greenhouses can assist crop development in mountainous regions. There are some parameters though that should be further studied in future research. One of them is the energy and auxiliary equipment for the operation of the greenhouse (electricity needed for the automatization systems, water tanks etc). Also an economic study to evaluate the feasibility of such an effort and the benefit of the local communities compared to the cost and dependence of food and products provided by other regions is needed.

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THE ROTARY TILLER WORKING SPEED INFLUENCE ON OPTIMAL KNIFE PROFILE IN CASE OF REVERSE ROTOR ROTATION DIRECTION

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Abstract. *The optimal shape of the knife profile is determined by the value of the working speed ranges from 0.43 to 1.08 m/s. Constructional parameters and parameters of a rotary tiller tillage: the radius of the rotor (R=0.25 m), angular velocity (ω=16,038 s^{-1}) and working depth (a=0.1 m). The optimal shape of the knife profile for reverse rotor rotation direction is determined by using the parametric equations of the blade top trajectory and an arbitrary point of the knife profile. The profile of the knife is defined as the distance ρ that is base on determines corresponding coordinates X and Y. The first derivative of the function is the tangent of the angle between the tangent curve at the selected point Y (X) and the axis X. The value of the angle at the top of the blade (α) for testing working speed ranges from 4.61 to 10.51°. There is almost linear dependence between working speed and changes the angle α. By rotating the coordinate system for value of the angle α gets new uv coordinate system. Between the shapes of optimum profile of the knife in the rotated coordinate system uv differences are minimal. Curve knife profile can be writing by equation of the second and fourth degree.*

Key words: *Rotary tiller, Shape of the knife, Working speed, Parametric equations, Nonlinear algebraic equations.*

1. INTRODUCTION

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 [3]. Increase of the knife position angle γ reduces the cutting angle ε.

The cutting angle of the moldboard on ploughs, cultivator mattocks and other working bodies with rectilinear motion ranges from 20–30° at minimal power [3]. 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 applied. The risk of reducing the cutting angle ε and cutting resistance implies the possibility that the mattock can friction 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 [5, 6, 7].

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, 18]. Optimal shape of knife profil was solved by parametric equation [15, 16].

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 [8]. In order to ensure proper operation of the rotary tiller with reverse rotor rotation direction 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 reverse 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 [8, 9]. The optimal shape of the knife profile for reverse rotor rotation direction is determined by using the parametric equations of the blade top trajectory and an arbitrary point of the knife profile.

There is almost linear dependence between working speed and changes the angle α. By rotating the coordinate system for value of the angle α gets new *uv* coordinate system. Between the shapes of optimum profile of the knife in the rotated coordinate system *uv* differences are minimal.

The equations were solved with SWP 5.5 (Scientific work place 5.5) program [11, 12, 13, 14]. The trajectories were drawn in SWP 5.5 and CorelDraw X5 (Corel Corporation) programs.

3. Results and discussion

3.1. Parameters of the knife profile

In paper [16], the procedure for obtaining the optimal profile of the knife Y (X) for the given processing parameters R, a, ω and v_m is shown, whereby each point of the knife profile comes out from the soil at the same place.

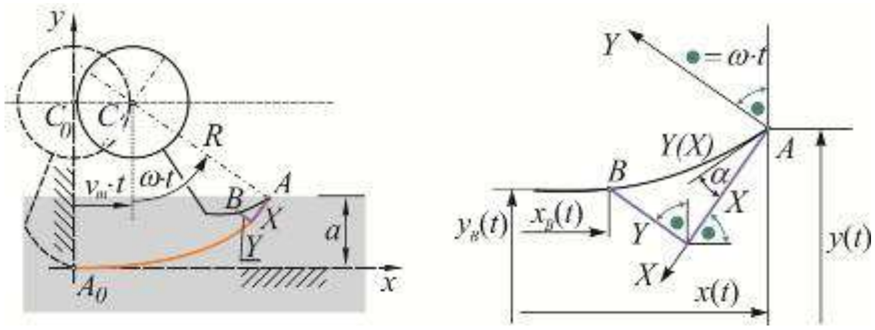

Fig. 1 The parameters that define the trajectory of the knife profile points

Parameter equations of the knife top point A trajectory and parameter equations of the knife profile arbitrary point B trajectory (Fig. 1).

$$x(t) = x_A(t) = v_m \cdot t + R \cdot \sin\omega t\,,$$

$$y(t) = y_A(t) = R - R \cdot \cos\omega t\,,$$

$$x_B(t) = x(t) - Y \sin\omega t - X \cos\omega t = v_m \cdot t + R \cdot \sin\omega t - Y \sin\omega t - X \cos\omega t$$

$$y_B(t) = y(t) + Y \cos\omega t - X \sin\omega t = R - R \cdot \cos\omega t + Y \cos\omega t - X \sin\omega t\,,$$

Where the parameters X and Y represent the displacement of the point B in relation to the top of the knife A.

The desired equation optimal knife profile for the given parameters *R*, *a*, ω and v_m in reverse rotation case implicit function define:

$$\begin{aligned} f(X,Y) &= \frac{v_m}{\omega} \cdot \left[\arccos z(X,Y) - \arccos\frac{R-a}{R} \right] + \\ &+ (R-Y) \cdot \sqrt{1 - z(X,Y)^2} - X \cdot z(X,Y) - \sqrt{R^2 - (R-a)^2} = 0 \end{aligned} \qquad (1)$$

Where is:

$$z(X,Y) = \frac{(R-a)\cdot(R-Y) - \sqrt{(R-a)^2 \cdot (R-Y)^2 - \left[(R-Y)^2 + X^2\right] \cdot \left[(R-a)^2 - X^2\right]}}{(R-Y)^2 + X^2}.$$

In this paper, the aim is to compare the optimal knife profiles for different working speeds in v_m. For easier comparison, in all cases distances ρ was defined (Fig. 2) as distance from the top of the knife of the optimal profile. By using the implicit function (1), the corresponding values of the coordinates X and Y are obtained.

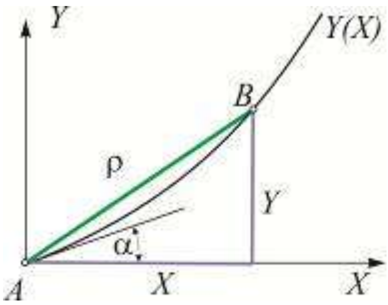

Fig. 2 The relations between coordinates X and Y that define knife profile and the arbitrarily distance from the top of the knife ρ

According to Figure 2, we have that:

$$X = \sqrt{\rho^2 - Y^2}\ . \tag{2}$$

Adding (2) to (1) is obtained:

$$\frac{v_m}{\omega}\cdot\left[\arccos\ z(\rho,Y) - \arccos\frac{R-a}{R}\right] + (R-Y)\cdot\sqrt{1-z(\rho,Y)^2} - \\ -\sqrt{\rho^2-Y^2}\cdot z(\rho,Y) - \sqrt{R^2-(R-a)^2} = 0\ . \tag{3}$$

Where is:

$$z(\rho,Y) = \frac{(R-a)\cdot(R-Y)}{(R-Y)^2+\rho^2-Y^2} - \\ -\frac{\sqrt{(R-a)^2\cdot(R-Y)^2-\left[(R-Y)^2+\rho^2-Y^2\right]\cdot\left[(R-a)^2-\rho^2+Y^2\right]}}{(R-Y)^2+\rho^2-Y^2}\ .$$

According to the adopted procedure, the arbitrarily distance ρ is set. Then the corresponding coordinates X and Y are determined from equations (2) and (3).

3.2. Analytical determination of the first derivative function of the optimal profile *dY/dX* based on the implicit function *f*(*X*, *Y*) = 0

The first derivative of the function represents the tangent angle between the tangent curve *Y*(*X*) and the *X* axis. At an arbitrary position of the curve B the coordinates have the values of X and Y, this angle is denoted by β (Fig. 3). The value of this angle is particularly important at the place of the coordinate start and it is marked with α.

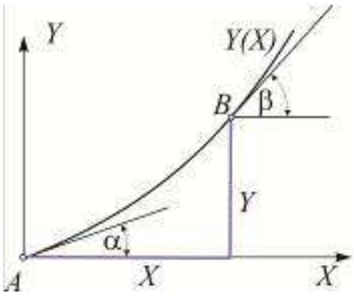

Fig. 3 The angles that the tangents curve *Y*(*X*) are graded with axis *X*

The total differential of the implicit function (1) is "zero" and there is:

$$\frac{\partial f(X,Y)}{\partial X}dX+\frac{\partial f(X,Y)}{\partial Y}dY=0\,. \tag{4}$$

On the basis of (4), the required first derivative, (the tangent angle β), defines the equation:

$$\frac{dY}{dX}(X,Y)=\tan\beta=-\frac{\dfrac{\partial f}{\partial X}(X,Y)}{\dfrac{\partial f}{\partial Y}(X,Y)}. \tag{5}$$

In this case, partial derivatives $\frac{\partial f}{\partial X}(X,Y)$ and $\frac{\partial f}{\partial Y}(X,Y)$ they are not written because they are too long mathematical expressions (stated in APPENDIX).

In the case of a coordinate start, where is $\beta=\alpha$ and X=Y=0, expression (5) becomes:

$$\frac{dY}{dX}(0,0)=\tan\alpha=-\frac{\dfrac{\partial f}{\partial X}(0,0)}{\dfrac{\partial f}{\partial Y}(0,0)}=\frac{\sqrt{a(2R-a)}\cdot v_m}{R^2\omega+(R-a)\cdot v_m}\,. \tag{6}$$

Based on expression (6), the angle α (expressed in radians), defines the equation:

$$\alpha=\arctan\frac{\sqrt{a(2R-a)}\cdot v_m}{R^2\omega+(R-a)\cdot v_m}\,, \tag{7}$$

which very clearly indicates the working speed impact on angle α.

In accordance with the expression (7), in Table 1 and Fig. 5, (data R = 25 cm, a = 10 cm and ω = 16.038s^{-1}), the dependence of the angle α of the working speed is shown in tabular and graphically form, respectively.

Table 1 Dependency of the angle *α* to the working speed

v_m $[m/s]$	α $[rad]$	α $[^0]$
0.40	0.075161123	4. 306415131
0.43	**0.08043533788**	**4. 608605384**
0.50	0.09255301216	5. 302896978
0.55	**0.101048827 3**	**5. 789671329**
0.60	0.109413675 1	6. 268941804
0.70	0.125757927 3	7. 205398474
0.77	**0.136899681 1**	**7. 843773943**
0.80	0.141600795 3	8. 113127946
0.90	0.156957405 4	8. 992996892
1.00	0.171842888 1	9. 845872227
1.08	**0.183422182 1**	**10. 5093169**
1.10	0.186272295 6	10. 67261638

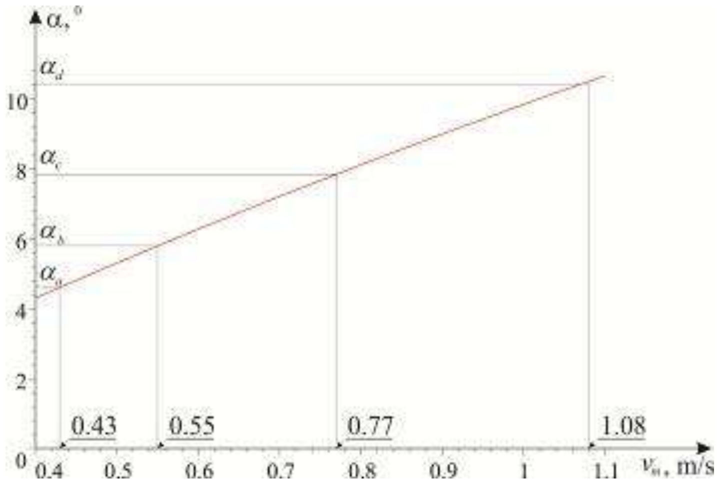

Fig. 4 Dependency of the angle *α* to the working speed

3.2. Optimal knife profile in the *u,v* coordinate system, rotated relative to *X,Y* coordinate system for angle *α*

Coordinates the knife profile *u* and *v*, depending on the angle *α* and the coordinates *X* and *Y*, (Figure 5), define the terms:

$$u = X\cos\alpha + Y\sin\alpha, \quad v = -X\sin\alpha + Y\cos\alpha\,. \tag{8}$$

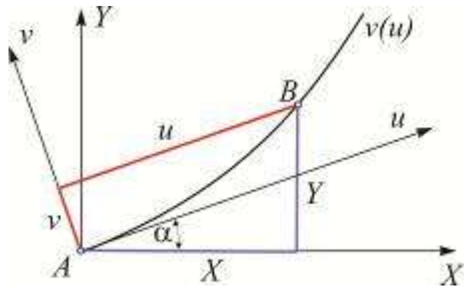

Fig. 5 The knife profile in the rotated *uv* coordinate system

The first derivative *dv/du* at the coordinate start equals zero. For the data R = 25 cm, a = 10 cm and ω = 16.038s^{-1} in the case where the working speed is v_m = 0,43 m/s (hence $\alpha=\alpha_a\cong 4.61°$), the coordinates of the optimum knife profile are shown in the coordinate systems *XY* and *uv* (Table 2). A nonlinear algebraic equation (3), in order to obtain the *Y* coordinate, was solved numerically by SWP program (Scientific Work Place).

Table 2 Optimal knife profile at working speed v_m=0.43 m/s ($\alpha=\alpha_a\cong 4.61°$) in coordinate systems *XY* and *uv*

ρ [mm]	*X* [mm]	*Y* [mm]	*u* [mm]	*v* [mm]
0	0	0	0	0
10	9. 949607535	1. 00265143	9. 998000353	0.199972325 8
20	19. 855014	2. 403834254	19. 98396400	0.800739018 1
30	29. 70400022	4. 203851943	29. 94573565	1. 803584361
40	39. 48419238	6. 403011166	39. 87100614	3. 20980825
50	49. 18303349	9. 00162299	49. 74728408	5. 020729685
60	58. 78775298	12. 00000415	59. 56186562	7. 237690474
70	68. 28533417	15. 39847841	69. 3018022	9. 862059207

The same procedure applied when the coordinates of the optimal knife profiles calculated (Tables 3,4 and 5) in cases where the working speed v_m were 0.55, 0.77 and 1.08 m/s.

Table 3 Optimal knife profile at working speed v_m=0.55 m/s ($\alpha=\alpha_a\cong 5.79°$) in coordinate systems *XY* and *uv*

ρ [mm]	*X* [mm]	*Y* [mm]	*u* [mm]	*v* [mm]
0	0	0	0	0
10	9. 926845354	1. 207369588	9. 998003383	0.199820813 8
20	19. 80130389	2. 812181434	19. 98397994	0.800341119 3
30	29. 61110764	4. 814800566	29. 94576111	1. 803161638
40	39. 34380737	7. 215595704	39. 87099835	3. 209905048
50	48. 98674272	10. 0149407	49. 7471336	5. 022220435
60	58. 52701018	13. 21321609	59. 56136756	7. 24178806
70	67. 95142855	16. 81081073	69. 30062550	9. 870324474

Table 4 Optimal knife profile at working speed v_m=0.77 m/s (α=α_a≅7.84°) in coordinate systems *XY* and *uv*

ρ [mm]	X [mm]	Y [mm]	u [mm]	v [mm]
0	0	0	0	0
10	9. 877267582	1. 56191713	9. 998013209	0.199328581 9
20	19. 68806902	3. 518513666	19. 98404501	0.798714694 4
30	29. 42006745	5. 870232653	29. 94593443	1. 800280879
40	39. 06070075	8. 617520337	39. 87129778	3. 206183591
50	48. 59714938	11. 76082787	49. 74749703	5. 018619276
60	58. 01630148	15. 30061315	59. 56160548	7. 239830954
70	67. 30471487	19. 23734274	69. 30037041	9. 872115312

Table 5 Optimal knife profile at working speed v_m=1.08 m/s (α=α_a≅10.51°) in coordinate systems *XY* and *uv*

ρ [mm]	X [mm]	Y [mm]	u [mm]	v [mm]
0	0	0	0	0
10	9. 794184226	2. 018404157	9. 998036999	0.198131699 1
20	19. 50410993	4. 42602484	19. 98422020	0.794319286 2
30	29. 11740777	7. 223334722	29. 94647396	1. 791283617
40	38. 62143367	10. 41080504	39. 87245227	3. 191794244
50	48. 00323403	13. 98890714	49. 74950478	4. 998677285
60	57. 24950774	17. 95811414	59. 5646398	7. 214823983
70	66. 34656423	22. 31890263	69. 30448335	9. 843200029

In accordance with the coordinates obtained in the *XY* coordinate system (Tables 2,3,4 and 5), at Figure 6 graphically depicts the optimal profiles of the knife in the considered four working speeds and the corresponding angles α. For working speed v_m = 0.43 m/s where α=α_a≅4.61° the optimum profile curve is indicated by *a*. For working speed v_m = 0.55 m/s where α=α_b≅5.79° curve of optimal profile is indicated by *b*. For working speed v_m = 0.77 m/s where α=α_c≅7.84° the optimum profile curve is marked with *c*. For working speed v_m = 1.08 m/s where α=α_d≅10.51° the optimum profile curve is denoted by *d*. In case of the same rotor rotation direction value of angle α were in range from 5.24-14.41° [17].

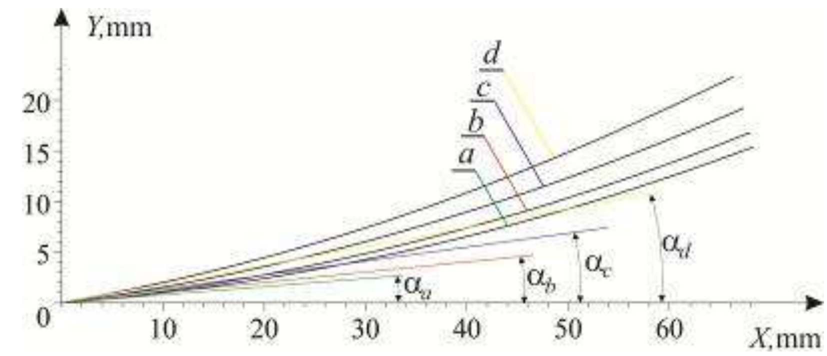

Fig. 6 Optimal knife profiles for the considered cases of working speed in the *XY* coordinate system

Between the optimal profiles *a*, *b*, *c* and *d* (Figure 6), at first glance, no greater similarity is noticed. However, it can be seen that the similarity of these profiles is actually very large in the optimal profil knife curve for the corresponding angle α, at the *uv* coordinate system. Figure 7 shows all four curves of the optimal profiles in the *uv* coordinate system.

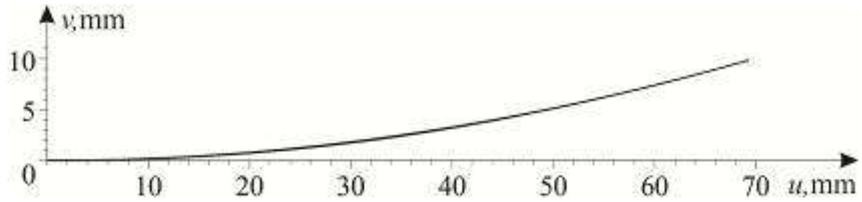

Fig. 7 Optimal profiles for considered cases of operating speed in the *uv* coordinate system

3.3. Functions that with high accuracy approximate the required optimal profiles in the *uv* coordinate system

It is clearly visible from the obtained results that the curves of optimal profiles in the *uv* coordinate system are such smooth functions that can be quite approximated with a number of different functions. For example, the shape features $\bar{v} = Au^B$, or $\bar{v} = Au^2 + Bu^4$ give a completely satisfactory approximation with the exact optimal profile. Tabular display of the difference between the exact solution shown in Table 2, 3, 4 and 5 regard to the approximate $\bar{v} = Au^2 + Bu^4$ and the corresponding coordinate values are given in the Table 6.

Table 6 Differences between exact solutions and approximate forms $\bar{v} = Au^2 + Bu^4$

v_m=0.43 m/s	v_m=0.55 m/s	v_m=0.77 m/s	v_m=1.08 m/s
$v-\bar{v}$, mm			
0	0	0	0
-0.0002040025	-0.0002581552	-0.0003471793	-0.0004493953
-0.0003063328	-0.0003911444	-0.0005306464	-0.0006911317
0	0	0	0
0.000515446	0.000676583	0.00094197	0.001248749
0.000716291	0.000960503	0.00136301	0.001829678
0	0	0	0
-0.002007916	-0.002898321	-0.004368407	-0.006085105

4. CONCLUSIONS

The angle value at the top of the knife (α) for the investigated operating speeds of 0.43-10.08 m/s, in the case of reverse rotor rotating, ranges within the range of 4.61-10.51°. There is practically linear dependence between the working speed and the change in the angle α. By rotating the coordinate system for the value of the angle α a new coordinate system is obtained. Due to the great similarity of the optimal profiles in the *uv* coordinate system for all cases of working speeds, it can be practically concluded that an optimal profile covers all working speeds, requiring a corresponding rotation of the blade profile.

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APPENDIX

For function $f(X,Y)$ by shape

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

where is

$$z(X,Y)=\frac{(R-a)(R-Y)-X\sqrt{X^2+(R-Y)^2-(R-a)^2}}{(R-Y)^2+X^2},$$

the value R, a, ω and v_m are constant, parcial derivations have shape:

$$\frac{\partial f}{\partial X}(X,Y)=-\frac{\partial z}{\partial X}\left[\frac{v_m}{\omega}\frac{1}{\sqrt{1-z(X,Y)^2}}+\frac{(R-Y)z(X,Y)}{\sqrt{1-z(X,Y)^2}}+X\right]-z(X,Y),$$

$$\frac{\partial f}{\partial Y}(X,Y)=-\frac{\partial z}{\partial Y}\left[\frac{v_m}{\omega}\frac{1}{\sqrt{1-z(X,Y)^2}}+\frac{(R-Y)z(X,Y)}{\sqrt{1-z(X,Y)^2}}+X\right]-\sqrt{1-z(X,Y)^2},$$

where is

$$\frac{\partial z}{\partial X}=\frac{1}{\left((R-Y)^2+X^2\right)^2}\left\{-\frac{2X^2+(R-Y)^2-(R-a)^2}{\sqrt{X^2+(R-Y)^2-(R-a)^2}}\left((R-Y)^2+X^2\right)\right.$$
$$\left.-2X\left[(R-a)(R-Y)-X\sqrt{X^2+(R-Y)^2-(R-a)^2}\right]\right\},$$

$$\frac{\partial z}{\partial Y}=\frac{1}{\left((R-Y)^2+X^2\right)^2}\left\{\left[-(R-a)+\frac{X(R-Y)}{\sqrt{X^2+(R-Y)^2-(R-a)^2}}\right]\left((R-Y)^2+X^2\right)\right.$$
$$\left.+2(R-Y)\left[(R-a)(R-Y)-X\sqrt{X^2+(R-Y)^2-(R-a)^2}\right]\right\}.$$

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TWIN ROW TECHNOLOGY FOR MAIZE SEEDING

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Abstract: *This paper presents the results of maize seeding with two different types of seeding machnes: standard – OLT PSK 4 and twin row – MaterMacc MS 8100 seeder. Research was carried out on experimental field of Agricultural faculty from Osijek (Klisa, Osječko – baranjska county, Croatia). Two maize hybrids were used: Zemun polje 488 (ZP 488) and Zemun polje 560 (ZP 560) in standard seeding with row spacing of 70 cm and in twin row seeding with row spacing of 22 cm (between plant lines) and 48 cm (between plat rows). The standard seeding for ZP 488 hybrid was performed on a predetermined set of 70297 plants/ha. Estimated set after emergence was 66 740 plants/ha. Yield of this hybrid with standard seeding was 14 055 kg/ha with st.dev. of 723.56 and c.v. of 5.23%. Yield with twin row technology was 15 028 kg/ha or 6.48% more than wth standard seeding. Predetermined set for this case was 71 544 plants/ha with 63 723 plats/ha estimated after emergence.The standard seeding for ZP 560 hybrid was performed on a predetermined set of 62 831 plants/ha.Estimated set after emergence was 53 073 plants/ha. Yield of this hybrid with standard seeding was 14 394 kg/ha with st.dev. of 319.84 and c.v. of 2.22%. Yield with twin row technology was 14 747 kg/ha or 2.40% more than with standard seeding. Predetermined set for this case was 63 346 plants/ha with 53 605 plats/ha estimated after emergence.*

Key words: *maize,yield, standard seeding, twin row seeding, twin row seeder*

1. INTRODUCTION

Maize (Zea mays L.) is one of the three leading agricultural crops along with wheat and rice, both in the world and in our country. Of all cereals, maize has the greatest fertility potential, that needs to be used in this and future period as well. Maize seeding in our area is performed at the row spacing of 70 and 75 cm. Recently, scientific research has been conducted for maize seeding in two rows, worldwide known as twin-row technology. Depending on the seeding machine producers, the twin rows are seeded on a spacing of 20, 22 or 25 cm, and the central spacing of the adjoining dotted rows is 70 or 75 cm, so that maize harvest can be done with standard maize harvesters.This sowing technology allows better soil and sunlight utilization, and contributes to achieving equal or greater yield per hectare in most experiments (Pedersen, P., 2002; Ogrizović, B., 2015; Banaj, A., 2017; Balem, Z., 2014; Robles, M., 2012).

According to available current literature of this scientific area, twin-row technology has been applied at the beginning of the nineteenth century in SAD as an attempt to enlarge yield by increasing the sowing of a larger number of plants (crops) per production area (ha). In the areas of the former Yugoslavia, Tadić, L. (1988)started experiments with maize seeding in double rows in 1976. Similar with this, according to Čuljat, M. (1989), the basic aim of enlarging the yield is by increasing the plant density. According to the same author, sowing in strips reduced the shading of plants, and the number of cracked and broken plants did not increase.There is a large number of sowing machine manufacturers on the agricultural technology market today, some of which are predominant such as *Great Plains,John Deere, Monosem, MaterMacc Crust Buster Speed King Inc., Kinze Manufacturing, Gaspardo* and many others. The differences between the offered models of these companies are certainly in the sowing system as well as the spacing between double rows that is 20, 22 or 25 cm.Banaj, A. et al. (2017) presents the results of the application of twin-row technology in the Republic of Croatia using the *MaterMacc Twin row - 2* planter. Studies were conducted in the eastern part of Croatia where optimal precipitation rates were recorded throughout the whole vegetation (2016) of maize growing.According to Blandino M., et al. (2013) a study of the row technology was conducted in Italy in 12 locations on different soils and climatic conditions. The hybrid DKC 6815, of the FAO Group 600, is sown on various circuits, from 7.5 to 9.5 and even 10 plants / m^2. The results indicate an increase in yields at 8 locations by 5.5% in average. Yield increase was 0.6 t/ha (+ 3.6%) and 0.9 t/ha, which is the increase of 6.2%.According to Mackey G.L. et al. (2016), there is an increased interest in narrow rows (<30 inches) for maize production in order of yield increment.Experiments were conducted in USA with three hybrids seeded at a 15-inch spacing, two rows at 8 inches (20.32 cm) and standard sown at 30 inches (76.2 cm) with circuits of 30 000, 35 000, 40 000 and 45 000 plants per acre.In other part of the USA, twin-row seeding has 6.7% higher yield compare to the standard which was not the case in the next year. However, a part of the author presented results with no significant differences in the yield between sowing on the standard row spacing and sowing with twin-row planters. Authors Ogrizović, B. (2015) and Robles, M. (2012) quotes that twin-row technology has advantages over the classic corn sowing because it increases the plant's complexity and improves the physical appearance of the plants which increases yield.

2. MATERIALS AND METHODS

The field experiment was conducted for 2016 growing season on experimental field of Agricultural faculty from Osijek (*Klisa, Osječko – baranjska county, Croatia).*Maize was seeded at 14th of April and harvested at 26thof September. Grain yields were calculated on 14% grain moisture basis.The basic technical features of *MaterMacc* twin row seedersectionsis shown in Figure 1. Working speed for *OLT PSK – 4* seeder was 7.69 km/h (σ = 1.17; c.v.=15.30%) and for *MaterMacc* seeder was 8.28 km/h (σ = 0.18; c.v.=2.21%). The depth of deposited seeds was 5.02 cm for *OLT PSK – 4* seeder(σ = 1.02; c.v.=20.43%) and 5.75 cm for *MaterMacc* seeder (σ = 0.56; c.v.= 9.80%).

Fig. 1The basic technical features of *MaterMacc* twin row seeder sections

Near the experimental field there is a meteorological station which measured the main temperatures and precipitation factors, shown at Table 1. Also, for this filed, the main soil properties are specified, Table 2.

Table 1 Total monthly precipitation (mm) and mean air temperature (^{0}C)

Meteorological station *Klisa*	Month						Total
	IV.	V.	VI.	VII.	VII.	IX.	
Mean air temperature (^{0} C)	11.5	16.5	19.8	21.6	20.8	16.7	-
Sum of hours with sunshine(h)	179.3	223.9	244.4	272.7	258.4	192.8	1371.5
Total precipitation(mm)	58.7	69.3	82.9	60.7	58.9	55.0	385.5
No. of clear days	5	5	6	9	11	9	45
No. of rainy days	12	13	12	10	9	9	65
No. of days with frost	2	0	0	0	0	0	2
No. of warm days ($t_{max} \geq 25^o$ C)	2	11	18	24	23	13	91
No. of hot days ($t_{max} \geq 30^o$ C)	0	0	5	11	10	3	29

Table 2 Soil properties and soil texture

<table>
<tr><td rowspan="3">Location
Klisa</td><td>Depth</td><td colspan="3">pH</td><td colspan="2">Humus content</td></tr>
<tr><td>cm</td><td>H_20</td><td>KCl</td><td>Evaluation</td><td>%</td><td>Evaluation</td></tr>
<tr><td>0-30</td><td>8.44</td><td>7.55</td><td>alkaline</td><td>3.71</td><td>Enough humus</td></tr>
<tr><td colspan="2">Carbonates</td><td colspan="3">AL-P_2O_5</td><td colspan="2">AL-K_2O</td></tr>
<tr><td>%</td><td>Evaluation</td><td colspan="2">mg/100g</td><td>Evaluation</td><td>mg/100g</td><td>Evaluation</td></tr>
<tr><td>9,63</td><td>Medium carbonated</td><td colspan="2">15,58</td><td>Moderate</td><td>24,29</td><td>Good</td></tr>
<tr><td>Coarse sand</td><td>Fine sand</td><td colspan="2">Coarse silt</td><td>Fine silt</td><td>Clay</td><td>Texture</td></tr>
<tr><td>2,0 - 0,2 mm</td><td>0,2 - 0,05 mm</td><td colspan="2">0,05 - 0,02 mm</td><td>0,02 - 0,002 mm</td><td>< 0,002 mm</td><td rowspan="2">Silty Loan</td></tr>
<tr><td>0,60%</td><td>3,48%</td><td colspan="2">42,62%</td><td>27,63%</td><td>25,67%</td></tr>
</table>

3. RESULTS AND DISCUSSION

Determined plant configuration of conducted research with *ZP 488* and *ZP 560* hybrids are shown in Table 3.

Table 3 Number of plants and spacing inside rows after emergence

<table>
<tr><td rowspan="2">Hyb.</td><td rowspan="2">Seeding rate (seed/ha)</td><td colspan="3">Number of plants/ha after emergence</td><td colspan="3">Plants spacing inside row (cm)</td></tr>
<tr><td>x_i</td><td>σ</td><td>c.v. (%)</td><td>x_i</td><td>σ</td><td>c.v. (%)</td></tr>
<tr><td rowspan="2">*ZP 488*</td><td>Standard (70 297)</td><td>66 740</td><td>1 314.66</td><td>1.97</td><td>21.10</td><td>3.46</td><td>16.43</td></tr>
<tr><td>Twin row (71 544)</td><td>63 723</td><td>11 499.66</td><td>18.05</td><td>37.97</td><td>2.93</td><td>7.72</td></tr>
<tr><td rowspan="2">*ZP 560*</td><td>Standard (62 831)</td><td>53 073</td><td>5 925.11</td><td>11.16</td><td>28.03</td><td>9.67</td><td>34.52</td></tr>
<tr><td>Twin row (65 346)</td><td>53 605</td><td>11 066.28</td><td>20.64</td><td>41.40</td><td>2.51</td><td>6.07</td></tr>
</table>

The standard seeding of *ZP 488* hybrid was performed on a predetermined set of 70 297 plants/ha. Estimated set after emergence was 66 740 plants/ha. Predetermined set for twin row seeding was 71 544 plants/ha with 63 723 plats/ha estimated after emergence.The standard seeding of *ZP 560* hybrid was performed on a predetermined set of 62 831 plants/ha. Estimated set after emergence was 53 073 plants/ha. Predetermined set for twin row seeding was 65 346 plants/ha with 53 605 plats/ha estimated after emergence.

Grain yields were calculated on 14% grain moisture basis and the results are shown in Table 4 and 5.

Table 4 Maize yield with standard and twin row seeding for*ZP 488*hybrid

Standard seeding – 66 740plants/ha in harvest – ***ZP 488***				
Harvest date		26th September 2016		
Yield (kg/ha)	σ	c.v. (%)	Minimum (kg/ha)	Maximum (kg/ha)
14 055	723.56	5.23	13 235	14 992
Grain moisture in harvest (%)				
x_i	σ	c.v. (%)	Minimum	Maximum
17.66	1.15	6.51	15.80	18.60
Twin row – 63 723plants/ha in harvest – ***ZP 488***				
Harvest date		26th September 2016		
Yield (kg/ha)	σ	c.v. (%)	Minimum (kg/ha)	Maximum (kg/ha)
15 028	476.71	3.17	14.355	15.410
Grain moisture in harvest (%)				
x_i	σ	c.v. (%)	Minimum	Maximum
19.80	1.11	5.62	18.00	21.10

Yield of *ZP 488*hybrid with standard seeding was 14 055 kg/ha with st.dev. of 723.56 and c.v. of 5.23%. Yield with twin row technology was 15 028 kg/ha or 6.48% more than with standard seeding.

Table 5 Maize yield with standard and twin row seeding for*ZP 560* hybrid

Standard seeding – 53 073plants/ha in harvest – ***ZP 560***				
Harvest date		26th September 2016		
Yield (kg/ha)	σ	c.v. (%)	Minimum (kg/ha)	Maximum (kg/ha)
14 394	319.84	2.22	13 965	14 714
Grain moisture in harvest (%)				
x_i	σ	c.v. (%)	Minimum	Maximum
15.60	0.68	4.37	14.90	16.40
Twin row – 53 605 plants/ha in harvest – ***ZP 560***				
Harvest date		26th September 2016		
Yield (kg/ha)	σ	c.v. (%)	Minimum (kg/ha)	Maximum (kg/ha)
14 747	1 170.88	8.09	13 337	16 026
Grain moisture in harvest (%)				
x_i	σ	c.v. (%)	Minimum	Maximum
17.12	0.79	4.63	16.00	17.90

Yield of *ZP 560*hybrid with standard seeding was 14 394 kg/ha with st.dev. of 319.84 and c.v. of 2.22%. Yield with twin row technology was 14 747 kg/ha or 2.40% more than with standard seeding.

4. CONCLUSION

Based on the meteorological data, primarily by observing the average monthly air temperature and monthly rainfall, it can be concluded that the vegetation year 2016 was suitable for maize production on experimental field of Agricultural faculty from Osijek.In the standard seeding with the pneumatic seeding machine *OLT PSK – 4*, hybrid *ZP 488* with set of 66 740 plants/ha after emergence, obtained the yield of 14 055 kg/ha of dry grain with an average humidity of 17.66%. Twin row seeding of the same hybrid, by using *MaterMacc* twin row seeding machine, obtained a yield 15 028 kg/ha of dry grain with an average moisture of 19.80%, which makes an increase of 6.48%, compared to the standard seeding.The standard seeding of the hybrid *ZP 560* with a set of 53 073 plants/ha after emergence, obtained the yield of 14 394 kg/ha of dry grain with an average moisture of 15.60%.Twin row seeding of the same hybrid with a set of 53 605 plants/ha obtained yield of 14 747 kg/ha of dry grain with an average moisture of 17.12 %, which makes an increase of 2.40%, compared to standard seeding. The mentioned results after one-year research, shows that twin row technology had bigger yields for both of the hybrids in research.

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AN IRRIGATION PREDICTION SYSTEM USING MACHINE LEARNING FOR PEARS

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Abstract *Irrigation is one of the most important works in agriculture. Farmers have to visit their farm day after day to check whether the products need to be irrigated or not. Moreover, since decision of irrigation necessity is depending on experience and intuition of each farmer, it is difficult for another person to alternate the task of irrigation necessity decision. In this paper, we propose to introduce machine learning methods to learn the farmer's decision for irrigation necessity. The proposed method is a hybrid learning mechanism between supervised learning and reinforcement learning. For the reinforcement learning, the farm state is observed through the sensors installed in the farm. Moreover, the farmer's subjective records are collected for the supervised learning.*

Key words (bold): *irrigation, prediction, machine learning, sensor, pear*

1. INTRODUCTION

Information and Communications Technology (ICT) has been advanced and available in various productive fields. Agricultural engineering is not an exception. For example, sensing technologies, which is a part of ICT, play an important role for agricultural production. Remote sensing technology, geographic positioning systems (GPS), and geographic information systems (GIS) are used to monitor the variability across fields. Unmanned aerial systems (UAS) become very popular for the same purpose recently. On the other hand, sensing technologies are used to monitor agricultural environments around agricultural products such as temperature, humidity, soil moisture and so on.

As above-mentioned, data in the agricultural engineering are easily collected, even though introduction and maintenance costs of the sensing technologies are relatively high. Moreover, how to process the collected data should be considered for agricultural management purposes. Artificial Intelligence (AI) is one of the most promising technologies that value farmers. AI is, however, the broader concept of machines being able to solve problems in an intelligent way. For the agricultural engineering field, machines that have an ability of judgement instead of a farmer are needed and Machine Learning (ML) is the technology in the field of AI to realize such an ability.

Introduction of ML into field analysis related with remote sensing has a relative long history [1]-[3]. Yamazaki and Gingras [1] have applied an Markov Random Field (MRF) model to classify remote sensing images. Duro *et al*. [2] compared pixel-based and object-based image analysis approaches for classifying land cover classes. They used three supervised machine learning algorithms: decision tree (DT), random forest (RF), and the support vector machine (SVM). More recently, a unique research of remote sensing image analysis was presented to be related with economic analysis by Jean *et al*. [3]. They demonstrated an accurate, inexpensive, and scalable method for estimating consumption expenditure and asset wealth from high-resolution satellite imagery. They used a convolutional neural network, which has ability to extract features from a huge image database automatically. Another research field where ML has been used is data mining [4]. One object of data mining is to obtain knowledge and trends collected agricultural data.

In these days, application of ML to irrigation has been collecting attention [5]. Since decision of irrigation necessity is depending on experience and intuition of each farmer, it is difficult for another person to alternate the task of irrigation necessity decision. In this paper, we propose an irrigation prediction technique based on ML to judge appropriate irrigation timing and to alleviate the daily tasks of farmers. Our research target is pears “Le Lectier” which are particular to Niigata prefecture in Japan, although they originate in France.

2. Supervised Reinforcement Learning

Algorithms of ML are categorized into two approaches based on how their training is proceeded: supervised and unsupervised learning. Supposed that the object of ML is to find out a mapping between inputs and outputs, sets of an input and an output are provided for supervised learning algorithms, while only inputs are provided for unsupervised learning algorithms. is the more commonly used between the two. Reinforcement learning, which is a kind of unsupervised learning, does not expect the existence of the outputs, but it proceeds training by obtaining feedback from its environment. This feedback is called reward in the algorithm of reinforcement learning.

We propose an irrigation system that mimics irrigation necessity decision by the farmer who grows “Le Lectier”. Since it is desirable to exclude reliance on the farmer, introduction of reinforcement learning is an appropriate solution. However, it is difficult to define and observe the reward from the environment in the case of “Le Lectier” planting. For example, when the reward is defined as quality of the final fruits, it takes so long time to observe the reward that learning speed must be too slow. Therefore, we adopt a hybrid learning mechanism between supervised learning and reinforcement learning as shown in Fig. 1. In the proposed system, there are three main entities: the automatic irrigation system, the farm as environment, and the farmer as a superviser. The automatic irrigation system observes state of the farm by sensing technologies and decides whether the action of irrigation is needed or not. As the result of the action decision, the reward is feedbacked to the automatic irrigation system. Since the reward definition and observation have difficulty as it is mentioned above, the farmer's direct decision of irrigation is provided to the automatic irrigation system as the command for action.

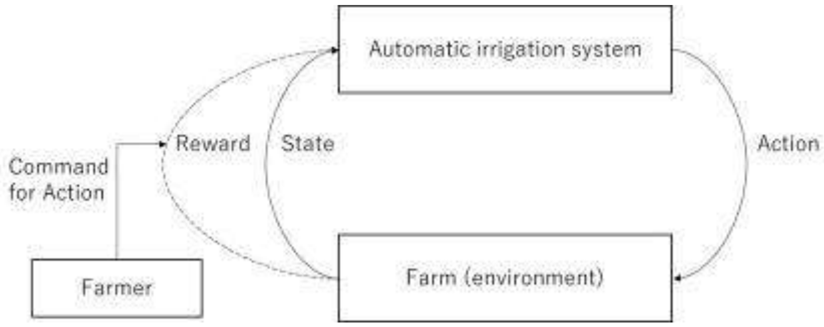

Fig. 1 Irrigation system with supervised reinforcement learning mechanism.

Supervised and reinforcement hybrid learning is not a novel concept. For instance, Rosenstein and Barto [6] have already examined a supervised actor-critic architecture, where the actor-critic framework belongs to reinforcement learning. Our contribution is that we introduce this hybrid learning mechanism into a real problem of agriculture irrigation and define the supervisor as the command for action from the farmer.

3. Sensing Environment

The automatic irrigation system observes the farm state through the sensors installed in the farm. Figure 2 present our field experimental sensor positioning. With the cooperation of a local pear farmer, we have installed sensors at pear fields: Field 1 and Field 2. Field 1 has the area of about 29m x 72m and Field 2 does the one of about 78m x 54m. The distance of two fields is about 100m. The sort and placement of the sensors are presented in Fig. 2, which shows that six pairs of soil moisture and water potential sensors were totally buried at the depth of 30 cm from the earth surface and a rain gauge was set up in Field 1 and a humidity and temperature sensor were set up in Field 2 respectively. These sensors were used to monitor the field environments.

4. Supervised Information

The automatic irrigation system needs the farmer's command for irrigation action. To collect the farmer's decision, we have developed an application to record work situation as shown in Fig. 3. The work starting time is recorded automatically. The farmer records the earth moisture at 7 levels, takes the pictures of the sky and the earth during the work, and writes some comments on the work.

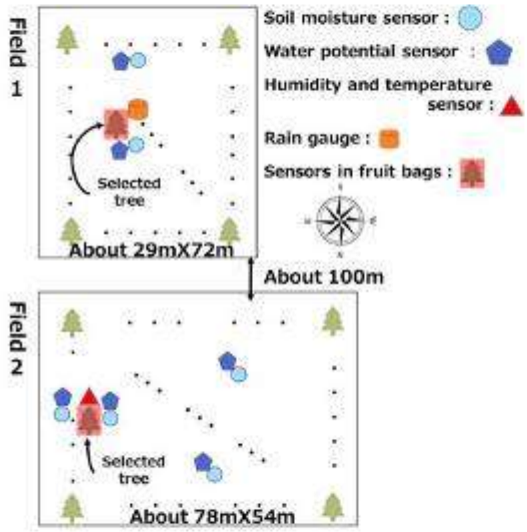

Fig. 2 Various sensor placement in the experiment.

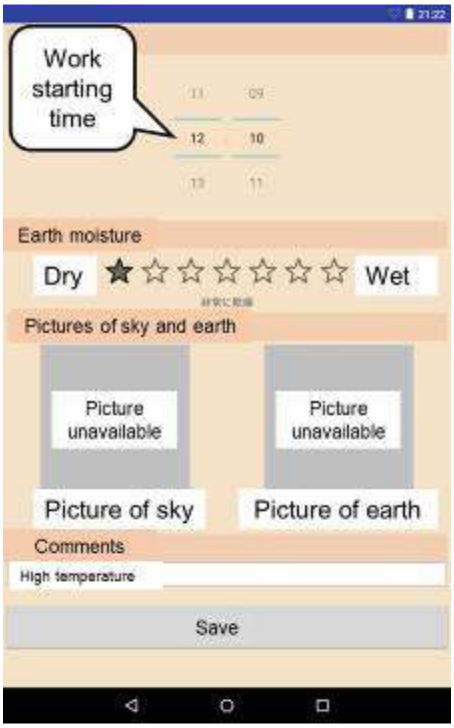

Fig. 3 Various sensor placement in the experiment.

5. CONCLUSION

Although irrigation is important for agriculture, manual irrigation needs every day's check of the farm and it must be a heavy burden for farmers. Also, suitable irrigation timing and quantity should be determined according to unstable environmental conditions such as weather for open-field cultivation. The automatic irrigation system is proposed to mitigate such a heavy work for the open-filed farmers. In the proposed system, machine learning methods are used to support the farmer's decision of irrigation. Especially reinforcement learning is selected as the most suitable scheme among machine learning methods. In reinforcement learning scheme, rewards must be defined to judge whether irrigation timing and quantity are appropriate or not. Definition of the rewards in the reinforcement learning scheme is, however, relatively difficult for agriculture application, because we should wait for substantial judgement of success or fail until the final harvest. This delayed judgement prohibits swift learning of appropriate irrigation. Therefore, supervised learning is combined with the reinforcement learning scheme, where farmer's commands substitute the rewards. Namely, the farmer's opinion judged from the sensing data is considered as the rewards of reinforcement learning in the initial learning phase. Based on the proposed scheme, we have developed a sensing system in the pear field and an application to collect work situation records from the farmer. The work situation records will be able to be used as the rewards in the reinforcement learning scheme.

In the future, a total automatic irrigation system will be constructed by combining the machine learning method presented in this paper.

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COMPARISON OF PESTICIDE APPLICATION QUALITY USING DIFFERENT TYPES OF ORCHARD SPRAYERS

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Abstract. *Quality application of pesticides means using minimum amount of protective liquid and its complete deposition on target surfaces. The procedure of pesticide application in perennial plantations is almost solely characterized by spraying process which uses air flow generated by the sprayer fan. The basic criterion of a successful pesticide application is the application and technical efficiency expressed through the distribution, retention and utilization of pesticide active substances. Classic sprayers with low-spray axial fans are dominant in local fruit growing practice.*

The testing included three types of orchard sprayers, namely: classic orchard sprayers with low-spray axial fan (A), recycling orchard sprayers (B) and orchard sprayers with backward angled air flow direction (C). The testing of the sprayers involved monitoring of: the amount of recycled liquid, pesticide deposit on the leaf surface and fruits, the amount of pesticide deposited on the soil surface and drift on the soil surface outside the working scope as well as drift made by floating of small droplets.

The main advantage of recycling sprayers is more efficient utilization of chemical agents and reduced soil contamination. The working fluid that does not reach the target surfaces is collected and returned to the tank, and drift is significantly lower than when classic sprayers are used.

Key words: *perennial plantations, types of orchard sprayers, deposit, drift.*

1. INTRODUCTION

Lately, researchers have been preoccupied by the idea of improving pesticide application technique, namely by enabling recycling of the portion of used liquid that does not deposit on the plant surface. Studies of drift occurrence during the use of sprayers have shown that technical parameters of fan defining the possibility to adjust the volume, velocity and direction of air flow, have crucial effect on protection quality [9, 10].

The total amount of protective agent that does not reach the target surfaces represents economic loss and causes ecological pollution. Depending on technical parameters of the machine and vegetation conditions of the plantation, pesticide loss during the application can be significantly smaller [6]. The incurred financial loss can be easily defined, but long-term effects pesticides have on the ecosystem by reaching the soil and atmosphere are not known. Having that in mind, all improvements resulting in reduction of drift on soil surface in orchards and vineyards are welcome. Finding optimal ratios between biological and technical parameters and their adjustment contributes to reducing drift during pesticide application in perennial plantations.

With technical bases of fan designs we are familiar with, but we lack information about kinetic behavior of droplets in the air flow that carries them, during penetration, distribution, retention and drifting while treating the plantation [7]. Once these phenomena have been completely defined, it will be possible to adjust the sprayer fans better to biological and physical conditions and thus increase the application and technical efficiency while causing less pollution to environment.

Depending on its structure, a plantation row is, more or less, a semi-permeable obstacle for the air flow and therefore may be considered to be a filter with all characteristic properties [4, 11]. Using sprayers in plantation protection is achieved by a two-phase flow, consisting of air and liquid. The twin fluid flow penetrates the plantation row and the possibility of penetration is determined by the inlet kinetic energy, mechanical resistance of leaves and the angle of air flow direction in a horizontal and vertical plane [13, 2]. After passing through the plantation row, the liquid phase should separate from the air phase and be distributed on the surface of plants. The tendency is for the total surface of plants, acting as a filter, to be evenly coated with protective film, in which case clean air would come out of the row. Separation of the two-phase flow and placing liquid on the plant surface is a very complex process [5, 12].

The results of the studies [1, 3] show that slightly less than one third of the total amount of protective liquid remains on the fruit trees in the late leafing stage in spring, and not more than two thirds remain in the full leaf stage in summer. The same studies show that approximately 30% of the used pesticide gets carried away outside the treated surface, so that a portion of it reaches the adjacent row of plants. The active pesticide deposited in such a way is located mostly on the upper face of the leaves in the outer area of the tree crown, in the direction of the wind.

2. MATERIAL AND METHODS

Perennial plantations protection is most frequently performed using a classic axial fan sprayer. The disadvantages characterizing the operation of such sprayers are: great consumption of water and protective agent per hectare, great loss of liquid and therefore of protective agent, bad droplets structure in relation to their size and tendency to drift, a relatively large portion of the chemical agent that reaches the surface layer of soil and causes its contamination.

Experimental tests have been performed on two types of sprayers:

- The first type of sprayer (A) is a classic orchard sprayer with low-spray axial fan.
- The second type of sprayer (B) is a recycling orchard sprayer that performs row cover during its operation.
- The third type of sprayer (C) is an orchard sprayer with deflectors enabling backward angled air flow direction at a 45° angle.

The paper shows the testing results for the above technical solutions of sprayers obtained by monitoring the following parameters:

- Amount of recycled liquid.
- Pesticide deposit on the leaf surface and fruits.
- Amount of pesticide deposited on the soil surface.
- Drift on the soil surface outside the working scope as well as drift caused by floating of small droplets.

Testing of technical solutions of sprayers was performed at working speed of v = 6 km/h and treatment norm of Q = 600 l/ha. Measurements were performed while applying pesticide on a wine-growing plantation at the stage with and without leaf mass on two grapevine varieties. Figure 1 shows the scheme of classic sprayer (A) and two tested types of recycling sprayers (B,C).

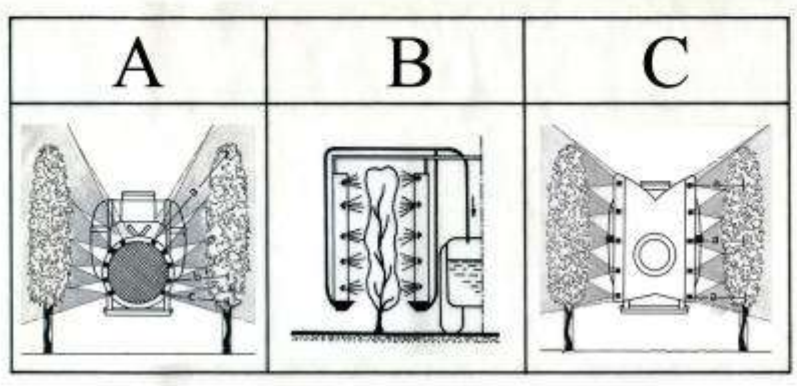

Fig. 1 Scheme of the tested types of sprayers.

The amount of pesticide that reaches the target surfaces represents the parameter reflecting the quality of treatment. Fluorometric method was used in this case, the sample being 100 grapevine shoots and 100 grape berries.

3. RESULTS AND DISCUSSION

The obtained measurements results for the recycling sprayer at the stage without leaf mass show that approximately 60% of liquid returns to the tank regardless of the grapevine variety. The percentage is significantly lower during the full leafiness and varies between 30 and 40% (Fig. 2).

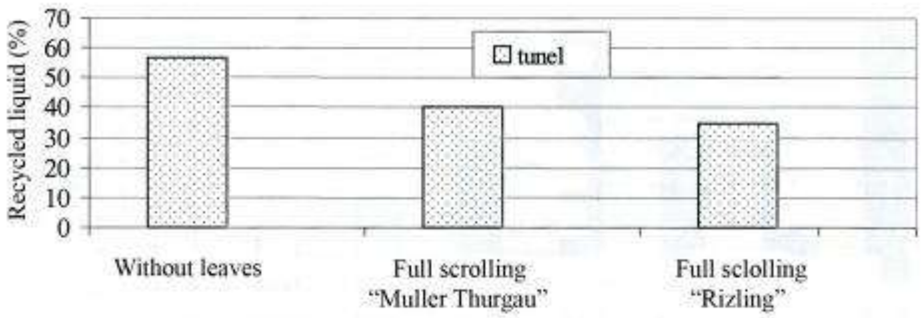

Fig. 2 The percentage of recycled liquid

The graph (Fig. 3) shows the absolute mass of pesticide in (µg) reaching (cm^2) of leaf surface. The presented results refer to the amounts of chemical agent that reach the underside of a leaf and they indicate that the deposition of best quality was achieved while using a classic axial fan sprayer. However, the differences observed in relation to the use of tunnel, as well as two-row collector and reflector solutions are not big enough to be evaluated as significant.

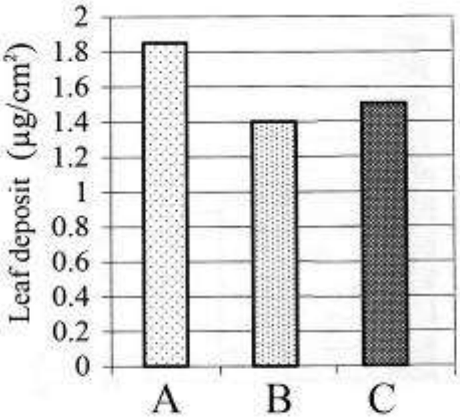

Fig. 3 Deposit of pesticide in leaf surface

The deposit on berries (Fig. 4) was also monitored along with the deposit on leaves. The graph shows that the sprayer C was most efficient, while the results of other designs were similar.

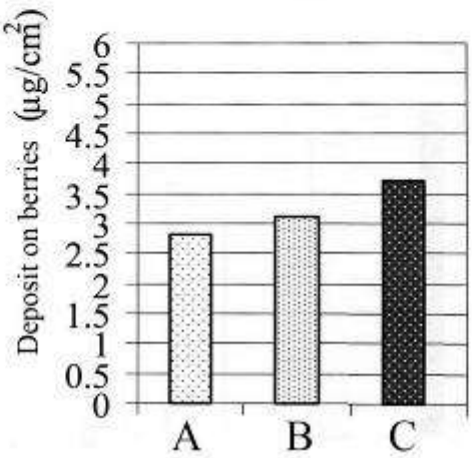

Fig. 4 Deposit of pesticide on berries

After the treatment, the vineyard was checked for the presence of Botrytis cinerea. The graph (Fig. 5) shows the percentage of the vineyard affected with this disease after the application of pesticide using different technical solutions. The results support the thesis about equal efficiency since the achieved differences are not significant.

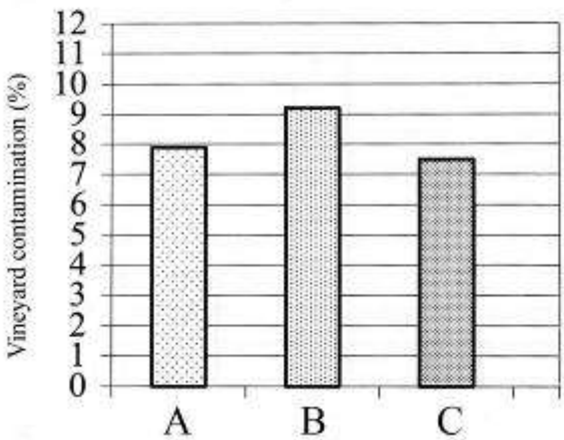

Fig. 5 Presence of Botrytis Cinerea after the treatment

Along with the relevant data on pesticide deposit on leaf mass and fruits, it is necessary to know the amounts that reach the surface layer of the soil. Soil contamination occurs due to a large portion of droplets missing the target surfaces, while a certain number of them does not stay on the plant surface after deposition but slips off from it causing drift. Drift causes deposition on the surface layer of the soil. Drift value is expressed in (µg/cm2) and represents an irretrievable loss of chemical agent (Fig. 6). From the viewpoint of preservation of the environment, the result indicates that it is the most disadvantageous to perform the application using a recycling solution.

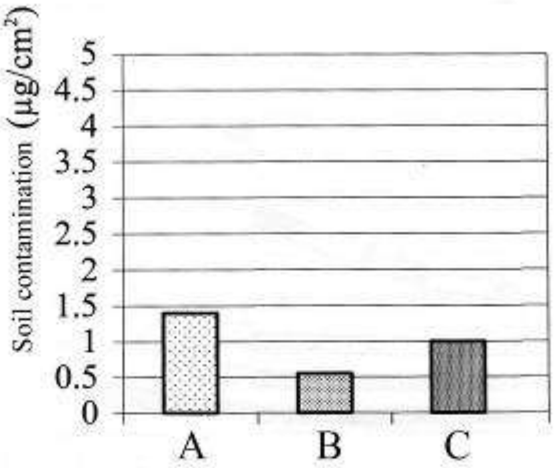

Fig. 6 Deposit of pesticide on the surface layer of the soil

Having in mind the fact that drift, during pesticide application, occurs in two forms: as the portion that reaches the soil surface outside the working scope width and as the portion caused by the small droplets floating and moving upwards. Drift caused by movement of the droplets outside the treated area was monitored at different distances from the machine passage with the distance range being from 0 to 30 m (Fig. 7). The obtained results clearly indicate the advantages of using the recycling solution in comparison with the solutions of other types of sprayers. When it comes to the use of the recycling sprayer, drift was measured at the distance of up to 5 m from the passage, and even then, it was significantly lower than when the classic sprayer with A and C was used. The drift component resulting from the floating of small droplets was monitored up to 10 m of height. That is how the graph (Fig. 8) almost identically indicating the disadvantages of the classic sprayer usage was obtained.

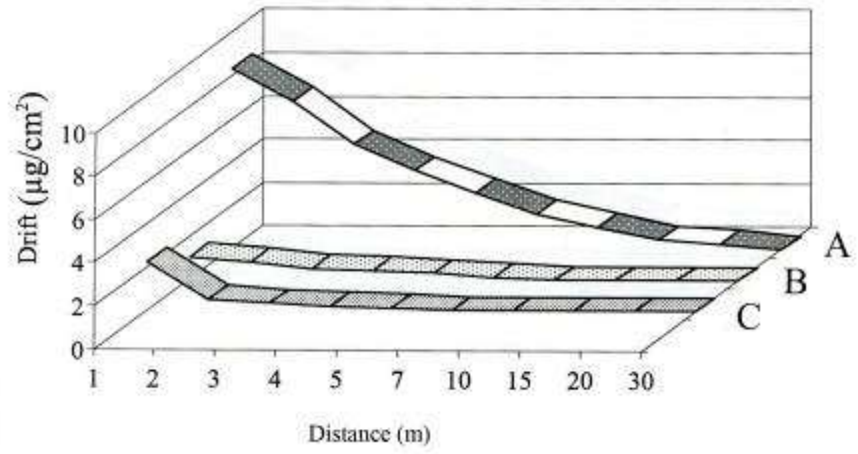

Fig. 7 Movement of the droplets outside the treated area

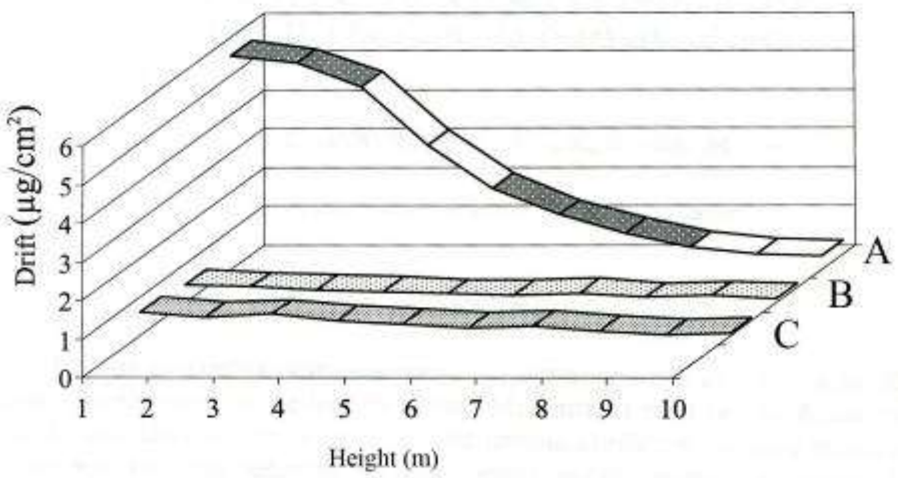

Fig. 8 Movement of the droplets outside the treated area (height)

4. CONCLUSIONS

The usage of the technical solution, that applies pesticides using the recycling method, has the following characteristics:

- Application of pesticides is performed in such a manner that, regardless of the vegetation period, variety and specific climate conditions of a particular year, protective liquid not deposited on the target surface is collected and returned to the tank, thus achieving a saving in approximately 30 – 40%,
- The quality of pesticide deposition on the leaf mass can be compared to the operation of a classic orchard sprayer,
- Monitoring pesticide application during the attack of *Botrytis cinerea* established that the achieved effect is similar regardless of the technical solution used.
- Using B sprayers causes far less soil contamination than using A and C sprayers and drift is much lower when using all recycling sprayers in comparison with the classic ones.

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SELECTION OF OPTIMAL TMA FOR SECONDARY SOIL TILLAGE IN ORCHARDS AND VINEYARDS

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Abstract: Increasingly pronounced climate changes create arid conditions, in which the local fruit and vine production is carried out without irrigation, imposing the need of soil tillage on the entire planting surface. Due to the fact that secondary treatment improves the water-air properties of the soil, breaks the crust, provides a favorable structure and destroys weed, it is necessary to apply the appropriate tractor machine aggregates. The adequate selection of aggregates from the standpoint of energy consumption is crucial for achieving high yields, the required quality and the necessary economical production in fruit growing.

The aim of this paper is to define the energy and exploitation parameters of the basic tractor-machine aggregates used in secondary soil tillage for perennial plantations. The comparison of the obtained energy and qualitative indicators enables us to select the optimal aggregate for secondary soil tillage in perennial plantations. The results of examining the mechanization means in the secondary soil tillage of surfaces between rows indicate that the lowest fuel consumption is achieved by using a chisel plow (8.1 *l / ha*). By using it, it is possible to achieve a work depth of 12.3 *cm*, a speed of 6.89 *km / h* and a performance of 8.57 *ha/day* with satisfactory quality.

For the sake of further savings in soil tillage operations, it is necessary to form complex tractor-machine aggregates, which can perform working operations in one passage, while cultivating the soil.

Keywords*:* *secondary soil tillage, tractor-machine aggregate, exploitation parameters*.

1. INTRODUCTION

Perennial plantations consume high amounts of water by transpiration in physiological processes during vegetation. In order to accumulate and preserve the necessary amount of moisture in the soil during the dry season, it is necessary to carry out secondary soil tillage on time and with high quality, especially in irrigated plantations. Secondary tillage not only improves mechanical properties, but it also ensures the accumulation and conservation of moisture in the soil [2,12]. The rational performance of this operation is a complex problem.

Soil tillage methods and procedures have a direct impact on the life of plants and their fertility, as well as on the quality of the achieved production. Secondary soil tillage in orchards provides optimal conditions for the development of the physical, chemical, biological and microbiological processes that increase soil potential. The soil is kept loose on the primary surface, interrupting capillarity and slowing down the evaporation of water [14]. In addition to that, soil tillage destroys weed vegetation, which competes with cultivated plants, taking moisture and nutritious matter from the soil. Therefore, the basic task of both, primary and secondary soil tillage, is to create and maintain the physical condition of the land, enabling thus the rational cultivation of fruit trees [11, 15].

Much of the previous research and practical knowledge suggests that soil tillage engages a large amount of energy. According to these results, the total energy consumption necessary for the tillage in the fruit production ranges from 24.5 to 34.5% of the total energy needed [3,13], out of which a significant part corresponds to the energy spent for secondary soil tillage. Test results obtained in the presented production conditions indicate the possibility of saving energy and increasing the productivity of aggregates in soil tillage [8]. Reduced tillage systems that use chisel plows instead of conventional plows generate significant savings in energy, machine work and human labor per unit of cultivated surface [7.9].

2. MATERIALS AND METHOD

Field tests were carried out in an apple plantation with a spacing of (3.5 x 1.5) and apple varieties Jonagold, Idared and Melrose. It is located on a wavy terrain at an altitude of approximately 85 *m*. The geographical location of the plantation is characterized by a moderate continental climate and a cambisol-type soil.

For the purpose of experimental testing, secondary soil tillage tools, such as: Vineyard plow with duck-leg hoes VP - 189, chisel plow PP-220, disc-harrow VVT-223 and cultivator IMT-642 were used. The basic technical data of the investigated tools are shown in Table 1.

Table 1.Technical characteristics of tools for tillage

Indicators	*Units of measures*	*Working tool*			
		Vineyard Plow VP -189	*Chisel plow PP-220*	*Plate cultivator VVT – 223*	*Cultivator IMT – 642*
Number of working groups		7	7	2	9
Dish diameter	cm	-	-	550	-
Working width	cm	200	210	250	200
Working depth	cm	18	40	23	20
Weight	kg	310	605	400	200
Power demand	kW	37 - 52	55	45	26

The experiment included the exploitation parameters of tractor-machine aggregates: speed, traction, rolling resistance, puling resistance and fuel consumption. The speed of the aggregates during the test was determined on the basis of time measurements by means of a stopwatch and a 180 m trip. The intensity of the puling force was measured with an Amsler's dynamometer and a tensiometer and the obtained values were recorded on the tape of the measuring device.

The tests also determined the basic physical properties of the soil: mechanical composition, resistance to movement, plasticity and compaction. As a significant exploitation parameter, the rolling resistance of the tractor-machine aggregate was determined by measuring the force with a dynamometer «Amsler», without load, in the given operating mode.

Aggregate performance indicators were defined on the basis of measurements of soil fragmentation before and after the passage of the machines, as well as of the height of the soil profile between rows in the orchard. The structural analysis of the soil was determined by using a set of sieves with openings between 1 *mm* and 10 *mm* (Savin's method) [6]. Compaction and earth pressure resistance was determined by using the Ejkelkamp Hand Penetrometer, Set A, while the ground mass was determined by means of the Copenhagen Cylinders.

The obtained exploitation indicators were used for calculating other parameters as well, such as: specific resistance and required traction power. Soil moisture was determined by using the Katchinski method [4], i.e. soil samples were taken at depths of 0-10 *cm*, 10-20 *cm* and 30-40 *cm* and their mass was measured before and after drying at 105 ^{o}C in the dryer.

The lower and upper limits of plasticity were determined on the basis of samples taken after opening two profiles: 0 - 20 and 20 - 40 *cm*. The index plasticity of the treated soil was determined on the basis of the difference in the quantity of water, with which the upper and lower plasticity limits were achieved [1].

3. RESULTS AND DISCUSSION

3. 1. Properties of the soil

The process quality and energy balance of mechanical soil tillage have a decisive impact on the physical properties of the soil. The results obtained after measuring the lower plasticity limit of the sampled orchard soil are shown in Table 2, while those corresponding to the upper limit are shown in Table 3.

Table 2.The lower limit of plasticity

Number of profiles	*Depth* (cm)	*Mass* (g)					*Upper limit of plasticity* (%)
		Sample	*Empty vessels*	*Before drying*	*After drying*	*Content in sample*	
1	2	3	4	5	6	7	8
1	0-20 20-40	14.46 13.50	27.68 23.79	42.14 37.29	39.79 35.04	2.35 2.25	15.58 15.51
2	0-20 20-40	15.93 15.74	23.75 22.44	39.68 38.18	37.28 35.89	2.40 2.29	14.00 15.31
3	0-20 20-40	17.44 16.94	22.79 28.10	40.23 45.04	37.46 42.13	2.77 2.91	14.88 15.65

Table 3.The upper limit of plasticity

Number of profile	*Depth (cm)*	Mass (g)					*Upper limit of plasticity (%)*
		Sample	*Empty vessels*	*Before drying*	*After drying*	*Content in sample*	
1	0-20 20-40	13.07 7.40	25.11 30.34	38.18 37.74	34.10 35.65	4.08 2.09	33.84 29.23
2	0-20 20-40	5.71 9.41	25.81 23.93	31.52 33.34	29.91 30.39	1.61 2.95	29.47 32.27
3	0-20 20-40	9.77 9.94	25.88 29.33	35.65 39.27	32.81 36.47	2.84 2.80	29.52 28.91

The results related to lower and upper plasticity show that the plasticity index of the soil under test conditions ranged from 8.23 to 19.21. Accordingly, the average value of the plasticity index is 13.72. The plasticity coefficient shows that the land, where the apple plantation is located, is plastic according to Aterberg's classification [10].

The results of the mechanical composition test for the land, where the apple orchard is located, are shown in Table 4.

The results presented in Table 4 show that, in horizon A, the content of colloidal clay fractions <0.002 *mm* varies between 41.3 and 54.5%, the content of powder between 31.9 and 42.3%, while fine sand is significantly less than 10.1, up to 21.9%. Coarse sand aggregates > 0.2 *mm* are not found in any profile.

By soil compactness we mean the soil mass in volume units, whereas the soil is considered homogeneous, although it is not the case in reality. The aforementioned properties of the soil depend on a number of factors such as: the shape and size of the particles, the size and shape of the pores between the particles, the content of water and air in the soil, the specific gravity of the particles, pressure (soil load) and the cohesion forces that act between the particles.

Table 4. Mechanical composition of the soil

Number of profile	*Depth (cm)*	*Content (%)*					
		Coarse sand >0,2 (mm)	*Fine sand 0,2- 0,02 (mm)*	*Powder 0,2- 0,002 (mm)*	*Clay < 0,002 (mm)*	*Total sand <0,2 (mm)*	*Total clay 0,002 (mm)*
1	0-20 20-40	0.00 0.00	14.7 10.1	37.2 34.4	48.1 54.5	14.7 10.1	85.3 88.9
2	0-20 20-40	0.00 0.00	20.6 20.9	31.9 37.8	46.9 41.3	20.6 20.9	79.4 79.1
3	0-20 20-40	0.00 0.00	21.9 14.2	33.0 42.3	45.1 43.5	21.9 14.2	78.1 85.8

During the tests, there was performed the penetrometry of the soil at depths of 0-40 *cm* with a space of 10 *cm*. The obtained measurement results are shown in Table 5. Soil moisture ranged between 15.06% and 22, 17% during the test.

Table 5. Soil density *(N cm-^{2})*

Zone	*Depth (cm)*			
	0-10	10-20	20-30	30-40
1	150.8	190.2	215.8	253.5
2	124.3	210.7	280.2	315.3
3	185.8	328.3	305.3	266.1
average	153.6	180.1	267.1	728.3
1a	272.3	458.6	550.5	564.2
2a	205.3	355.4	399.2	445.4
3a	227.4	380.1	451.3	443.6
average	235.0	398.0	467.0	484.4
1b	294.2	415.0	*	*
2b	265.6	416.1	402.3	382.0
3b	262.5	515.9	554.3	539.0
average	275.0	449.0	-	-

*beyond the scope of instrument measurement, greater than

The measuring points of the penetrometer were arranged along the middle of the space between rows of plants (1,2,3), three on the right (1a, 2a, 3a) and three on the left (1b, 2b, 3b). The obtained results show that soil compactness in the space between cultivated rows is lower at all depths and especially in the tillage zone 0-10, 153 *N cm*-^{2} and 10-20 *cm* 180.1 *N cm*-^{2,}compared to the part that remained uncultivated, 235.0 and 275.0 *N cm*-^{2} (0-10 *cm*) and 398.0 and 449.0 *N cm*-^{2} (10-20 *cm*).

3. 2. Exploitation parameters of TMA in the secondary tillage of the space between rows in the orchard

Secondary soil tillage between rows is carried out during vegetation, in order to store moisture in the soil, break the crust and destroy weed vegetation, keeping thus the land surface in a loose state.

Table 6 presents the results of the tests made to the tools used for secondary tillage in an aggregate with a tractor.

Table 6. Exploitation indices of machines for additional soil tillage

Indices	*Unit of measure*	*Number repeat*	*Connecting tools*			
			Chisel plow	*Plate cultivator*	*Cultivator*	VP – *Plow*
The depth of work	cm	1. 2. 3.	9.60 7.83 8.71	10.73 8.78 9.74	10.08 6.75 8.41	12.93 13.24 13.00
Working width	cm	-	212	240	218	200
Working speed	km/h	1. 2. 3.	7.12 8.37 7.74	5.88 7.31 6.59	5.89 7.86 6.85	4.45 4.23 6.19
Fuel consumption	l/ha	1. 2. 3.	7.20 5.87 6.53	8.37 6.85 7.59	8.42 5.98 6.85	12.41 12.71 12.48
Output (7 h)	ha	1. 2. 3.	9.56 10.64 11.28	5.63 7.12 6.40	7.65 10.19 8.88	5.42 5.01 6.14
Operating time	%	1. 2. 3.	74.38 76.34 75.36	73.52 74.53 75.54	73.87 72.88 74.86	73.42 71.05 71.08
Turn time	%	1. 2. 3.	20.86 19.81 20.34	22.09 20.18 21.13	21.46 19.95 20.46	22.10 23.03 21.16
Networking hours	%	1. 2. 3.	95.24 96.15 95.70	95.61 94.71 96.65	95.33 92.83 95.32	95.52 94.08 92.24
Total losses	%	1. 2. 3.	4.76 3.85 4.30	4.39 5.29 3.35	4.67 7.17 4.68	4.48 5.92 7.76
Protection zone	%	1. 2. 3.	147.99 128.36 138.17	125.55 122.63 128.48	124.52 118.56 121.54	148.44 139.38 130.32
Untreated surfaces	%	1. 2. 3.	33.78 36.23 38.94	33.04 32.27 33.81	31.26 31.95 32.70	34.29 39.10 36.67
Treated surfaces	%	1. 2. 3.	66.22 63.77 61.06	66.96 67.73 66.19	68.80 68.05 67.54	65.71 60.90 63.33

By analyzing the results shown in Table 6, it is possible to conclude that the highest speed value was achieved with the chisel plow (8.37 $km\ h^{-1}$), while the lowest one was obtained with the VP-plow with hoes (4.23 $km\ h^{-1}$). The highest average effect was achieved with the chisel plow (11.28 *ha/day*), while the lowest one was obtained with the Vp-plug (5.01 *ha*).

The lowest fuel consumption of the tested tools during secondary soil tillage was achieved by the chisel plow (5.87 *l ha*$^{-1}$), while the highest one was obtained with the VP-Plug (12.71 *l ha*$^{-1}$).

The share of uncultivated land between rows moved from 31.26% (cultivator) to 39.06% (VP-Plow), which can be considered to be even.

3. 2. The work quality of certain tools

The work quality of the tested aggregates was determined by measuring soil fragmentation before and after the passage of the aggregates, as well as the soil profile between rows in the orchard.

After measuring the work quality indicators of the aggregates during tillage, the results were presented in Table 7, which contains the percentage content of individual soil fractions.

Table7. Indicators of aggregate work quality after tillage

Fraction (mm)	Connecting tools							
	Chisel plow		*Plate cultivator*		*Cultivator*		VP – *Plow*	
	g	%	g	%	g	%	g	%
< 1	949	33.37	925	27.53	505	17.56	260	9.02
1 – 5	560	19.69	818	24.32	270	9.39	510	17.86
5 – 20	522	18.35	958	28.47	580	20,18	560	19.71
20 – 35	264	9.28	283	8.41	412	14.33	765	26.79
> 35	549	19.31	379	11.27	1108	38.54	760	26.62
	2844	100.00	3363	100.00	2875	100.00	2855	100.00

The results presented in Table 7 show that soil fractions smaller than 1 *mm* were least present in the case of the VP-plow, with a value of 9.02%, and most present in the case of the chisel plow, with 33.37%. Soil fractions between 1 and 5 *mm* were most present in the case of the disc-harrow, with 24.32%, and least present in the case of the cultivator, with 9.39%. Soil fractions between 5 and 20 *mm* were least present in the case of the chisel plow, with 18.35% and most present in the case of the disc-harrow, with 28.47%. Soil fractions between 20 and 35 *mm* were most present in the case of the VP-plow, with 26.79% and least present in the case of the disc-harrow, with 8.41%. Soil fractions larger than 35 *mm* were most present in the case of the cultivator, with 38.54% and least present in the case of the disc-harrow, with 11.27%.

The appearance of the cultivated surface between rows of perennial plants is a significant quality indicator, which is obtained by measuring surface unevenness. According to this criterion, a good tillage quality means that the cultivated surface has no distinctive elevations and depressions. Such cultivated surface is characterized by the smallest specific surface, reducing thus the total transpiration surface of the soil.

The experience acquired during the tests shows that the entire soil tillage of orchards, consisting of basic and secondary tillage, should be carried out in combinations: basic and secondary tillage with chisel plow at different depths; chisel plow in the primary tillage and cultivator in the secondary one; VP plow in the primary tillage and chisel plow in the secondary one; or walking plow in the primary tillage and chisel plow in the secondary one.

CONCLUSIONS

By examining the tools for the secondary tillage of the soil between plant rows, it has been established that the most rational secondary treatment is achieved by means of the chisel plow. By using this tool in secondary tillage at a tillage depth of 7.83 *cm*, with a speed of the aggregate of 8.37 *km/h* and a fuel consumption of 5.87 *l/ha*, it is possible to achieve a performance of 10.64 *ha* for 7 hours. The chisel plow provides a satisfactory quality in secondary tillage in terms of soil fineness and evenness of the cultivated profile.

Taking the aforementioned facts into consideration and keeping in mind energy and tillage quality factors, the best quality was achieved by using the chisel plow. The results of fuel consumption for soil tillage, in the case of perennial plants, should be examined taking into consideration that soil tillage also includes the surface between plant rows.

The practical and theoretical experience in the secondary tillage of surfaces between rows has shown that, depending on soil conditions, as well as on the situation and type of weed vegetation, it is necessary to use machines with different kinds of work accessories.

In the case of perennial plantations, secondary soil tillage with modern technology implies the application of technical solutions to the machines that process the area around plants, which require a certain degree of adaptation to cultures, in order to fulfil their task. Further studies on secondary tillage should include various types of cultivators with different types of hoes and soil.

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INFLUENCE OF NUMBER OF REVOLUTION OF DEVICE FOR PRUNING WITH CIRCULAR ON QUALITY CUTTINGS OF BRANCHS

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Abstract: *The paper presents results investigationof number of revolution of device for pruning with circular with different of number of saw teeth. Number of revolution was 500-2000 min^{-1}. and number of saw teeth the circular is 60, 90 and 120. Diameter the circular is 483,5-486,2 mm. Investigation of number of revolution of divace for pruning with circular saws with same diameter and different number of saw teeth shouved that the best the best quality of cat was achieved with the option of circular saws with 120 teeth and 2000 min^{-1}. Based on the research carried out, the quality of the cuttings with a description of the intersection in 10 points is also given.*

Key words: *Pruning, Number of revolution, Evaluation cut quality, Indicator.*

1. INTRODUCTION

Pruning fruits is a regular pomotechnical measure in the production process and a condition for achieving high yields of quality fruit fruits. When done manually, it is a very hard (Komnenić et al. 2006) and expert work where the consumption of the mechanical energy of a person is significant. Pruning in the period of fruiting should enable and prolong the full fertility period. The first cutting devices originated in the 50-s in the United States, and the real expansion came about in the 80-s of the 20-th century. Gerasimov and Kuteinikov (1972) seek a rational scheme for the discus working organ for contour cuttings of fruit trees. Baraldi (1973) describes and examines a cutting machine with rotary blades mounted on a rotating support. Privalov (1978) investigates a cutting disc working disk in which the cutting edge creates a spiral of the Archimedes and is positioned one against the other for 180o.

2. MATERIAL AND METHODS

Testing of the speed of movement of the cutting apparatus with circular saw blades with different number of rotations and teeth was performed during the pruning season. The used cutting machine is a hydraulic cutter HR-85, a Slovenian factory SKIP. (Fig. 1).

Measurement of the number of revolutions of the tester was done by hand tachometer Rheintacho handtachometer XT 64/50 at the level 300-5000 min^{-1}. Circular saw blades were used with 60, 96 and 120 teeth, and the number of turns is equal to 500, 750, 1000, 1250, 1500, 1750 and 2000 min^{-1} .

After the passing of the pruning machine from the b, the hand-cut scissors were cut in the cuts, and in the laboratory the diameter of the trees was performed.

Based on the research carried out, the quality of the cuttings with a description of the intersection in 10 points is also given.

3. RESULTS AND DISCUSSION

In order to compare the quality of the cut on the cut branches, we needed to numerically characterize each section. We have adopted our estimates of the quality of the cut from 1-10. Each grade has accurately described and defined cross section quality (Table 1., Fig. 2).

Fig. 1. Pruning machine HR-85 in operation

Fig. 2. Evaluation quality pruning of brench the circular for the

Table 1. Evaluation for the quality pruning of brench the circular

Evaluation	Description
1	The tissue is tinted throughout the entire intersection. A broken twig in length. The surface is severely cut off - the injuries are large. The brench is significantly cut in length.
2	The tissue is torn. Traces of cutting are found. The cut area is with small stairs.
3	The surface is properly cut off with more traces of tissue breakage.
4	The cut surface flat with more folds of 1mm and in places traces of tissue breakage.
5	The cut surface is flat with two folds of 1 mm and with traces of tissue breakage.
6	The cut surface flat with more folds smaller of 1mm.
7	The cut surface is flat with two folds of 1 mm.
8	Straightened cut surface with in places folds without traces of tissue breakage.
9	Straightened cut surface with in places folds less of 1 mm.
10	A completely straightened cut surface.

Circular saw blades used in the tests are 500 mm factory diameter with 60, 96 and 120 teeth. At the time of testing, the diameter of the saw was 483.6 mm with 120 teeth up to 486.2 mm with 96 teeth. The stoutness of the circular saw was uniform and was 3.5 mm. The tooth step at the circular 60 teeth was 25.40 mm, with 96 teeth 15.40 mm and with 120 teeth 12.65 mm. The depth of the tooth is at the circular with 60 teeth 13.4 mm, with 96 teeth 8.2 mm and with 120 teeth 6.4 mm (Tab. 2).

Table 2. Characteristics in investigation of the circular

Indicator	Unit	Number of tooth		
		60	96	120
Diametar the circular	mm	485.4	486.2	483.6
Stoutness of the circular	mm	3.5	3.5	3.5
Step of the tooth	mm	35.40	15.40	12.65
Dept of the tooth	mm	13.4	8.2	6.4

The influence of the rotational speed of the cutting bodies with circular saw blades with 60 teeth on the quality of cut branches is given in Table 3.

For the diameter of the branch <3.9 mm for all the tested speeds (500-2000 min^{-1}), the cutting quality of the branches is at the level of the grade 1.00 as well as in the diameter of the branch 4.0-5.9 mm for the numbers of revolutions 500-1750 min^{-1}. At speed of 2000 min^{-1}, the rating is 1.10 for the diameter of the branch 4.0-5.9 mm.

For a diameter of 6.0-7.9 mm, the cutting quality score is 1.00 for the circulation numbers of the circles 500, 750, 1250, 1500 and 1750 min^{-1}, while for 1000 min^{-1} the score is 1.10, and at 2000 min^{-1} the score is 1.20.

For the diameter of the branch 8.0-9.9 mm the cut quality evaluation ranged from 1.00 at 500 min^{-1} to 1.60 at 2000 min^{-1} min-1.

For a branch diameter of 10.0-11.9 mm, the cut quality evaluation ranged from 1.12 at 500 min^{-1} to 1.90 at 2000 min^{-1}.

For the diameter of the branch 12.0-13.9 mm the cut quality evaluation ranged from 1.42 at 500 min-1 to 1.80 at 2000 min^{-1}.

For a branch diameter >14 mm, the cut quality evaluation ranged from 1.52 at 500 min-1 to 2.20 in 2000 min^{-1}. It can be seen that the evaluation above 2.10 is recorded on all speeds of 1000-2000 min^{-1}.

Table 3. Influence of number of revolution of device for pruning with circular with 60 teeth on quality pruning of branch

Diameter of Branch (mm)	Number of revolution (min^{-1})				
	500	1000	1500	1750	2000
	Evaluation	Evaluation	Evaluation	Evaluation	Evaluation
< 3.9	1.00	1.00	1.00	1.00	1.00
4.0-.5.9	1.00	1.00	1.00	1.00	1.10
6.0-7.9	1.00	1.10	1.00	1.00	1.20
8.0-9.9	1.00	1.28	1.36	1.42	1.60
10.0-11.9	1.12	1.48	1.76	1.80	1.90
12.0-13.9	1.42	1.08	2.10	2.14	1.90
> 14.0	1.52	2.10	2.22	2.20	2.20

The influence of the rotational speed of the cutting bodies with circular saw blades with 96 teeth on the quality of cut branches is given in Table 4.

For the diameter of the branch <3.9 mm for all the tested speeds (500-2000 min^{-1}), the cutting quality of the branches is at the level of the grade 1.00 as well as in the diameter of the branch 4.0-5.9 mm for the numbers of revolutions 500-1750 min^{-1}, while its code is the number of revolutions of 2000 min^{-1} evaluation 1.40.

For a diameter of 6.0-7.9 mm, the cutting quality evaluation is 1.00 for the circulation numbers of the circles 500-1500 min^{-1} while for 1750 min^{-1} evaluation 1.62, and at 2000 min^{-1} the evaluation is 1.65.

For the diameter of the branch 8.0-9.9 mm the cut quality evaluation ranged from 1.15 at 500 min^{-1} to 2.20 at 2000 min^{-1}.

For a branch diameter of 10.0-11.9 mm, the cut quality evaluation ranged from 1.00 at 500 min^{-1} to 4.00 at 2000 min^{-1}.

For the diameter of the branch 12.0-13.9 mm the cut quality evaluation ranged from 1.92 at 750 min^{-1} to 3.80 at 2000 min^{-1}.

For a branch diameter >14 mm, the cut quality evaluation ranged from 2.00 at 500 min^{-1} to 5.20 in 2000 min^{-1} . It can be seen that the evaluation above 2.10 is recorded on all speeds of 1000-2000 min^{-1}.

Table 4. Influence of number of revolution of device for pruning with circular with 96 teeth on quality pruning of branch

Diameter of Branch (mm)	Number of revolution (min^{-1})				
	500	1000	1500	1750	2000
	Evaluation	Evaluation	Evaluation	Evaluation	Evaluation
< 3.9	1.00	1.00	1.00	1.00	1.00
4.0-.5.9	1.00	1.00	1.00	1.00	1.40
6.0-7.9	1.00	1.00	1.00	1.62	1.65
8.0-9.9	1.15	1.67	1.50	1.93	2.02
10.0-11.9	1.00	2.00	2.25	4.00	3.28
12.0-13.9	2.00	-	-	3.70	3.80
> 14.0	2.00	4.00	4.00	-	5.20

The influence of the rotational speed of the cutting bodies with circular saw blades with 120 teeth on the quality of cut branches is given in Table 5.

For the diameter of the branch <3.9 mm for all the tested speeds (500-1750 min^{-1}), the cutting quality of the branches is at the level of the grade 1.00 while its code is the number of revolutions of 2000 min^{-1} evaluation 1.18.

For the diameter of the branch 4.0-5.9 mm for the tested speeds 500, 750, 1250 and 1750 min^{-1} the cutting quality of the branches is at the level of the grade 1.00 while its code is the number of revolutions of 1000, 1500 and 2000 min^{-1} evaluation 1.20.

For a diameter of 6.0-7.9 mm, the cutting quality evaluation is 1.00 for the circulation numbers of the circles 500, 750 and 1250 min^{-1} while for 1750 min^{-1} evaluation 1.70, and at 2000 min^{-1} the evaluation is 1.84.

For the diameter of the branch 8.0-9.9 mm the cut quality evaluation ranged from 1.46 at 500 min^{-1} to 2.98 at 2000 min^{-1}.

For a branch diameter of 10.0-11.9 mm, the cut quality evaluation ranged from 1.60 at 750 min^{-1} to 3.40 at 2000 min^{-1}.

For the diameter of the branch 12.0-13.9 mm the cut quality evaluation ranged from 3.00 at 500 min^{-1} to 3.90 at 2000 min^{-1}.

For a branch diameter >14 mm, the cut quality evaluation ranged from 3.20 at 500 min^{-1} to 6.68 at 2000 min^{-1}.

It can be seen that the evaluation above 3.00 is recorded on all speeds of 1750 and 2000 min^{-1} (diameter of branch 10.0-11.9 mm), 500, 1750 min^{-1} and 2000 min^{-1} (12.0-13.9 mm) and 500 min^{-1} (>14.0 mm).

It can be seen that the evaluation above 4.00 is recorded on speeds of 1000 and 1500 min^{-1} (diameter of branch >14.0 mm).

It can be seen that the evaluation above 6.00 is recorded on a speeds of 1750 and 2000 min^{-1} (diameter of branch >14.0 mm).

Table 5. Influence of number of revolution of device for pruning with circular with 120 teeth on quality pruning of branch

Diameter of Branch (mm)	Number of revolution (min^{-1})				
	500	1000	1500	1750	2000
	Evaluation	Evaluation	Evaluation	Evaluation	Evaluation
< 3.9	1.00	1.00	1.00	1.00	1.18
4.0-.5.9	1.00	1.20	1.20	1.00	1.20
6.0-7.9	1.00	1.10	-	1.70	1.84
8.0-9.9	1.46	1.68	2.00	2.50	2.98
10.0-11.9	1.68	3.00	2.00	3.00	3.40
12.0-13.9	3.00	-	-	3.20	3.90
> 14.0	3.20	4.00	4.00	6.00	6.68

4. CONCLUSIONS

Based on the results of influence of number of revolution of device for pruning with circular on quality cuttings of branchs can be concluded:

- Investigation quality pruning of branch was carried out with circulars with 60, 96 and 120 teeth with a rotational speed of 500, 750, 1000, 1250, 1500 and 2000 min^{-1}.

- The cut quality ratings of cuts from 1 to 10 with a description of the cross section for each evoluation are given.

- The lowest cut quality estimates were obtained for cutting with 60 tooth circulators in all variants of the number of revolutions (1.00-2.20).

- The lowest evaluation were from 500 min^{-1}.

- The best result was with cirkullar with 120 teeth and 2000 min^{-1}.

- With the increase in the diameter of the branch, the quality evulation is also growing. The branchs of the smaller diameter were mostly broken.

- Where possible, the recommendation is to use circulars with a larger number of teeth and smaller teeth.

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NEW HARVESTER OF FLOWER INFLORESCENCES FOR THE GERMAN CHAMOMILE

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Abstract. *For the chamomile large-scale production, hand picking is not suitable; a mechanization of the chamomile harvest was established for economic reasons. The new Slovakian type of chamomile picker is designed for its direct harvesting of chamomile inflorescences. The guarantee of length of green stalks is up to 20 mm in an extent from 60 to 80 % of raw-material capacity. Chamomile flower heads are collected by the pneumatically transporters to accumulate bin under air cooling. Chamomile inflorescences into full bin are possible to transport for additional movement respectively for a next processing (a drying, sorting, cutting etc.). The main advantage of the type of chamomile picker is its application of engine (a driving unit) of easy available tractor (like VALTRA N123 for example), which is possible to use for multiplicity operating activities in agriculture, transport and building.*

Key words: *Chamomile, Flower, Picker, New Design, Multifunction*

1. INTRODUCTION

The large-scale cultivation of herbs and aromatic plants belongs to a special plant growing and it is the only way how to provide necessary amount of a quality material for processing industry. Chamomile presents a decisive part among medicinal plants which are cultivated in Slovakia [3]. By the seventies the Slovak agricultural enterprises in large-scale chamomile cultivation used a low productivity technique, which required a considerable number of workers. That is why the constructive group was formed in 1980 to ensure the complex mechanization of picking and post-harvesting processing of chamomile production. Their first successful models in former Czech-Slovakia were the harvesters, types: VZR 4 and VZR 6. In the large-scale cultivating of chamomile, these pickers appear to be key machines for effectiveness and economy of labour power. The old picker of chamomile collects the flower anthodia using a comb roller. The flowers fall into the collecting channels and then they are sucked in by under pressure tubes into collecting trimmers. This under pressure system is preferable, because it does not damage the harvested flower heads [2]. Furthermore, it should be considered that the chamomile flower harvest takes only 3 or 4 weeks so that harvest machinery is using only short time.

The cultivation of chamomile is relatively specific in comparison to other agricultural crops. Therefore, the machine manufactures do not show great interest because of low demand [1].

New construction alternative is to use the standard available tractor (like VALTRA N123 for example) and the adapters: a comb dresser and cutting roller. This paper presents actual configuration layout in the construction of new multifunction chamomile harvester at the agricultural company: Agrokarpaty, Ltd., in Plavnica, the Eastern Slovakia.

2. INITIAL DESIGN: CHAMOMILE HARVESTER, TYPE VZR 4

Fig. 1 Chamomile flowers picker VZR 4 in field operation.

Specially designed adapter, enabling chamomile flowers collection, is attached to the basic harvester unit Fortchritt E-303, creating the self-propelling collector of chamomile flower heads – the type VZR 4 [5].

The picker of VZR 4 is specified for direct collection of German Chamomile (*Matricaria recutita* L.) flowers. Torn flowers are pneumatically transported to the dividing supply tank. When the supply bin is full, flowers are reloaded mechanically to the available transport vehicle and transferred to an object for further processing.

The self-propelling collector of chamomile heads VZR 4 consists of the following main functional parts: the adapter for collection of chamomile plant parts, the adaptive chassis E-303, two vacuum pneumatic transporters and the supply tank. The chassis E-303 consists of these main parts: the frame with wheels, the engine, the gears, the hydraulic unit and the platform with the cabin.

The front wheels provide propulsion, while the rear wheels are used for steering. The rare hydraulically controlled wheels are adaptive with respect to the front wheels, enabling the track width changing of about ±120 mm. Design of such kind enables the rare wheels to follow the front wheels ruts. In addition, turning of the machine in the field operation is improved, because the independent brake function of driving wheels is possible.

The propulsion of driving wheels is provided by four-cycle Diesel engine D–50, reaching 41 kW at 1,700 min^{-1}. Rear wheels countershafts from the engine are propelled by the joint shaft across the taper gear. The one chain variator of travel is on the right side this countershaft. The one disk declutching dry coupling for travel in front is behind the variator. The same declutching coupling for travel in back is propelled two V-belts from the left side of the end countershaft. The couplings together with the declutching mechanism form the quick- working reversing of machinery of travel. The simple gearbox with the sliding front gears, without the synchronization, is between coupling and in the back is differential. The brake barrels are seated in the half-axis and they are controlled by hydraulics- by the pedal and by mechanically- the hand lever. The motive wheels of chassis E-303 are propelled over the end chain gears in the supporting structure.

The lowest range of machine operational velocity lays in the range between 3.4 and 8.6 km•h^{-1} at the first gear. However, this speed is not suitable for collection of chamomile flowers. Therefore the chain gear with the inserting joint shafts is installed between the end chain gears in the supporting structure and the coupling for the travel.

The propulsion of adapter of chamomile picker is derivate from the left side of the end countershafts by the three V-belts on the declutching one-disk coupling, the same as at the reversing machinery.

The front great shaft is adaptive by the inserting gear wheel, from which is transported of propulsion on the gear wheel of the outlet shaft of adapter of chamomile flower collector over the chain and two tension wheels.

The shaft with the cog is affixed to the pulley of propulsion of the ventilator of cooling and water pump in the end part of motor. The pulley for propulsion of two ventilators is fitted on the shaft. The ventilators are propelled from the pulley over V-belts and the tight-ending pulleys.

3. NEW TYPE OF CHAMOMILE PICKER

The main advantage of the new type of chamomile picker is based on application of existing driving unit (tractor VALTRA N 123), used for multiplicity operating activities in agriculture, transport and building. This tractor completely replaced the chassis E-303, which has not been manufactured for many years ago.

Fig. 2 New chamomile flowers harvester, mounted on the tractor VALTRA N 123.

VALTRA N Series represents Nordic practicality at its best, encouraging year-round use even in the most demanding conditions. The N Series with its compact design and power range up to 163 HP offers the ideal solution for most tasks on livestock and crop farms – as well as for municipal and forest applications in keeping with Valera's philosophy. N Series benefits in a nutshell: - outstanding front-loader tractor, - reliable AGCO Power engine in all models, - spacious and ergonomic cab offers excellent visibility in all directions, - Valtrex Arm - ergonomically located controls in Verso and Direct models, - very quiet working environment with noise levels as low as 70dBa, - TwinTrac reverse drive controls as option in all models, and - AgCommand™ telemetry system as option.

The connected adapter, for the chamomile flower harvest, consists of these main parts: frame, graduated gather roll, cutter, wiper roll, the right and left rotary threaded transporter, distributions, dividers and safety covers.

Technical Data

Table 1. Adapter for Chamomile flower picking

Type: formerly the ' VZR-4', which is adapted.

Dimensions:	
length	4,230 mm
width	2,100 mm
height	1,180 mm
weight	1,943.8 kg

Hourly output of chamomile flower head harvesting: 0.30 ha. h-1

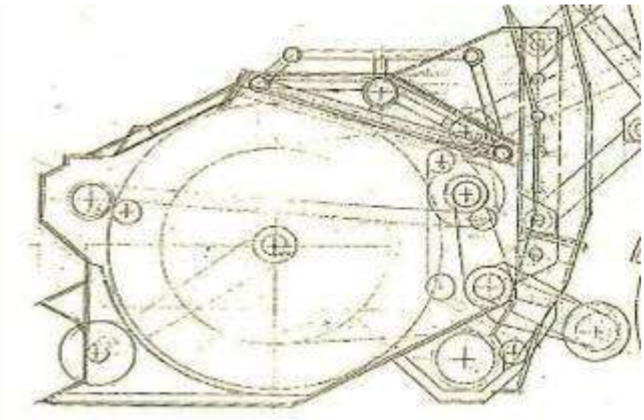

Fig. 3 Technical design of adapter

Tasble 2. Safety-related bin

Dimensions:	
length	1,220 mm
width	2,210 mm
height	1,580 mm
volume	4.25 m^3 (cca. 600 - 800 kg of fresh chamomile raw-material)

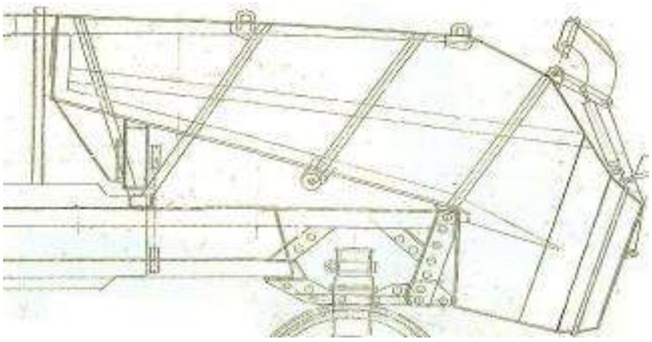

Fig. 4 Techncal design of bin

The frame is the tube welded construction, on which are fixed the sides and the wall of the gears for the position of houses of the bearing of the shafts for the harvest of chamomile flowers. The graduated gather roll is seated in the front part of the frame and it consists of ten gather combs with the inclined teeth. The graduated cutter is seated in from of the gather combs. The knives move in the direction to the gather roll, that the space between knifes and combs was the smallest.

The graduated wiper roll is seated in the upper end part of the frame and it wipes the catch heads of chamomile plants to the left and right- rotary threaded transporter. The wiper roll consists of the plastic brushes that they do not damage the flowers of chamomile.

The countershaft is seated in the end part of the frame; it is driven by the chain gear from the motor.

The distribution of the function parts of the adapter of chamomile flowers is seated in the middle of it in the along axis. Three dividers serve on the distribution of stalk of chamomile flowers at working of adapter. Two dividers are on the edges of adapter and one is in the middle. The construction solution of the middle divider is only account of the wide mesh.

The safety covers serve on the safety of the workers in front of the touch of rotary function parts.

The vacuum pneumatically transporter carrying in the chamomile flowers to the graduated supply storage tank. It consists of the bending piping of the diameter 160 mm fixed on collector mounts in the channel of the threaded transporter and on the filling holes in the front side of supply tank. The transport is protected by the vacuum, which two ventilators develop. They suck off the air from the supply tank by two aspirated channels. The mouth of these channels is protected by the screens against the aspiration of the material.

The propulsion of the ventilators is protected by V-belts from the crankshaft of the power source traction engine across the cog.

The purpose of supply bin is to pick chamomile flowers. It represents the independent part of harvester, fixed at the rear-side of the tractor. The vacuum ventilators are fixed on supply tank for the pneumatically vacuum transport of raw material. The lower edge of supply tank is above the surface of field in the height 900 mm. The bin is symmetric on the longitudinal axis of plane of symmetric of machine.

Two outlet doors are on the end part harvester supply bit. They must be closed hermetically, because ventilators do not suck an useless air from out.

Propulsion power of chamomile harvester adapter is derived from motor across the front gear shaft, and the chain gear at the outlet shaft of adapter.

4. CONCLUSIONS

At present, this new chamomile flowers picker simply represents a prototype. It is designed to pick chamomile flowers with maximum length of stem up to 20 mm.

This new picking machine can be installed on almost any carrier with the front tree-point suspension and the front power take-off driving shaft. The transport of chamomile flowers from the adapter to the bin is pneumatic, which is simple and does not require any changes in the carrier design. The bin can be solved as a common tractor trailer, or in the form of an attached tilting container in the rear part of the carrier.

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WORKING QUALITY OF TWO ROTARY MOWERS IN MOUNTAINOUS AREA

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Abstract. *Research results of two tractor rotary mowers, disc mower IMT 627.716 and drum rotary mower PZ Zweegers CM185 H in cutting the first swath of grass clover mixtures are presented in this paper. The average yield of green mass was 38.10 t ha^{-1}. The aim of this research was to determine productivity, quality of work and losses made by different types of tractor rotary mowers in cutting the first cut of grass clover mixtures. In both variants the same operating unit Tractor LTZ T40AS was used. In the first combination tractor operated with drum rotary mower PZ Zweegers CM185 with max speed of 13.81 kmh^{-1}, achieving performance of 2.30 ha h^{-1}. In the second variant tractor operated with disc rotary mower IMT 627.716 with max speed of 12.04 km/h, achieving performance of 1.57 ha h^{-1}. At given speeds, the efficiency of work operations ranged from 0.90 to 0.97, averaging 0.93 in the first variant and 0.79 to 0.92, averaging 0.86 in the second version. Similarly, with the increasing speed of operation an increase in the average height of cut by given speed intervals from 5.97-6.41 cm for disc and 5.28-6.20 cm for drum rotary mower has been observed. Analogously with increasing of mowing speed occurred the increase in total losses of 3.31 % to a maximum of 4.02 % of the total yield.*

Keywords: *drum rotary mower, disc rotary mower, operational productivity, cutting height, losses.*

1. INTRODUCTION

In the sequence of technological operations – phases in the procedure of storage of hay, green animal feed and haylage, mowing is the first work operation. Mowing is done as a separate work operation or in combination with other work operation such as crushing or conditioning. Mowing of the plant mass is conducted in the period when the plant contains most of the nutritive matter and in order to preserve the values of plant mass, mowing should be done in the shortest time limit possible. Machines which are used for mowing of grass should fulfil several basic conditions, such as: universality of use, the cleanness of cut, preventing soil pollution of mowed mass, high working speeds – performance, easy, simple maintenance – technical aging, working with the lowest amount of losses. Almost all types of tractors and self-propelled mowers fulfil the named conditions. During the storage of hay of grass clover mixtures and meadows, the biological yield of green mass should be utilized as much as it can, among other things, in order to lessen the losses. Regardless of which mower is used in mowing, the occurrence of losses is inevitable. The losses can appear due to a high cut of grass and due to the shredding of cut grass, which cannot be collected during the manipulation with hay, but it remains on the parcel. Even though self-propelled oscillatory mowers with small effects are mostly present in mountainous area, in the last 10 years more and more rotary mowers of both types: with a drive on upper and lower side. The lack of this type of mowers in mowing of grass mass, besides the losses due to post-shredding, are often pollution of grass mass and significantly higher consumption of power. If we bear in mind that the highest amount of shredded mass are parts of the leaf in which the highest amount of nutritious matter is stored, special attention should be paid to this kind of losses. The speed of mower movement has an impact on the increase of losses. It is opposite to the named kinds of losses. With the increase of the working speed, losses due to the height of the cutting are increased, while the losses due to the shredding decrease. Accordingly, it is essential to find optimal working speed to make both kinds of losses minimal.

In that way, for example, if we examine which are the optimal values of cutting height, considering morphological and biological conditions of individual plant types, in alfalfa, in order not to damage clusters, the optimal cutting height is considered to be 6 to 8 cm, i.e. it should not be cut more than 6 cm, while at natural meadows that height is somewhat lower up to 4 cm, which again depends on the flatness of the parcel and floristic content of the natural meadow. Nowadays mostly two types of tractor mowers are used mostly, oscillatory and rotary. Many authors did research on individual parameters, as well as working speeds that can be achieved during the mowing. In that way, for example *Gašparac* (1985/86) names studies of two types of mowers where he made conclusions that optimal value of working speed is around 11.8 km h^{-1} in mower HMEZAD 160LPH, while for the TSK – Superior it was from 9 – 10 km h^{-1} with satisfactory working quality- The author states that in the first type of mower cutting height ranged from 4.8-6,6 cm, with deviation of constructional width of operation from 5.8 – 20.6%, while in the second type that amounted to 7.0 – 8.6 cm with deviation of operation from 3 – 11%. *Tanevski* (1990), during the study of the self-propelled mower-crusher, gives the average speed of movement from 5.35 km h^{-1}. The same author states that the coefficient of the use of working operation in average amounts to 95.5% of yield. With the increase of the movement speed of the mower comes the increase of losses due to the cutting height, but also the losses that occur due to shredding are decreased. Gašparac (1988) achieved the height of cutting from 4.30-6.28 cm and the width of operation 132-154 cm in his research of rotary mower SIP 165 during the working speed of 8.5-12 km h^{-1}. According to *Potkonjak* (1986) self-propelled mower "Fortschritt", deviated significantly from the optimal height of cutting. The deviation amounted to 9.47 cm, so due to that there was an increase of losses of the alfalfa mass on the heights of cutting, in average 1.63% of yield. *Koprivica* (1996), during the research of self-propelled mower-crusher in mowing of alfalfa names the speed of mower movement in the interval of 3.71 to 6.41 km h^{-1}. In order not to damage alfalfa cluster, the optimal height of cut is considered to be from 6 – 8 cm, which can be realised during working speeds for classic mower from 5 -8 km h^{-1}, and for the rotary from 8-15 km h^{-1} (*Zoranović, 1995*). According to *Zoranović* and *Potkonjak* (1996), total losses during the use varied in the interval from 0.90 to 2.29% from yield, or in average 1.59% from yield. The height of cutting of the stem was in average 6.42 cm. According to the recommendations of *Wiersma and Wiederholt* (2001), alfalfa should be mowed to the height of 2 inches (5.08 cm). *Potkonjak et al.* (2009), state that the most convenient height of cutting is made by classic mowers, because they maintain the set height of cutting better. According to the same authors classic mower made lowest total losses (in average 1.27% of green mass yield). Rotary mowers made bigger total losses: mower with 6 disks from 3.16%, and with 14 disks 2.75%. *Vuković* (2009), states that with the increase of the movement speed working operation of mowing machines decreases, with an increase of total losses. Also, the losses made due to the height of cutting increase, and the losses made due to the shredding decrease. Total losses made on classic cutting machine were 1.18% of alfalfa yield, in self-propelled 1.52% and in rotary 2.99%, stated the same author. The amount of losses during the mowing should not be higher than 5%. Obtained working productivity varied from 0.72 ha h^{-1} (oscillatory), up to 1.00 ha h^{-1} (rotary mower). (*Vuković et al. 2011*). According to the research of *Barać* (2012) the lowest height of cutting was recorded in drum rotary mower and it amounted to 5.83 cm, during the average speed of movement of aggregate of 9.53 km h^{-1}. The lowest height of cutting in this mower was measured during the speed of movement of 8.40 km h^{-1} and it amounted to 5.19 cm, and the highest was 6.48 cm during the speed of 10.84 km h^{-1}. Mower with classic cutting machine made somewhat bigger height of the cutting in comparison with rotary and in average it was 6.32 cm, during the average speed of movement of the aggregate of 5.79 km h^{-1}. The lowest height of cutting of 5.42 cm was during 3.72 km h^{-1}, and the highest was during the speed of the movement of the aggregate of 8.23 km h^{-1} and it was 7.38 cm. According to the research of Sila-Bogosavljev (1985), carried mower Dubrava, Gramip TSK Superior during the working speed of 6.0-14.8 km h^{-1} had the performance of 0.81-2.00 ha h^{-1}, the coefficient of the use of constructional width of working operation was 89-97%, and the height of the cutting varied from 7.0-8.6 cm.

2. MATERIAL AND METHOD

Research was conducted on family agricultural farmland on the site of Mokro, within the reach of the town of Pale, during the mowing of the grass clover mixture. Mowing was done using two tractor rotary mowers: disc mower IMT 627.716 and drum rotary mower PZ Zweegers CM185 H, on the parcel with average yield of green grass mass of 38.10 t ha^{-1}. Green mass yield was determined based on measuring of the green mass by method of accidental square, calculated into hectare. Mower movement speed was determined by chronometric method. Speed intervals of work on the length of 30 m were measured with hand stopwatch. The height of the cutting was determined in the way in which for every test on appropriate surface of one metre of swath the height of all small grains was measured and the average was calculated. Losses during the use were measured from the surface of one metre of swath, in the width of working operation of the mower, on the same place where the height of cutting was determined. Total losses were presented as the sum of losses made due to the height of cutting and losses made due to the shredding. Determination of losses was conducted in four tests.

3. RESULTS AND DISCUSSION

Back side drum rotary mower PZ Zweegers CM185 H falls into a programme of classic mowers made for smaller and medium farmhouses. They are characterized by simple construction and power transfer to drive of the drums via PTO shaft and gear in carrying case. Rotary mower PZ Zweegers CM185 H has vertical drums or cylinders, on which, from the lower side, knives for cutting are located. Drums or cylinders are positioned in order to work in pairs, and both drums have 3 knives each. During the work, drums have opposite directions of spinning one towards the other in pairs. During the movement knives cut plant mass and store it into swath between the two drums. Lowering into work position and going back to transport position is done using hydraulic cylinder.

Table 1. Technical characteristics of rotary mower PZ Zweegers CM185 H

Parameter	**Unit**	**Value**
Category of hanging points	-	II
Working width	m	1.85
Mass	kg	450
Transport width	m	1.50
Transport length	m	-
Shaft rpm	min^{-1}	540
Drum rpm	min^{-1}	2250
Number of drums	-	2
Number of knives	-	6
Required driving power	kW	30
Height of cutting	mm	40-70
Performance	$ha\ h^{-1}$	up to 2.5

Rotary disc mower IMT 627.716 is intended for mowing of all types of natural and artificial grass, surfaces beside the roads and for communal works. They attach to tractors of categories 1 and 2 with the system of attaching at three points. They have the ability of mowing even in hard working conditions, such as flattened and tangled grass, moist ground, rain and terrain covered with molehills. Power distribution on drive of discs is via the belt and gear in carrying case. Drive of discs is obtained over the lower side over the carrying case on which two pairs of discs are located. Lifting and lowering in transport and working position are done manually, mechanically.

Table 2. Technical characteristics of rotary disc mower IMT 627.716

Parameter	Unit	Value
Category of hanging points	-	I + II
Working width	m	1.65
Mass	kg	366
Transport width	m	1.50
Transport length	m	-
Shaft rpm	min^{-1}	540
Drum rpm	min^{-1}	3000
Number of discs	-	4
Number of knives	-	8
Required driving power	kW	21
Height of cutting	mm	38-70
Performance	$ha\ h^{-1}$	1-1.5

Research was conducted on parcels of artificial meadow in the first swath. The average yield of green mass was 38.10 t ha^{-1} and it moved in the limits of 23.50-46.50 t ha^{-1}. The height of grass mass moved between 50 and 150 cm, in average 90.50 cm. Technical characteristics of rotary mower PZ Zweegers CM185 H and IMT 627.716 are given in Tables 1 and 2.

Both types of rotary mowers are of a carrying type with the attachment in three points. They represent standard equipment for mowing, firstly on smaller and medium agricultural farmhouses. They are equipped with safety device for detachment, and are characterized by simple, but strengthened construction and exceptional durability.

In both variants the same drive aggregate was used, Tractor LTZ T40AS. In the first combination in aggregate with rotary mower PZ Zweegers CM185 H maximum speed of 13.81 km h^{-1} was made, having a performance of 2.30 ha h^{-1} (Table 3). In the second variant, i.e. aggregate with disc mower IMT 627.716, during maximum speed of 12.04 km h^{-1} the performance of 1.57 ha h^{-1} was made (Table 4).

Constructional work operation of the mower Zweegers CM185 H is 1.85 m and during the examination the coefficient of the use of work operation ranged in the interval from 0.90 to 0.97, in average 0.93 from constructive depending on the speed of movement, where the tendency of lowering of coefficient of the use of work operation with the increasing of movement speed can be observed, which is in compliance with the research made by Tanevski (1990), Gašparac (1985/1986), Zoranović (1995). Similarly to previous case, mower IMT 627.716 of constructive operation of 1.65m during the examination it made a somewhat lower coefficient of the use of work operation in the interval of 0.79 to 0.92 in average 0.86.

Table 3. Operational productivity of PZ Zweegers CM185 H

Degree of transmission	Work speed (km h^{-1})	Work operation (cm)	Height of cutting (cm)	Coefficient of use of the work operation width (η)	Operational performance (ha h^{-1})
I	4.93	179.0	5.28	0.97	0.88
II	6.50	172.2	5.31	0.93	1.12
III	7.75	170.8	5.42	0.92	1.32
IV	9.31	168.4	5.55	0.91	1.57
V	13.81	166.4	6.20	0.90	2.30

Table 4. Operational productivity of IMT 627.716

Degree of transmission	Work speed (km h^{-1})	Work operation (cm)	Height of cutting (cm)	Coefficient of use of the work operation width (η)	Operational performance (ha h^{-1})
I	4.99	151.2	5.97	0.92	0.75
II	6.51	144.8	6.18	0.88	0.94
III	7.41	143.0	6.27	0.87	1.06
IV	9.43	140.6	6.35	0.85	1.33
V	12.04	130.8	6.41	0.79	1.57

In alfalfa by optimal height of cutting in order not to damage the stems is considered to be the height of cutting from 6 to 8 cm, i.e. it should not be mowed under 6 cm, while in natural and artificial meadows that height is somewhat lower up to 4 cm and more, which again depends on the flatness of the parcel and floristic content of the meadow itself. The results in Tables 4 and 5 show that the change of the mowing speed has a significant impact on the height of cutting of examined mowers. The average height of cutting of plants was 5.55 cm with mower PZ Zweegers CM185 H, and the lowest height of cutting was 5.20 cm during the movement in the first degree of transmission and speed of 4.93 km h^{-1} and the biggest height of cutting was 6.20 cm during the speed of 13.81 km h^{-1}. Disc mower IMT 627.716 made average height of cutting of 6.24 cm with the interval of 5.97 cm and speed of 4.99 km h^{-1} to 6.41 cm during the maximum speed of 12.04 km h^{-1}. Therefore, the results obtained during this study are in accordance with the results obtained by many other authors who have dealt with this topic.

Table 5. Losses during the work (% of yield)

Mower type	Type of loss	Degree of transmission				
		I	II	III	IV	V
PZ Zweegers CM185 H	L_{hc}	1.67	1.93	2.17	2.72	3.12
	L_s	1.76	1.52	1.40	1.15	0.90
	T_l	3.43	3.45	3.57	3.87	4.02
IMT 627.716	L_{hc}	1.71	1.91	2.15	2.56	2.97
	L_s	1.60	1.47	1.31	0.95	0.75
	T_l	3.31	3.38	3.46	3.51	3.72

L_{hc} –losses due to the height of cutting

L_s – losses due to shredding

T_l – total losses

In examined mowers we can observe the tendency in which with the increase working speed of aggregate movement there is an increase in losses due to the height of cutting and losses due to shredding decrease. results shown in Table 5 show that losses due to the height of cutting in rotary mowers varied depending on the speed in the range of 1.67 to 3.12%, of yield, and losses due to shredding ranged between 0.90 and 1.76% in the first and 1.71 to 2.97% for the height of the cutting, and 0.75 to 1.60% due to shredding in the second variant. Total losses represent the sum of previous two types of losses and during the study both types of rotary mowers, the average value of total losses was 3.48% of yield for IMT 627.716, and 3.67% for PZ CM185H, or, that with the increase of the mowing speed it came to the increase of total losses of 3.31% up to maximum of 4.02% of total yield. We still do not have the information about allowed value of total losses, but based on the analysis of our own studies, as well as the studies of other authors, maximal value of 5% of yield can be closely determined.

4. CONCLUSION

Based on obtained results of the study of quality of mowing of drum rotary mower PZ Zweegers CM185 H and disc mower IMT 627.716 we can say that both types of rotary mowers made optimal and consequent losses in variants. In that way, the lowest height of cutting was 5.28 cm during the speed of 4.93 km/h, and the highest was during the movement speed of 12.04 km/h and was 6.41 cm. Cutting heights of 4 cm on the meadow entirely depends on the flatness of the parcel, condition and the amount of weed. Total losses during the mowing of grass mass are composed of two types of losses: due to a bigger height of cutting and due to shredding. The first increase and the second decrease with the heightening of technological working speed. Rotary mower PZ Zweegers CM185 H made losses due to the height of cutting in the range of 1.67 to 3.12% of yield, and losses due to shredding ranged from 0.90 to 1.76%, so total average losses were 3.67%. In the second variant of disc mower IMT 627.716 the losses of grass mass were 1.71 to 2.97% for the height of cutting and 0.75 to 1.60% due to shredding. If we have in mind that maximal allowed value of losses is 5% of yield, we can make the conclusion that both types of rotary mowers made optimal values of losses and mowing quality.

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ANALYSIS OF PRODUCTION AND ECONOMIC RESULTS OF RAINBOW TROUT BROODSTOCK FARMING ON 3 DIFFERENT FARMS IN BOSNIA AND HERZEGOVINA, FRY MACEDONIA AND REPUBLIC OF SERBIA

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Abstract: *Rainbow trout (Oncorhynchus mykiss) broodstock farming for production of eggs for obtaining fry is increasingly losing on significance, both in the world and in the region. In the past 20 years, trend of purchasing eggs of rainbow trout in the stage of the eyes from the specialized farms is very expressed. The reasons for this practice can be found in the costs of keeping the broodstock and producing eggs, the organization of work on breeding the broodstock, as well as the possibility of purchasing eggs from specialized farms at any moment during the year, which is hardly achievable in own production. The analysis carried out on three fish farms in Bosnia and Herzegovina, the Republic of Macedonia and the Republic of Serbia showed that there are differences in technology and production results of rainbow trout broodstock breeding on the observed fish farms. With calculation based on direct costs, economic results of the broodstock farming were compared.*

Key words: *rainbow trout, broodstock, eyed eggs, production results, contribution margin*

1. INTRODUCTION

The rainbow trout (*Oncorhynchus mykiss* Wal.) is one of the main cultivated salmonid fish species in Europe (1) and many countries of the world. The technology of cultivation of rainbow trout has reached a high level, but they nevertheless always present challenges (environmental conditions, diseases, etc.) that directly and indirectly influence the production process. So, for example, viral diseases present a permanent challenge for the sustainable development of aquaculture (2). Many developed countries where rainbow trout is grown have developed specific ways of doing business and the production of rainbow trout. This primarily relates to the artificial selection of rainbow trout with the ultimate aim of creating strains of better production characteristics (better utilization of food, resistance to diseases, etc.). The selected broodstock are used to produce eggs that are sold worldwide at a certain stage of embryonic development (in the eyed stage). A large number of salmonid fish farms in the region, especially producers with significant annual production, have reoriented from rearing their own rainbow trout broodstock and spawning to import eggs of rainbow trout in the eyed stage from USA, Denmark, France, Poland etc. The reasons for switching from own production to the import of rainbow trout eggs is multiple: the offspring of better production characteristics and greater resilience, the possibility of purchasing at any moment during the year, economic reasons etc. Certainly, the import of eggs carries with it some risks regarding the introduction of the diseases, which is why special attention should be paid to the control of the eggs that are imported to prevent the eventual introduction of the disease.

Over the past two decades the production of rainbow trout in the Republic of Srpska (Bosnia and Herzegovina) has been steadily growing (3). In Serbia, the production of rainbow trout is interesting due to the production effects that provide the possibility of achieving stable and solid profit (4). Successful management of the production of rainbow trout requires complex knowledge of the technical-technological and economic parameters of production (4). Although the production of rainbow trout can produce good profitability (production and engaged funds), a relatively small number of fishing farms record or analyze economic indicators of business in a satisfactory way, which ultimately leads to a reduction in planning efficiency when making business decisions (4).

The aim of the paper is to analyze the production indicators and determine the cost of breeding the broodstock of rainbow trout, spawning and embryonic development of eggs to stage eyes on one hatchery in Republic of Srpska (Bosnia and Herzegovina), once in the Republic of Serbia and once in the Republic of Macedonia.

2. MATERIAL AND METHODS

The study covered three salmonid fish farms with their own broodstock of rainbow trout; in the Republic of Srpska (BiH), in the Republic of Serbia and in the Republic of Macedonia. Data on production characteristics, costs and prices were obtained from the owners of the farms based on a structured interview and represent a multiyear average.

The economic result of eggs production was determined using the calculation method based on direct costs. These universal calculative methods are used for calculating costs in different cases, and the methodological procedure is explained by number of authors Andrić J. (5), Milanov and Stočeska-Martinovska (6), Ivankovic M. (7), Ćejvanović et al. (8). This approach, precisely on the example of the production of rainbow trout, was explained by Vasiljević et al. (4). The essence is to compare the value of production (VP) and direct costs (DC), which some authors equate with variable costs, and the difference represents the contribution margin (CM) for covering the remaining (indirect) costs.

$$CM = VP - DC \tag{1}$$

The systematization of aquaculture costs on fixed and variable was done by C. Engle (9). In the examined case, the income is calculated for two products, the eggs in the eyed stage per piece and per stripped rainbow trout mother fish in pieces/kg. Only direct costs of production of eggs, food, work, services, chemicals, small inventory and other variable costs are calculated, based on actual consumption and average prices, or on the basis of an aggregate annual cost estimation (lump sum). The difference in revenue and direct costs represents a contribution margin, i.e. margin for covering the remaining (indirect) costs, in the direct costs are included the costs of replacement of the initial broodstock of rainbow trout. The contribution margin is calculated per m^3 of fishponds, per piece of the parent flock and per liter of water in second. Also, the cost of eggs in the embryonic stage of eyes appearance is calculated per piece.

3. RESULTS AND DISCUSSION

Production objects for rearing broodstock of rainbow trout, spawning, embryonic development and rearing fry have specific requirements regarding the quality of water for supplying the hatchery, and usually it is supplied from water sources that have sufficient water for the projected production capacity. The stability of the quality of the water for supplying the salmonid hatchery is a prerequisite for good production conditions, the lower the possibility of occurrence of diseases which are often the result of deterioration of the environment, it is better for survival of the eggs in the embryonic stage of development, breeding of the fry etc. The selection of a good location, with enough quantities of quality water for the supplying of hatchery, is a basic precondition for achieving good production results. There are usually certain differences in some of the water quality indicators (within the allowed variations) between production objects at different locations, and primarily in water temperature, the content of dissolved oxygen etc. which has a direct impact on production and economic results. Hoitsy et al. (10) reported that trout in grown conditions sometimes sexually mature earlier than in natural conditions if the water temperature is higher and nutrition is better. In practice there are different approaches to technology of breeding from the insemination of eggs to the embryonic stages of the appearance of the eyes, which is reflected in the use of different equipment (Weiss or Zuger type incubator jars, vertical incubators, breeding troughs for salmonid eggs etc.) for the embryonic development of rainbow trout. In principle, this should not have a greater effect on production results if the incubators are properly used, and the fertilized eggs are incubated in the prescribed way, if the workers in charge of working in the salmonid hatchery know the principles of the incubator work and know the embryonic development phases, and in the prescribed manner they take care of the eggs in the stage of embryonic development. Significant differences in the production parameters of broodstock of rainbow trout, eggs and younger ones, in addition to differences in quality and quantity of water, technology of growing the rainbow trout broodstock and nutrition in a different hatchery, occur due to absence of more serious work on the artificial selection of rainbow trout, so accordingly, in the region significant heterogeneity is present. Different approaches to technology of rearing, the selection of broodstock for reproduction and the spawning procedure contributes to a different success in the spawning and getting good quality fry (3).

Tab 1. Production results of broodstock farming on 3 different rainbow trout farms (the Republic of Srpska - Bosnia and Herzegovina, the Republic of Macedonia and the Republic of Serbia)

	Fish Farm 1 - RS (BIH)*	Fish Farm 2 – RM*	Fish Farm 3 – RS**
Farming unit/capacity	Concrete raceway, 66 m^3	Concrete raceways, 100 m^3+80 m^3	Concrete raceway, 135 m^3
Number and average weight of brood fishes	200 females, 2.0 kg/pcs 150 males, 0.7 kg/pcs	800 females, 1 kg/pcs 250 males, 0.7 kg/pcs	562 females, 2.5 kg/pcs 342 males, 1.7 kg/pcs
Number of production (spawning) seasons	Brood fishes are used 3 years females and 2 years males for artificial spawning	Brood fishes are used 5 years for artificial spawning	Brood fishes are used 2 years for artificial spawning
Average mortality p.a.	40 females, 0 males	40 females, 10 males	96 females, 48 males
Feed type and quantity	Broodstock feed: 600 kg	Broodstock feed: 4000 kg	Grower feed: 1800 kg
Broodstock reconstruction p.a.	150 females/year 150 males/every two years	200 females, 40 males	377 females 148 males
Sales of old brood fishes p.a.	(110 pcs*3 kg) ~330 kg females /year (150 pcs*0.9 kg)~ 135 kg males /every 2 years	(160 pcs*1.5 kg) ~ 240 kg females/year (30 pcs*0.9 kg) ~ 27 kg/year males	(281pcs*3 kg) ~ 840 kg/year females (100*2 kg) ~ 200 kg/year males
Number of spawning times in one season	12 spawnings	6 spawnings	6 spawnings
Number of eggs per 1l	~9000 pcs/l	~9500 pcs/l	~8500 pcs/l
Quantity of eggs per female brood fish	1500 pcs/kg	1400 pcs/kg	1461 pcs/kg
Losses during the incubation till eyed eggs	~20%	~20%	~25%

*Average for 10 years; **Average for last 2 years; Source: data obtained on farms and calculated by authors

Egg production requires the maintenance of an adequate number of good quality broodfish at low stocking densities (11) and optimal ichtio-sanitary measures (12).

The optimal water temperatures for the rearing of rainbow trout are 12-17^{o}C, for the growing of young trout requires the somewhat lower temperature (10-12^{o}C), and for the incubation of eggs and the rearing larvae the optimum value is 8-10^{o}C (13). The average water temperature in the hatchery is around 9^{o}C in Republic of Srpska (BiH) with a slight variation during the year, in Macedonia 12^{o}C and in Serbia around 9^{o}C.

The production indicators of the analyzed hatcheries in the Republic of Srpska (BiH), Serbia and Macedonia (Table 1) were used to determine the economic indicators (costs and prices of the eggs in eyed stage) indicate some differences in production capacity, mass and time of use of brood fish in spawning, fertility etc. Female rainbow trout reach sexual maturity in third year of age, and males in the second year, in the rearing conditions female brood fishes are used in the spawning 4-6 years and males 6-7 years (10). The period of use of female brood fish in the spawning at analyzed fish farms is somewhat shorter, so females in the spawning are used for 2 years in Serbia, 3 years in Republic of Srpska (BiH) and 5 years in Macedonia, which means that females are excluded at the age of five years in Serbia, in the sixth year in the Republic of Srpska (BiH) and in the eight year in Macedonia. The stocking density of brood fishes is 5.3 pcs/m^3 at the investigated fish farm in the Republic of Srpska, 5.8 pcs/m^3 in Macedonia and 6.7 pcs/m^3 in Serbia, in accordance with the allegations to Hoitsy (10) which suggests that the density of the stocking of the brodfish should be up to 6-7 pcs/m^3. The number of eggs per kilogram of body weight of females at the examined fish farms in the Republic of Srpska (BiH) is 1,500 pcs/kg of body weight, 1,400 pcs/kg of body weight in Macedonia and 1,461 pcs/kg in Serbia. According to Bascinar & Okumus (14), the absolute fertility of females of rainbow trout ranges from 1,000 to 10,000 eggs/females, and relative 1,600-3,000 eggs/kg body weight of females. The number of eggs per 1 l at the analyzed fish farms is 8,500 eggs/l in Serbia, 9,000 eggs/l in Republic of Srpska (BiH) and 9,500 eggs/l in Macedonia. The number of eggs per 1 l depends on the individual size of the egg (smaller/larger). Egg production of more than 6-year-old females will gradually reduce both quantitatively and qualitatively because of the accumulated effect of different stresses experienced by fish (10). The volume of 1,000 eggs may be 79–90 cm^3 (10). The incubation length of the fertilized egg is in a high degree of water temperature dependence. Bascinar and Okumus (14) state that from insemination of eggs to the eyed stage needs 160 degree days, to hatch 310 degree days, and up to 500 degree days to swimming. Average mortality during incubation up to the phase of appearance of the eyes at analyzed fish farms in the Republic of Srpska (BiH) and Macedonia is the same (20%), while at the analyzed fish farm in Serbia slightly higher (25%). In general, for all analyzed fish farms can be said that the mortality from insemination to the stage of appearance of the eyes is high. Savić et al (3) state that mortality from fertilization to the hatching should be around 10%.

In the table 2 are shown: value of production, direct costs and margin (contribution margin) in total, per unit of production volume, per one female brood fish and per liter of water in second, as cost per unit of one egg.

Production phase: Broodstock farming with egg production
Production time: 365 days
Production unit: concrete raceways

Tab 2. Direct costing calculation for Rainbow trout broodstock farming

Value of Production		Farm 1			Farm 2			Farm 3		
Product	Unit	Quantity	Price	Value	Quantity	Price	Value	Quantity	Price	Value
Eyed eggs	Pcs	480,000	0.015	7,200.00	896,000	0.015	13,440.00	1,540,000	0.015	23100.00
Brood fishes for sale (female)	Kg	330	2.5	825.00	240.00	3.5	840.00	840	3.2	2688.00
Brood fishes for sale (male)	Kg	67.5	2.5	168.75	27.00	3.5	94.50	200	3.2	640.00
Value of production (€)		**8,193.75**			**14,374.50**			**26,428.00**		
Direct Costs (€)										
Stocking	Kg	367.50	3.0	1,102.50	136	3.5	476.00	526.5	2.9	1526.85
Feed	Kg	600	2.2	1,320.00	4,000	1.8	7,200.00	1800.0	1.4	2520.00
Labor	Month	12	320.0	3,840.00	12	300	3,600.00	24.0	300.0	7200.00
Services	lump sum			100.00			150.00			200.00
Chemicals, medicine	lump sum			50.00			200.00			400.00
Inventory	lump sum			100.00			80.00			250.00
Other direct c.	lump sum			200.00			200.00			600.00
DC - Sum		**6,712.50**			**11,906.00**			**12,696.85**		
Contribution Margin (€)		**1,481.25**			**2,468.50**			**13,731.15**		
CM (€/m^3)		66		22.44	180		13.71	135		101.71
CM (€/pc Broodstock)		350		4.23	1050		2.35	904		15.19
CM (€/l/s water)		30		49.38	40		61.71	50		274.62
Unit cost (€/pcs)		**480,000**		**0.014**	**896,000**		**0.013**	**1,540,000**		**0.008**

Source: Authors calculation

In the case of production eggs of rainbow trout in the eye stage in BIH value of production of eggs is 7,200 €, and together with sale of extracted brood fish 8,193.75 €. The biggest cost is labour cost, one worker has monthly salary of 320 €. The cost of feed is 1,320 €, and rest (services, medicine, inventory and others) of direct costs are additionally 450 €. In order to start the production of the eggs in the eyed stage, it was necessary to obtain the initial broodstock from elderly brood fishes, female and male (total 350 pieces), which, with regard to their age, can be effectively used only two years, and later replaced from own production. Due to that in yearly direct cost are included and half costs of renewed broodstock. Total annual cost of production of eggs in the eyed stage in the case of BIH is 6,712.50 €, and contribution margin is 1,481.25 €, or 18.08% of Total value of production. The cost of eyed eggs production per piece (based on Direct costing calculation) is 0.014 €.

In the case of farm in the Republic of Macedonia value of produced eggs in the eyed stage is 13,440 €, and additional revenue from extracted brood fish is 935 €. The biggest cost is cost of feed (7,200 €), significant higher than in the case of other two farms. Labour cost has relative smaller participation because one worker serve three times bigger broodstocks than in the case of BIH. Female brood fishes are used longer in the case of this farm, so annual cost of their replacement is lower. And some other depended direct costs are lower, bearing in mind capacity of farm, while costs of eggs production in the case of farm in Macedonia is 0.013 €/pc. Given that the large number of brood fish units are growing, total contribution margin per farm is 2,468 €.

The farm for production of rainbow trout eggs in the eyed stage in Serbia achieved the most advantageous economic parameters, and cost of production of eggs is the lowest (0.008 €/pc). That is because it has the lowest cost of feed compared to two others farms. Due to significantly bigger broodstocks and production of more eggs on the farm in Serbia where are engaged two workers during whole year, but labour cost per piece of eyed eggs stayed around the same as in Macedonia, but two times lover than in BIH. Contribution margin on the farm in Serbia is 13,731.15 €, or even 52% of the total value of production.

If the financial parameters are compared on all three farms, the cheapest production of rainbow trout eyed eggs is on the farm in Serbia, mostly due to the lowest cost of feed. After that, approximately the same production price of eggs is in Republic of Macedonia (0.013 €/pc) and BiH (0.014 €/pc). Wherein in the Republic of Macedonia is the biggest cost for feed, and in BIH the biggest costs are labour costs, as a consequence of the smallest broodstock. The labour cost in this case has character of relative-fix cost because it is necessary permanent presence of one worker, regardless of the size of parent flock, and in the case of its significant increase, there is need of employment of one more worker. On the other side, the size of available fish pond dictates the size of broodstocks which can be grown.

The recommendations in a way of reducing production costs of eggs of rainbow trout in the eyed stage on the farm in BIH are enlargement of fish pond and increase of number of brood fishes, to take advantage of present labour force. In the case of the farm in Macedonia recommendations are to re-examine validity of high consumption of fish feed and to increase the productivity of broodstock (the least eggs is obtained per one brood fish). In the case of the farm in Serbia, which is the most efficient, possible reserves are in possibilities of additional decrease of cost for feeding and lowering feed conversion ratio.

4. CONCLUSION

The total numbers of females at the analysed fish farms are different, which reflects on total production and economical effects of manufacturing eggs to the embryonic stage of appearance of the eyes. Different concepts are present at the analyzed fish farms (valid in means of reproduction) of growing brood fishes of the rainbow trout, which are used for spawning. Significant heterogenity is present in the duration of using brood fishes in spawning and average mass of brood fishes (both male and female), which with females expresses in different number of eggs gotten per one kilogram of the female's weight, in total number of eggs per one female, and the egg size as well. Number of eggs per 1 kg of female's weight at analyzed fish farms is not optimal, which can be a result of weaker genetic potential of the females and weaker nutrition of brood fishes.

In the case of production rainbow trout eggs of eyed stage the most efficient is the farm in Serbia, and approximately the same but less efficient are farms in the Republic of Macedonia and in BiH. Based on different sizes of production capacities it is not practical to compare absolute values of gross margins, e.g. contribution margins, than it is better to keep everything down on the gross margin per unit of broodstock or on unit cost of produced eggs. By far the largest gross margin per unit of broodstock has the farm in Serbia, and the smallest farm in the Republic of Macedonia. However, due to difference in direct cost, the close to same cost of production per eyed eggs have farms in the Republic of Macedonia (0.013 €/pc) and BIH (0.014 €/pc). Significantly lower cost of production per unit of egg achieved the farm in Serbia (0.008 €/pc).

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NUMERICAL INVESTIGATION OF 2-D UNSTEADY, TURBULENT FLOW AROUND CONSTRUCTION FOR LOW REYNOLDS NUMBERS

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Abstract. *Microclimate around constructions and specifically the growth of small or large vortexes can significantly influence the quality of air, the thermal environment and the ventilation conditions of rural buildings. The formation, the size and the intensity of the vortexes which are result of the phenomenon of separation and reattachment of the boundary layer are influenced by the kind of flow (laminar or turbulent) and also by the building geometry. In this paper is presented the study of flow for two small Reynolds numbers, 250 and 500, around a two dimensional construction. The airflow is two-dimensional, unsteady and turbulent and simulates flow in a wind tunnel with a mathematical model of fluid viscosity, using the Navier-Stokes equations and the equation of continuity with specific boundary conditions. The DNS model is solved numerically by means of H / Y and the Galerkin finite element method. Instant and mean streamlines, instant and mean velocity distributions are shown and compared. Also, the separation and reattachment length for both Reynolds numbers are compared. The results are contradicted and qualitatively compared with results of other researchers.*

Key words: *Vortex, Reynolds number, Turbulent flow, DNS model, Galerkin finite element method*

1. INTRODUCTION

The parameters and properties of air flow are significantly important to designers and manufactures of buildings. For example, the velocities and pressures around greenhouse and livestock buildings determine the orientation of the construction, the positioning of the windows, their opening and affect the internal environment and microclimate. In real circumstances, the air flow is turbulent and the Reynolds number ranges between 2.000 and 100.000. In this case, although the studied Reynolds numbers are 250 and 500 the flow is unsteady and turbulent due to the presence of the established obstacle. During turbulent flow the fluid molecules along with their movement towards the main direction of the flow, they move randomly in all directions. Because of these transverse and vertical movements of the molecules, small and large vortexes are caused, which in their movement can grow, diminish or even change shape. Investigation of turbulent flow and vortexes generated around structures and buildings is important as these phenomena have a significant impact on physical environment, human activity [11], and also on the agricultural buildings [5].

The formation, the size and the intensity of the vortexes are affected by a variety of factors according to the results of other experiments. In particular, when the Reynolds number is great, the phenomenon of fluctuation disappears and the recirculation of the flow becomes smaller downstream of an obstacle that occupies the full width of a wind tunnel [5]. The proportion of structure's dimensions is also important. The increase of the ratio causes the production of smaller vortexes [2]. At the same time, the influence of the geometry of the top is apparent more downstream of the obstacle than upstream [9]. Also, fluid velocity, roof configuration, and the structure design can influence the interaction between the building and the wind [12]. Numerous researchers have dealt with the influence of all the above parameters on the phenomenon of detachment and reattachment of the boundary layer [6].

In this study, the airflow is two-dimensional, unsteady and turbulent. The construction is two dimensional and occupies the whole width of the wind tunnel. A lot of researches take for granted a two dimensional flow [3, 8, 11, 1], and although in fact there are no two-dimensional constructions, many structures are significantly elongated so that the effect of the other dimension is considered remarkably small [5, 7].

The purpose of this numerical experiment is to extract conclusions about the flow behavior in small numbers of Reynolds. The DNS model which belongs to the class of models of full turbulent flow analysis is used. The Navier-Stokes equations and the continuity equation are immediately solved, without making hypotheses that is without any assumptions. Thus, due to the direct solution of our equations, we are able to obtain instantaneous values of the flow parameters, while other models focus on averaging. Also, the ability to obtain instantaneous values is a clear advantage over laboratory experiments, in which such flow analysis is virtually impossible. For this numerical experiment the Reynolds number were selected to be small, 250 and 500 because was observed serious instability. Equations were resolved with the Galerkin finite element method. Instantaneous and statistical processing results were compared qualitatively to verify our approach with published studies.

2. MATERIAL AND METHODS

2.1. Mathematical model

Navier-Stokes and continuity equations for unsteady, viscous, incompressible, two-dimensional turbulent flow are presented. The direct numerical simulation model is used to give us information about flow parameters such as velocity, upstream and downstream of the structure, and across the computing field. The model was performed in accordance with the study of Fragos et al. [4]. The flow is turbulent due to the presence of the structure.

2.1.1. Governing equations

Navier–Stokes and continuity equations (1) and (2) are given below:

$$\frac{\partial U}{\partial t} + U \cdot \nabla U = -\nabla p + \frac{1}{Re} \cdot \nabla^2 \cdot U \tag{1}$$

$$\nabla \cdot U = 0 \tag{2}$$

Where $U = (u, v)$ is the velocity vector of the fluid with streamwise velocity (u) and cross-wise velocity (v), its components in the (x) and (y) direction respectively, (t) is the time, (p) is the pressure. Re is the Reynolds number (equation 3) based on the characteristic length (h) (height of structures) and the characteristic (U_0) velocity (uniform flow velocity in m/s).

$$Re = \frac{U_0 \cdot h}{\nu} \tag{3}$$

The previous equations have been made dimensionless by using the following characteristic magnitudes (h, U_0, P_0, Re), where: h is the height of the construction (m), (U_0) is the uniform approaching velocity of the fluid (inlet free stream velocity, $m \cdot s^{-1}$), $P_0 = P \cdot u^2$ is the pressure intensity ($N \cdot m^{-2}$), ρ is the density of the fluid ($N \cdot s^2 \cdot m^{-4}$), $Re = \frac{U_0 \cdot h}{\nu}$ is the Reynolds number with respect to the height of the construction h and ν is the kinematic viscosity of the fluid ($m^2 \cdot s^{-1}$).

2.1.2. Basic parameters of the flow and the computational domain

The height of the structure was $h = 0.061$m, the height of the tunnel was $H = 9.6\,h$, the length before the structure was $14\,h$ and after $45\,h$. Air was chosen as a working fluid with a kinematic viscosity $\nu = 1.57 \cdot 10^{-5}$ $m^2 \cdot s^{-1}$ and a density $\rho = 1.2$ $kg \cdot m^{-3}$. The inlet velocity of the fluid was $U_{250} = 0.064$ $m \cdot s^{-1}$ when Reynolds number was 250 according to the height of the structure and when Reynolds was 500, the inlet velocity was $U_{500} = 0.128$ $m \cdot s^{-1}$ .The airflow is uniform at a distance of $3\,h$ before it enters the wind tunnel so that a uniform velocity distribution has been developed at $x = 0$. The structure is located at a distance of $14\,h$ from the entrance (zero point of the x address), so the flow is developed before being disturbed by it. The width of the structure is $1\,h$ and the height of the structure is $1\,h$. The wind tunnel exit has been chosen to be $60\,h$ from the entrance (fig. 1).

2.1.3. Boundary and initial conditions

The initial condition was chosen in order to avoid any computational interference and was considered the initial condition of any experiment. At the beginning of every experiment ($t = 0$), the Reynolds was 1, which corresponds to initial velocity

U_0 =0.0025m/s. There are non-slip conditions in the walls of the wind tunnel and the construction, at the entrance of the wind tunnel the flow is uniform and at the exit a free boundary condition is imposed for both the u and the v component of the velocity (fig. 1).

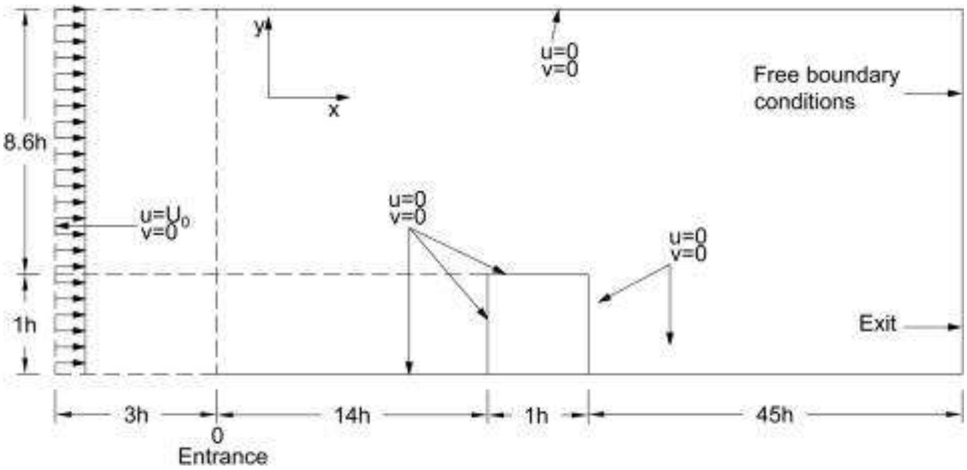

Fig. 1 Wind tunnel.

2.1.3. Computational mesh and data

The computing mesh consists of 14,645 square pieces, 59,299 nodes and 133,603 unknowns. In the figure below (fig 2) the mesh is denser in these areas as we wanted to see the flow behavior more accurately. The dimensionless time step applied was 0.01, corresponding to real time dt = 0.0025sec, and at each time step three repetitions were needed to converge the results. Each repetition needed 11.76 seconds to take place. A computer with the following features was used to perform the numerical experiment, Intel® Core ™ i7CPU 870 @ 2.93GHz and 4GB RAM. The total number of arithmetic forecasts received in the case of the Reynolds 250 was 15,000, in the case of Reynolds 500 it was 45.000.

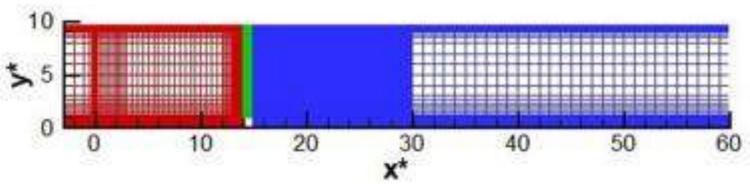

Fig. 2 Computational mesh.

2.2. Statistical analysis

The Direct Numerical Simulation model provides for instantaneous streamlines and velocity. The statistical processing of the instantaneous variables of flow provides in the form of time distributions, average velocity and average streamlines. The dimensionless equations which calculate the average values of the velocity components (4, 5), at every point of the computational field and the dimensionless equations which calculate instantaneous (6, 7) and time-mean averaged streamlines (8, 9) are presented:

$$\bar{u} = \frac{1}{T}\int_0^{\tau} u\,dt \tag{4}$$

$$\bar{v} = \frac{1}{T}\int_0^{\tau} v\,dt \tag{5}$$

Where $\bar{u}$ is the time-mean averaged stream-wise velocity, $\bar{v}$ is the time-mean averaged cross-wise velocity, u is the instantaneous stream-wise velocity, v is the instantaneous cross-wise velocity and T is the total time.

$$u = -\frac{\partial \Psi}{\partial y} \tag{6}$$

$$v = -\frac{\partial \Psi}{\partial x} \tag{7}$$

$$\bar{u} = \frac{\partial \bar{\Psi}}{\partial y} \tag{8}$$

$$\bar{v} = \frac{\partial \bar{\Psi}}{\partial x} \tag{9}$$

Where Ψ is the instantaneous flow and $\bar{\Psi}$ time-mean averaged flow.

3. Results and discussion

The Reynolds numbers figures presented are 250 and 500. The times were selected in order to understand the evolution of the behavior of the flow by the reader. At the end there is a comparison of the results. Streamlines are a tool for imaging and analyzing the flow. Each streamline is a line that is everywhere tangential to the velocity range. If the flow is constant, nothing at a certain point changes, including the direction of the velocity, over time and so the flow lines are unchanged. In unstable flow, flow lines can change shape over time.

3.1 Instantaneous streamlines and velocity contours of airflow

3.1.1. Instantaneous streamlines of airflow Re=250, Re=500

Figure 3 shows the instantaneous streamlines when the Reynolds number is 250. The selected time units (7.5, 18, 48, 146) show that even in when the Re is very small, there are vortices around the structure.

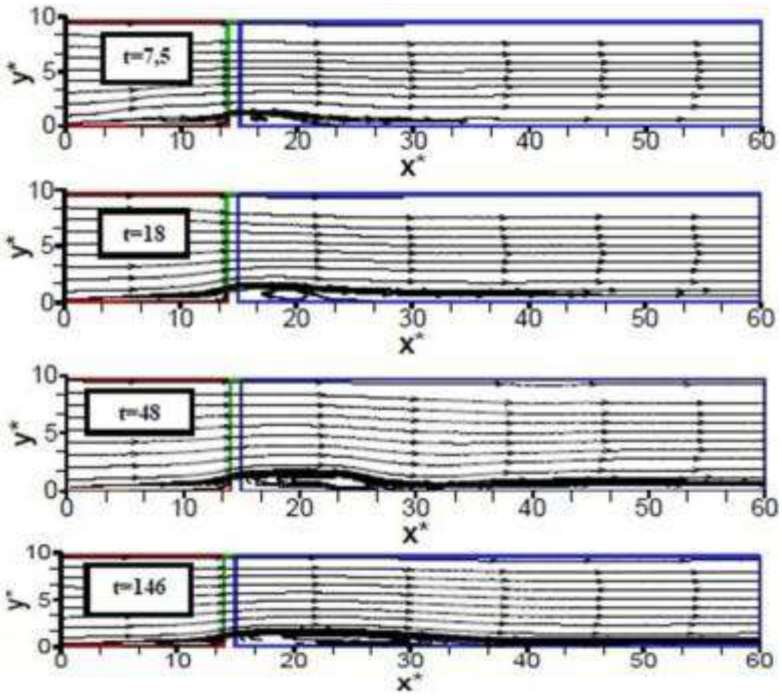

Fig. 3 Instantaneous streamlines of airflow Re=250.

Specifically, at time unit 18, a vortex unrolls downstream, x =20. Also, upstream of the structure, x =11, there is a small vortex. The shape and the size of the vortexes change, but after a while, time unit t =48 the phenomenon is normalizing. For Re= 500 (fig 4) more time units where needed to describe the flow specifically. There are a lot of vortices at t =146 downstream and normalization is observed at time unit 434. The fluctuation of the downstream reattachment point position and upstream separation and reattachment points form vortexes.

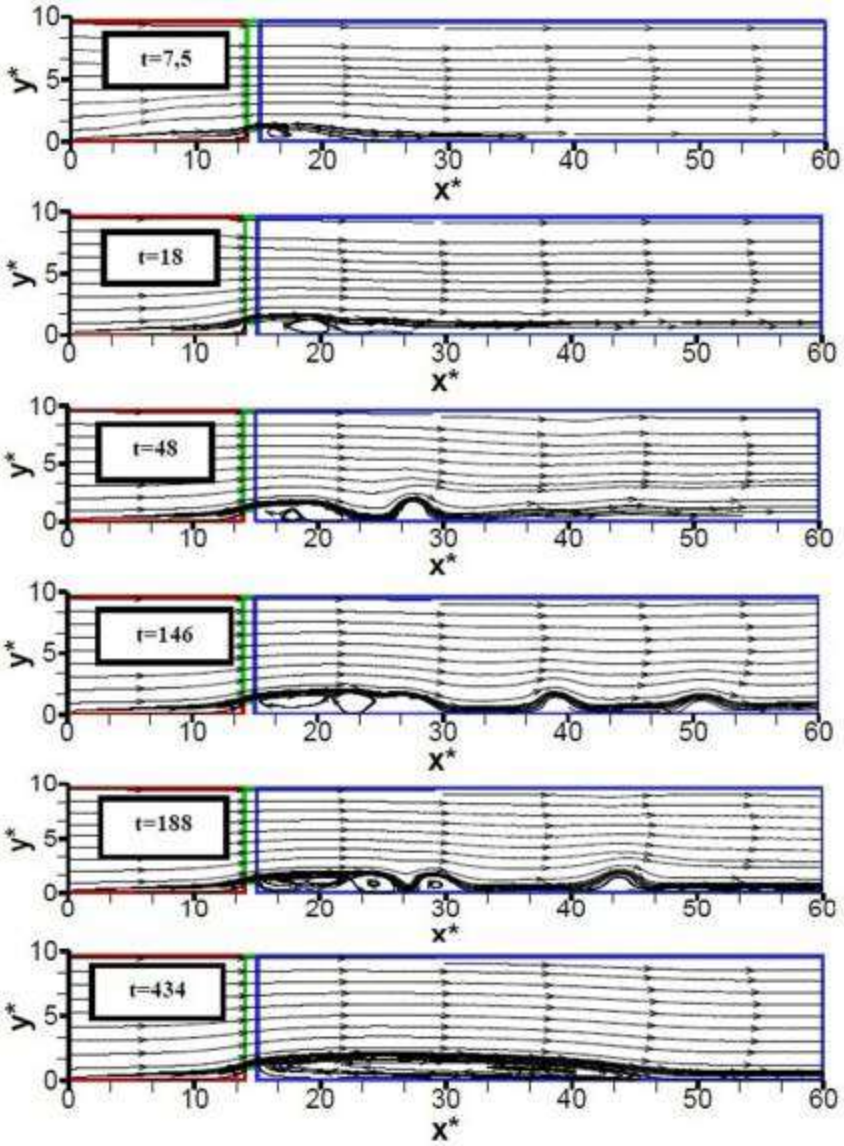

Fig. 4 Instantaneous streamlines of airflow Re=500.

3.1.2. Contours of instantaneous stream-wise and cross-wise velocity Re=250, Re=500

For Reynolds 250 the stream-wise velocity contours (fig 5) show that velocity has negative values at the downstream of the structure and at the top of the wind tunnel. At time unit $t = 116$ the values of stream-wise velocity stabilize all over the wind tunnel. Cross-wise velocity contours (fig 6) shows positive values around the structure and mostly at the left edge. Also, at time unit $t = 48$ negative velocities are observed at $x = 28$, probably because of the presence of a vortex. Figures 6 and 7 present stream-wise and cross-wise velocity contours for Re=500. At the upstream side of the structure there not significant fluctuation, but downstream velocity varies between negative and positive values, because of the flow.

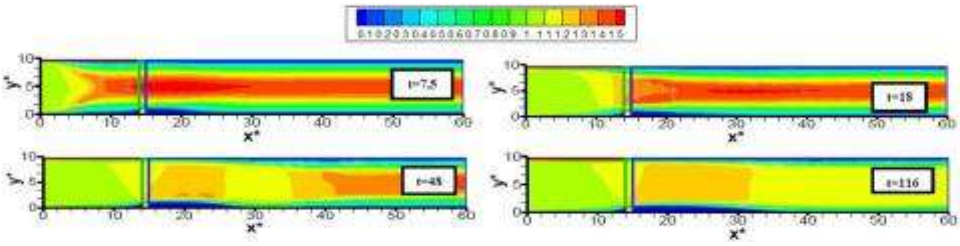

Fig. 5 Instantaneous stream-wise velocity, Re=250.

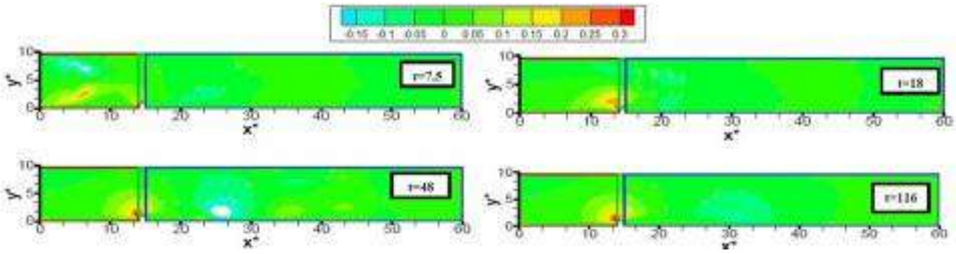

Fig. 6 Instantaneous cross-wise velocity, Re=250.

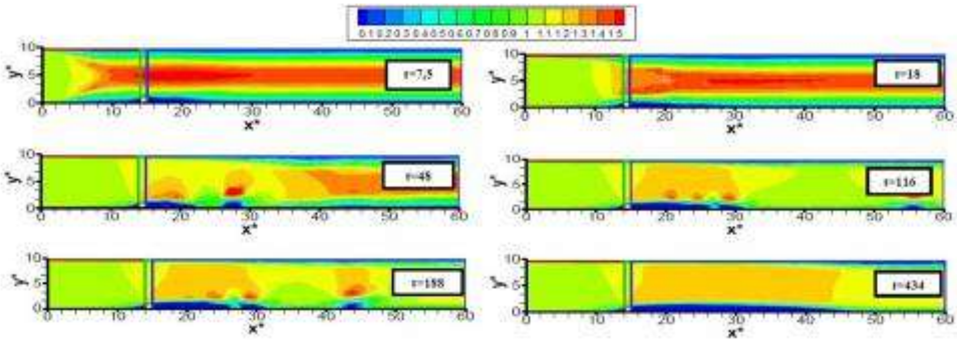

Fig. 7 Instantaneous stream-wise velocity, Re=500.

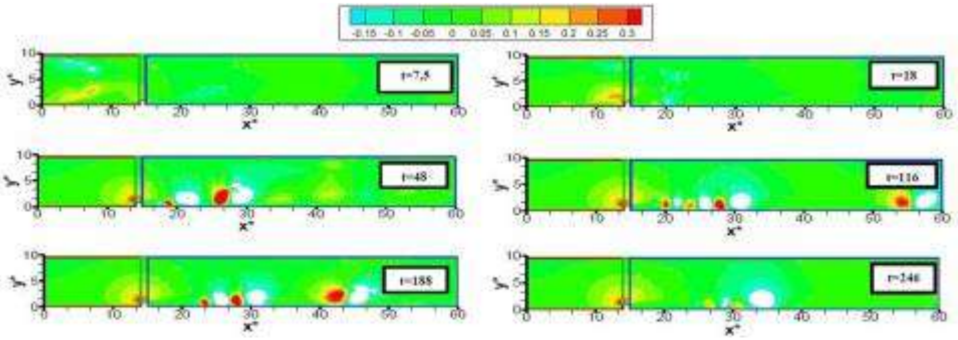

Fig. 8 Instantaneous cross-wise velocity, Re=500.

3.2. Averaged streamlines and velocity contours of airflow

3.2.1. Averaged streamlines Re=250, Re=500

The following figures (fig 9) show the average values of streamlines for Re= 250 and 500. In the case of Re= 250 the existence of a vortex upstream of the structure is observed, extending from $x = 13.5$ to $x = 14$ and by $y = 0$ to $y = 0.5$. Downstream of the structure there is not the same intense presence vortex as in the upstream, yet a vortex whose center is about $x = 17$ and $y = 1$ is stretched where the average flow lines appear to be more intense. In the case of Re= 500 upstream of the obstacle the flow appears stronger and unlike the vortex of Re= 250, here it ranges from $x = 12.5$ to $x = 14$ and $y = 0$ to $y = 0.5$. Downstream we observe the existence of two vortexes. A comparison with the Rouvreau et al. [10] (fig 10), which is for Reynolds 1000, shows that the vortex appears upstream of the barrier continues to grow and grow as Reynolds grows, which demonstrates the safety of the results.

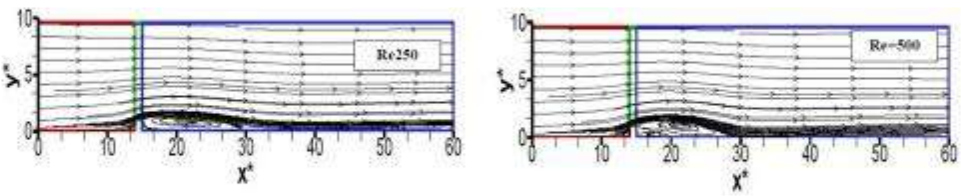

Fig. 9 Average streamlines Re= 250, 500.

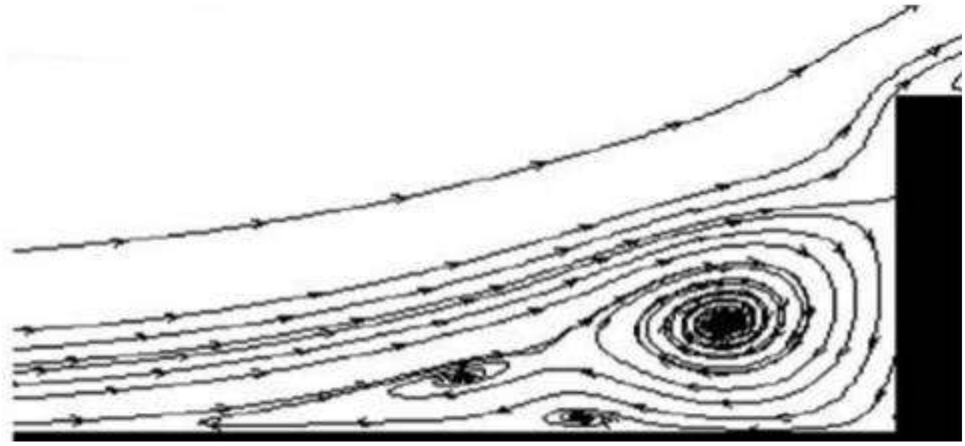

Fig. 10 Average streamlines Re= 1000 (Rouvreau et al., 2005)

3.2.2. Averaged stream-wise and cross-wise velocity contours Re=250, Re=500

Contours of averaged stream-wise velocities for both Re= 250 and 500 do not show significant differences. In both cases (fig. 11 and 12) upstream and downstream of the structure, the velocities range between $y = 0$ to $y = 1$ and start to take higher values above the roof of the structure with a stronger increase in the upper left edge. Quite higher than the ceiling, values are rising to reach the maximum value. While in both cases the similarity is obvious, however in the case of Re= 500 the increase in the stream-wise velocity values is made with a spatial delay compared to Re= 250. As in the case of the average values of stream-wise velocity, there are no large differences between the values of the cross-wise velocities between Re= 250 and 500.

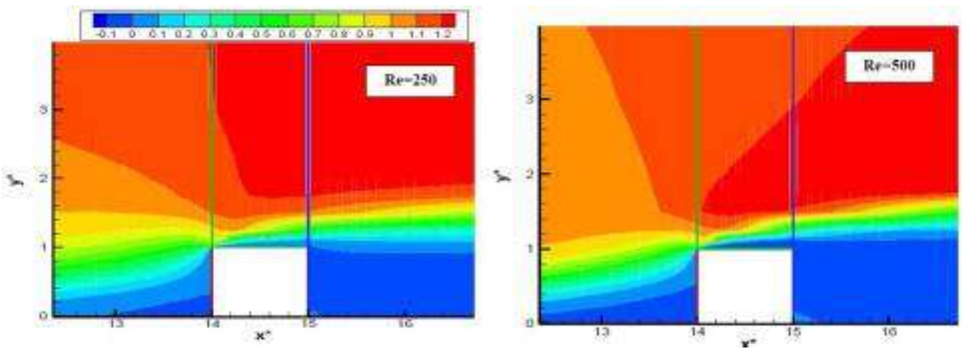

Fig. 11 Averaged stream-wise velocity contours Re= 250, 500

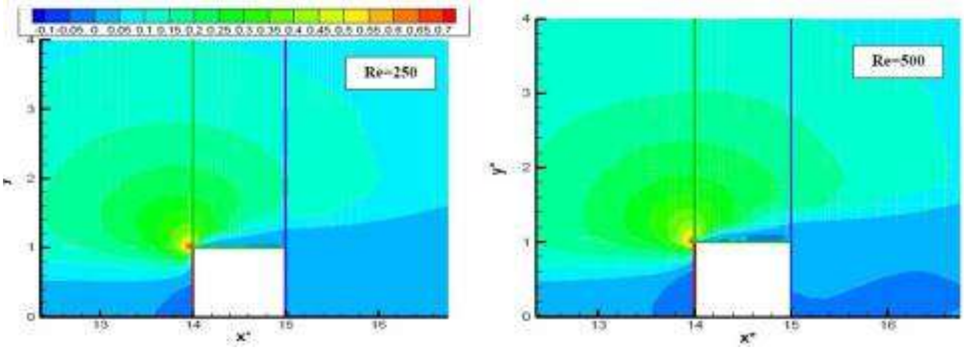

Fig. 12 Averaged cross-wise velocity contours Re= 250, 500

3.3. Separation and reattachment length

3.3.1. Separation length

The diagram below (fig 13) shows the separation length upstream of the construction for numbers Re = 250 and 500 in relation to time. For Re = 250 there is a variation from time t =0 to t =80. At time unit 0 length is 0.6.

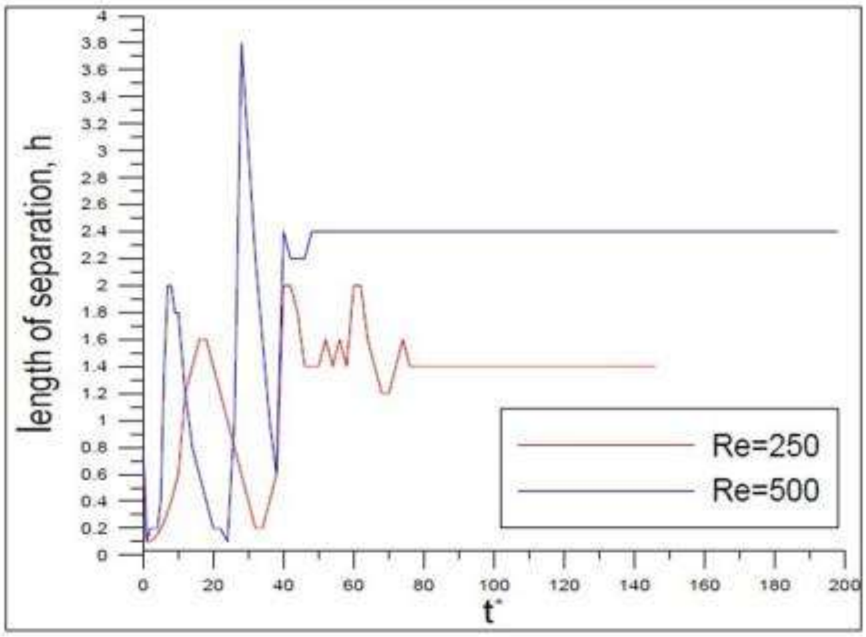

Fig. 13 Separation length.

There are fluctuations during time and separation length is stabilized to h =1.6 at t =80. For Re = 500, the separation length is stabilized earlier, t =50. However, there are larger fluctuations. Maximum separation length is observed at t =30 and it is h =3.8.

3.3.1. Reattachment length

Figure 14 shows the length of the vortex reattachment downstream of the structure. For a number of Re= 250 we observe an increasing path, continuous, to stabilize the condition for t = 140 and h = 20. In contrast, for Re= 500, the reattachment length increases slightly relative to the initial value, but there are large fluctuations. The smallest value of length is 5 at time t = 50, and the highest value is 25 at t = 340, which remains constant until the end of time points.

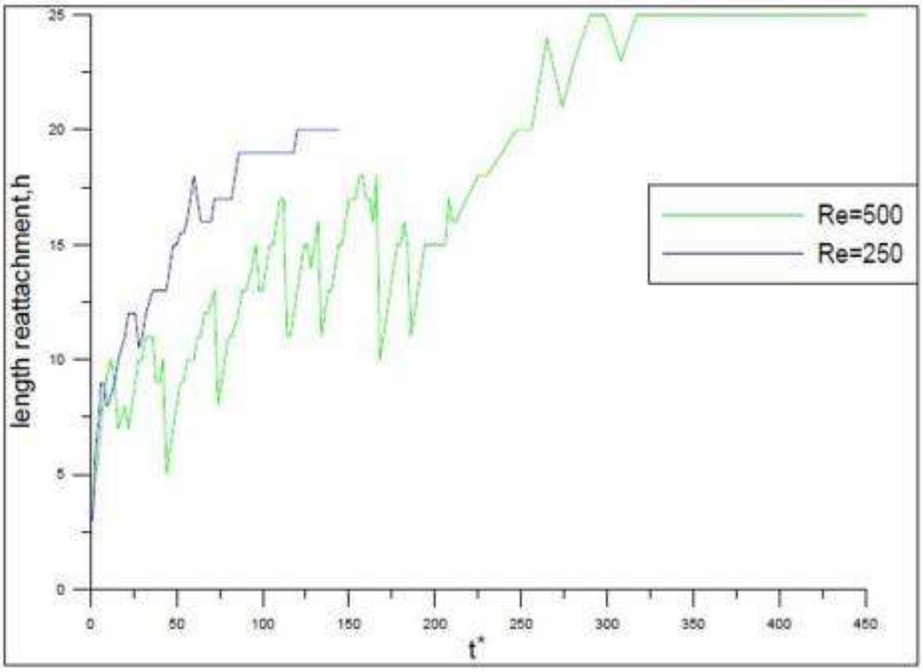

Fig. 14 Reattachment length.

4. CONCLUSIONS

The comparison of the results for Reynolds 250 and 500 as well as the comparison with other published papers lead to the following:

In the case of Re= 500 the production of the flow lines is stronger both upstream and downstream of the obstacle relative to Re= 250. Also the flow in both cases tends to stabilize according to the streamline charts, but when Reynolds is 500, it takes more time for the vortices to extinguish.

From average streamlines is evident the strong presence of intense fluctuation upstream of the construction at the base of the wind tunnel for Reynolds 500.

Regarding the average values of the stream-wise and cross-wise velocities, it is generally shown that the velocities developed for both Reynolds numbers, upstream and downstream of the obstacle, are low. However, in both Reynolds cases, the lower average velocities are located at the upper left edge of the construction.

The separation length upstream of the construction is stabilized earlier for Re= 500 compared to 250, although for Re= 500 the instability is greater. However, the reattachment length, downstream of the construction, as expected, is greater for Re= 500 and requires more time to stabilize.

Finally, we can point out that despite the small Reynolds numbers selected, the flow exhibits instability which is reinforced for Re= 500 versus 250. Also, while the initial condition is the steady uniform flow and the specific Reynolds numbers are small, instability is obvious and we can agree with other researchers [9] to the conclusion that it is due to the presence of the obstacle, its geometry and possibly its distance from the incoming flow.

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DESIGN OF HYDROSTATIC TRANSMISSION OF AGRICULTURE MACHINES

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Abstract. *This paper focuses on the use of hydrostatic transmissions for an agriculture machine. A hydrostatic transmission modifies and transmits power from the engine to the final drive, or directly to the wheels or tracks. An entire text could be devoted to the analysis required to properly match prime mover and load characteristics to achieve optimal productivity and efficiency. The objective in this paper is to understand the characteristics of a hydrostatic transmission so that it can be compared with mechanical transmissions.*

Key words: *servo pump, hydromotor, hydrostatic transmission.*

1. INTRODUCTION

The hydrostatic transmission is used in heavy vehicles such as earth moving machines, agriculture machines, forest machines, industrial and mining lifters. Nowadays, the demand of that kind of transmissions is increasing because of hydraulic drives have many advantages over other technologies. That is because of hydrostatic transmission has a high output capacity combined with high overall efficiency over a wide velocity range, and all that, with a low weight and volume.

Hydrostatic transmission is the conversion of mechanical energy to hydraulic energy using pump driven by a prime mover, supplies pressurized fluid to a utilization point, and its conversion back to mechanical energy to drive a hydraulic motor (fig.1) which in turn, drives a load connected to its shaft. Two parameters, torque (T) and speed (n), are converted to two different parameters, pressure (P) and flow (Q), using a pump. The two new parameters, P and Q are converted back to torque (T) and speed (n) using a hydraulic motor. The principal reason for converting to fluid power is the convenience in transferring energy to a new location. The pressurized fluid, defined by the P and Q parameters, easily flows around corners and along irregular pathways before reaching the point where it is reconverted to T and n. The product of T and n is called mechanical energy and the product of P and Q is called hydraulic energy. The HST system can provide smooth change of output speed, output torque and hence output power according to the design requirements. If the displacement of the pump and the motor are fixed, the HST system simply acts as a gearbox to transmit power from the prime mover to the load. The majority of HST systems, however, use a variable-displacement pump and a fixed displacement motor or both pump and motor may be of variable displacement type so that, speed, torque or power can be suitably regulated [1], [2], [3].

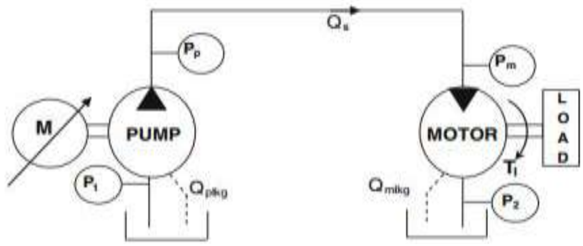

Fig. 1 Schematic diagram of the hydrostatic transmission

A general view of the system that is going to be designed can be observed in the fig.2 with a diesel engine which sends the power to the hydrostatic transmission. This hydrostatic transmission is made up of one variable pump and one variable motor. It sends a different shaft speed and torque depending on the displacement settings of both hydrostatic units to the machinery wheels but to have different possibilities it has a gearbox with at least two gear relations [4].

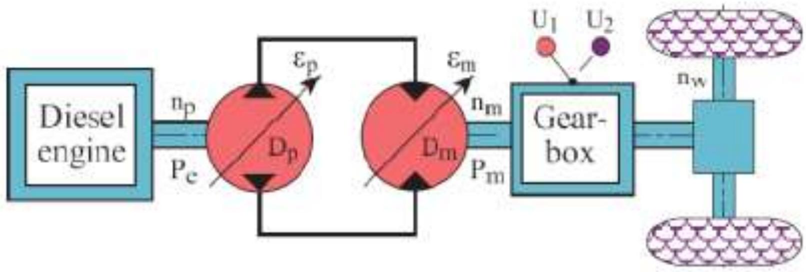

Fig. 2 The hydrostatic transmission of an agriculture machine

2. COMPARISON OF HYDROSTATIC AND MECHANICAL DRIVES

A vehicle with rear-wheel drive with mechanical transmission has the components shown in fig.3. The power from the engine through the clutch is transmitted to the mechanical transmission. In the mechanical transmission the revolution per minute is decreased and the torque is increased. Then, through the universal joint and differential the torque is transferred to the wheels. The mechanical transmission can be thought of as a black box with gears inside. The engine can deliver torque over a given range. A gear mesh is selected to match required output torque to available input torque. The clutch disconnects output shaft from driveline so that the gears in the transmission can be shifted to a new mesh. With a manual clutch, the operator manually engages the clutch and manually shifts the transmission to a new gear mesh [5], [6].

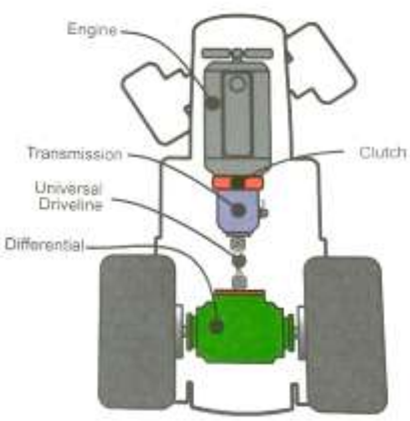

Fig. 3 Diagram of the rear-wheel drive vehicle with mechanical transmission

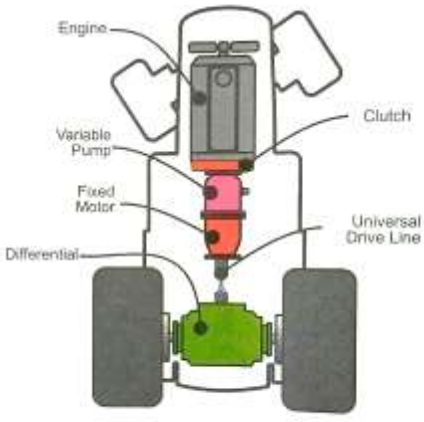

Fig. 4 Diagram of the rear-wheel drive vehicle with hydrostatic transmission

The same vehicle shown in Fig. 3 is shown in Fig. 4 with the mechanical transmission replaced with a hydrostatic transmission; all other components remain the same [5], [6].

To provide a specific example, we will begin by specifying a variable displacement axial piston pump and a fixed displacement axial piston motor, fig.5. Pump output is increased by stroking the pump, thereby increasing the speed of the motor. The vehicle can be speeded up and slowed down by moving the hand control that strokes the pump.

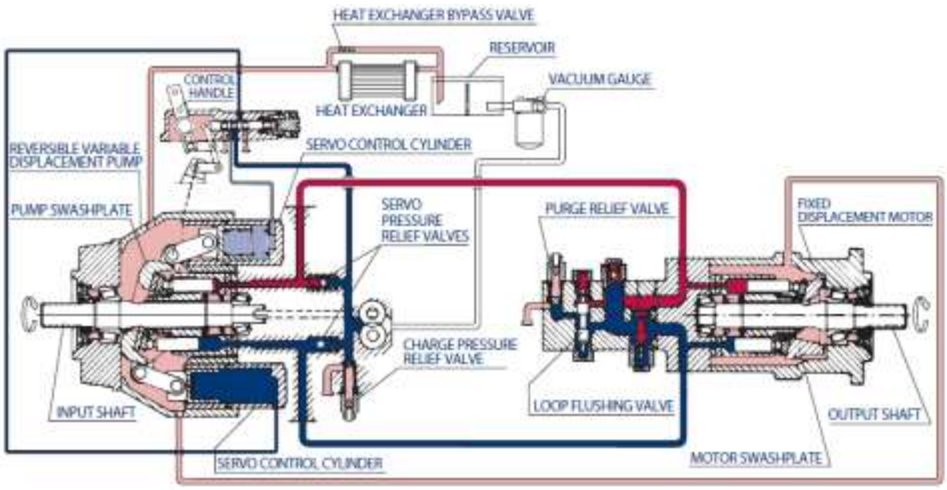

Fig. 5 The principle of operation of hydrostatic transmission systems

The rotation of the motor shaft can be reversed by moving the swashplate control through the neutral position and displacing it in the opposite direction. The reverse position of the swashplate causes fluid to flow in the opposite direction, which causes the motor to turn in the opposite direction, thus reversing the vehicle. Vehicle motion can be changed from forward to reverse with a simple hand movement. This maneuverability is often the justification for installing a hydrostatic drive on a vehicle. It is tiring and time-consuming when an operator has to shift a mechanical transmission each time the direction of motion is changed. Vehicle productivity is increased with a hydrostatic transmission. A hydrostatic transmission, like an automatic shift transmission, connects the engine and load with a fluid connection. The key disadvantage, as with all fluid devices, is some decrease in efficiency [7].

This type of hydrostatic transmission is called closed-circuit hydrostatic transmission. It consists of a reversible variable displacement servo pump, fixed displacement hydro motor and additional accessories like filter, heat exchanger and reservoir.

In the hydrostatic circuit there is a charge pump. A charge pump (generally a small, fixed displacement pump) is built into the housing with the main pump and operates off the same input shaft as the main pump. The purpose of the charge pump is:

- It replaces the fluid that leaks past the pistons into the pump housing. The same leakage flow occurs in the motor. This flow is essential, because it provides lubrication and seals clearances.
- It provides a flow of cooling fluid through the pump and motor housings. When the high-pressure fluid in the main circuit leaks into the housing, mechanical energy is converted into heat energy. In addition, heat results from friction between the moving parts. A flow of cooling fluid is required to remove this heat.

3. SERVO-CONTROLLED PUMP

The variable displacement servo pump is of axial piston design. When the control piston extends, it moves the swashplate to increase the amount of fluid pumped by the pistons. (Displacement of the pump is increased.) Flow of fluid to the control piston, and thus its position, is controlled with a servo valve. A pump with these features is called a servo-controlled pump.

A servo valve operates like a directional control valve. The spool shifts in one direction to direct pressurized fluid to Port A, and in the other direction to direct pressurized fluid to Port B. The spool in a servo valve is precisely machined; consequently, the cost is higher than the cost of a standard directional control valve. It is helpful to first consider a manually controlled servo pump (fig.6.). Suppose the manual control lever is moved to the left (rotated in the counter-clockwise direction). The spool of the servo valve is shifted to the left. High-pressure fluid is directed to the bottom control piston, causing it to extend. The top control piston is connected to the case drain; thus it retracts when the bottom control piston extends. As the two control pistons move, the swashplate is rotated clockwise, thus increasing the amount of fluid pumped. When the swash plate moves, it pushes the yoke feedback link to the right. The link pivots and pushes the spool of the servo valve to the right. This spool movement closes the two ports of the servo valve, thus locking the control piston in a position that corresponds to the new position of the manual control lever. This position of the swash plate is held until the manual control lever is moved to e new position [5].

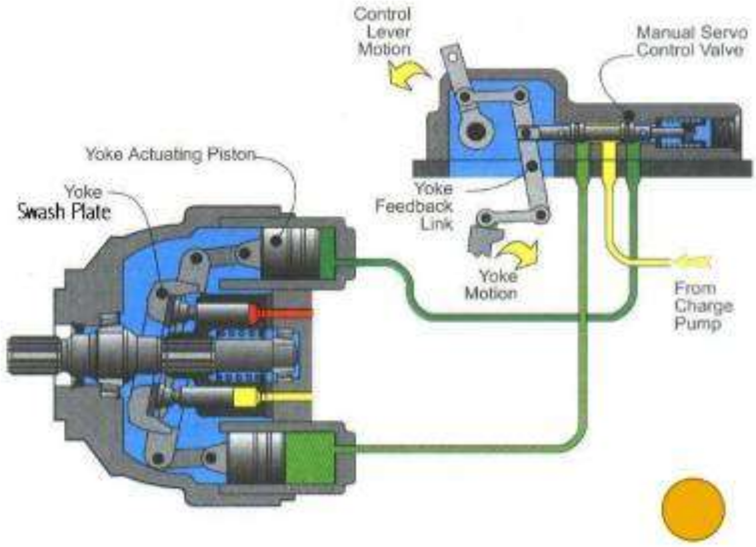

Fig. 6 Manually operated servo pump

The servo pump on fig.7 operates like the one presented on fig.6 except the control lever is shifted hydraulically, using a pilot hydraulic circuit and a remote control valve. The feedback mechanism works in the same way.

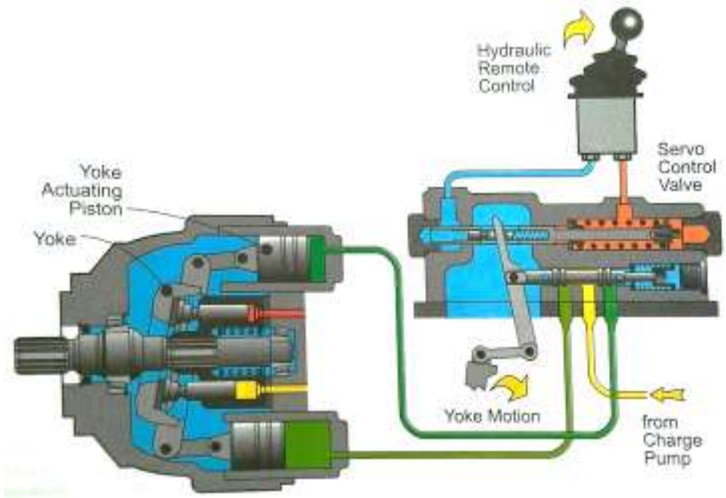

Fig. 7 Hydraulically operated servo pump

The servo pump shown in fig.8 is like that shown in fig.7, except a torque motor is used to position the spool of the servo valve. A torque motor rotates through several degrees of rotation, when a current is passed through the winding. The torque motor shown has a flapper attached to the armature. This flapper is centered in the nozzle such that the pressure drop on both sides is equal. Pressure on both ends of the servo valve spool is equal. This design is called a flapper nozzle servo valve.

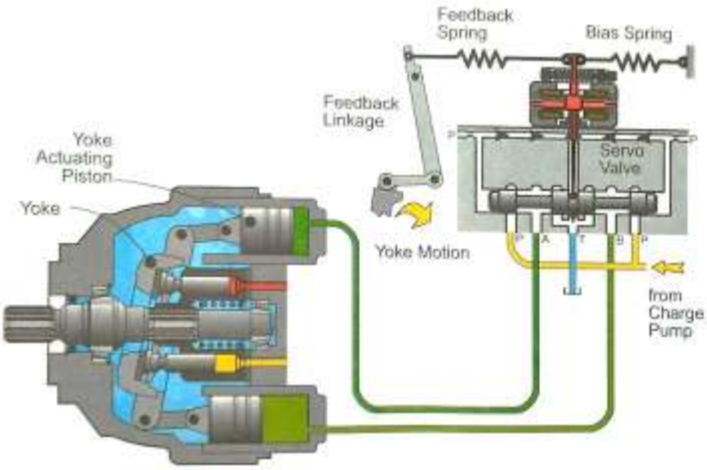

Fig. 8 Servo pump operated with flapper-nozzle torque motor

4. SERVO-VALVE CIRCUIT

The key features of the electrical circuit for a closed-circuit, closed-loop hydrostatic transmission are shown in fig.9.

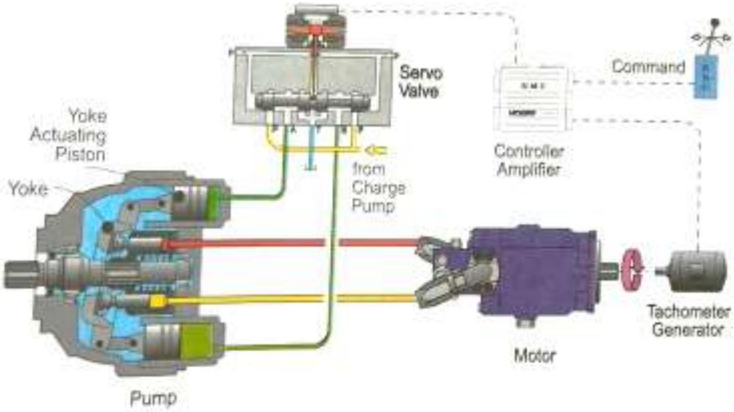

Fig. 9 Servo speed control

The motor output shaft drives a transducer, typically a tachometer generator. Voltage output from the tachometer generator is directly proportional to shaft speed. As shaft speed increases, voltage increases, and vice versa. The controller compares the tachometer generator voltage with the command voltage. The difference between the two is the error voltage. If the tachometer generator voltage is equal to the command voltage, meaning that the motor is turning at the desired speed, then the error voltage is zero.

The error voltage is fed to a servo amplifier. The servo amplifier produces an output current proportional to the input voltage. This current is fed directly to the coil of the torque motor. The armature rotates, initiating the sequence of events described in the previous figure.

5. Advantages of the Hydrostatic Transmissions

A hydrostatic transmission provides improved maneuverability, but at a cost. The efficiency of a hydrostatic transmission is always lower than a discrete-gear transmission. A discrete-gear transmission will typically have an efficiency of 95% or greater, meaning that 95% of the input energy is delivered to the load (wheels). A hydrostatic transmission has an efficiency of around 80%. Some well-designed units will have an efficiency slightly above 85%, but none can approach the efficiency of a discrete-gear transmission. A designer always poses the question: Does the gain in vehicle productivity offset the loss in efficiency and resultant higher fuel cost? In addition to increased maneuverability, a hydrostatic drive vehicle offers several other advantages:

1. It operates over a wide range of torque/speed ratios. Once a gear ratio is selected with a direct-drive transmission, the only speed variation available is that achieved by controlling engine speed. Once the engine speed reaches a maximum, the transmission must be shifted to a lower ratio to increase vehicle speed. With a hydrostatic transmission, vehicle speed is continuously variable from a slow creep up to a maximum.
2. It can transmit high power with low inertia. When a large mass is rotated at a given speed, it takes an interval of time to change this speed. A hydrostatic transmission adds little inertia to the total rotating mass associated with vehicle operation; consequently, a hydrostatic transmission vehicle tends to change speed more quickly (have less inertia) than a direct-drive or automatic shift transmission vehicle.
3. It provides dynamic braking. A hydrostatic drive vehicle can be stopped by destroking the pump. Imagine that you are traveling forward and you suddenly move the swashplate control to the neutral position. What will happen? A pressure spike will develop, and fluid will flow across the relief valve. The vehicle’s mechanical energy will be converted to heat energy, and the vehicle quickly slows (probably sliding the wheels).
4. It remains stalled and undamaged under full load. Vehicle hydrostatic transmissions are almost always designed for wheel slip to occur before a relief valve is actuated. The relief valve’s role is to clip off peaks and attenuate shocks. If the vehicle loses traction and bogs down, the pressure increases until the relief valve opens. Stalling the vehicle in this manner does not damage the transmission. Holding

it in a stalled condition causes the fluid temperature to rise, and this is undesirable. Most HST pumps today are available with a pressure limiter function that provides the “stall and undamaged” feature with little heat generation. The pressure limiter destrokes the pump by shifting the swashplate much like a pressure compensator.

5. There is no interruption of power to wheels during shifting. Anyone who has watched the driver of a direct-drive vehicle with discretegear transmission shift gears while climbing a hill can appreciate the advantage of continuous power flow over a speed range.

6. Conclusion

A hydrostatic transmission is simply a pump and motor connected in a circuit. Other components are included in the circuit design to ensure that the functional objective is achieved. The pump and motor can either be included in the same housing or separate components connected with hoses or tubing.

Typically, mechanical transmissions have efficiencies of 95% or greater, whereas hydrostatic transmissions have an efficiency of around 80%. Some well-designed units have an efficiency of 85% over a certain operating range.

Hydrostatic transmissions are used to increase vehicle maneuverability. They also provide continuous speed control from a slow creep up to maximum speed. Before a hydrostatic transmission is chosen over a mechanical transmission, a study is done to ensure that the advantages yield an increase in vehicle productivity to offset the lower efficiency.

A variable displacement axial piston pump can have a control piston mounted in the pump housing. This control piston is used to control the position of the swashplate and thus the displacement of the pump. A servo valve controls the flow, which extends (or retracts) the control piston. The servo valve shifts when current is delivered to a torque motor mounted on the valve. A typical closed-loop transmission operates as it is presented. The voltage signal from the transducer that senses motor speed is fed to a servo amplifier to obtain a current. This current causes the torque motor to rotate, which opens the servo valve and ultimately increases (or decreases) the pump displacement. Using a feedback design of this type, transmission output speed can be held constant as load varies.

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APPROXIMATE METHOD FOR THE ESTIMATION OF ENERGY PERFORMANCE OF HEAT PUMPS CONNECTED TO THE SYSTEM OF ENERGY MANAGEMENT OF FACILITIES

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Abstract. *Due to their efficiency heat pumps have found great application in the building industry, the process industry, in various technological processes in the production of food, to the space technology system, etc. When heat pumps are coupled to the energy management system which monitors and optimizes work parameters not only of the heat pump but also work parameters of other systems, such as solar and photovoltaic panels, thermal energy storages, electric batteries and the whole system, it is necessary to have a mathematical model that with sufficient accuracy and without great complexity estimates energy performance of the heat pump itself and the whole energy system. In this article a relatively simple mathematical model of a heat pump, with which it is possible to get values for the COP at any given time and under given conditions, was given. The obtained results of the model, applied to the air-water heat pump, used the input meteorological data of the mean air temperature for Belgrade, were presented. The verification of the obtained results of the model was made by using the catalogue data for the COP of the the Ecodan Monobloc Air Source Heat Pumps manufactured by Mitsubishi Electric.*

Key words: *Heat pumps, Carnot cycle, modeling, energy management system.*

1. INTRODUCTION

Current efforts to reduce energy consumption in all areas that cover human needs lead to the ever-increasing use of technical solutions that are energy efficient but also reliable at the same time. In order to get the most efficient energy systems, these solutions need to be integrated into a smart, functional energy system, energy management system. In the case of housing or industrial buildings, those are building energy management systems. These energy management systems constantly monitor and collect data related to the energy consumption in buildings (buildings, individual parts of buildings or building equipment), as well as data that include, for example, the daily schedule of use of building premises, all in order to reduce energy consumption for heating, cooling, lighting, etc. In energy efficient facilities whose energy systems include photovoltaic panels, solar panels, heat pumps, heat accumulators, batteries, systems for the delivery of electricity to the distribution network, etc., it is necessary to predict the energy consumption for the operation of certain technical systems, i.e. it is necessary to know in advance the energy inputs and outputs of each of the existing systems. In the case of heat pumps, it is necessary to predict the energy performance of the heat pump (electricity consumption, heating power, heating coefficient). A mathematical model that enables the assessment of the energy performance of a heat pump is a sub-model of the mathematical model of the energy management system of an object used to optimize the energy costs of an object [1]. Bearing in mind the fact that a large number of heat pumps are present on the market, which, apart from their construction, differ in the used working media (R22, R404A, R407C, R410A, ...), it is necessary that the mathematical model of the heat pump as part of the complex mathematical model of the energy management system object, be as general as possible, but at the same time sufficiently accurate. In this regard, a model that relies on Carnot reversed cycle is given below, which avoids the dependence on the working medium but retains the dependence on the temperature ranges in which the heat pump operates.

2. MATHEMATICAL MODEL

The reversed Carnot cycle is a comparative cycle for comparison with the actual cycles that take place in cooling devices and heat pumps. For the needs of the model, the concept of the ideal heat pump is assumed. The scheme is shown in Figure 1. Thermal source is an environment that can be, for example, air from the environment, gases from industrial plants, water, soil, etc. The average water temperature used for heating purposes is determined based on the following equation:

$$T_m = \frac{T_{w,in} + T_{w,out}}{2} \tag{1}$$

where $T_{w,in}$ and $T_{w,out}$ are temperatures of the heating fluid i.e. the water from the heating system. The ambient temperature that represents the heat source is denoted by T_{env}. For Carnot heat pump, the cycle for the given temperature ranges are presented in Figure 2.

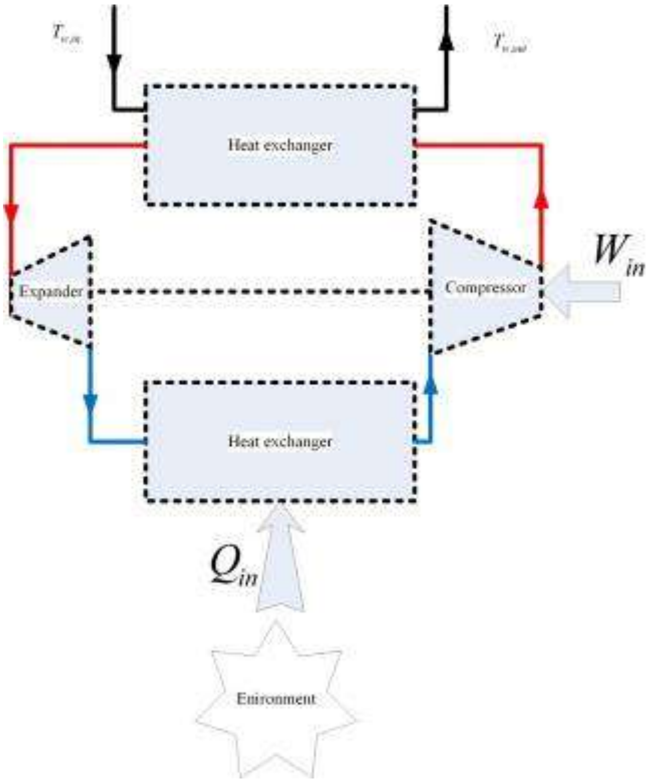

Fig. 1 Theoretical Carnot Heat Pump

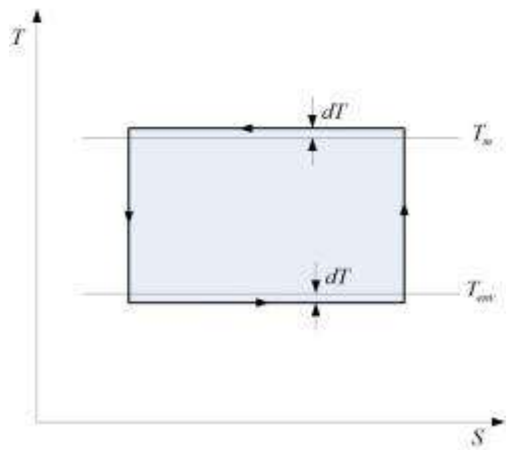

Fig. 2 Carnot reversed cycle in u T-S diagram

Figure 2 shows the temperature difference (the mean temperature difference) that must exist between the working media in order to carry out a spontaneous heat exchange process. In practice, this temperature difference ranges from 4 to 7 K. Thus, to achieve an approximate dependence of the energy consumption of an actual cycle, the Carnot ideal cycle occurs between the actual temperatures of the heating fluid T_m and the ambient temperature T_{env}. The heating coefficient of the Carnot circular process is determined on the basis of the expression:

$$COP_{CHP} = \frac{Q_{out}}{W_{in}} = \frac{Q_{out}}{Q_{out} - Q_{in}} = \frac{\left(T_m + dT\right)\Delta S}{\left(T_m + dT\right)\Delta S - \left(T_{env} - dT\right)\Delta S} \tag{2}$$

$$COP_{CHP} = \frac{T_m + dT}{T_m - T_{env} + 2dT} \tag{3}$$

The heating coefficient of an actual heat pump can be presented as a percentage of the heating coefficient of Carnot reversed cycle that would occur between the same heat source (T_{env}) and heat sink (T_m) temperatures. If the proportionality coefficient f, then the coefficient of heating of a real heat pump is:

$$COP_{RHP} = f \cdot COP_{CHP} = f\,\frac{T_m + dT}{T_m - T_{env} + 2dT} \tag{4}$$

The proportionality coefficient depends primarily on the isentropic efficiency of the compressor and ranges from 0.5 to 0.7[2][3].

3. Results and discussion

For the purpose of analyzing the accuracy of the simplified heat pump model, the air-to-water heat pump will be monitored, whilst the average air temperature for the City of Belgrade for the month of December 2016 is used for the air temperature (Figure 3).

If the heating water input temperature in the heat exchanger $t_{w,in} = 30°C$ and the outlet temperature of the water $t_{w,out} = 35°C$, are known, then for the given temperature of the source, heating coefficient/time dependence can be determined by the simplified model (Figure 4).

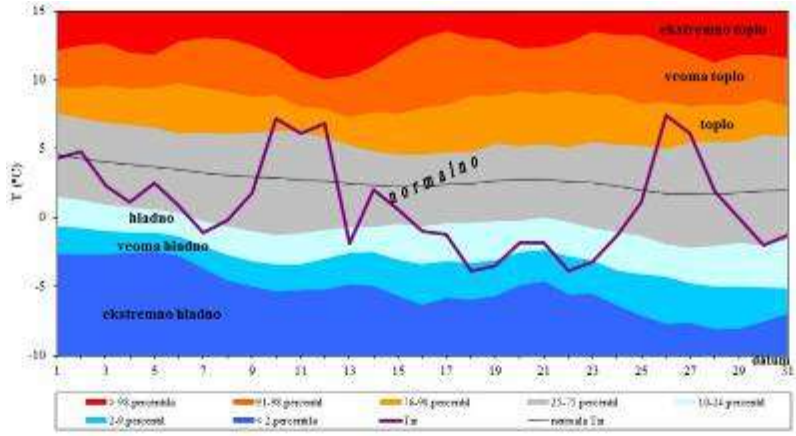

Fig. 3 The average daily air temperature for Belgrade in December of 2016 [4]

The values obtained for the heating coefficient of the actual heat pump shown in Figure 4 can be checked using the catalog values for the heating coefficient of the heat pumps given by the manufacturer. For the purposes of this paper, data from Mitsubishi Electric, i.e. data for heat pumps Ecodan Monobloc Air Source Heat Pumps type air-water are used. Based on the manufacturer's data (Table 1), it can be seen that the heating coefficient of the heat pumps for the outdoor air temperature of -3 ° C and the water inlet / outlet temperature of 30/35 ° C ranges from 2.8 to 3.01.

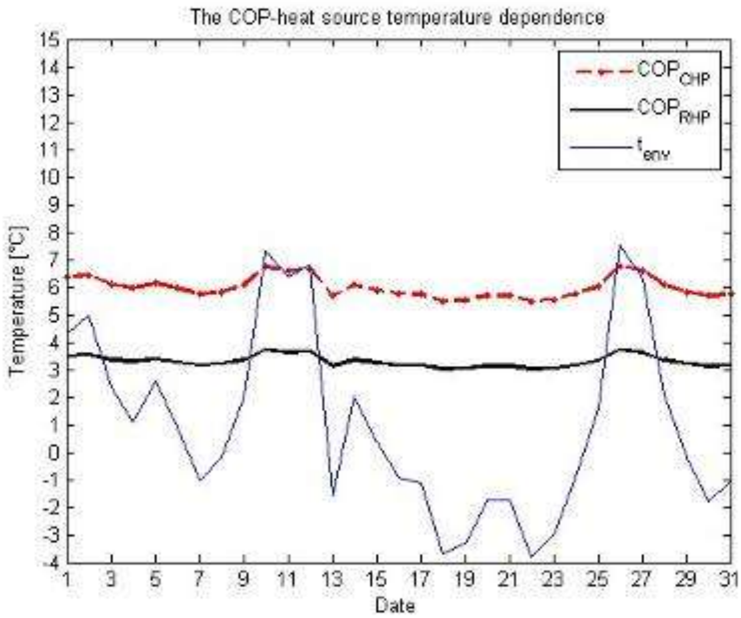

Fig. 4 COP – heat source temperature dependence

Table 1 Ecodan Monobloc Air Source Heat Pumps [5]

OUTDOOR UNIT		PUHZ-W50VHA2(-BS)	PUHZ-W85VHA2(-BS)	PUHZ-W112VHA(-BS)	PUHZ-HW140VHA2(-BS)	PUHZ-HW140YHA2(-BS)
HEAT PUMP SPACE HEATER - 55°C	ErP Rating	A++	A++	A++	A++	A++
	ηs	127%	128%	125%	126%	126%
	SCOP	3.25	3.27	3.2	3.22	3.22
HEAT PUMP SPACE HEATER - 35°C	ErP Rating	A++	A++	A++	A++	A++
	ηs	162%	162%	164%	157%	157%
	SCOP	4.12	4.12	4.18	3.99	3.99
HEAT PUMP COMBINATION HEATER - Large Profile*1	ErP Rating	A	A	A	A	A
	ηwh	99%	97%	100%	96%	96%
HEATING*2 (A-3/W35)	Capacity (kW)	4.8	8.3	11	14	14
	Power Input (kW)	1.63	2.96	3.65	4.81	4.81
	COP	2.95	2.8	3.01	2.91	2.91
OPERATING AMBIENT TEMPERATURE (°C DB)		-15 ~ +35°C	-20 ~ +35°C	-20 ~ +35°C	-25 ~ +35°C	-25 ~ +35°C
SOUND PRESSURE LEVEL AT 1M (dBA)*3*4		45	48	53	53	53
LOW NOISE MODE (dBA)*3		40	42	46	46	46
WATER DATA	Pipework Size (mm)	22	22	28	28	28
	Flow Rate (l/min)	14.3	25.8	32.1	40.1	40.1
	Water Pressure Drop (kPa)	12	13.5	6.3	9	9
DIMENSIONS (mm)*7	Width	950	950	1020	1020	1020
	Depth	330+30*5	330+30*5	330+30*5	330+30*5	330+30*5
	Height	740	943	1350	1350	1350
WEIGHT (kg)		64	77	133	134	148
ELECTRICAL DATA	Electrical Supply	220-240v, 50Hz	220-240v, 50Hz	220-240v, 50Hz	220-240v, 50Hz	380-415v, 50Hz
	Phase	Single	Single	Single	Single	3
	Nominal Running Current [MAX] (A)	5.4 [13]	10.3 [23]	11.2 [29.5]	14.9 [35]	5.1 [13]
	Fuse Rating - MCB Sizes (A)*6	16	25	32	40	16

*1 Combination with EHPT20X-MHCW Cylinder

*2 Under normal heating conditions at outdoor temp: -3°CDB / -4°CWB, outlet water temp 35°C, inlet water temp 30°C.

*3 Under normal heating conditions at outdoor temp: 7°CDB / 6°CWB, outlet water temp 35°C, inlet water temp 30°C as tested to BS EN14511.

*4 Sound power level of the PUHZ-W50VHA2 is 61dBA, PUHZ-W85VHA2 is 62.5dBA, PUHZ-W112VHA is 65dBA, PUHZ-HW140VHA2 is 65.5dBA, PUHZ-HW140YHA2 is 67.5dBA. Tested to BS EN12102.

*5 Grille.

*6 MCB Sizes BS EN60898-2 & BS EN60947-2.

*7 Flow Temperature Controller (FTC) for standalone systems PAC-IF062B-E Dimensions WxDxH (mm) - 520x150x450

ηs is the seasonal space heating energy efficiency (SSHEE) ηwh is the water heating energy efficiency

Comparison of these data with the data for the heating coefficient obtained by the model (Figure 4), it can be clearly concluded that there is a satisfactory agreement, whereby the coefficient of correlation in the model is considered to be $f = 0.55$. In real conditions, it is necessary to measure the performance of the heat pump, i.e. experimentally determine the value of the correlation coefficient f.

4. Conclusions

Bearing in mind that it is practically impossible to create a heat pump model that would be applicable in all energy management systems, which would include all the specificities of the heat pumps that are in the market, the Carnot reversed cycle with the introduction of the correlation coefficient can be used for the optimization of energy consumption in facilities with sufficient accuracy. The heating coefficient f represents the Carnot cycle percentage approximation of the actual cycle. In this way, a connection is established between the external ambient temperature (air, water, ...) variable and the variable of the temperature of the water in the heating system. Therefore, the given model for optimization requires the monitoring of the temperature of the heat source, the input and the exit temperature of the water temperature, and the mass flow of heating water over time. The given model provides sufficient accuracy and the possibility of correcting the input parameters of the model, providing at the same time a possibility for application for the largest number of heat pumps used for heating objects for different purposes.

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INFLUENCE OF TRACTOR KUBOTA M135GXS WORKING REGIME ON THE GAS EXHAUST EMISSION AND ENERGY EFFICIENCY

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Abstract.*This paper gives the results from the studies dealing with the energy balance, energy utilization rate and share of the energy input in soil tillage in the total energy input required for the production of mercantile maize in relation to different working regimes the tractor Kubota M135GXS. It also provides an analysis how different tractor working regime and in what percentage, influences on exhaust gases of the engine. Control of the exhaust gases included the measurement of the nitrogen oxides NOx, nitrogen dioxide NO_2, carbon monoxide CO and sulphur dioxide SO_2, using the portable gas analyzer Testo 350.*

Key words: *agricultural tractor, working regime, energy, gas emissions*

1. INTRODUCTION

The complexity of the tractor's purpose is determined with construction, energy, ergonomic and ecological adaptation to the conditions of use. Beside correct adjustment of the implement for the primary soil tillage, additional energy efficiency and reduced fuel consumption can be achieved with the proper selection of the tractor's operating mode and transmission gear.

In tractors of a newer generation, electronics has a big part of handling. In order to properly adjust the tractor's operating mode, it is necessary to know tractors exploitation features, traction characteristics and manufacturer's recommendations.

Alternative biofuels for the diesel engine drive have a very strong impact on: power, torque, intake air and fuel consumption, exhaust gas spectrum, exhaust gas recirculation flow and, consequently, exhaust emissions into the atmosphere [1]. Transient changes in engine speed and torque and their impact on fuel consumption and the change in exhaust emissions of off-road vehicles, are also significant from the point of view of reducing the emissions of exhaust gases into the atmosphere [4]. Off-road vehicles are used to perform various operations, with different engine loads, and the fuel consumption and emission of exhaust gases of such vehicles depend precisely on the type of operation.

The results show that the quantity of exhaust gases obtained from the measurement cycle prescribed in European and international standards are not representative for real use off-road vehicles [8]. The effects of the improvement of different soil treatment systems in the direction of sustainable agricultural production, the structure of energy inputs in vegetation processes and the characteristics of tractors for the same from the aspect of environmental impact are the subject of research by a large number of authors [3,5, 6 and 7].

The article presents the the results about impact of the tractor working regime on the production energy efficiency of and the exhaust gas emissions. Energy efficiency was calculated for commercial maize production.

2. MATERIAL AND METHODS

In this paper conventional production technology of maize is analysed. In the first place fuel consumption in the primary soil tillage was measured. Tractor "Kubota M135GXS" was in aggregate with four furrows plough “Moro Aratri”, with the working width of 1.44 m (Table 1). Plough "Moro Aratri", model Step, is intended for ploughing up to 30 cm deep, with a clearance of 74 cm. The interbody clearance is 90-95 cm and its weight is 1080 kg.

Table 1 Technical characteristic tractor Kubota M135GXS[11]

	Parameters	Unit	
1	Engine type		V6108-TI-CRS, Common rail
2	No. of cylinders		4/Turbocharger with intercooler
3	Net power	kW	100.7
4	Rated engine speed	rpm	2200
5	Total displacement	cm^3	6124
6	No. of speeds		24/24
7	Max. travelling speed	km/h	40
8	Main gear shift		8-speed powershift, with auto mod
9	Range gear shift		3
10	PTO speed	o/min	540/1000
11	3 point hitch category		II
12	3 point hitch lift capacity	kg	6.100
13	Tractor net weight / weight with ballast mass	kg	4.780 / 6.000 kg
14	Fuel tank capacity	L	190
15	Dimensions w/l/h/ clearance from crop/wheel base	mm	2.175/4.400/2.885/510/2.680

During the test, the following options were included:

- Engine speed memory was limited to 1.900 (rpm)
- Automatic gear mode intended for the heavy work, which changes 4, 5 and 6 gear depending on the current load.
- The potentiometer for regulation of the gear change was turned to the right.
- RPM constant engine speed.

Soil condition during the experiment are shown in Table 2 [9].

Table 2 Soil samples taken with the Kopecky cylinders

No.	Soil samples	Wet samples (g)	Dry samples (g)	Mass of Kopecki cylinders (g)	Moisture (g)	Dry soil (g)	Moisture (%)	Bulk density of soil (g/cm^3)
1	Surface	300.97	257.79	135.45	43.18	122.34	35.295	1.223
2	Depth 27 cm	316.72	276.57	129.35	40.15	147.22	27.272	1.472
3	Surface	302.18	265.41	141.24	36.77	124.17	29.612	1.241
4	Depth 27 cm	316.93	274.48	131.01	42.45	143.47	29.588	1.434

The treatment of samples showed that the soil moisture was in range from 27 to 35%. Bulk density of soil was from 1.43 - 1.47 g / cm^3, taken from the surface and at a working depth from 27 cm. The depth of the work was measured by the depth meter.

The current fuel consumption in a specified working mode of the tractor is supported by reports from the DLG and Agroscope tests performed for this tractor model. For other work operations that were carried out within the mercantile corn production technology, the current consumption was calculated based on the DLG and OECD tests, for the given working conditions [11, 12].

Exhaust gas emission measurement was carried out with a portable flue gas analyzer model Testo 350 (table 3).

Table 3 Testo 350 technical data

Measured parameter	Measured range	Resolution	Accuracy	Response time
O_2	0...25 vol. %	0.01Vol%	± 0.2 Vol. %	< 20 s (t95)
NO	0…4000 ppm	1 ppm	± 5 ppm (0…199 ppm) ± 5% of reading (100…1999 ppm) ± 10% of reading (rest of range)	< 30 s (t90)
NO_{low}	0…300 ppm	0.1 ppm	±2ppm (0…39.9ppm) ±5% of reading (rest of range)	< 30 s (t90)
NO_2	0…500 ppm	0.1 ppm	±5ppm (0…99.9ppm) ±5% of reading (rest of range)	< 40 s (t90)
SO_2	0…5000 ppm	1 ppm	±5ppm (0…99ppm) ±5% of reading (100…1999ppm) ±10% of reading (rest of range)	< 30 s (t90)
CO_2 - (IR)	0...50 Vol. %	0.01 Vol. % (0…25 Vol. %) 0.1 Vol. % (> 25 Vol. %)	±0.3Vol. % ±1% of reading (0…25Vol.%) ±0.5Vol.% ± 1.5% of reading (rest of range)	< 10 s (t90) heat-up time < 15 min

Direct energy input were only calculated for the usage of fuel that has a energy equivalent of 42 MJ/kg with an assumption that about 81 l/ha of fuel was used in maize production technology. The fuel consumption in the soil processing was measured in three variants of the regime, so that the oscillations were described in the analysis. For other technological processes, consumption was taken from literary sources and corrected by factors for the given conditions [3,5], with the density of fuel l = 0,83 kg [10].

3. RESULTS AND DISCUSSION

Fuel consumption, field performance and energy efficiency testing were analysed for three different gears, (4, 5, 6) in the middle range M.

The fuel consumption in primary soil tillage was measured before and after the completion of the ploughing operation, which determined the fuel consumption of 155 litres on the surface of 4.86 ha. The calculation also includes the amount of fuel used for transport from the farm to the fields, 26 km in both directions. If it is assumed that 10 litres are used on transport, a consumption of 29.83 litres of Euro diesel per hectare is obtained for ploughing operation.

During the work, Kubota M135GXS hydraulic 3 point hitch system can be set up in two positions, a fixed position and in the "floating" position, whereby the tractor itself levels the height of the hydraulic levers in relation to the current resistance of the soil. In the concrete case, the levelling of the hydraulic-lifting system was carried out manually, i.e. if the operator had noticed that the tractor started to slip more (at places of increased soil moisture), he raised hydraulic levers and thus reduced the working depth, and also lowered them in the opposite case. The measured working depth ranged from 21 to 29 cm, while the average depth on the most part of the field was 27 cm (Table 4).

Table 4. Values of exploitation measurements

No.	Gear speed	Depth (cm)	Working with (m)	t_{ime} (s) on 10 m	Tractor speed with slippage (km/h)	slip (%)
1	4M	29	1.45	7.68	4.68	24.74
2	4M	28	1.47	7.28	4.94	20.60
3	5M	27	1.37	7.25	4.97	31.03
4	5M	25	1.41	6.51	5.53	23.20
5	6M	24	1.41	5.84	6.16	28.76
6	6M	24	1.44	6.27	5.74	34.29

From the table it can be seen that the slip was in range from 20.6% to 34.29%, due to the increased humidity of the soil, as already mentioned.

With a review of the DLG test graphs, that show specific fuel consumption, the consumption of the Kubota M135GXS, with engaged engine speed memory and electronic engine speed control at 1.900 (rpm) , was 255 g / kWh [11].This value is taken as a reference value for the fuel consumption at each gear, for a plough operation.

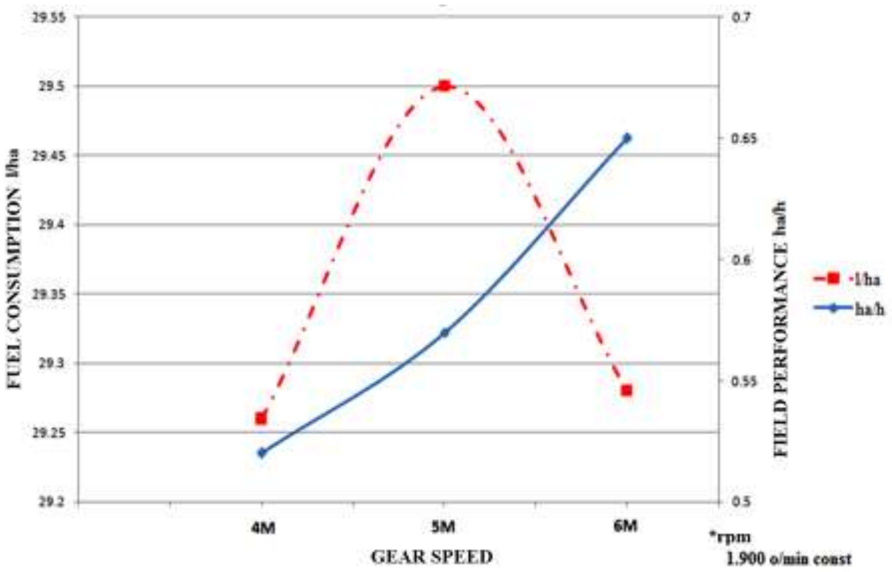
The working speed, for the relevant gear was obtained by measurement. Obtained average working speeds for the given gears are presented in table 5.

Table 5. The optimal exploitation range of tractor in each gear speed

Gear speed	n_M [rpm]	V [km/h]	S [%]	Q [l/h]	Q_{ha} [l/ha]	W_h [ha/h]	E_{ha} [kWh/ha]
4M	1.900	4.81	22.67	15.51	29.26	0.53	62.43
5M	1.900	5.25	27.11	16.81	29.50	0.57	63.17
6M	1.900	5.95	31.52	19.03	29.28	0.65	62.69

As the engine speed was constant, it was assumed that the specific fuel consumption was constant. From this it follows that the change in fuel consumption practically depended on the tractor's working speed at a certain gear speed, the percentage of wheel slip and performance.

The lowest fuel consumption, according to the calculation, was in the 4M speed gear 29,26 l/ha, and in 6M speed gear it was little diffrent, 29.28 l/ha. In 5M gear speed, in which the tractor worked most of the time, the consumption was 29.50 l/ha (Graph 1).



Graph 1. Relation between fuel consumption, field performance and the gear speed

In the energy analysis process, a methodology based on the determination of the energy input and energy output was used. It is based on the measured quantities of the consumed material, the yield realized and given energy equivalents [7].

The energy output in this case is energy expressed through the yield of grain, whose energy value is 17.6 MJ/kg [5]. Grain yield was slightly higher than 8t/ha. The total energy output was,thus, 141.120,00 MJ/ha.

Table 6. Energy balance of direct energy inputs in maize production.

Operation	4M	5M	6M
Direct energy inputs (MJ/ha)	2,847.04	2,861.88	2,852.64
Yield of corn grain (kg/ha)	8,018	8,018	8,018
Energy output (MJ/ha)	141,120	141,120	141,120
Specific energy input (EL) (MJ/kg)	0.355	0.357	0.356
Energy ratio (ER)	49.567	49.310	49.469
Energy productivity (EP) (kg/MJ)	2.816	2.802	2.811

By reviewing the energy indicators from table 6, the highest degree of energy utilization is in the 4M gear speed 2,816, then in 6M 2,811 and finally in the 5M gear 2,802 kg / MJ. Therefore, from the point of view of energy efficiency, it would be best if the primary soil tillage is done in the 4M gear speed. In the 6M gear speed, the slip level is too high, and for this reason most of the working time is spent in 5M gear, which has the lowest energy efficiency.

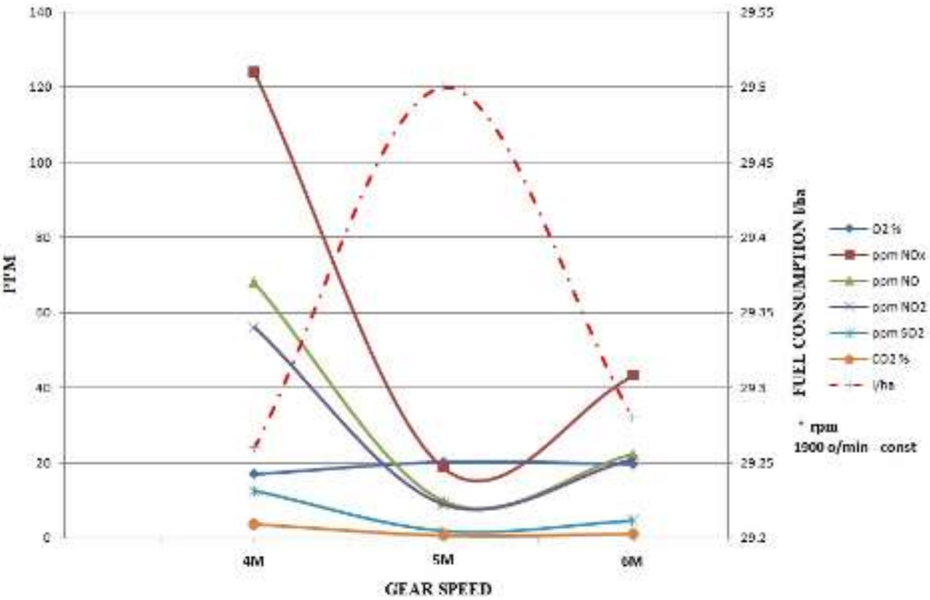
At the same time, whith fuel consumption and other operating parameters measurments, the emission of exhaust gases in different transmission levels, with a portable flue gas analyzer model "Testo 350", was measured. Measurements were recorded in the work process when the tractor reached its operating temperature.

By reviewing graph 2 it can be seen that the exhaust gas concentrations are the highest in the 4M gear speed, with the exception of the molecular oxygen content O_2, which is reversely proportional to exhaust gases production. The exhaust gas concentration was reduced in 6M gear and was lowest in the 5M gear. The concentration of nitrogen oxides, carbon monoxide and sulphur oxides depends primarily on the combustion temperature in the cylinder and the stoichiometric ratio in combustion.

To reduce the concentration of NO_x, NO_2 and NO, is used the EGR valve, which regulates the ratio of clean air and exhaust air in the suction line, and he is responsible for reducing the speed and temperature of combustion. Nitrogen oxides fit a good stoichiometric relationship, so it comes to the conclusion that in 4M degree, this ratio is most favourable. In this way, the fuel combustion reaction was firmer than in 5M and 6M gear speed, resulting in a higher working temperature as well as an elevated concentration of nitrogen oxides.

The measuring device "Testo 350" optionally did not record the concentration of particulate matters (PM), but a literature review showed that the increase in the combustion temperature decreases the PM concentration. According with that, it can be expected for the PM concentration to be highest in the 5M gear speed, and the smallest in the 4M gear speed.

The concentration of sulphur oxides is proportional to nitrogen oxides, so the highest concentration was recorded in the 4M gear speed of 12.5 ppm, then in the 6M gear speed of 4.5 ppm and the lowest concentration in the 5M gear speed of 1.75 ppm.



Graph 2. Graphic show relation between measured exhaust emissions and the fuel consumption per unit area depending on the gear speed.

’’The formation of carbon monoxide depends on the concentration of O_2, i.e., the concentration of CO_2 in the cylinder of the engine. By decomposing CO_2 at high temperatures carbon monoxide is produced. As the diesel engine works with enough quantity of air, carbon monoxide does not present such a problem in exhaust gases.” [2]

From Graph 2, it can be seen that in the 4M gear speed ,the share of carbon dioxide was 3.71%, then it decreased slightly to 1.14% 6M gear, in order to have the smallest share in the 5M gear speed, 0.75 %.

According to the previous, it can be seen that the most unfavourable gear speed from the environmental aspect is 4M. On the contrary, it has the lowest fuel consumption of 29.26 l/ha. 80% of working time was spent in the 5M gear, due to the field condition. In this gear, the highest fuel consumption of 29.50 l/ha was recorded, while the nitrogen oxide values were the lowest. In the 6M gear speed, the exhaust emission values were much lower than in the 4M gear, while the fuel consumption was slightly higher 29.28 l / ha.

3. Conclusions

Analyzing the obtained data from the field, reviewing the tests for the examined tractor and the literatures dealing with a similar topics, it can be concluded that from the aspect of energy efficiency, there are no significant differences in gear speeds. If the energy productivity is analysed the highest value was obtained for 4M working regime

(EP 2,816 kg/MJ) and the lowest in the 5M working regime (EP 2,802 kg/MJ) but the difference was only 0.014 (kg/MJ).

However, if we look from the aspect of ecological impact, values are more pronounced in each of the three gear speed.

Completely opposite of the energy efficiency, most of the exhaust gases were at the lowest level in the 5M gear speed. Considering both parameters, the fuel consumption of 29.28 l/ha and the amount of exhaust gases NOx 43.15 ppm; NO 22.25 ppm; NO_2 20.9 ppm; SO_2 4.5 ppm, the most favourable gear speed would be 6M.

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COMPOSITE INDICATORS CONSTRUCTION IN CASH FLOWS MILK PRODUCTS BASED ON IVANOVIC DISTANCE

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Abstract. *The aim of this research is using the statistical approach to composite indicators construction based on Ivanovic distance (I - distance). An indicator or index represents a quantitative or qualitative measure that comes from a series of facts, and is able to relative information about the entities and their positions in the area of interest, allowing for their mutual comparison and ranking. Ranking of entities is a very popular topic. In this research we use this method for cash flows. In order for a company to make a profit, you need to have much investment. However, this rule is often in conflict with the need to hold cash that is needed to maintain the company's liquidity. In this sense, there are three groups of costs: the opportunity cost of holding cash (missed yield, cash on hand and current account makes no yield); expenses for transactions with cash (administrative costs, commissions, credit insurance costs, costs of issuing commercial papers, registration costs, in fact, the cost of flotation of securities); the cost of the lack of cash. The research was done at the company Milkop DOO from Raska.*

Key words: *Composite indicators, Ivanovic distance, cash flows, milk products.*

1. INTRODUCTION

Performance measurement entities, with the aim of evaluating, comparing and ranking is a very important goal. In a general sense, the indicator or indicator of a quantitative or qualitative measure which comes from a set of facts, can detect the relative information about the entities, as well as their positions in the respective areas. The indicator as a measure, may indicate the direction of change in a certain area, or be related to a phenomenon in various units over time. The indicators are very useful for identifying trends and directing attention to specific issues of interest.

The system of financial accounting is one of the most important system for the provision of information in the enterprise, but within it there is the financial reporting whose role consists of achieving a stable and reliable infrastructure to communicate with enterprise environments. In addition, the financial statements are important source of information about the transactions that the company has with the environment, and without which it is impossible to adequately organize the company's operations and make the right decisions. Traditional financial statements, balance sheet and income statement, are not able to sufficiently answer the increasingly complex demands of business in modern conditions, which are primarily related to the analysis and assessment of certain aspects of business operations in decision-making or business planning. The balance sheet shows the state assets and resources on a particular day, and the income statement shows the performance of the company, and his earning capacity in a given reporting period, usually a year. In these reports there is not enough information on the acquiring company and spending cash, which is very important information to enterprise management, because it is not a rare situation that the income statement expressing shows, and that the company in its business recorded a reduction of the balance of cash and has a problem with liquidity. For these reasons, with the balance sheet and income statement, is there the Cash Flow Statement which provides an overview of the cash flows of the enterprise during the reporting period. The statement of Cash flow contains information on inflows and outflows (use) of cash classified by operating, investing and financing activities. It is a financial statement which makes it possible to follow the money that goes in and out of the company.

The aim of this research is to determine the model using the statistic ranks of the cash flows of the companies engaged in the sale and production of the milk production (food).

2. MATERIAL AND METHODS

2. 1. I - distance

Ivanovic distance (I-distance) is a composite indicator, which aggregates more individual indicator in an indicator, thereby providing the measurement multicriteria phenomenon. The only distance is based on measuring the distance between the multidimensional entities. In that way the duplication of information that carries a set of related indicators is avoided.

For measuring the performance of the entity and establishing the mutual relations between the occurrence of complex (system) the flooded variables can be used, where the each variable in part describes the performance of entities [1, 2, 3].

I - the distance is defined with the idea to avoid duplicate entries of information that carries a number of the same variables [4]. Let X (x1, x2, ..., xk) select set of variables, and E (e1, e1, ..., en) of entities that are compared on the basis of "size". It is possible to notice that the two entities ma er and es and compare their respective values of all insignia of X. If all the differences of these values are equal to zero, then there is no difference in the "size" of these two entities. This may change if the set of X introduces another variable. If the above is valid for the entire set of X, will be adopted that for each xi (i = {1, 2, ..., k} => xir = xis) entities er and es of the same "size". If at least one of these differences is different from zero, it can be argued that the entities are the same "size". Differential di (r, s) = xir-xis, define the effect of discriminatory variables Xi to an ordered pair of entities (er, fr). The discriminatory effect together variables X is a vector dx (r, s) = (d1 (r, s), ..., dk (r, s)), while the matrix

$$d_x(P)=\begin{bmatrix} 0 & d_x(1,2) & \cdots & d_x(1,n) \\ -d_x(1,2) & 0 & \cdots & d_x(2,n) \\ \vdots & \vdots & 0 & \vdots \\ -d_x(1,n) & -d_x(2,n) & \cdots & 0 \end{bmatrix}$$

represents the effect of discrimination from X in E.

Let the variables be selected to I n these entities described variables. Through the elements of the correlation matrix R = [rij] between the variables it is possible to calculate the partial correlation coefficients [5].

$$r_{ji.t}=\frac{r_{ij}-r_{jt}r_{it}}{\sqrt{\left(1-r_{jt}^2\right)\left(1-r_{it}^2\right)}} \qquad i>j \qquad \{j,i\}\in\{1,\ldots k\} \qquad t\notin\{j,i\}$$

The iterative process can be calculated and the next partial correlation coefficients [6]

$$r_{ji.12\ldots j-1}=\frac{r_{ji.12\ldots j-2}-r_{j-1,i.12\ldots j-2}r_{j-1,j.12\ldots j-2}}{\sqrt{\left(1-r_{j-1,i.12\ldots j-2}^2\right)\left(1-r_{j-1,j.12\ldots j-2}^2\right)}}$$

For a particular vector XT variables (X1, X2, ..., XK) that describe the observed properties, I-distance between the two entities is (x1r, 2 R, ..., xkr) and es (x1s, X2S, ..., xks) is defined as

$$D(r,s)=\sum_{i=1}^{k}\frac{\left|d_i(r,s)\right|}{\sigma_i}\prod_{j=1}^{i-1}\left(1-r_{ji.12\ldots j-1}\right)$$

Where d is the distance between the values of variables Xi entities er and es are discriminatory effect, σi is the standard deviation of Xi.

I-distance is formed gradually: starting with the integration of the entire discrimination effect values X1, values that contains the greatest amount of information about the entity that is rated. Then he adds that part discriminatory other effects (by rank) variables who was not involved in the discriminatory effect of the first variable, so that part of the discriminatory effect of a third variable that was not included in discriminatory effect of the first two variables, etc.

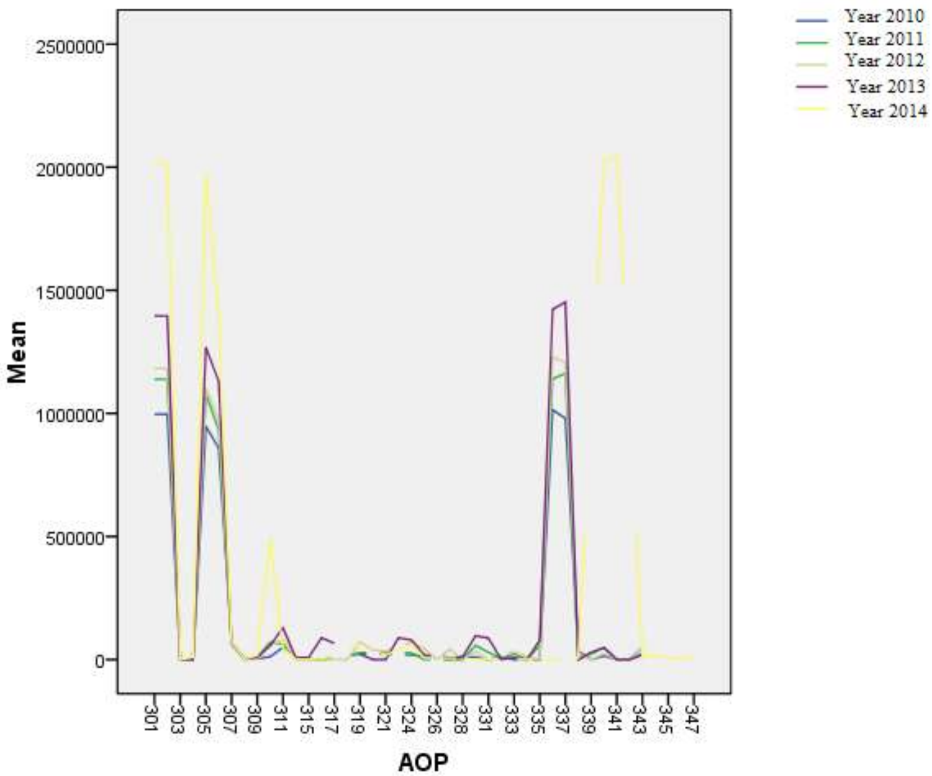
2. 2. Cash Flows

The statement of cash flow contains information on inflows and outflows (use) of cash classified by operating, investing and financing activities. It is a financial statement which makes it possible to follow the money that goes in and out of the company. The information from the report of cash flows, if it is to adequately connect with information from other financial statements (balance sheet, income statement and certain general ledger accounts) assist management companies, as well as external users to gain complete insight into the liquidity and solvency of the company.

According to MRS 7 - cash flow statement, all the cash flows that the company realizes there may be as follows: the Cash flows from operations (operating) activities, the cash flows from investing activities and the cash flows from financing activities. International accounting regulations allow two methods for the preparation of the Report on cash flows: direct and indirect, each of which has its advantages and disadvantages, but it is recommended to MR 7 when compiling this report use direct methods [7] which is the case for assembling cash flows of this company [8].

3. RESULTS AND DISCUSSION

The cash flow, based on the financial statements for the period 2010-2014 were observed at the company DOO Milkop from Raska. The company is engaged in the production and sale of dairy products. After years of each AOP movement is shown in Graphic 1.



Graphic 1. Review of AOP's age. The X-axis represents the position of data processing times while the Y axis indicates the value of the AOP (RSD).

Based on the I-distance, the methodology described in the methodology section, we performed the ranking of each of the AOP positions in the cash flows. First, we examined the correlation of data per year (Table 1).

Tab. 1 Correlation AOP positions by year

Correlations		2010	2011	2012	2013	2014
2010	Pearson Correlation	1	.998**	.999**	.997**	.608**
	Sig. (2-tailed)		.000	.000	.000	.001
	N	34	34	32	33	27
2011	Pearson Correlation	.998**	1	.999**	.999**	.618**
	Sig. (2-tailed)	.000		.000	.000	.001
	N	34	34	32	33	27
2012	Pearson Correlation	.999**	.999**	1	.998**	.596**
	Sig. (2-tailed)	.000	.000		.000	.001
	N	32	32	36	32	26
2013	Pearson Correlation	.997**	.999**	.998**	1	.603**
	Sig. (2-tailed)	.000	.000	.000		.001
	N	33	33	32	35	27
2014	Pearson Correlation	.608**	.618**	.596**	.603**	1
	Sig. (2-tailed)	.001	.001	.001	.001	
	N	27	27	26	27	32

**. Correlation is significant at the 0.01 level (2-tailed).

For AOP ranking positions from the cash flows we used the methodology described in the above section. After AOP tanking positions we got data presented in Tab. 2.

Tab. 2 Rank AOP positions in cash flow based I distance.

AOP	Rank
301	1
304	2
305	3
325	4
326	5
316	6
308	7
322	8
320	
306	9
327	10
319	
309	
307	
332	11
331	
329	
328	
324	
321	
318	
317	
315	
313	
311	
310	
303	
302	

4. CONCLUSIONS

A detailed analysis of the balance sheet and income statement, cash flows after analysis from which to see the changes of business during 2014 compared to the previous year, came to the following conclusions:

- 2011 - 2012 increase in fixed assets it is cash outflows for 13.72%
- 2012 - 2013 reduction of fixed assets and to the inflow of 9.23%
- 2013 - 2014 increase in fixed assets and that the outflow of cash to 2.08%
- 2011- 2012 increase in receivables it is prospective cash inflows of 39.19%
- 2012 - 2013 A decrease in claims to the cash for 55.17% (payment defaults and sale in 12-2012 and payment in 2013)
- 2013 - 2014 Increase in receivables but this is potentially a cash inflow of 15.01%

Whenever there is potentially an increase in claims then and outflow of VAT to 10% or 20%

- 2011 - 2012 increase enough product to Su Potential cash outflows for 49.09%
- 2012 - 2013 simply reducing a product that is potentially a cash inflow of 3.23%
- 2013 - 2014 increase stocks of goods and that is potentially a cash outflow of 11.36%
- 2011 - 2012 increase in liabilities to suppliers are potential cash outflows for 52.66%
- 2012 - 2013 a reduction of liabilities to suppliers and the outflow of cash for 60.08% (52.66% of the 2011 to 2012 and from this year)
- 2013 Stat 2014 reduction obligations a supplier to the outflow of cash for 15.71%

What is all rejected the result of the correlation device itself through cash flows.

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TECHNICAL REVIEW ON PROPERTIES, UTILIZATION AND DRYING OF APPLE POMACE

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Abstract: *Apple pomace is one of the byproducts of the juice industry and represents a huge waste of biomass. According to many authors, the apple pomace comprises round 25% of overall mass of the fresh apples used in juice industry. Not only it represents a huge waste of useful material, but there is also an emerging problem of its disposal. In order to perceive all the benefits and possibilities of the apple pomace utilization, a review was needed to be written. This article describes the properties of the apple pomace and its potential uses. Furthermore, the drying process of apple pomace was reviewed as one of the best ways for preserving food and organic materials. The different drying methods and parameters of the apple pomace were reviewed.*

Key words: *Apple pomace(AP), AP Properties, AP Applications, Drying*

1. INTRODUCTION

The annual worldwide apple production for 2016 was round 84.6 million tons (UN Food & Agriculture Organization 2017). Of this amount round 13% is converted to apple juice concentrate (Shalini & Gupta 2010). In apple juice production, round 75% of the apples is converted to juice, while the rest, round 25% is the waste product comprised of apple skin, seeds and stem, known in the literature as apple pomace (Yates et al. 2017), (Dhillon et al. 2013), (Shalini & Gupta 2010). This huge quantity of juice produced has for a consequence significant amount of waste. In particular, the production of apple juice generates up to 12 million tons (Mt) of waste. The types of by-products from apple processing is given in figure 1 (Rabetafika et al. 2014). The disposal of this type of waste presents a big challenge and economical issue. One of the best ways to solve this problem is certainly the reuse of such materials. According to the number of researches (Shalini & Gupta 2010),(Reis et al. 2012),(Figuerola et al. 2005), apple pomace contains significant amount of nutritive value substances, such as pectin, antioxidants and vitamins. By recovering a part of the nutrients, it is not only possible to make use of the recycled food, but also tackle another important problem, i.e. disposal of the apple pomace. According to (Shalini & Gupta 2010) apple pomace disposal represents a big environmental problem, because the process of fermentation requires 250-300g/kg amounts of chemical oxygen. Furthermore, there is an emission of green house gases related with its disposal (Yates et al. 2017), which are known for its detrimental effect on the atmosphere. Fresh apple pomace contains significant amount of water, what makes it susceptible to spoilage, and thus makes the process of storing for longer time difficult (Shalini & Gupta 2010). One of the best ways for preserving the apple pomace from a spoilage is by drying it, what in addition helps preserving valuable nutritive substances, if dried properly (Shalini & Gupta 2010). Also, apple pomace drying is one of the most economically feasible ways, because it drastically reduces the volume and consequently lower transportation costs (Sato et al. 2010). In this work, the characteristics and nutritive values, as well as utilization and drying methods of apple pomace will be reviewed.

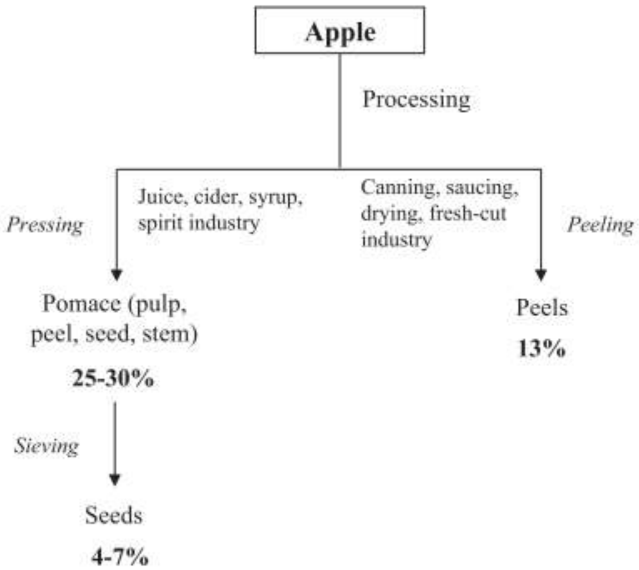

Fig. 1 By-products from apple processing

2. PROPERTIES AND NUTRITIVE VALUE OF APPLE POMACE

Apple pomace (AP) is the main by-product of apple juice industry and consist mainly of carbohydrates, dietary fibre and small amounts of protein, fat and ash. In addition, AP is also a good source of phytochemicals such as phenolic acids and flavonoids, which makes AP a valuable source of antioxidants (Rana et al. 2015), (Reis et al. 2012). Concerning the antioxidant properties of AP, it is both beneficial for the human health and would play an important role in diseases prevention (Sato et al. 2010), (Reis et al. 2012), (Sudha et al. 2007), (Schieber et al. 2003), (Rana et al. 2015).

Regarding moisture content, AP typically has 66.4–80% moisture on wet basis and contains between 23.7-26.4% of dry matter. Glucose, fructose, and sucrose comprise 14% of its total soluble solids. AP is composed of pulp and epidermis (95.5%), seeds (4.1%), and stems (1.1%). The dietary fiber content ranges from 11.6 to 44.5% with 35.8% on average (Schieber et al. 2003). Pectin in AP is present with 3.5% - 18%, i.e 10-15% on average. In addition, AP contains 4.0% proteins, 3.6% sugars, 6.8% cellulose, 0.38% ash, 0.42% acid and calcium and 9.5–22.0% carbohydrates.

AP including seeds has been proven to be a rich source of polyphenolics, and some phenolic constituents, such as the procyanidins and quercetin glycosides, have been shown to have strong antioxidant activity. Dietary fibers are proven to have very important role in improvement and preservation of human health, especially regarding gastrointestinal system. (Rana et al. 2015). Type and source of dietary fiber greatly influence their functional properties. Presently, the primary sources utilized in food industries are of cereal origin with minimal contribution from fruits and vegetables. However, AP has additional benefits because of the presence of number of bioactive components, especially antioxidant molecules, for which it has enormous potential as dietary food component.

The major part (approx. 95%) of the AP are skin/pulp tissues, which consists of cell wall polysaccharides (e.g. pectin, cellulose, hemicellulose, lignin and gums) and skin bound phenolic compounds, such as dihydrochalcones, flavonols, flavanols and phenolic acids (Rana et al. 2015).

3. UTILIZATION OF THE APPLE POMACE

The AP has traditionally been used as cattle feed. The reason is that the AP in its wet form is susceptible to spoilage, and therefore, the range of fresh AP utilization purposes is generally reduced (Shalini & Gupta 2010). Common applications of this by-product are the direct disposal to soil in a landfill and for pectin recovery (gelling agent, stabilizer and source of dietary fiber). (Reis et al. 2012). AP contains many valuable compounds that proved to be useful in human diet, such as carbohydrate, pectin, crude fiber and minerals. However, the main reasons why the AP is at this stage not exploited enough are economical.

In the review of (Yates et al. 2017) the AP has been used till now for number of purposes: production of biofuels, substrate for enzymatic processes, extracted for antioxidants, as a source of bioenergy, or sorbents for effluent cleaning. (Figuerola et al. 2005) and (Sudha et al. 2007) discussed the AP as a source of the fibres and polyphenols. Another use of AP is making alcoholic apple spirits as discussed in (Rodríguez Madrera et al. 2013). AP was also studied in (Ahmad et al. 2017) for the formulation of gluten free crackers. According to (Rabetafika et al. 2014) the production of fibre concentrate and pectin from AP is currently the most economically justified process and has potential to be commercialized. In (Bhushan et al. 2008) review is discussed about AP processing for bioactive molecules such as dietary fibre and pectin, xyloglucan, etc. The author suggested that in last period there is a growing trend of utilization AP for extracting valuable nutritive substances. In the next paragraphs we will review the most common uses of AP with a special focus on bioactive components extraction.

Food products. In the review of (Shalini & Gupta 2010) few authors have reported the making of food products from AP in the past including AP jam, sauce and papad and citric acid. In the same review is also mentioned that Rotova GP developed a technology for preparation of apple powder, Wang and Thomas used drum dried AP in bakery products, Shah and Masoodi prepared beverages from apple pulp that were satisfactory, while Kaushal and Joshi prepared cookies by incorporating different amounts (10–50%) of apple pomace powder in dough. (Rodríguez Madrera et al. 2013) made AP spirits were from dry pomace and selected yeasts strains. Recently, the AP flour was developed in Austria (Obstpresse Bramberg, Kulturverein Tauriska & Olschnögger n.d.). The AP is squeezed, grinded and packed, and is excellent to use for bakery products. (Sudha et al. 2007) prepared the blend of finely grounded AP and incorporated it in wheat flour with 5%, 10% and 15% and studied the mixture for rheological characteristics. Finally, they prepared a cake of wheat flour with 0–30% AP incorporated in it. AP was also studied in (Ahmad et al. 2017) for the formulation of gluten free crackers. The authors studied the formulation of gluten free crackers based on the two varieties of brown rice flour and AP. The percentage of AP in the flour were 0%, 3%, 6% and 9%.

Pectin extraction. The extraction of pectin from AP is a well-known process discussed a lot in last few decades (Shalini & Gupta 2010). Pectin is used in food as a gelling agent, thickener, texturizer, emulsifier and stabilizer. The production of pectin is considered the most reasonable way of AP utilization both from an economical and ecological point of view, and as well one of the most practical approaches (Sato et al. 2010), (Bhushan et al. 2008)

In the work (Sato et al. 2010), the eleven selected apple cultivars were mixed and treated in order to explore the characteristic of every composition. The principal component analysis established the efficiency of total phenol compound, antioxidative capacity, total fiber and total reducing sugars to identify the best cultivar set as source of bioactive compound. Samples of selected apple cultivars were 10 kg each. The method included juice extraction in a vertical press. Then, the AP was rinsed once with tap water (1:1:w:v) and centrifuged at 860 x g in a small scale domestic equipment until total drainage. The rinsed AP was then spread as a thin layer in circular bamboo support in each of the six trays of a laboratory oven, and was left to dry under circulating air at 60ºC. The extraction of pectin in this paper was made in accordance with the procedures previously described by Fertonani et al. (2006). A mixture of raw material (10 g) with 400 ml aqueous HCl (100 mM) was boiled during 10 min and the reaction was stopped in an ice bath; the slurry was filtered through cheese cloth and the pectin was precipitated from the clear extract using alcohol (1:2::v:v). After filtration through cheese cloth and drying in an oven with circulating dry heated air at 50 ºC, pectin was triturated in a Waring blender and stored at 22ºC±3ºC in plastic bags containing silica gel for further analysis. The average total polyphenol content detected in this study was 4620 mg kg-1 and the average antioxidant activity was 36.69 mMol g-1. One of the conclusions of this paper is that the polyphenolic compounds in the AP have a high correlation with the antioxidant activity.

In (Schieber et al. 2003) the process for combined recovery of pectin and phenolic compounds from AP is described. The process includes extraction of dried AP with diluted mineral acid and adsorption of phenolic constituents by a hydrophobic styrene–divinylbenzene copolymerisate. Acidic pomace extracts and dried apple seeds were held frozen at -20 ^{o}C until use. The acidic pomace extract was preheated at 60 ^{o}C in a water bath and then applied to the column at a flow rate of approximately 10 bed volumes per hour. The pectin-containing effluent was collected, and residues of pectin were removed from the column with distilled water until no pectin could be detected by alcohol precipitation. The authors concluded that the apple seeds are a promising source of valuable compounds which may be used as healthy food.

In (Constenla et al. 2002) the pectin was extracted from dried apple pomace in a nitric acid solution (pH=2.5) for 1 h with solid:liquid ratio of 0.04 kg:L,at 80 ^{o}C. After extraction, the pectin solution was filtered through a Buchner funnel with a filter paper and diatomaceous earth pre-coat, and concentrated under vacuum (60^{o}C) in a Buchi Rotova-porator, volume ratio 4:1. Concentrated pectin solution was precipitated with ethanol (0.96mL/mL) and the resulting product washed twice with 0.70mL/mL and 0.96mL/mL ethanol, respectively. Pectin precipitate was then filtered through filter paper and dried under vacuum at 45^{o}C to constant weight. Dry pectin was ground to pass a 100-mesh sieve.

Source of fiber. Dietary fibre comprise of soluble and insoluble part constituted mainly by carbohydrate polymers with ten or more monomeric units that are non-hydrolysable by the endogenous enzyme in small intestine of human. It includes associated compounds like lignin in the case of plant origins. According to (Rabetafika et al. 2014), many studies report the feasibility of dietary fibre extraction at large scale.

In (Ahmad et al. 2017) soluble, insoluble and total dietary fibre content of the samples was measured according to the method described by Asp et al. (1983). Sample (1.0 g) was homogenized in 20 ml of sodium phosphate buffer (0.1 M, pH 6.0) and was treated with heat stable a-amylase (Termamyl) (90 ^{o}C, 15 min) and then digested with pepsin (40 ^{o}C, 60 min) and incubated with pancreatin (40 ^{o}C, 60 min). Soluble and insoluble dietary fibres were separated by filtration. The filtrate was subjected to ethanol precipitation and filtered to obtain soluble dietary fibre and both the precipitates were dried overnight at 105 ^{o}C and were incinerated at 500 ^{o}C for 6 h. Total dietary fibre was then calculated as combined value of soluble and insoluble dietary fibre.

(Figuerola et al. 2005) evaluated the functional properties of fibre concentrates from apple and citrus fruit residues, in order to use them as potential fibre sources in the enrichment of foods, was carried out. Residues from juice extraction of grapefruit (Ruby and Marsh cultivars), lemon (Eureka and Fino 49 cultivars), orange (Valencia cultivar) and apple Royal Gala (Granny Smith and Liberty cultivars) were used as fibre source. Apple fibres were obtained by washing, coring, chopping, and separation of juice from pomace by pressing. AP was washed twice with warm water (30 °C); then it was dried at 60 °C during 30 min in an air tunnel drier and ground to a particle size of 500–600 lm. Fiber concentrates were analyzed for their proximate content (moisture, lipids, protein and ash); caloric value; dietary fibre composition and functional properties (water retention capacity – WRC, swelling capacity – SW, fat adsorption capacity – FAC and texture). The conclusion was that all the fibre concentrates had a high content of dietary fibre (between 44.2 and 89.2 g/100 g DM), with a high proportion of IDF. Protein content ranged between 3.12 and 8.42 and lipids content ranged between 0.89 and 4.46 g/100 g DM. The caloric values of concentrates were low (50.8–175 kcal/100 g or 213–901 kJ/ 100 g). It was found out that the texture was strongly dependent on the particle size and it was increased by the heat treatment.

4. APPLE POMACE DRYING

Drying is one of the oldest and well-known methods of food preservation. Fresh fruit has a short shelf life because it has a high moisture and sugar content, allowing microorganisms to grow, which makes it susceptible to spoilage. Thus, drying helps extend the shelf life of fruits through reducing water activity (Aldosari 2014). Direct drying without pretreatment is the most common industrial operation and economical approach for obtaining valuable fractions from the AP. (Rabetafika et al. 2014). The goal of the drying is to remove moisture from AP in order to avoid growth of microorganisms and reduce the activity of enzymes, while saving valuable quality components, such as antioxidants and phenolic compounds.

In (Aldosari 2014) the AP was dried with three different methods: freeze drying, cabinet drying and drum drying. The goal of the experiments was to determine the effect of the three different drying methods, mentioned above, on color, antioxidants and phenolic compounds of the material. The samples were prepared differently for each type of drying. For drum drying samples of 1.6 kg of AP were mixed with water (1:2) to pour the slurry onto a drum dryer. For the hot air drying the perforated tray was loaded with approximately 150g for each temperature.

Drum drying. This drying method has favorable characteristics for commercial production, such as low cost, rapid drying time, and large throughput. Samples of 1.6 kg of AP were mixed with water (1:2) to pour the slurry onto a drum dryer. The experiment was conducted three times. Drum drying was run continuously for 15 minutes at a drum surface temperature of 140 °C. The temperature of the drum was estimated using an infra-red thermometer. The sample slurry was dried by pouring it on to the hot surface of the drums, then by using knives to continuously scrape off the sample from the drum so that the dried product was collected in stainless steel trays.

Hot-air Drying. The samples were dried at different air temperatures at 60 °C, 80 °C, or 100 °C. The drying time was 25, 20 and 15 minutes respectively. The relative humidity was 30.7%, 35.3% and 39% respectively. After drying, the content of moisture in AP was 3.0%, 3.0% and 3.2% respectively. The perforated tray was loaded with approximately 150g for each temperature. The velocity of air was 15.2 m/s measured with a hot-wire anemometer.

Freeze drying. The freeze drying of AP was accomplished with Virtis Genesis (25L Genesis SQ Super XL-70, 2010). The freeze dryer has a sample chamber, seven shelves, a vacuum pump and a refrigerated condenser chamber. The shelf temperature was lowered to −30 °C, and the sample was placed onto shelves with the chamber closed. The condenser was lowered to –60 ºC and the vacuum pump was turned on until it pulled a near complete vacuum, approximately 50 mTorr. Then, the shelf heater was turned on to warm up the samples to around 20 ºC. Samples were dried for 3 days under these conditions, until the dryer had a stable reading of around 10 mTorr pressure inside the freeze dryer. The samples were removed and kept frozen in dark colored polyethylene bags at −20 °C.

The results of this study demonstrated that freeze drying was the best method to process AP for value-added ingredient use. The next best method was cabinet drying at lower temperatures, and finally drum drying. Although drum drying showed the most detrimental effect on color, phenolics, and antioxidants, its significantly lower cost and faster speed of drying may offset the negative nutritional effects. Drum-dried AP could be used as a low-percentage ingredient or blended with premium-dried AP to meet both cost and nutritional requirements, for example.

In the study of (Shalini 2010) the AP was dried in order to obtain the drying characteristics of AP.

The goals of the study were:

1. To study the drying behavior of wet AP under thin layer drying conditions in relation to drying air temperature, air velocity and layer thickness.

2. To determine the equilibrium moisture content of AP.

3. To test mathematical models for predicting wet AP drying rates.

4. Sensory evaluation of the dried AP powder at different conditions of temperature and layer thickness.

5. To optimize the drying air temperature and layer thickness on the basis of sensory evaluation.

Experiments were planned to develop dried AP powder. The wet AP cake with different layer thickness (2, 4, 6 mm) in three replicates was exposed to different temperatures in the range from 50°C to 70°C with an increment of 10°C at constant air velocity of 1.5m/s and different air velocity in the range of 1.5 to 2.5m/s with an increment of 0.5m/s at a fixed temperature of 70°C and fixed layer thickness of 2mm. Experiments were also conducted to study the effect of drying on color. The selected drying models were attempted on experimental data to describe the phenomena of drying process. The drying behavior of AP was mathematically analyzed by testing the validity of selected models. The mean prediction error and maximum error corresponding to 90% of the data points were calculated for the best fit model. The effect of drying air temperature, drying air velocity and layer thickness on color was studied by colorimetric method. The sensory evaluation for overall acceptability of dried AP powder was also studied to optimize the drying conditions. On the basis of experimental results and data analysis, the author concluded the following:

1. Drying of AP takes place in falling rate period.

2. The overall drying rate linearly increased with increase in temperature and decreases with increase in layer thickness.

3. As the temperature increased, equilibrium moisture content of the AP decreased.

4. Page's model most closely predicted the drying behavior of AP with maximum error at 90% data points (E90) less than 12% and average mean error in the range of 0.084 to 0.305 % for the different individual set of conditions.

5. AP should be dried at 60 °C with 4 mm of layer thickness at 1.5 m/s or higher air velocity, as these drying conditions resulted in best quality of the product (dried AP powder) on the basis of overall acceptability of the product.

In the paper (Constenla et al. 2002) the effect of temperature used for drying apple pomace on apple pectin characteristics, including chemical composition, color and gelpoint temperature (Tg) was determined. The AP was obtained from commercial Granny Smith apples. Apple fruits were washed and crushed. Juice was extracted by pressing in a hydraulic rack-and-cloth press (180 kPa for 10 min) and pomace dried in the same continuous, rotary drier used by Pelegrina et al. (1998). Drying conditions were speed of rotation - 17 rpm; air velocity - 1.5 m/s; initial pomace load - 2.3 kg; and four values of air temperature (Tdr = 60°C,70°C,80°C and 105 °C) measured at the air outlet. Initial pomace moisture content was approximately 0.80 g/g. A typical experimental run lasted 6–8 h to reach a final to initial water content ratio (X/Xo)<0.07, where X is the water content, depending on the air temperature. The author concluded that the temperature during AP dehydration in a rotary drier affected both the degree of esterification and the degree of polymerization (molecular weight) of extracted pectin. The higher Tg value was obtained with pectin extracted from AP dried at 80 °C. Gel point was shown to be more sensitive to Tdr than other quality parameters: while DM had the same value both at 80 °C and 105 °C, minimum Tg occurred at the higher temperature. This behavior author attributed to the heat-induced reduction in Mw.

In (Ahmad et al. 2017) apples were cut into small pieces and crushed into the juicer mixer. The juice was squeezed completely from the pulp and pomace was dried in tray drier at 40°C and grounded with grinder mill and sieved into a fine powder.

In (Figuerola et al. 2005), AP was dried at 60 °C during 30 min in an air tunnel drier and ground to a particle size of 500–600 lm. Drying at temperatures below 65 °C avoids changes in the functional properties and in the content of poly- phenols, tannins, anthocyanidins and proteins.

For the study of (Rodríguez Madrera et al. 2013) the apple pomace came from industrial hydraulic presses with an operating capacity of 15,000 kg belonging to the same cellar in two consecutive harvests (2010 and 2011). Nine batches of 50 kg were taken during each harvest, each of which was dried in an oven with air circulation at 60◦C for 48 h. The different batches of dry pomace were homogenized and placed in 6.8 kg portions, keeping them in sealed bags to preserve them from moisture until the time of fermentation.

In (Schieber et al. 2003) wet apple pomace (25–30% dry matter) of industrial juice production was dried in a three-stage drum dryer within 5–8 min by hot air (300–700 °C). The temperature of the pomace did not exceed 50–60 °C during the drying process.

In the table 1, it was given a short review of the methods and few parameters of AP drying.

Table 1 Methods and parameters of AP drying

Drying method	Temperature [°C]	Drying time	Air velocity [m/s]	Reference
Drum dryer	140	15 min	-	(Aldosari 2014)
Hot air dryer	60	25 min	15.2	
	80	20 min		
	100	15 min		
Freeze dryer	-30	3 days	-	
Hot air drying	50	-	1.5	(Shalini 2010)
	60		2	
	70		2.5	
Rotary dryer	60	6-8h	1.5	(Constenla et al. 2002)
	70			
	80			
	105			
Tray dryer	40			(Ahmad et al. 2017)
Air tunnel dryer	60	30 min		(Figuerola et al. 2005)
Oven with air circulation	60	48h		(Rodríguez Madrera et al. 2013)
Drum dryer	300-700	5-8 min	-	(Schieber et al. 2003)

5. CONCLUSIONS

Apple juice industry produces large amount of by-products called apple pomace (AP). In the past it was almost exclusively treated as a waste and disposed. However, the efforts have been made to prove that the utilization of AP is feasible and convert it from cattle food or waste into raw material for extraction of valuable nutritive substances, such as phenolic compounds, fibres, antioxidants, pectin, etc. In this work, the properties and nutritive values of apple pomace were reviewed. Then, the utilization of apple pomace for food production, pectin and fibre extraction was reviewed. At the end, the drying methods and parameters were summarized. The AP has a potential for becoming so called re-used or up-cycled food in the human food chain.

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CONVECTIVE DRYING OF BLUEBERRIES: EFFECT OF EXPERIMENTAL PARAMETERS ON DRYING KINETICS AND MATHEMATICAL MODELING

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Abstract. The hot air convective drying characteristics of thin layer blueberries (Vaccinium corymbosum) *were evaluated in a laboratory scale dryer. The drying experiments were carried out at 60, 70 and 80^{o}C and the air velocity of 0,5 and 1,5 m/s. The convective drying process of raspberries took in falling rate period, and drying time decreased with increasing air temperature and air velocity. The experimental data obtained during the drying process were fitted to five different mathematical models. The Midilli et al.s model was found to best appropriate model for explaining the drying behaviour of raspberries convective drying. Effective moisture diffusion coefficients were calculated by Ficks diffusion model and their values varied from 9,66 x 10^{-12} m^2/s to 9,67 x 10^{-11} m^2/s. It was found to increase proportionally with the increase in air drying temperature and air velocity.*

***Key words**:* Blueberries, Air drying, Mathematical modeling.

1. INTRODUCTION

Blueberries (Vaccinium corymbosum) are rounded and indigo-colored fruits that belong to genus Vaccinium together with cranberries, bilberries and grouseberries. The fruit contains a lot of medicinal substances and is the largest natural antioxidant. It has been proven that the consumption of blueberries slows down the aging process, strengthens the immune system, prevents infarction and strokes, helps in the prevention of cardiovascular diseases and improves vision. Blueberries are sold fresh or are processed as individually quick frozen fruit, puree, juice, or dried or candied berries.

Last year in Serbia (around Backa Topola) it's raised the new plantation about 100 ha with plan to increase the surface by another 30 ha. The owner is foreign investor who has plan to export the first and second class in frozen state. The third class is staying for processing, one of the possibilities are convective drying of blueberries.

The objective of this research were to investigate the effects of air temperature on the drying behaviour of blueberries, to select the best mathematical model for convective drying curves, to calculate the effective diffusivity and activation energy.

2. MATERIAL AND METHODS

Fresh blueberries (Vaccinium corymbosum) were used in the experiment. These were bought every day before each experimental unit at the local market. Each batch of blueberries was selected so that the fruit had a similar size, color, and firmness. About 1,800 g of the fruit were used for each drying experiment units. blueberries with initial moisture content of x_o = 4,55 kg/kg d.b. on average (x_o = 0,82 kg/kg w.b.), dimensions length 15.90 mm, width 15.47 mm and thickness 10.69 mm.

Convective drying experiment were carried out an a laboratory dryer "IVA-2". Dryer is equipped with an acquisition system which allows to measure and observation of drying kinetics [6]. Fresh, untreated blueberries were dried at thin layer at air temperatures 60, 70 and 80 ^oC with air velocity 0.5 and 1 m/s. Blueberries dried to the moisture content x_{eq} = 0.26 ± 0.02 kg/kg d.b on average by 6 different drying programs.

The initial moisture content was measured gravimetrically according to AOAC methods (925.09, 1990). The moisture content X (kg/kg d.b.) was according to the following equation [7, 9]:

(1)

where m_t, and m_0 are sample mass at the time t (kg); and dry matter mass (kg).

Analysis of data

The moisture ratio (MR) of convective drying samples at any time is calculated according to the following equation [11, 16] :

(2)

where X_t, X_0 and X_{eq} are moisture content at any time (kg/kg d.b.); initial moisture content (kg/kg d.b.) and equilibrium moisture content (kg/kg d.b.).

The drying rate during convective drying was calculated using [4, 8]:

(3)

where $X_{t+\Delta t}$, X_t and t are moisture content at t + Δt (kg water per kg dry matter), moisture content at t (kg water per kg dry matter) and time t (h), respectively. Drying behavior was determined using a graph of drying rate vs time.

The effective moisture diffusivity (D_{eff}, m/s^2), which is generally accepted to be an important kinetics parameter, describes the transport of moisture from the material to the surrounding in the falling rate period and can be defined by Fick's second law for a sphere [1]. For the solution of Fick's equation is assumed uniform initial moisture distribution, negligible external resistance, constant diffusivity, constant temperature and negligible shrinkage. Solutions of equation for long drying periods becomes [11, 12, 1]:

or (4)

where X_t, X_0 and me are moisture content at any time (kg water per kg dry matter) initial moisture content (kg water per kg dry matter) and equilibrium moisture content (0.015 kg water per kg dry matter) respectively, t drying time (s), r – radius of sphere (m).

The temperature dependence of the effective diffusivity may be described by an Arrhenius-type relationship as follows [16]:

(5)

where: D_0 is the pre-exponential factor of the Arrhenius equation (m^2/s), E_a is the activation evergy (kJ/mol), R is the universal gas constant (kJ/molK) and T is the absolute temperature (K). From the slope of the straight line of $\ln D_{eff}$ versus reciprocal of T, described by the Arrhenius equation, the activation energy, Ea, could be calculated.

Mathematical modeling

The drying curves (MR – t) were fitted by means of five different moisture ratio models that are widely used in most food and biological materials (Table 1). Those models are generally derived by simplifying the general series solution of Ficks second law. Non-linear regression analysis was used to estimate the parameters of models.

Table 1 Mathematical models applied to the drying curves

No.	Model	Name of model	References
1.	$MR = \exp(-kt)$	Newton	[13, 16, 1]
2.	$MR = \exp(-kt^n)$	Page	[4, 16, 1]
3.	$MR = a\exp(-kt)$	Handerson and Pabis	[5, 16, 1]
4.	$MR = a\exp(-kt) + c$	Logarithmic	[6, 16, 1]
5.	$MR = a\exp(-kt^n) + bt$	Midilli et al.	[14, 3, 16]

The determination of coefficient (R^2), reduced chi – square (χ^2) and root mean square error (RMSE) were used as the primary criterion to select the best equation to account for variation in the drying curves of the dried samples. Reduced χ^2 is used to determine the goodness of the fit. The lower the values of the reduced χ^2, the better goodness of the fit. The RMSE gives the deviation between the predicted and experimental values and it is required to reach zero. These parameters can be calculated by using the following equations [14, 3, 16]:

$$\chi^2 = \frac{\Sigma_{i=1}^{N}(MR_{\exp(i)} - MR_{pre(i)})^2}{N-n} \tag{6}$$

$$RMSE = \left[\frac{1}{N} \Sigma_{i=1}^{N} (MR_{pre(i)} - MR_{\exp(i)})^2 \right]^{1/2} \qquad (7)$$

where: $MR_{exp(i)}$ – is the *i*th experimental moisture ratio, $MR_{pre(i)}$ – is the *i*th predicted moisture ratio, N is the number of observations, n is the number of constants in the drying model

3. RESULTS AND DISCUSSION

3.1. Effect of air drying temperature and velocity

The drying curves of blueberries at the tree different air temperatures and two different air velocity are shown in Fig.1.

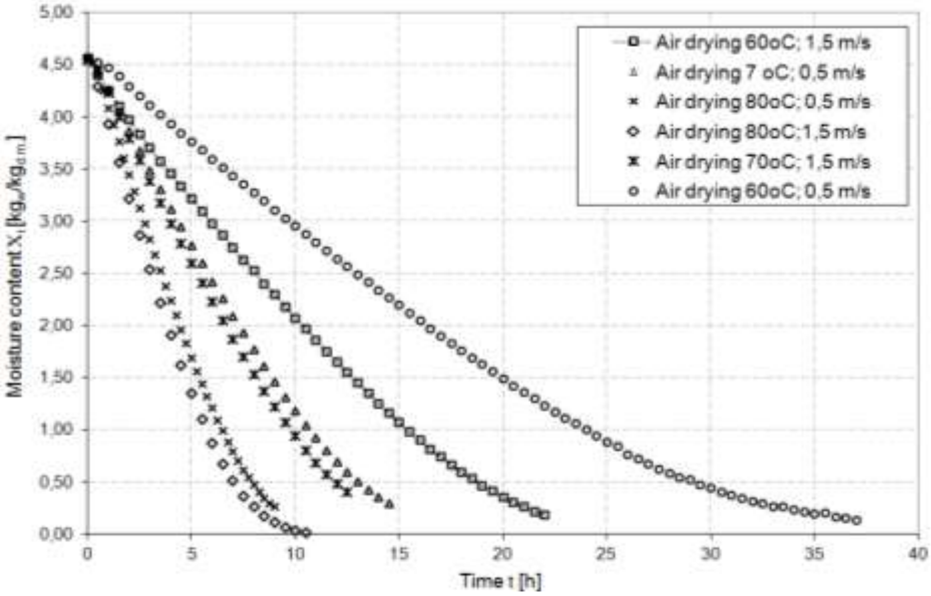

Fig. 1 Air drying kinetics of blueberries at the air temperatures, 60, 70 and 80°C and air velocity 0.5 and 1.5 m/s

As seen in figure the drying time decrease with increasing drying air temperature and velocity. Drying time to reach final moisture content were found to be 535, 890 and 2010 minutes at the air temperature 80, 70 and 60 for air velocity 0,5 m/s respectively. For air velocity 1,5 m/s at air temperature 80, 70 and 60 drying time to reach final moisture content were found to be 480, 810 and 1265 minutes respectively. When air temperature increased from 60 to 80°C drying time was reduced by almost 3 times. This decrease in drying time can be explained that increasing air temperature enhances vapor pressure in the fruit which causes the faster removal of moisture from the inside of blueberries. Similar results have earlier been reported for raspberries and hawthorn fruit [*2*, *11*,*15*].

As can be see from figs. 2 and 3, a constant rate period was not observed in convective drying the blueberries. Drying process took place in a falling rate period except a very short period at the beginning of the process. Drying rates decreased continuously with drying time. It can be explained by the movement of the moisture within the fruit as drying is a diffusion controlled process and may be represented by Ficks second law of diffusion. The results are in agreement with results from literature for various products [3, 4, 5].

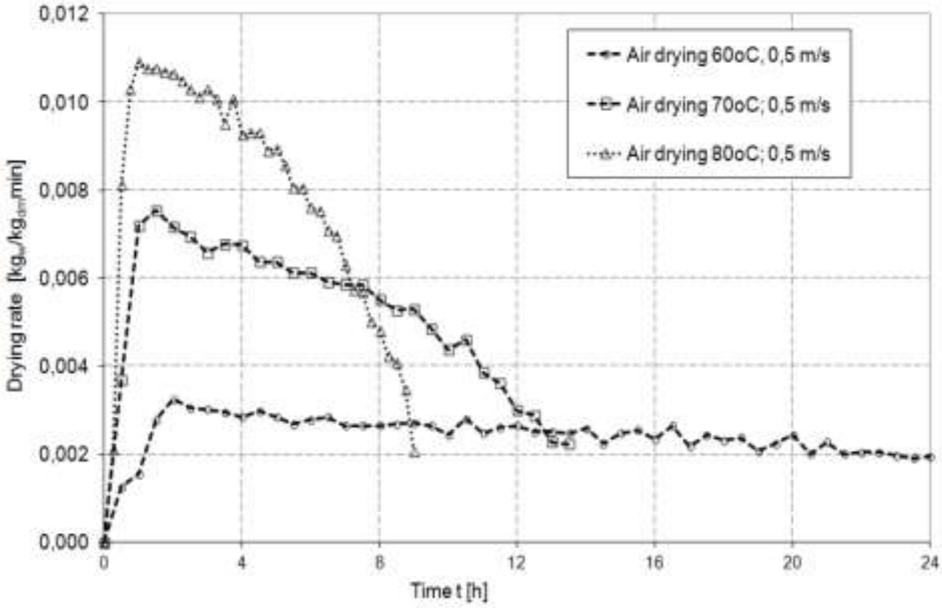

Fig. 2 Drying rate kinetics of blueberries at the air temperatures, 60, 70 and 80°C and air velocity 1.5 m/s

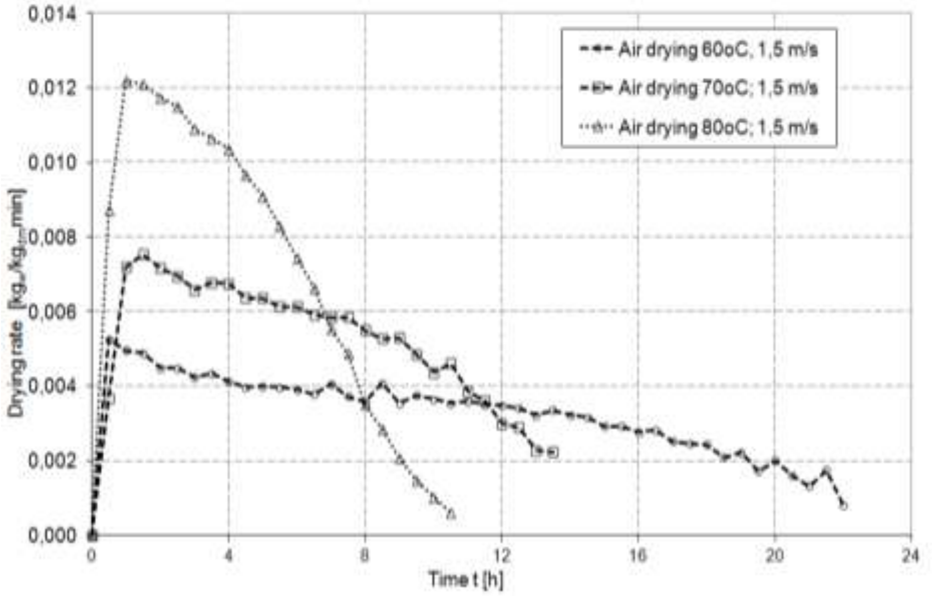

Fig. 3 Drying rate kinetics of blueberries at the air temperatures, 60, 70 and 80^{o}C and air velocity 0.5 m/s

The determined values of the effective moisture diffusivity values are shown in table 2. and were found to range between 9,67 x 10^{-12} m^2/s to 9,67 x 10^{-11} m^2/s. The results shown that D_{eff} value increased greatly with increased heating energy which increases kinetics energy of water molecules, moisture diffusivity was increased. The values of D_{eff} obtained from this study are within the general range of the reported diffusivities for fruits and vegetables 10^{-12} – 10^{-9} m^2/s. The values are within the general range determined for fruits and vegetables [7, 9].

Table 2 The effective moisture diffusion coefficients for raspberries

Air temperature (^{o}C)	Air velocity (m/s)	D_{eff} (m^2/s)	R^2
60	0.5	9,67 x 10^{-12}	0,997
	1.5	1,45 x 10^{-11}	0,996
70	0.5	3,38 x 10^{-11}	0,998
	1.5	3,87 x 10^{-11}	0,998
80	0.5	4,83 x 10^{-11}	0,998
	1.5	9,67 x 10^{-11}	0,998

The values of ln D_{eff} versus 1/T according to the linearized Arrhenius equation were plotted for determined activation energies. The values of activation energy were found 92,78 kJ/mol for air velocity 1,5 m/s and 79,11 kJ/mol for air velocity 0,5 m/s. The values are within the general range determined for fruits and vegetables [15, 16].

3.2. Mathematical modeling of drying curves

The five thin-layer drying models (Table 1) were evaluated in terms of the statistical parameters R^2, χ^2 and RMSE. The statistical analysis values are summarized in Table 3.

Table 3 Statistical results of five models at different drying conditions

Name of model	drying air velocity (m/s)	Drying air temperature								
		60°C			70°C			80°C		
		R^2	χ^2	RMSE	R^2	χ^2	RMSE	R^2	χ^2	RMSE
Newton	0,5	0,952	0,00188	0,005225	0,953	0,00426	0,0115	0,946	0,00503	0,0115
	1,5	0,962	0,00153	0,005544	0,954	0,00419	0,0120	0,957	0,00423	0,0153
Page	0,5	0,998	0,0000251	0,000598	0,996	0,000349	0,00324	0,997	0,000219	0,00236
	1,5	0,992	0,000389	0,002938	0,996	0,000333	0,003325	0,998	0,000581	0,005496
Henderson and Pabis	0,5	0,970	0,001119	0,003996	0,969	0,02876	0,009316	0,968	0,00304	0,00882
	1,5	0,971	0,001106	0,004951	0,970	0,00282	0,009677	0,970	0,00173	0,00948
Logarithmic	0,5	0,998	3,36E-05	0,000687	0,998	0,000152	0,002105	0,997	0,000204	0,00225
	1,5	0,999	1,74E-05	0,000614	0,998	0,00135	0,002075	0,998	0,00297	0,01201
Midilli et al.	0,5	0,999	9,08E-06	0,000354	0,999	4,1E-05	0,001074	0,9997	2,201E-05	0,000728
	1,5	0,999	2,26E-05	0,00069	0,999	3,29E-05	0,001003	0,999	0,00353	0,012602

In all cases, the R^2 values for the models were greater than 0.95, indicating a good fit. The R^2 values varied between 0,952 and 0,999, χ^2 values between 0,0287 and 9,08E-06, and RMSE values between 0.0153 and 2,26E-05. Generally, Midilli et al. model gave higher R^2 and lover χ^2 and RMSE values. Thus, it was selected to represent the thin-layer drying characteristics of blueberries satisfactorily. When the Midilli et al. model analyzed according to the different drying air temperature and velocity conditions, individual constants could be obtained (Table 4.)

Table 4 Statistical results of Midilli et al. model and its constants and coefficients at different drying conditions

Drying air velocity (m/s)	Drying air temperature											
	60°C				70°C				80°C			
	k	a	b	n	k	a	b	n	k	a	b	n
0,5	-0,053302	1	-0,079042	0,831829	0,056566	1	-0,009186	1,266339	0,094989	1	-0,011632	1,36660
1,5	-0,049115	1	-0,011937	1,061867	0,063416	1	-0,010367	1,263571	0,126450	1	-0,014185	1,28856

Figs 4 and 5 compare experimental data with the predicted ones using Midilli et al. model for blueberries at air temperature 60, 70, 80°C and air velocity 0.5, 1.5 m/s. It has been reported that the Midilli et al. model gives better results from other models for apples, apple pomace and hawthorn fruit [13, 16].

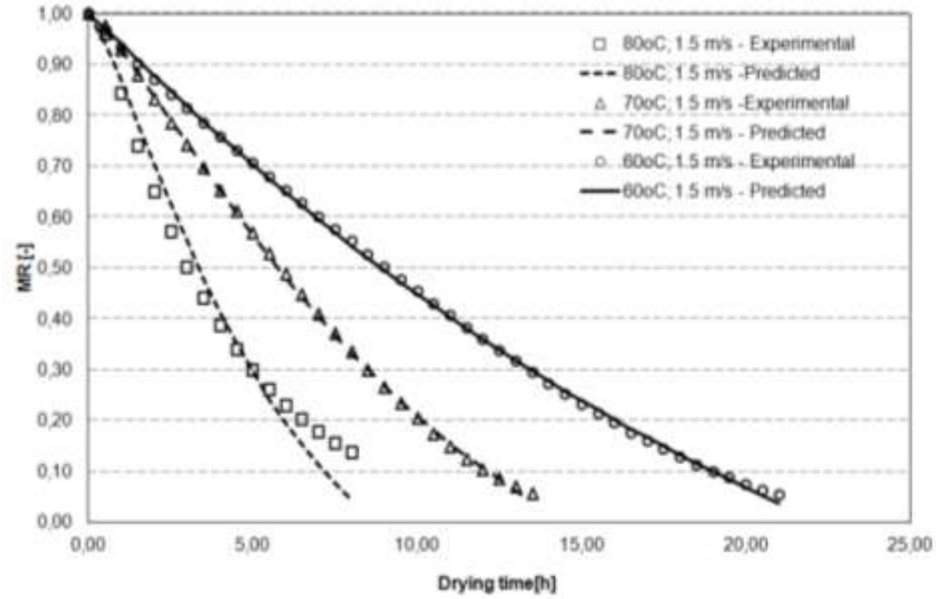

Fig. 4 Experimental and predicted moisture ratio changes (MR) with drying time at at the air temperatures, 60, 70 and 80^{o}C and air velocity 1.5 m/s

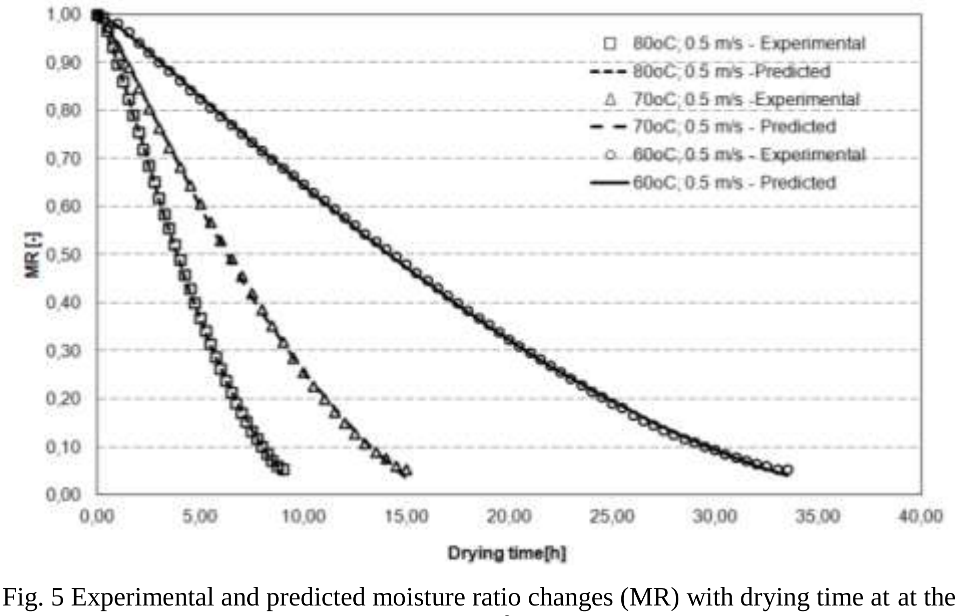

Fig. 5 Experimental and predicted moisture ratio changes (MR) with drying time at at the air temperatures, 60, 70 and 80^{o}C and air velocity 1.5 m/s

4. CONCLUSIONS

In this paper, the effects of different air temperature and velocity on drying characteristics of blueberries fruit were investigated using a convective dryer. The increases in air temperatures and velocity shortened the drying time. Drying process of blueberries occurred in the falling rate period. The experimental data was fitted to five thin layer models and Midilli et al. was found to be a best model for describing the characteristic of blueberries for all of experimental conditions. The values of the effective moisture diffusivity values were calculated to range between 9,67 x 10^{-12} m^2/s to 9,67 x 10^{-11} m^2/s in experimental conditions. D_{eff} increased with increasing of air velocity and air temperature.

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DETERMINATION OF VOLATILE COMPOUNDS IN SERBIAN RED WINES FROM CABERNET SAUVIGNON, FRANKOVKA AND MERLOT VARIETIES

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Abstract. *In this study, the volatile composition of six red wine samples of different grape varieties (Cabernet Sauvignon, Frankovka and Merlot) and vintages originating from Serbia were investigated by detailed GC-MS analysis. In total, the analyses allowed the identification of 39 compounds in the extracts, accounting for 94.9–97.1% of the detected GC peak areas. No significant differences in the volatile composition were observed among the six wine samples. The most abundant aroma compound in all wine samples was 2-phenylethyl alcohol, a well known product of yeast metabolism responsible for flowery notes of wine aroma. Identification and origin of the other volatiles present in lesser amounts and their contribution to the wine aroma characteristics were also discussed.*

Key words: *Wine, GC-MS, Volatile Composition, Cabernet Sauvignon, Frankovka, Merlot.*

1. INTRODUCTION

Probably the most important characteristic of wine quality is wine aroma. More than 800 odorants have been found, but only some of them significantly affect in the sensory perception of each wine [1]. Recent development of analytical techniques and instruments has moved the focus of the investigations to minor and trace volatile compounds that might play noticeable roles in the sensorial quality of wines. Although thoroughly investigated, the main volatiles do not necessarily represent the key odorants responsible for specific aromas. Trace constituents with very low odor thresholds could have a great impact on aroma attributes and olfactory perception. A detailed analysis of volatile constituents and identification of characteristic aroma compounds might be useful in differentiation of wines produced from different grape varieties, establishing criteria for quality, genuineness and geographical origin, and preventing fraud.

Having in mind above mentioned, the aim of this study was set to perform a detailed compositional analysis of the volatile compounds of a set of commercial red wine samples originating from Serbia.

2. MATERIAL AND METHODS

2.1. Wine samples

A set of 6 monovarietal red wine samples (Cabernet Sauvignon, Frankovka and Merlot; 3, 1 and 2 samples, respectively, of vintage ranging from 2013 to 2015) used in this study were produced and bottled in local winery after aging in oak barrels for 3 months. All wine samples were taken directly from the producer and analyzed during the May 2016.

2.2. Sample Extraction

The wine samples were extracted following the usual liquid-liquid extraction procedure. Thus, 100 ml of wine sample and 25 ml of dichloromethane were stirred in an ice bath for 30 min. After separation, the organic layer was dried over anhydrous sodium sulphate and concentrated at rotary evaporator to approx. 0.2 mL of the extract and then a volume of 1 µL was injected into the GC-MS system. Extraction yields were as follows (sample code (see Table 1), yield in mg/100 ml of wine): CaSa13, 92; CaSa14, 58; CaSa15, 77; Fra15, 100; Mer13, 58 and Mer15, 70.

2.3. GC-FID and GC-MS Analyses

Chemical composition of the wine extracts was investigated by GC and GC-MS. The GC-MS analyses were performed in triplicate on a Hewlett-Packard 6890N gas chromatograph equipped with a DB-5MS phenyl methyl siloxane capillary column (30 m × 0.25 mm, film thickness 0.25 µm, Agilent Technologies, USA) and coupled with a 5975C mass selective detector from the same company. The injector and interface were operated at 250 and 320 °C, respectively. Oven temperature was raised from 70 to 315 °C at a heating rate of 5 °C/min and then isothermally held for 10 min. As a carrier gas, helium at 1.0 ml/min was used. The samples (1 µl of the extract solutions) were injected in a pulsed split mode (split ratio 40:1). The MS conditions were as follows: ionization energy 70 eV, acquisition mass range 35–650 amu and scan time 0.34 s. GC-FID analysis was carried out under the same experimental conditions using the same column as described for the GC-MS.

2.4. Qualitative and quantitative analysis

Volatile compounds were identified by comparison of the their linear retention indices (determined relative to the retention times of C_8–C_{25} *n*-alkanes on the DB-5MS column [2]), to those reported in the literature [3], and by comparison of their mass spectra to those of authentic standards, as well as those from Wiley 6, NIST05, Adams and MassFinder 2.3 libraries. Also, a homemade MS library with the spectra corresponding to pure substances was used, and finally, wherever possible, the identification was achieved by coinjection with an authentic sample. The percentage composition was computed from the GC-FID peak areas without the use of correction factors.

3. RESULTS AND DISCUSSION

The results of the analysis of volatile compounds in six red wine samples are reported in Table 1. In total, GC-MS analyses allowed the identification of 39 compounds, accounting for 94.9 – 97.1% of the detected GC peak areas. No significant changes (neither qualitative nor quantitative) in volatile composition were observed among the six wine samples – β-phenethyl alcohol and succinic acid esters predominate in all wine samples, making up 87.8 – 92.7% of the total GC peak areas. The most abundant aroma compound in all wine samples, β-phenylethyl alcohol, is a well known product of yeast metabolism formed during alcoholic fermentation of wines responsible for flowery notes of wine aroma. Succinic acid esters, as one of the main products of fermentation process, also contribute positively to the wine aroma, since they are responsible for sweet, fruity and floral sensory notes. Volatile fatty acids responsible for sour, mild, rancid and cheesy notes (*e.g.* hexanoic and decanoic acid) were also present, but in lesser extent [4]. Other compounds, present in less amounts, such as benzyl alcohol and tyrosol, also represent the subproducts of alcoholic fermentation and contribute to the overall aroma complexity.

Barrel maturation adds complexity to wine due to leaching of odorants from the wood and their subsequent transformation in the wine. Volatile lactone 4-carbethoxy-γ-butyrolactone, identified in all analysed wine samples, originate from oak wood and migrate to wine during maceration with oak chips or aging. Important odour-active volatile phenolic compounds identified in the samples such as vanillin, ethyl vanillate and syringaldehyde are also associated with the ageing of wine in wood [5,6]. These compound, together with the other compounds of the same origin play an important role in wine quality [4,7].

Volatile sulfur-containing compound methionol, detected in two wine samples (CaSa13 and Mer13), originating from methionine. Although present only in trace amounts, sulfur-containing compounds can be potent aroma volatiles, due to its low sensory threshold values [4]. Generally, in wines, the majority of sulfur-containing compounds are mostly responsible for the production of unpleasant flavours like rotten egg, cooked cabbage, onion and rubber, considered by many as undesirable. Methionol, detected in CaSa13 and Mer13 samples, gives potato, cauliflower and cooked cabbage note to wines [7]. Indole-3-ethanol, identified in all wine samples, originate from tryptofan. Indole and its derivatives were identified as the cause of a ‘plastic/chemical-like’ off-flavours in wine predominantly produced under sluggish fermentation conditions [8].

Table 1 Percentage composition of the volatile compounds in Cabernet Sauvignon (sample codes: CaSa13, CaSa14 and CaSa15), Frankovka (sample code: Fra15) and Merlot (sample codes: Mer13 and Mer15) red wines

RI[a] ***calc.***	***Compound***	***Content [%]***[b]						***Method of identification***[c]
		CaSa13	**CaSa14**	**CaSa15**	**Fra15**	**Mer13**	**Mer15**	
965	Hexanoic acid	tr	0.2	tr	tr	tr	tr	RI,MS,CoI
976	Phenol	-	-	-	tr	-	tr	RI,MS,CoI
978	3-(Methylthio)-1-propanol (=Methionol)	tr	-	-	-	tr	-	RI, MS
997	Ethyl hexanoate	-	tr	-	-	-	-	RI,MS,CoI
1035	Benzyl alcohol	0.3	0.4	0.2	0.1	0.3	0.2	RI,MS,CoI
1051	Unknown	0.2	0.2	0.6	0.3	0.1	0.8	
1068	1-Octanol	-	-	-	-	0.2	-	RI,MS,CoI
1107	Ethyl methyl succinate	tr	tr	-	tr	tr	-	RI, MS
1117	β-Phenylethyl alcohol	52.5	49.0	58.6	49.9	42.7	67.9	RI, MS
1134	N-(3-methylbutyl)acetamide	1.7	2.5	0.9	0.2	0.8	0.2	RI, MS
1177	Monoethyl succinate	30.8	18.0	30.0	38.4	20.4	22.5	MS
1179	Diethyl succinate	9.2	20.8	1.3	4.4	25.3	1.4	RI, MS
1195	α-Terpineol	tr	-	-	-	-	-	RI, MS
1236	Thymol methyl ether	0.4	0.1	0.2	0.3	0.6	0.2	RI, MS
1244	2-Phenylacetic acid	-	-	-	-	-	tr	RI,MS,CoI
1258	2-Phenylethyl acetate	tr	tr	tr	tr	0.2	tr	RI, MS
1267	Diethyl malate	0.9	1.4	tr	tr	0.9	0.1	RI, MS
1292	Thymol	tr	tr	tr	0.4	tr	0.2	RI,MS,CoI
1302	4-Ethoxycarbonyl-γ-butyrolactone	0.4	0.6	tr	0.3	0.5	0.2	MS
1366	Decanoic acid	tr	-	-	tr	tr	tr	RI,MS,CoI
1380	Diethyl 2-hydroxyglutarate	0.4	0.5	tr	tr	0.7	tr	MS
1400	Vanillin	tr	tr	-	tr	tr	-	RI,MS,CoI
1422	Tyrosol	0.5	1.1	1.9	2.0	2.1	2.5	RI, MS
1430	Unknown	0.9	0.3	0.8	0.8	1.3	0.5	
1443	Ethyl 2-hydroxy-3-phenylpropanoate	0.3	0.3	0.2	0.2	0.4	0.3	RI, MS
1487	Acetovanillone	tr	-	-	tr	tr	tr	RI, MS
1510	*N*-(2-Phenylethyl)acetamide	tr	1.1	0.6	tr	0.2	tr	RI, MS
1532	Homovanillyl alcohol	-	-	-	-	-	tr	RI, MS
1590	Ethyl vanillate	tr	0.3	tr	tr	0.2	tr	RI, MS
1600	Hexadecane	tr	-	-	tr	tr	tr	RI,MS,CoI
1662	Syringaldehyde	tr	tr	-	-	tr	-	RI, MS
1700	Heptadecane	tr	-	-	tr	tr	tr	RI,MS,CoI
1755	Indole-3-ethanol	tr	0.5	1.0	0.5	0.2	0.4	RI, MS
1800	Octadecane	tr	-	-	tr	tr	tr	RI,MS,CoI
1832	Unknown	tr	tr	0.3	0.8	0.3	0.4	
1900	Nonadecane	tr	tr	-	tr	tr	tr	RI,MS,CoI
2000	Eicosane	tr	tr	tr	tr	tr	tr	RI,MS,CoI
2100	Heneicosane	tr	tr	tr	tr	tr	tr	RI,MS,CoI
2200	Docosane	tr	tr	tr	tr	tr	tr	RI,MS,CoI
2300	Tricosane	tr	0.1	tr	tr	tr	tr	RI,MS,CoI
2400	Tetracosane	tr	0.2	tr	tr	tr	tr	RI,MS,CoI
2500	Pentacosane	tr	tr	tr	tr	tr	tr	RI,MS,CoI
	Identified	97.4	97.1	94.9	96.7	95.7	96.1	
	Unidentified (>0.5%)	1.1	0.5	1.7	1.9	1.7	1.7	
	Total	**98.5**	**97.6**	**96.6**	**98.6**	**97.4**	**97.8**	

[a] Linear retention indices experimentally determined on the HP-5MS column. [b] Values are means of three individual analyses. [c] RI − Retention indices matching with literature data, MS − mass spectra matching, CoI – coinjection with pure reference compound. [d] MS, 70eV, RI 1051, *m/z* (rel. int.): 87 (100), 74 (99), 73 (74), 69 (49), 61 (63), 55 (72), 45 (36), 43 (95), 42 (47), 41 (35); RI 1430, *m/z* (rel. int.): 130 (4), 129 (55), 102 (6), 101 (100), 74 (5), 73 (15), 71 (10), 55 (29), 43 (8), 41 (6); RI 1832, *m/z* (rel. int.): 105 (32), 104 (100), 103 (7), 101 (10), 91 (5), 79 (5), 78 (12), 77 (5), 73 (4), 55 (6). t − Trace amounts (<0.05%).

4. CONCLUSIONS

In this study, a set of commercial red wine samples originating from Serbia was subjected to detailed analysis using GC and GC-MS. Although the analysis undertaken in this investigation showed that there were no significant differences in the volatile composition among the six wine samples, such a detailed analysis of volatile constituents and identification of characteristic aroma compounds proves to be fast and could be useful in establishing criteria for quality, genuineness and differentiation of wines samples. For this purpose, a comprehensive analysis with a larger set of samples needs to be conducted in the future.

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EXPERIMENTAL RESEARCH OF THE INFLUENCE OF DRYING MEDIUM HUMIDITY IN CONVECTIVE DRYING OF PEAS IN A STAGNANT BED

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Abstract. *The results obtained during the green peas convective drying in a stagnant bed are presented in this paper. The aim of this investigation is to determine influence of drying medium humidity on drying time. Comparison is made in several experiments with different drying regimes with surrounding air and dry nitrogen as a drying medium. Obtained results show very similar results and there is no reason to use dry medium instead surrounding humid air.*

Key words: *Convective drying, Stagnant bed, Peas, Humidity.*

1. INTRODUCTION

Solid drying is a common process in food, pharmaceutical and chemical industry applications and other (material for civil engineering, wood, tobacco…). The major objective of drying of food products are the reduction of the moisture content to a level, which allows safe storage over an extended period. Hot air drying, sun drying, solar drying, microwave drying, and freeze drying are among the most commonly used methods to dry and preserve fruits and vegetables [1]. Several papers deal with peas drying. Green pea is a leguminous vegetable of huge importance consumed in several forms such as fresh green peas, dehydrated peas and processed canned peas. Drying kinetics is very important to understand the fundamental mechanism of a process with the aim to make energy efficient dryer with optimized and controlled operating conditions [2]. The drying air temperature during the falling rate drying period had a great effect on drying kinetics. The drying rate reached its maximum values at higher drying air temperatures. Drying rate decreases continuously with decreasing moisture content or improving drying time. In stagnant bed drying, complex unsteady-state heat and mass transport phenomena took place. The most important parameter is heat and mass transfer rates which affect on drying product quality as well as energy consumption. The heat and mass transfer rates are associated with the local values of drying air temperature, humidity and velocity [3,4].

The aim of the paper was to determine whether there is a significant difference in the grain material drying in the stagnant bed by the ambient air with natural humidity and with droughty drying medium. Relatively simple connection of nitrogen bottle to the existing installation was the reason for choosing nitrogen for the droughty drying agent.

Approximately spherical particles of green peas used as the experimental material. The green peas were selected because its' membrane represents an additional significant resistance to the transport of moisture through the material and to the drying process.

2. EXPERIMENTS AND RESULTS

Experimental investigation of heat and mass transfer process, during drying materials in fixed bed, were carried out with installation designed and made in Laboratory for Thermal Engineering and Energy [5].

Radial fan (1) supplies with air long horizontal pipe internal diameter of 0.1m (4). By-pass valve (2) and control valve (3) enable regulation and maintenance of given airflow rate. At the standard distance from the fan, a flow-measuring orifice plate (5) is installed. Differential pressure transmitter (6) is used to detect the orifice pressure difference. Accuracy of measured flow rate was calculated as 1.12%. Air is heated in an electrical heater (7), controlled by electricity voltage change. Heated air is introduced into the air-flow equalization chamber (10) and the sample-vessel (9) with internal diameter of 150 mm. Air temperature after orifice plate (T_0), after the heater (Th) and at the inlet of the sample-vessel (Tv), are measured by means of the pre-calibrated thermocouples (K-type i.e. chromel-alumel, with accuracy of ± 0.5 ^{o}C). The temperature of the drying medium, before entering the sample container, was monitored during the experiment and its value was changed within 1 °C.

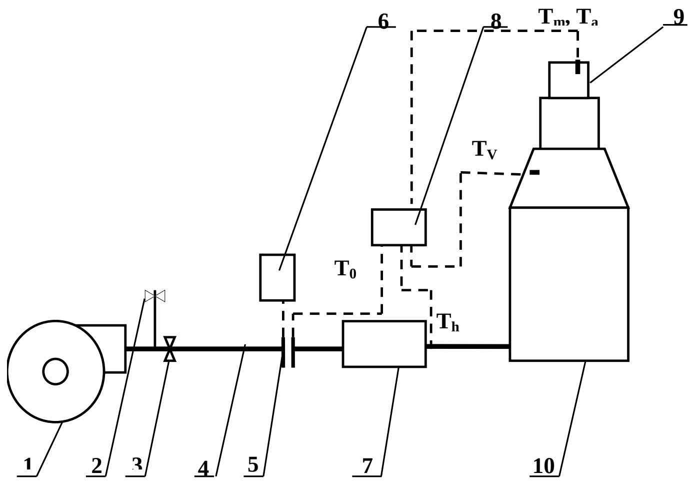

Fig. 1 Experimental installation (schematic).

1-radial fan, 2-by-pass valve, 3-air-flow control valve, 4-pipe (d_i = 100 mm), 5-flow-measuring orifice plate (d_0 =33 mm), 6 – differential pressure transmitter, 7 - electric heater (2 kW), 8 - acquisition system, 9 - sample-vessel (d_{vi} = 150 mm), 10 - air-flow equalization chamber

Turning on the fan and electric heater, experimental installation was preliminary heated during some period. Sample-vessel was preliminary connected to the installation, while desired airflow rate and temperature were controlled. After obtaining desired steady air parameters, measurement was started when weighed mass of wet material was inserted into the vessel. From that moment all mentioned temperatures were measured in equal time intervals, differential pressure on flow-measuring orifice plate as well as static pressures were controlled and measured. Air humidity as well as atmospheric pressure of ambient air were also measured. After determined time in each experiment, sample-vessel was disconnected, and dried material was weighted quickly on digital scale with accuracy of 0.1g and return to the experimental installation.

After completion of the experiments with ambient air, the drying medium was switched to nitrogen. The nitrogen flow and all other drying parameters were very close in both drying regimes (air - nitrogen). The procedure for determining the drying kinetic curve was the same as for air.

All experiments were performed with a pea layer height of 10 cm, and with apparent drying agent speed of 1.45 m/s. Experiments were conducted with the same pea type. The temperature and humidity (absolute and relative) of drying agent for all experiments are presented in Table 1. Experiments with ambient air as a drying agent were carried out for four different temperatures: 40.6 °C, 52.3 °C, 60.2 °C and 69.8 °C. The results are shown in Figure 2.

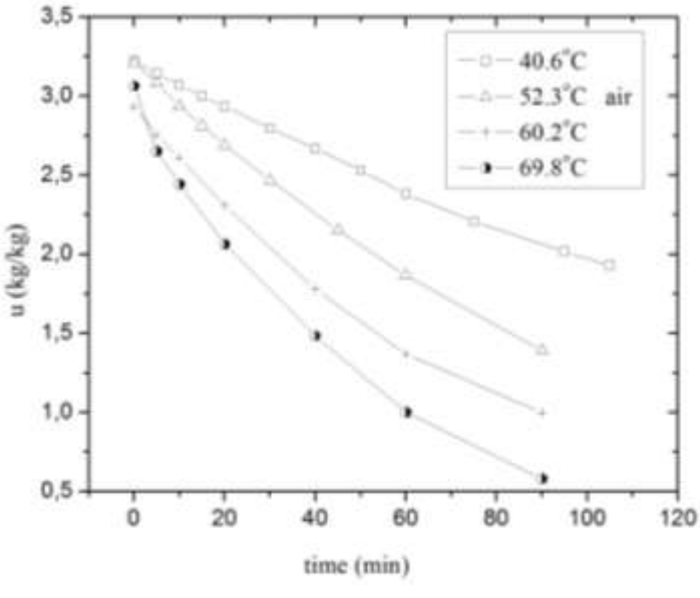

Fig. 2 Experimental results of drying kinetics of peas in fixed bed

Time duration of the experiment with nitrogen as a drying agent, was depending on the possibility of maintaining a constant flow of nitrogen from the bottle. The experiment was interrupted when the pressure of nitrogen in the bottle was no longer sufficient to maintain the predicted flow. As a result, nitrogen experiments took less of time. Figures 3, 4 and 5 show the results of determining the kinetics of pea drying with ambient air and nitrogen at close temperatures.

Table 1 Ambient air and nitrogen parameters during appropriate experiments: t_m – mean temperature, x- absolute humidity

No. of Experiment	**Ambient Air**	**No. of Experiment**	**Nitrogen**
1	t_m=40.6 ºC x=0.0082 kg/kg (RH = 17.2%)	**5**	t_m=40.7 ºC
2	t_m=52.3 ºC x=0.0098 kg/kg (RH = 11.3%)	**6**	t_m=52.2 ºC
3	t_m=60.2 ºC x=0.0095 kg/kg (RH = 7.5%)	**7**	t_m=60.8 ºC
4	t_m=69.8 ºC x=0.0112 kg/kg (RH = 5.8%)		

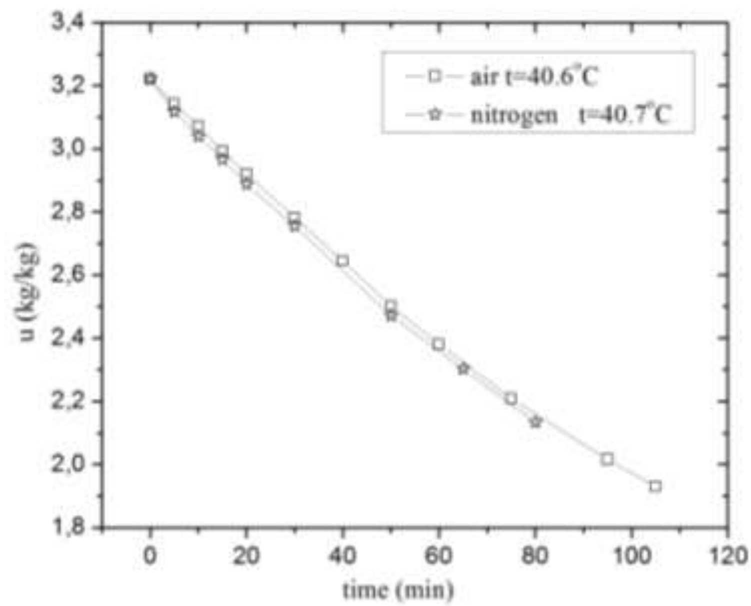

Fig. 3 Comparison of drying kinetic curves at 40 ºC with surrounding air and nitrogen as a drying agent

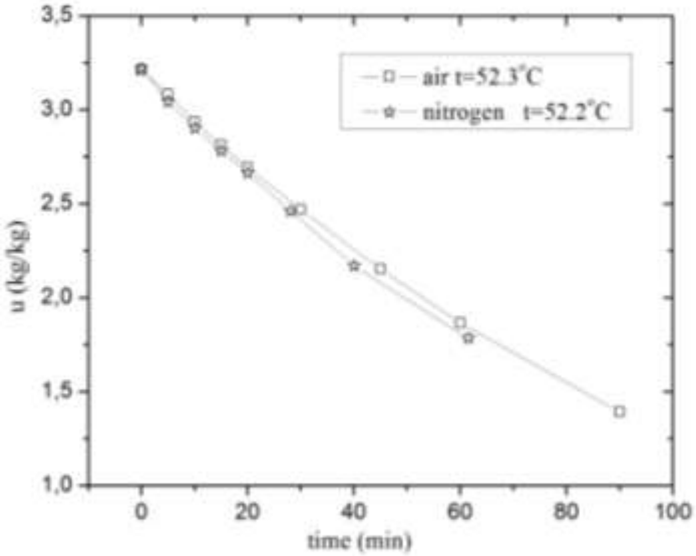

Fig. 4 Comparison of drying kinetic curves at 52 ºC with surrounding air and nitrogen as a drying agent

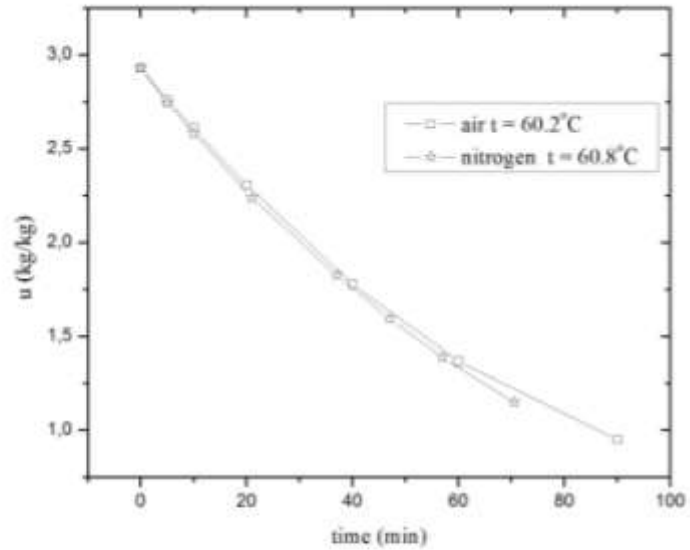

Fig. 5 Comparison of drying kinetic curves at 60 ºC with surrounding air and nitrogen as a drying agent

The results of the measurement indicate that, when drying the pea with velum, there is no significant influence of the drying agent moisture content on the drying kinetics. It must be taken into account that the measurements were made in October when relative humidity of the ambient air has slightly higher values (average maximum daily temperature for Belgrade is 18.4 ºC and mean relative humidity of 71% [4]). The relative air humidity values at the drying temperatures ranged from 5.8% (for Experiment No. 4) to 17.2% (for Experiment No. 1). The maximum difference in moisture content in dried material was between experiments 2 and 6 (at the end of nitrogen drying time) and amounted to about 4.5%. These results show that the crucial influence on the pea drying process is the transport of moisture through the material and the membrane itself.

Based on the foregoing, it can be assumed that other agricultural fruits, which have a membrane, would behave similarly.

4. CONCLUSIONS

Results of experimental investigation of drying kinetics of green peas in the fixed bed are presented in this paper. The exploration which was carried out has shown the following:

- The increase in drying agent temperature from 40.6 ^{o}C to 69.8 ^{o}C causes notable increase of drying rate,
- There is no significant difference between drying with humid ambient air and dry nitrogen: max difference in moisture content in dried material is 4.5%,
- The crucial influence on the pea drying process has the transport of moisture through the material and the membrane itself, and
- There is no reason to use droughty drying medium instead of humid air from surroundings.

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POTENTIAL AND LIMITATIONS OF PLUM DRYING AND SALES: CASE OF OSEČINA MUNICIPALITY

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Abstract: *The sale of processed products to suppliers brings higher value than the sale of fresh products, which is the main motive for investing in plums drying. The Municipality of Osečina is perhaps the best example. It has plum orchards, the tradition of plum drying, and and in the last few years a great number of new plum drying facilities were built. The reason of such development in the municipality of Osečina is primarily prunes demand in international markets. The subject of this paper is to examine the potential and limitations for drying and selling dried plums. The data for this research were collected from personal interviews with key stakeholders in Osečina engaged in the plum production or drying. A person employed in the advisory department and the person in charge of the organization of the Plum Fair that is held each year in Osečina in August have also been interviewed. Finally, the National Statistical Office data were also used. This paper shows, in particular, that 94% of plum drying facilities in Osečina have the daily capacity for drying of up to 1000 kg of plums. The production of fresh plums in the municipality ensures the operation of a drying facility for half a month during the year.*

Key words: *Prunes, drying, sales, Osečina.*

1. INTRODUCTION

Although considered to be the fruit cultivating region, the highest portion of farming land in the municipality of Osečina are used for crop production, while orchards account for 13% of the total farming land (Fig. 1), out of which land under plum account for 55%. Only a small share of them uses irrigation systems and therefore yields depend exclusively on weather conditions.

In order to increase the value of production, investments in plum drying facilities is significant.. There are 160 drying facilities in the municipality, out of which 94% of facilities have the daily capacity of drying of up to 1000 kg of fresh plums. Since fresh plums producers are small private family farms, and since there is a great number of small capacity drying facilities, it may be concluded that full competition is present both in terms of demand and in terms of supply. Consequently the price of fresh plums cannot be changed either by an individual producer or by the owner of a drying facility.

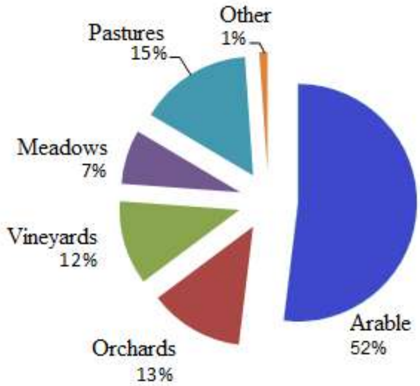

Fig. 1 Land – Municipality of Osečina (Source: National Statistical Office)

However, this situation could be changed as traders from other regions could significantly change the situation and affect the prices. This paper aims at presenting the current situation in terms of plum drying and sales, as well as potential challenges to primary producers and prune traders.

2. MATERIAL AND METHOD

Since fresh fruits are products that are prone to rot due to which can only be sold in a fresh condition in a short period of time, processing does not only increase the value, but it also increases the sales potential until the next harvest.

The total number of drying facilities in the Republic of Serbia is 5625, of which 95% are family-owned and mini drying facilities. The remaining 5% account for industrial drying facilities. Products obtained in family-run production are dried, with a low percent of drying service or purchase of fresh products from other farmers. . In the municipality of Osečina, the first two categories account for about 97% of all drying facilities, while the remaining portion of 3% account for comparatively bigger drying facilities (Interview 1.3)

In the municipality of Osečina, drying facilities are intended only for plum drying, mainly of the daily capacity of up to 1000 kg per one tunnel. Plums are dried during the period from 30 to 60 days, which results in the low capacity utilization on the annual level. Drying facilities are of tunnel type, mainly consisting of two rows of wagons, where trays are located. Some of drying facilities are designed and constructed by plum producers, which sometimes brings useful innovations, but in certain cases problems arise due to poor knowledge of plum drying technology.

Estimated construction costs of the drying facility with the daily capacity of 1000 kg, range from 13.900 to 16.100 EUR. The difference in the costs results from the type of facility, equipment quality, type of insulation and similar (8).

The procurement of drying facilities is mostly financed from own resources. The greatest number of drying facilities was installed during the period 1982–1989 when the complete equipment was procured from the local state-owned companies “Cer” and “Iverak”.. During this period, zinc plated pipes were used, which came out of use subsequently due to standards applied in recent times. Stainless steel is mostly used for shelves and other equipment in recent times – it is more expensive but it has a longer life cycle.

After this period, procurement was mostly organized for equipment parts that were subject to physical depreciation, such as boilers due to burning of fire-proof clay, fireplace, breakdown of the heat exchanger, etc. The current procurement price of boilers ranges between EUR 2500 and 3000.

Shelves for drying were purchased at favorable prices since they were mostly purchased as second-hand items from state-owned companies that had gone bankrupt.

Investors mostly invest in the facilities and then purchase equipment and use an indirect type of drying.

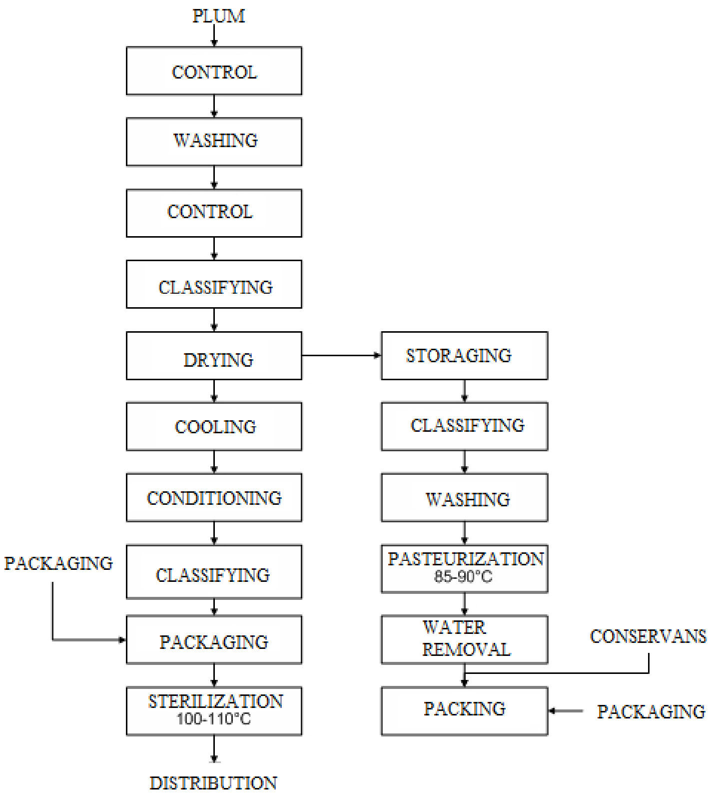

Fig. 2 Plum drying technology

During the last several years, about 110 new tunnels for plum drying were installed in the wider area, while the areas under plum plantations have been slightly increased.

The increase of number of drying facilities has increased the demand for fresh plums, which has affected its price which amounted to 50 RSD/kg in this area in 2017, while this price ranged between 10 and 20 RSD/kg in previous years. The increased demand made space for unscrupulous traders and suppliers who offered the goods of lower quality or committed other fraudulent activities. Such activities reduced the export to foreign markets, which resulted in the need to make new adjustments (7).

Prunes are a product with stable demand at the local market (4), while international demand increased during certain years.

In order to show the current situation in terms of plum drying and sales, the period 2015-2017 was analyzed. This period was chosen due to the fact that significant changes and external shocks took place during this period and also due to the fact that the interviewed persons remembered this period best, while they described the period before the observed period as a comparatively calm period. This period was also chosen since it is crucial for understanding the functioning of the process of plum drying and sale, as well as for understanding the future development.

For prune marketing purposes, in addition to drying process other technological processes should be implemented. Traders and producers call the entire process “12 steps before sales”. The actual sale represents the 13th step. The processes shown in Figure 2 must be performed in order to prepare prune for marketing activities in retail.

3. Discussion on the results

Taking into account the current situation in terms of production of fresh plums and prunes and the sales of the same, the analysis results are as follows:

- The increased number of drying facilities for plum drying is a response to the increased demand for prunes, primarily coming from international markets. The increased foreign demand was the result of poor supply from other foreign suppliers, which created a favorable starting position for local suppliers. However, during the high foreign demand, some unscrupulous traders appeared and offered the goods of inadequate quality and performed other activities that were not in accordance with good trading practice. Such behavior resulted in low number of foreign customers in the upcoming period and increase in prune stocks.
- The increase of the drying facilities’ capacities was not followed by the increase of surface covered by plum trees, which in the conditions of the increased demand resulted in the increase of the fresh plum price by 2,3 times. The fresh plum price increase positively affected the fresh plum producers, but it negatively affected other participants in the marketing chain.
- Since small plum producers and manufactures dominate in the municipality of Osečina, they cannot influence the price individually. However, external

factors can significantly affect the situation. For example, if a dominant trader appears, as in 2015, it can affect the balance and cause a sudden increase in the price of fresh plum, causing problems to local drying facilities.

- Newly-built drying facilities are of lower capacity, poorly equipped, resulting in the heat loss and making the drying process more expensive. Automation is usually lacking.
- Due to such situation in plum drying process, a typical trader’s calculation regarding prune is as follows: the estimated cost price of prune production ranges between 1,3 and 1,8 EUR/kg. Contribution margin of 30% is added to this price by processing firms in Osečina. The precise amount of cost price would require the analytical calculation (Andrić, 1998).
- Taking into account the existing capacities for plum drying in Osečina and surfaces under plum trees, it cannot be expected that the price of fresh plum intended for drying will decrease in the future.
- In order to increase plum produiction it is necessary to develop new and modern orchards. Taking into account current prices and relations in marketing channels, it is considered that the minimal surface of the orchard with the trees planted in rows with modern cultivation systems – irrigation and hail protection systems – should be 12 ha. Such investments are currently supported by banks (Interview-1).
- Currently, participants in the marketing chain operate independently and have no interest in taking into account the position of other participants. For example, small producers sell fresh plums to traders willing to pay a better price, regardless of the agreements. At the same time, processors often use their dominant position in purchasing plums.
- It appears that the participants in the marketing chain of prune sales lack knowledge of the entire vertical chain and processes starting with fresh plum, investments in the facility and equipment, good process management, plum finishing process, storage, packing, preparatory sales actions, sale and customer behavior.

4. CONCLUSION

Plum drying capacities in the municipality of Osečina were significantly increased in the last several years, which were not followed by the increase fresh plums production. Consequently,, utilization of drying facilities were on the low level.. With the current fresh plum production quantities, the drying capacities could be used only half a month during a year. The production and processing activities are dominated by small producers who cannot influence the prices. The appearance of fresh plum traders from other regions can significantly change the situation. Prune demand exist on both, the domestic and in the foreign market. Marketing chain participants lack knowledge in vertical chain operation and modern marketing which negatively affects the sale of prune. In order to achieve a better sale results it is necessary to improve functioning of the local market. The increase fresh plum supply can be achieved only by planting modern orchards.

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IMPACT OF THE SENSOR HEIGHT IN THE MEASUREMENT OF THE CORN VEGETATIVE INDEX

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Abstract. *This paper presents field scouting of corn in order to determine the content of nitrogen in the green parts of the plants. The aim was to measure the vegetative index using two optical sensors by OptRx AGL Technology. The sensors are positioned at a distance of 3.5 m, individually observing five rows of corn. The sensors are designed and constructed to allow sensors to be moved in altitudes relative to the ground and the green part of the plant, adjusting is manual, so that the height of the sensor varies from 50 to 70 cm above the plants, or at 5 different distances for 5 cm shifts. The speed of movement of the tractor also varied. The measured vegetative index of the plants is correlated with the height of the sensor. It was noticed that the correlation exists, but that it does not significantly affect the mapping of nitrogen content.*

Key words: *Optical sensors, Corn, Nitrogen, Normalized Difference Red Edge*

1. INTRODUCTION

Remotely sensed spectral vegetation indices are widely used and have benefited numerous disciplines interested in the assessment of biomass, water use, plant stress, plant health and crop production [3,4,5]. The study of Kothawale et al. suggested that Normalized Difference Vegetation Index (NDVI) at (R650 and R770) using spectroradiometer can be used as a reliable tool for fertilizer N management in cotton [2]. For corn, it is usually to use Normalized Difference Red Edge (NDRE). A combination of surface reflectance at two or more wavelengths designed to highlight a particular property of vegetation, Figure 1. NDRE is calculated as:

$$NDRE = \frac{NIR_{780} - RE_{720}}{NIR_{780} + RE_{720}} \qquad (1)$$

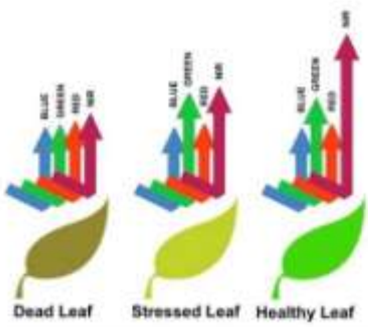

Fig. 1 Reflectance at RED and NIR wavelengths

NIR is Near-infrared, a region of the infrared spectrum of light used for Near-infrared spectroscopy. Wavelength of NIR is 0.75–1.4 µm, in this case exactly 780 nm. RE, red edge, is the term used to describe the part of the spectrum centered around 715 nm, in this case exactly 720nm. With the NDRE, one can notice the difference between the individual areas of corn that is characterized by the different visual appearance of biomass as a result of different nitrogen content and vegetative index, Figure 2.

Fig. 2 Area of the field with N stress (NDRE=0.789) compared to an area of the field without N stress (NDRE=0.934) made by Institute for Ag Professionals, University of Minnesota

There are various methods for measuring the vegetative index through the NDRE as well as the different devices for which this is accomplished. Measurement can be done using satellites, using unmanned aircraft equipped with appropriate sensors for spectrometry or using sensors mounted on a work machine or a special platform that is aggregated by a tractor. Hand-held sensors are also in use. The most precision are sensors mounted on work machine. This paper examines exactly these devices, whether the height of the sensor positioning as well as the optimal speed of the aggregate carrying the sensors affect the measurement results.

2. MATERIAL AND METHODS

OptRx Crop Sensors uses a red-edge light wave to scan plants. Most competitive products use only a red wavelength, which has been shown in studies to be non-responsive at high plant density. The red-edge lightwave stays responsive to health-stress on plants at later growth stages than other competitive products. OptRx crop sensors use a single algorithm application. Trials have been conducted in multiple states that have shown positive results of using a single algorithm in comparison to multiple algorithms. Design of OptRx Crop Sensor by AG Leader Teshnology is shown in Figure 3.

Fig.3 Design of OptRx Crop Sensor by AGL Technology

The sensors are positioned at a distance of 3.5 m, individually observing five rows of corn, Figure 4.

Fig. 4 Design of sensors-stand and measuring on the field

The sensors-stand are designed and constructed to allow sensors to be moved in altitudes relative to the ground and the green part of the plant, adjusting is manual, so that the height of the sensor varies from 50 to 70 cm above the plants, or at 5 different distances for 5 cm shifts. The speed of movement of the tractor also varied 5-8 km/h. Measuring was implemented on field near Banatsko Novo Selo in June. The length of the field was about 250 meters.

3. RESULTS AND DISCUSSION

3.1. Descriptive statistics

Results od descriptive statistics using SPS Statistic 21 are shown in Table 1, histogram in Figure 5 and normal as well detrended normal P-P Plot of NDRE are shown in Figure 6.

Table 1 Descriptive statistics

	N	Minimum	Maximum	Mean	Std. Deviation
NDRE	1188	0.087	0.283	0.16659	0.027146
Valid N (listwise)	1188				

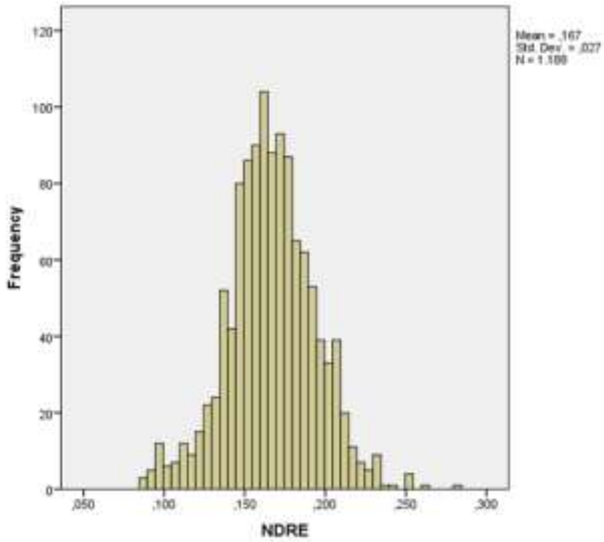

Fig. 5 Histogram of NDRE

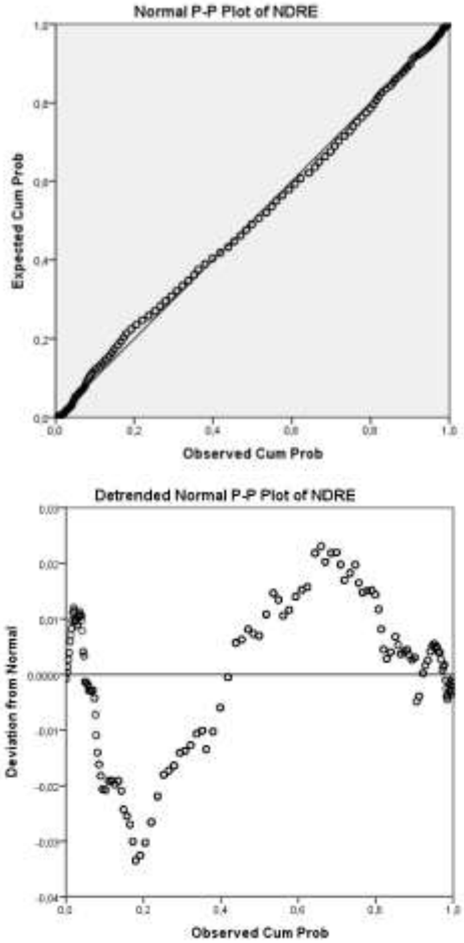

Fig. 6 Normal and Detrended Normal P-P Plot NDRE

3.2. Impact of the sensor high to NDRE

The testing method is based on combining the results for both groups and their ranking in an ascending sequence, saving the origin of observation. Let m be the number of observations in a smaller-size sample and n in a larger-size sample. The U-statistic, used for testing, is defined by the number of cases, so that the result for a larger-size sample comes before the result for a smaller-size sample in the process of ranking.

Mutual values of Z_{ij} for all five analyzed high of sensor are shown in Tab. 2. For small-size samples, i.e., when m and n < 10, a special table with significance levels for obtained U-statistic values is applied, whereas for large-size samples, like the one used here for moist grain mass yield, the approximation of U-statistic distribution by normal distribution [1], i.e., the statistic used, is:

$$Z = \frac{U - \frac{mn}{2}}{\sqrt{\frac{mn(m+n+1)}{12}}} \tag{2}$$

Table 2 Values of Z_{ij} and statistical significance

Z_{ij} (p)	1 (50 cm)	**2 (55 cm)**	**3 (60 cm)**	**4 (65 cm)**	**5 (70 cm)**
1 (50 cm)		-0.790 (.415)	-1.064 (.124)	-0.211 (.833)	-0.606 (.344)
2 (55 cm)	-0.790 (.415)		-0.535 (.311)	-1.467 (.057)	-0.665 (.378)
3 (60 cm)	-1.064 (.124)	-0.535 (.311)		-1.268 (.083)	-1.428 (.056)
4 (65 cm)	-0.211 (.833)	-1.467 (.057)	-1.268 (.083)		-0.733 (.464)
5 (70 cm)	-0.606 (.344)	-0.665 (.378)	-1.428 (.056)	-0.733 (.464)	

For the case of comparing pass 1 (high of sensor above top plant is 50 cm) and pass 2 (55 cm), Z-statistic equals -0.790 with significance level p=0.415, which leads to the conclusion that the null hypothesis is accepteded, i.e., there is not a significant difference in average NDRE for pass 1 and pass 2.

4. CONCLUSIONS

Values of statistical significance are given in parentheses. It is evident from the Table that among adjacent passes and NDRE there is no statistically significant difference. All this is supported by the small Z values and values of statistical significance > 0.05. Sensors are available today which can accurately detect crop nitrogen status during the growing season. Algorithms have been developed which relate crop canopy reflectance in specific wavebands to how much nitrogen fertilizer is needed. Sensors can be either passive (using sunlight) or active (using an internal light source). Sensors can be used on a variety of platforms: handheld, ground or aerial vehicle, satellite. Active sensors can be used around the clock, regardless of cloud cover or sun angle. For ground sensors, high of mounted in rang 50 to 70 cm above plant have no impact to NDRE.

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INNOVATION AND MULTIDISCIPLINARY APPROACH FOR DEVELOPING AN INNOVATIVE IT CONTROL SYSTEM FOR WATERING IN THE GREENHOUSES

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Abstract. *Innovation aspect of developed control system is asked on the basis of agricultural producers needs of the on the specific area. In the area of Novi Pazar and surrounding municipalities most producers have small number of greenhouses, which are often on the scattered over hilly and hard reachable terrain. On the global level there are existing solutions which integrate automatic watering systems with advanced monitoring of the different aspects of the greenhouse conditions. On the National level only existing system is Smart Watering System which is system specialized for the Fruit production and management system is based on the SMS messages through cellular network providers. Innovation and multidiscipline approach are of the essence in the modern world, IT technologies are involved into controlling wide number of the processes. Emerging open source and cheap platforms as Arduino enable small teams to develop cheap and reliable control systems. In this work authors gave overview of the process which can be used for the development and implementation of control systems in agriculture.*

Key words: *innovation, control system, arduino, greenhouses, watering*

1. INTRODUCTION

Innovation and multidisciplinary are buzzwords often used for describing needs for socio-economic development [1].Can we use approaches in order to promote teaching and provide innovative ideas and solutions to the market developed by the students or University spin-off companies?

First we need to elaborate innovation and multidisciplinary and then we will elaborate application of this approach on development of IT control system for watering of greenhouses.

Innovation is application of better solutions that meet new requirements, unarticulated needs, or 3 existing market needs [3].

This is accomplished through more-effective products, processes, services, technologies, or business models that are readily available to markets, governments and society. The term "innovation" can be defined as something original and more effective and, as a consequence, new, that "breaks into" the market or society [4] it is related to, but not the same as, invention [5]. Innovation is often manifested via the engineering process, since in the modern engineering in the different field usage of modern IT technologies and management related approaches we need to introduce multidisciplinary and constructive approach.

This brings into game second aspect to develop innovative solution is multidisciplinary approach involves drawing appropriately from multiple academic disciplines to redefine problems outside normal boundaries and reach solutions based on a new understanding of complex situations [6].

During the process of developing innovative system, we worked with students introducing first economical aspects and methods of developing innovative idea, then we introduced IT solutions for control management of the greenhouse a watering systems and finally we use in future constructive approach to develop design for the future laboratory on the agriculture study program using innovative products designed by students. All this steps will be covered in presented work.

2. INOVATIVE SOLUTION FOR WATERING OF GREENHOUSES

2.1. Innovative solution for watering of greenhouses - economic aspect

Innovation aspect can be related to the innovations either on global or regional or small level. Innovation aspect of developed control system is based on the needs of the agricultural producers on the specific area. In the area of the Novi Pazar and surrounding municipalities most producers have small number of greenhouses, which are often on the scattered over hilly and hard reachable terrain [7].

On the global level there are existing solutions which integrate automatic watering systems with advanced monitoring of the different aspects of the green house conditions. On the National level only existing system is Smart Watering System which is system specialized for the Fruit production and management system, based on the SMS messages through cellular network providers.

Since there are existing solutions on the market first discipline which was used for development of the innovative design were skills from management and economic.

Before developing of the system, analysis of the proposed solution was done using CANVAS method (Fig.1.). This is a strategic management and lean startup template for developing new or documenting existing business models. It is a visual chart with elements describing a firm or product's value proposition, infrastructure, customers, and finances. It assists firms in aligning their activities by illustrating potential trade-offs [8].

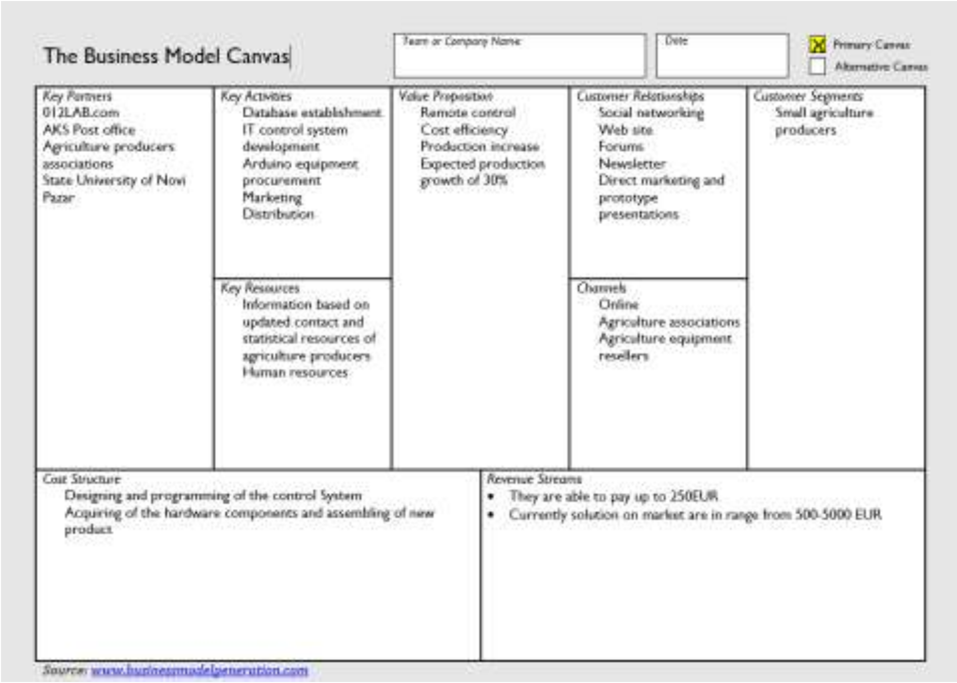

Fig.1 Canvas model for development of watering control system

2.2. Innovative solution for watering of greenhouses - IT aspect

Proper implementation of the cheap watering control system became achievable by development of the Arduino platforms. Arduino is an open source computer hardware and software company, project, and user community that designs and manufactures single-board microcontrollers and microcontroller kits for building digital devices and interactive objects that can sense and control objects in the physical world.

All products, related to Arduino, are distributed as open-source hardware and software, which are licensed under the GNU Lesser General Public License (LGPL) or the GNU General Public License (GPL), permitting the manufacture of Arduino boards and software distribution by anyone. Arduino boards are available commercially in preassembled form, or as do-it-yourself kits. This approach enabled wide spread application of this platform for development of variety of solutions which were, because price, out of reach to global community [9-12].

There is wide number of offered free solution for different control systems, but all this solutions lack reliability needed for implementation of green houses watering system. In order to prepare this solution brand new reliable control code should be developed. Most system offered on the market of Serbia are to expensive for small producers since they offer wide number of additional functions applicable for big agricultural companies. Only other solution existing in Serbia is developed for fruit producers while this system is designed for vegetable production. Also their solutions use SMS messages as medium for control which issues additional costs while this solution is based on the usage of Wi-Fi connections creating additional cost reduction.

To achieve this, team developing this solution coded new management system, which is easily connected with Wi-Fi networks. On this stage with acquiring code customer with small knowledge can implement system as DIY kit.

Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The boards feature serial communications interfaces, including Universal Serial Bus (USB) on some models, which are also used for loading programs from personal computers. The microcontrollers are typically programmed using a dialect of features from the programming languages C and C++. In addition to using traditional compiler toolchains, the Arduino project provides an integrated development environment (IDE) based on the Processing language project.

Before development of the Arduino based control system, user case for the system is developed which define roles of the subjects in the planned control system (Fig.2.).

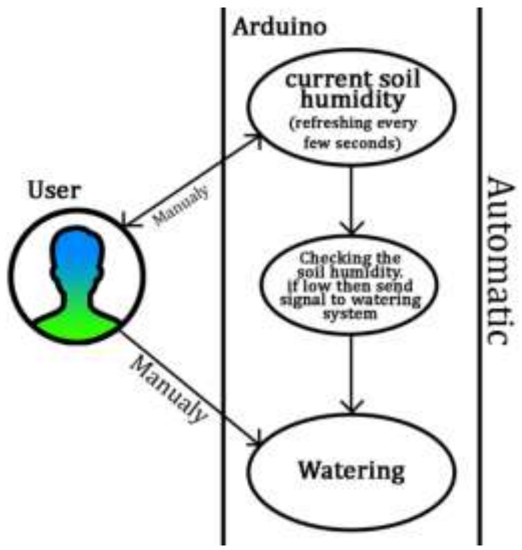

Fig. 2 Use case diagram for the coding of watering control system

In order to promote functionality of control management system application for management of Arduino platform is developed using Arduino open source IDE. Part of the code and front end of the application is given in Fig.4. Beside remote control, program enables control of the watering system also based on the sensor information on the soil moisture, if adequate sensor system is developed.

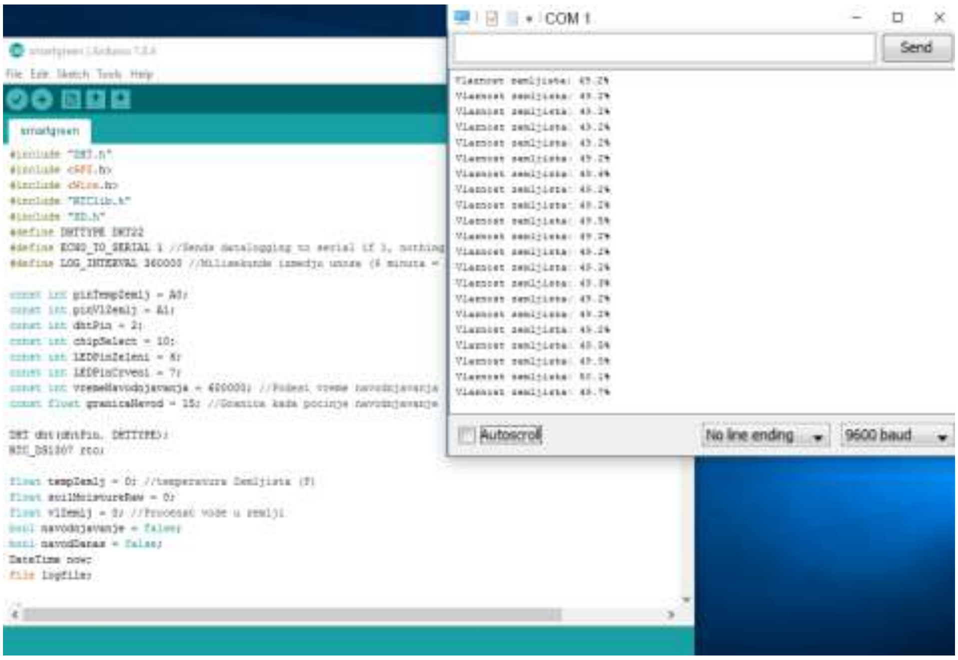

Fig. 3. Control system for management of water system code and front end application

With this control system any user can assemble this device as DIY kit purchasing Arduino system and appropriate additional sensor or electromechanical elements.

This paper proposes new approach to deal with the practical problems that arise in the agricultural production. Basis of this process is developing and recognition of innovative idea which will provide benefit to production. In order to validate this idea before we try to offer to the market we need thr usage of economical methodologies which will prove idea applicability. During developing this system CANVAS method was implemented. After proving that developing of this system is worthwhile it is given to engineers to develop solution. In our case this software solution can be delivered as the final product to market thanks to existing Arduino platforms. After overview of idea other innovative ideas glow to further develop project are observed. In the further development we will try to integrate all solution into one product which will be prototyped on the laboratory in State university of Novi Pazar and after that offered to market as fully developed system. Model overview is given on Fig.4.

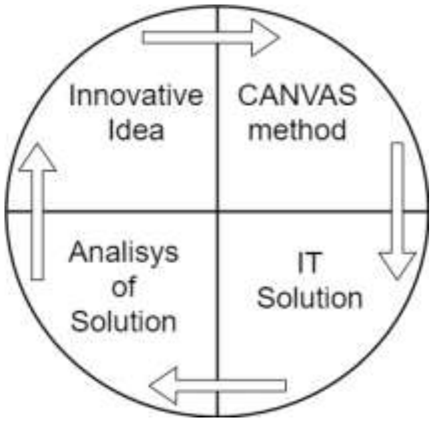

Fig. 4 Innovation and multidisciplinary approach for developing Watering control system

3. CONCLUSION

Innovation and multidiscipline approach are of the essence in the modern world, IT technologies are involved into controlling wide number of the cycles. Emerging open source and cheap platforms as Arduino enable small teams to develop cheap and reliable control systems. But before involving effort into developing solution we need to listen to the beat of the socio economic environment. All his create paramount need to reach for multidisciplinary solution. In this work we gave overview of the process which can be used for the development and implementation of control systems. This model is actually repeating himself since new solutions open rage for further developing of new and improved functionalities of control system.

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RESULTS OF THE EXAMINATION OF CONE RESISTANCE AND EFFECTS OF SOIL COMPACTION CHANGE ON YIELD OF WINTER WHEAT

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Abstract*. The great ecological problem in plant production is soil compaction, which is a consequence of the mechanization and movement of people. The consequences of excessive soil compaction are manifested through the reduction of soil porosity, volume, productive capacity, and adverse effects on the development of plants and yield. The paper presents the results of measuring the cone resistance at penetration at a depth of 0-20 cm and the effect of changes in soil compaction on the yield of winter wheat. The tests were carried out under the conditions of Srem, and the cone resistance was measured by the Eijkelkamp 6.0 penetroler, by penetrating the cone of the surface 1 cm^2 with the tip of the cone 60^0, in accordance with the standard EN 5140. The cone was standard in size according to the standard ASAE S313.1, while the humidity of the soil was measured by the Theta probe. The resistance of the cone was measured on the inner part of the plot and after the planting in the emergence stage, before harvest and after harvest, and the obtained values were compared with the control (harvested soil on which there was no firing). The aim of the research was to determine the effect of soil compaction on changes in cone resistance during penetration and the amount of yields achieved. The obtained results show that the maximum resistance of the 5.80 MPa cone was measured at the recess at a depth of 20 cm at the harvesting stage, while at the control and in the interior of the plot, much lower values were measured. Increasing soil compaction has had a major impact on yield reductions, so the yield of winter wheat was lower by an average of 38.10% on the slopes compared to the inner part.*

Key words*: cone resistance, compaction, soil, yield, wheat*.

1. INTRODUCTION

Agricultural machinery is one of the key elements for successful plant production. In addition to the numerous benefits it brings, the movement of agricultural mechanization leads to increased land consolidation. It is estimated that around 68 million are around the world ha agricultural land only due to wheeling and transport [6]. Land consolidation is one of the main forms of degradation and is present in total degradation with 11%, while in Europe the cause of degradation is 33 million hectares of agricultural land [1, 14]. It creates a series of problems that are manifested by reducing porosity, limited growth of the root system, increasing resistance to processing and reducing yields by over 30% [7, 10, 11, 21]. Land consolidation is especially expressed up to a depth of 0.5 m, so it is difficult to adopt water and nutrients, increased risk of erosion, increased energy consumption for processing [4, 5, 8, 20]. The occurrence of harmful soil compaction resulting from the movement of mechanization and the depth of processing and consequences are analyzed by other authors [2, 15, 19, 22, 25]. Excessive soil compaction affects the increase of specific resistance by 2.0-2.5 times, reduction of yield by 10-40% and increased investments in machinery, facilities and personnel by 10-25% [17]. According to these authors, the realized losses that result from overcompensation of land amount 224.5 USD ha^{-1} annually or for the largest agricultural holding of about 15,000 ha of arable land 3,367,500 USD per year. According to [16], with the help of lighter mechanization, soil compaction can be significantly reduced and the consumption of energy products reduced. Due to the lower speed of rotation and due to the high number of passages, the soil compaction is more manifested on the slopes compared to the inner part of the plot [13, 18,]. Compaction is particularly manifested after the first passage of machinery, so that at a depth of from 0.24 m to soil density greater than 39% in relation to the depth of from 0.34 m [12]. Land compaction problems are analyzed [9] and state that the cone resistance is at a depth of 20-30 cm was 2 MPa. According to the results of the research by the authors [23], the soil compaction in the inner part of the plot during the emergence phase was on average 30.56% lower compared to the slope and in the collection phase by 37.56%, so in the internal part of the parcel yields were on average higher by 26% compared to the slopes. The resistance of the cone to measure the soil compaction at the collection stage was higher on the recess and amounted to an average of 3.82 MPa, while in the inner part it was less than 2.53 MPa, so that the resistance of the cone on the slope was higher by 50.97% [24] compared to the inner part of the plot. Land share in the phase of harvesting crops of winter rye was smaller in the inner part of the plot amounted to 2.84 MPa on average and 4.31 MPa on the slope, which represents a higher compression rate of 51.76%, so the yield in the inner part of the parcel was 35.48% higher [3].

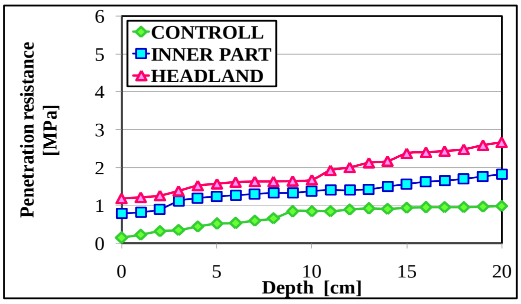
2. MATERIAL AND METHODS

During 2016/17. In agro ecological conditions of Srem (44°44'36.8"N 20°14'54.9"E), measurements of cone resistance during penetration and impact on winter wheat yield of the variety Pobeda were made. In the production of wheat, the usual technology was applied. The tools were assembled for a 46.5 kW tractor, and the plowing was carried out with a two-rack-mounted ram plow at an average depth of 20.3 cm, after which discing was carried out with a disc harow after that a pre-seedbed preparation was done, and at the end sowing with the seed drill IMT 634.23. In the course of the vegetation, two mineral fertilizer feeds were carried with a carried spreader and one treatment with herbicides carried by a tractor sprinkler. Harvesting was carried out on Combine Zmaj 143. The soil fertility was measured by the penetrologer Eijkelkamp hardware version 6.0, software version 6.03. For conveying the surface cone was used 1 cm^2 with a peak of 60^0, in accordance with the standard NEN 5140, the penetration rate of 2 cm sec^{-1}, and the deviation was no greater than 0,5 cm sec^{-1}. The cone is of standard size, defined according to the ASAE standard (ASAE S313.1). Before the start of the measurement, a reference plate of depth was set, the position of the plot (GPS) and the humidity of the soil were determined. When measuring soil compaction, the penetroller's inclination did not exceed 3.5^0 in relation to the vertical (the penetroller was used), and the penetration rate was monitored by the speed indicator in the display that was close to the median position. The soil moisture at the moment of compression measurement was determined by the Theta probe and expressed in % vol. Measurements were performed at a depth of 0-20 cm on the soil of the type Eutric cambisol, at the depth of the layer which was treated with plows. The cone resistance was measured in the 5 repetitions with a distance of 2 m between the measuring points, with the center point located in the middle of the slope. In order to consider the right slope, the parcels were selected along with the road, so that the rotation of the machine-tractor units is carried out only on the plot where the right slopes are formed. The width of the mouth was 10 m. The penetration resistance of the cone during penetration into the soil was measured in three variants. The first variant was the control (without hitting for minimal impact on soil compaction), while the other two variants included measurements of the cone resistance when penetrating the land after moving mechanization in the inner part of the plot and on the swing. The first phase of the measurement was during cropping, the second before harvest and the third after harvest. At the harvesting stage, the yield achieved according to the tested variants was determined.

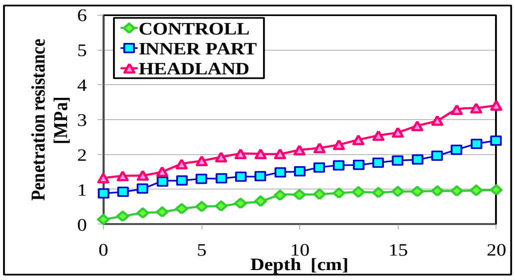
Fig. 1 The satellite snapshot of the field of the research

3. Results and discussion

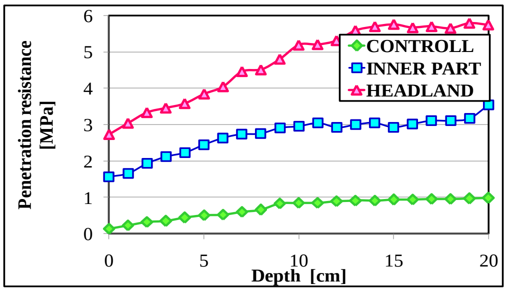
Figure 2 shows the values of the cone resistance when penetrating the soil during the production of winter wheat in three phases the sprouting phase (Fig. 2a), before harvest (Fig. 2b) and after harvest (Fig.2c). In accordance with the expectations, different values of the cone resistance were measured during all measurements in all the examined variants and phases, and the growth in the cone resistance generally increased along the depth of measurement and was the largest at 20 cm. Resistance increased during all stages of measurement, and the lowest values were in the emergence phase, and highest after the harvest.



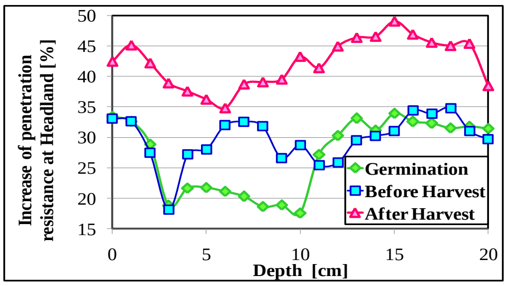
(a)



(b)



(c)



(d)

Fig. 2 Soil compaction parameters: (a) penetration resistance at germination phase [MPa]; (b) penetration resistance before harvest [MPa]; (c) penetration resistance after harvest [MPa]; (d) percentual increase of soil compaction at headland with respect to inner part o experimental plot in different phases of crop production [%]

The resistance of the cone on the control variant was in the phase of emergence of 0.98 MPa at a depth of 20 cm, with the average soil moisture 24.40% (Fig. 2a), and in the inner part of the plot 1.83 MPa at 20 cm depth, with an average moisture content of 24.50% (Fig. 2a). The highest values of penetration resistance of the cone during penetration into soil during the cropping phase were measured at the recess and amounted to 2.67 MPa (Fig. 2a) at average soil moisture of 25.38%.

When the penetration resistance of the cone during penetration into the soil prior to harvest, it is noted that the highest values were measured at a depth of 3.41 MPa at a depth of 20 cm, an average humidity of 18.24%, while the internal part of the pellet was measured at 2.40 MPa with an average humidity of 19.16% (Fig. 2b). In the control variant the least values are measured and they are close to those from the beginning of the measurement.

In the phase of harvesting crops after the passage of the combine, the highest values of cone penetration resistance in soil were measured on the recess and they amounted to 5.80 MPa at a depth of 20 cm, with the average soil moisture being 17.30% (Fig. 2c), while the lowest values were at a control of about 1.2 MPa with an average humidity of 16.91%. In the inner part of the plot at a depth of 20 cm the cone resistance was 3.54 MPa, with the average humidity of the land amounting to 17.88%.

Figure 2d shows the percentage increase in cone penetration resistance, and the relative difference in terms of resistance increase penetration is lowest in the emergence phase, and the highest in the phase after winter wheat harvest. The highest values of magnification were measured on the slope in relation to the control and the inner part of the plot in all stages of the measurement.

The research results of this work are similar to the other researchers results [3, 4, 9, 12, 13, 18, 23, 24]

Figure 2 shows the average values of the realized yields according to the tested variants. The yields were calculated on the basis of five repetitions according to the tested variants and are presented in absolute values (Fig. 3a) and relative amounts (Fig. 3b).

On the basis of the obtained results, it is noted that in the internal part of the plot the yield was within the range of 5.2 - 5.4 t ha^{-1}, while on average the yield of winter wheat varied in the range of 3.2 - 3.4 t ha^{-1}, which represents an average yield reduction of around 38.10%.

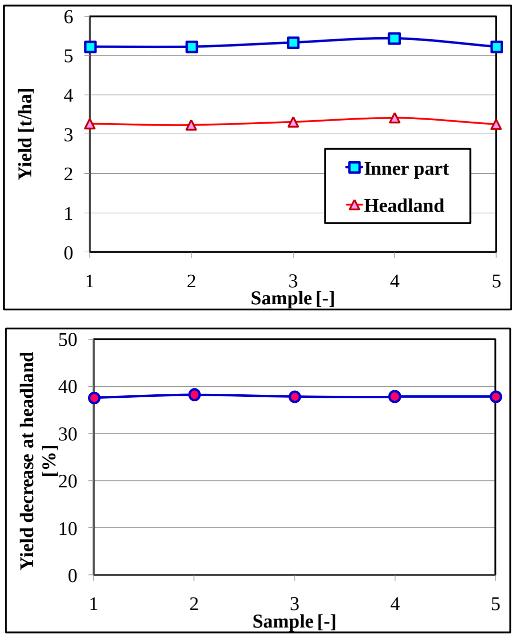


Fig. 3 Comparison of the average yield of winter wheat at the inner part and headland of the experimental plot: (a) absolute values [t ha^{-1}] and (b) relative percentual decreasing of the yield

On the basis of the obtained results, it is noted that in the internal part of the plot the yield was within the range of 5.2 - 5.4 t ha^{-1}, while on average the yield of winter wheat varied in the range of 3.2 - 3.4 t ha^{-1}, which represents an average yield reduction of around 38.10%.

The obtained results in terms of realized yields show that the negative impact of the compaction of the site has been confirmed in the examined conditions and has shown a significant influence on the amount of yields yielded by the conditions of the test.

The results we obtained on out study were in accordance with the results presented by other authors [3, 7, 10, 11, 17, 21, 23].

4. CONCLUSIONS

On the basis of obtained results of measurements of cone resistance of penetration into soil under conditions of Srem and the influence of changes in the soil compaction on changes in soil and the yield of winter wheat, the following can be concluded:

- During the measurement, different values of the cone resistance were measured in all examined variants and phases, and the increase in cone resistance generally increased by the depth of measurement and was the largest at 20 cm

- Resistance increased during all stages of measurement, and the lowest values were in the emergence phase, and the highest after harvest
- The smallest resistance of the cone was measured in the phase of cropping in the control variant of 0.98 MPa, the largest on the recoil of 2.67 MPa, which is a greater resistance of 2.7 times. In the inner part, the resistance of the cone was 1.83 MPa
- At the pre-harvest stage, the minimum resistance of the cone was measured at the control and was close to the values from the beginning of the measurement, and the largest in the recess was 3.41 MPa, while in the inner part of the cone resistance it was 2.40 MPa which is a smaller resistance of 1.42 times
- In the phase of harvesting crops, the highest value of cone penetration resistance in soil was measured at the recess and they amounted to 5.80 MPa while the lowest values were at control of 1.22 MPa, which is 4.58 MPa the difference. In the inner part of the plot, the resistance of the cone was 3.54 MPa
- The relative difference in terms of increasing resistance to penetration is the lowest in the emergence phase, and the highest in the phase after winter wheat harvest. The highest values of the percentage increase were measured on the recipe in relation to the control and the inner part of the plot in all stages of the measurement
- The achieved yield in the inner part of the parcel was within the limits of 5.2 - 5.4 t ha^{-1}, while on average the yield of winter wheat varied in the range of 3.2 - 3.4 t ha^{-1}, which represents an average reduction in the yield for the eye 38.10%
- The general conclusion of the study is that the negative impact of soil compaction on the development of winter wheat and the amount of yields achieved in the agro ecological conditions of the investigated area.

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PHYSICAL PROPERTIES OF ORGANIC FERTILIZER PELLETS

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Abstract. *The aim of this study was to analyze the selected mechanical properties of the organic fertilizer pellets as the base parameters for the depositor's production. During the test a commercial organic fertilizer pellets were used having the bulk density of 646.1 kg/m^3 and a moisture content of 17.50%$_{wb}$. Physical properties of these pellets depend to a large extent on their moisture content. The tests were carried out for pellets moisture content ranging from 4.48 to 20.81% $_{wb}$. For lower pellets moisture content the values of mechanical properties (Hardness and Work Input) increase. The value of the static friction angle increased approximately linearly with increasing pellets moisture content and ranged from 18 to 24.5°. Originally the organic fertilizers pellet contained 5.20%, scattered fraction. After application trough the depositor, share of the scattered fraction mass increased to 13.55%. The indicated pellets damage does not affect the quality of the depositor's work. From a point of degradation rate, pellets granules larger than 4 mm showed high quality.*

Based on the investigated physical properties of organic fertilizer pellets, a depositor was constructed, and successfully applied organic fertilizer pellets in practice.

Key words: *organic fertilizer, pellets, physical properties, mechanical properties, static friction angle, degradation rate*

1. INTRODUCTION

A large number of authors mention the importance of soil fertilization with organic fertilizers. Improvement of physical properties of soil and C and N content can be achieved only by fertilization with organic fertilizer or integrated fertilization treatments, while at the same time there is a significant increase in yield [10]. The same authors, the best effects of fertilization were obtained with the local application at the sowing time in the development zone of the young plant root system. In this regard, it is economically justified to use granular organic fertilizers with appropriate physical and mechanical properties. The physical properties organic fertilizer pellets also investigated Pocius et al, (2016), and they avoid result of the most indicate parameters (moisture content, bulk density, inrush failure angles and mechanical durability) for newly pellet produced in diameter of 4, 5 and 6 mm. Paré et al, (2009), also examined the physical properties of organic-mineral fertilizers and their impact on the transport, storage, handling and application in field conditions. The same authors state that through parameters that can be easily measured such as untapped bulk density, moisture content, mean weight diameter (MWD), and crushing strength, they can express other essential parameters.

The constructional solution of the depositor has a great influence on application rate precision [3]. The organic fertilizer pellets had specific physical and mechanical properties. The examined organic fertilizer pellets was intended for mechanized application by specially designed depositors. Construction of depositor shout has the possibility of achieve the demanding and variable fertilization rate.

2. MATERIAL AND METHODS

The aim of this study was to analyze the selected mechanical properties of the organic fertilizer pellets as the starting parameters for the production of new constructions of depositor. Analysis of the physical properties organic fertilizers pellets was carried out using measuring equipment and procedures used within the Laboratory for biosystem engineering, as well as Laboratory for mechanization at vegetable production, Department of Agricultural Engineering, Faculty of Agriculture, Novi Sad (Tab. 1). The following mechanical properties of organic fertilizer pellets were analyzed:

- dimensions,
- bulk density,
- moisture content,
- mechanical properties,
- static friction angle,
- sieve analysis and
- degradation rate.

The pellets of organic fertilizer have cylindrical shape. Pellets length and diameter were measured by caliper of 0.1 mm accuracy class. The dimensions of the sample have great impact on the mechanical properties in process of their determination.

Bulk density was measured by calibrated glass measuring cylinder and digital analytical scale [4].

Determination of the organic fertilizer pellets moisture content was carried out by thermo gravimetric method by drying at 104°C for 24 hours [9]. The sample was previously crushed.

The mechanical properties of organic fertilizers pellets were defined by using the TMS-PRO, Food Technology Corporation, Virginia, USA, with the measuring cell of up to 500 N [2, 6, and 7]. The speed of the metal plate during the test was 30 mm/min. During the test, a pressure test for a deformation of 30% was performed, and Hardness (N), Input work (mJ) and Initial modulus (N/mm) being determined.

Tab. 1 Measuring equipment used during the test

Measured quantities and units	Name of equipment, manufacturer, model	Measurement range, resolution, accuracy instrument
Length and diameter of pellet (mm)	Caliper, TMA INOX, D-6-1, Germany	0-200 mm; 0.1 mm; ±0.05 mm
Mass (g)	Analytical scale, KERN 440-33N, Germany	0-200 g, 0.01g, ±0.02 g
Volume of sample (cm^3)	Glass measuring cylinder	500 ml; 10 ml; ±5 ml
Mechanical properties (N), (mm/s),	TMS PRO, Food Technology Corporation, Virginia, USA	±2500 N, 0.015%
Static friction angle, (°)	The steep plane for determining the friction coefficient	0-90°; 1°; ±0.5°
Moisture content, ($\%_{vb}$)	Laboratory dryer Sterimatic ST-11 "Instrumentarija", Zagreb	
Sieve analysis	Retsch Sieving Machine Type AS 200 control	0-10 mm; 0.25 mm
Degradation rate	New Holmen Pellet Tester, NHP 100, TekPro Ltd, Norfolk, United Kingdom)	
Number of revolutions, (min^{-1})	Device for number of revolutions measurement	0-999 min^{-1}; 1 min^{-1}; ±0.5 min^{-1};
Organic fertilizer pellets application	Depositor for organic fertilizer pellets Agria, Subotica	11.96 g/revolution;

The static friction angle was measured by a steep level that has the ability to change the material of surface and has the ability the angle of inclination determined accurately [1]. The static friction angle is determined for the metal surface.

Sieve analysis was carried out by a series of sieves of aperture size, 5.6; 4.0; 3.15; 2.0 and 1.0 mm. Screening mode was: amplitude 2 mm/"g", a time interval 1 min. Sections of the same sieve aperture diameters are indicated by [4, 5].

Degradation rate was determined by laboratory device Pellet Tester for a period of 30 seconds, and a sieve aperture, for screening before and after treatment, was 4.0 mm in diameter.

3. Results and discussion

The mechanical properties were measured by a compression test for a deformation of 30%. For this reason, it was of crucial importance to select a sample of uniform dimensions (diameter). The mean value of the pellets diameter (ranged from 4.42 to 4.62 mm with a low value of variation coefficient (6.12 to 10.40%). Investigation of mechanical properties was conducted depending on the moisture content exchange. The significant differences were found for *Hardness* (Fig.1) and *Work Input* (Fig.2), while no differences were found for *Initial Modulus*.

Tab. 2 Organic fertilizer pellets dimensions and mechanical properties depend on moisture content

Parameters	Moisture content (%)	Length (mm)	Diameter (mm)	Hardness (N)	Work Input (mJ)	Initial Modulus (N/mm)
X*	4.48	**12.68**	**4.55**	**338.54**	**198,83**	**26.18**
Sd**		0.78	0.27	23.21	32.37	4.02
CV*** (%)		6.12	5.90	6.86	16.28	15.35
X	8.57	**13.18**	**4.43**	**294.20**	**158.33**	**23.01**
Sd		1.37	0.27	32.60	23.52	6.23
CV(%)		10.40	6.05	11.08	14.86	27.08
X	15.86	**13.03**	**4.62**	**100.00**	**68.83**	**29.52**
Sd		0.74	0.24	19.67	15.92	5.84
CV(%)		5.67	5.11	19.67	23.12	19.78
X	16.58	**12.57**	**4.53**	**60,86**	**37.86**	**29.09**
Sd		1.14	0.15	13.38	9.84	9.77
CV(%)		9.09	3.38	21.99	25.99	33.59
X	17.50	**12.44**	**4.57**	**58.20**	**37.80**	**27.99**
Sd		1.04	0.47	15.02	5.45	6.77
CV(%)		8.37	10.20	25.81	14.42	24.19
X	20.81	**12.71**	**4.42**	**62.63**	**40.88**	**32.72**
Sd		0.97	0.27	10.27	8.37	5.59
CV(%)		7.65	6.04	16.39	20.49	17.08

*Average,
**Standard deviation
***Coefficient of variation

In order to avoid additional losses of nutrients, organic fertilizer should be applied immediately after the original package opening. The moisture content of original packed fertilizer pellets was 17.5%. This value drops to 16.5% within one hour. These are the moisture content pellets values that are most often used in practice. For the listed values of moisture content, measured were the lowest and uniform values for hardness ranging from 60.86 to 58.2%. After several hours standing in the depositor, the pellet moisture content droped to 15.86%, with a significant increase in *Hardness* of about 40%. By standing of the organic fertilizer pellet for several days the moisture content dropped to 8.57%, an additional *Hardness* incensement of 4.9 times was observed, and at pellets moisture content of 4.48%, the *Hardness* was even 5.66 times higher. After the subsequent wetting of organic pellets after opening the original package, there was no change in value for *Hardness* (Fig. 1). For *Work Input*, the same dependencies as for *Hardness* were observed, depending on the pellet moisture content.

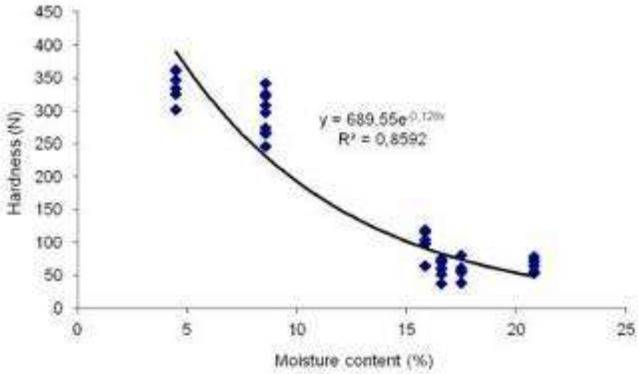

Fig. 1 Hardness depend on organic fertilizer pellet moisture content

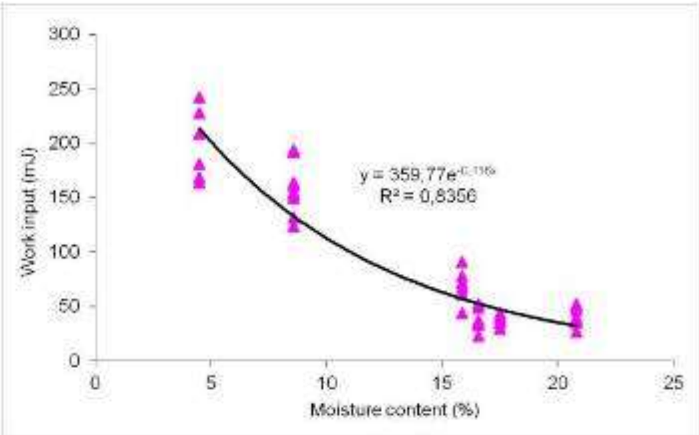

Fig. 2 Work Input depend on organic fertilizer pellet moisture content

Depending of organic fertilizer pellets moisture content, the value of static angle of friction also changed (Fig. 3). For pellets moisture value of 17.5%, the value of the static friction angle was 22°. A lower value of the static friction angle (18 and 19°) was measured for lower pellet moisture values of 4.48 and 8.57%. Pellets moisture content of 20.81% had the value of static friction angle 24.5°. Higher values of the organic fertilizer pellets moisture content affect the increase in the value of the static friction angle, resulting in increasing operation resistance of the device for the fertilizers application and the difficulty of run-off and filling cavities in the lower part of the depositor reservoir. The listed organic fertilizer pellets physical properties where the base point for new depositor construction.

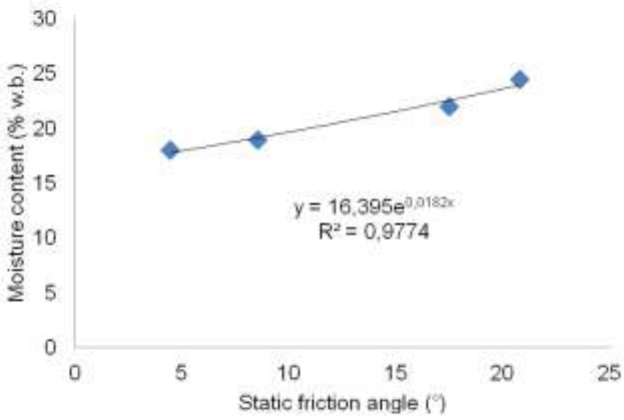

Fig. 3 Static friction angle depend on organic fertilizer pellet moisture content

The size of the fertilizers pellets damage, due to the passage through the depositor, was assessed by a sieve analyses. The pellets average diameter was in range of 4.42 to 4.62 mm. The rule that the damaged pellet has a diameter less than 4 mm was accepted. In the base mass of organic fertilizer pellets, the damaged pellets were 5.20%. After passing through the depositor, comes to partial pellets damage. The share of pellets smaller than 4 mm after passing through the depositor increased to 13.55%, which represents increasing of 2.6 times.

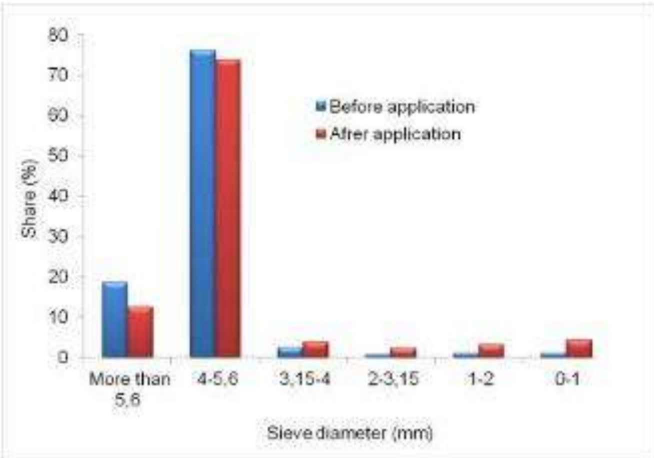

Fig. 4 Share of the individual fractions of organic fertilizer pellet

Measured values of the degradation rate before and after passing through the depositor were in the range of 2.33 and 1.91% (Figure 4). According to measuring degradation rate for organic fertilizer pellets, there determined good physical properties. Mechanical durability values more than 86% (which represent degradation rate up to 14%) stated [5].

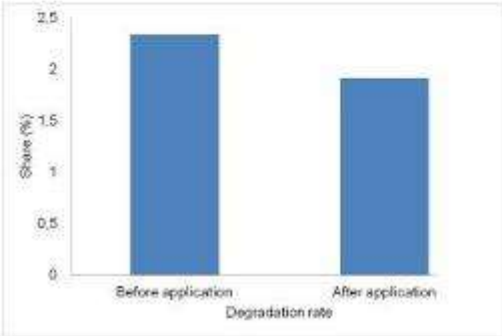

Fig. 5 Degradation rate before and after application by depositor

Based on the examined physical properties of organic fertilizer pellets, a depositor was constructed and organic fertilizer pellets successfully applied in practice [8].

4. CONCLUSIONS

For the purpose of constructing the depositor, the selected physical properties of the organic fertilizer pellets were determined. Physical properties depend to a large extent on the pellets moisture content. The test was carried out for pellets moisture content ranging from 4.48 to 20.81%. For lower pellet moisture values, the values of mechanical properties (Hardness and Work Input) increased. The value of the static friction angle of pellets increased approximately linearly with moisture content increasing and ranged from 18 to 24.5°. From the point of degradation rate, investigated pellets showed high quality. In the basic mass of organic fertilizers pellets, the content of the scattered fraction was 5.20%, and after the passage through the depositor the share of the scattered mass increased to 13.55%. The indicated pellet damage does not affect the quality of the depositor's work.

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FABRICATION AND APPLICATIONS OF MULTIFUNCTIONAL NANOSTRUCTURED TiO_2

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Abstract *Nanomaterials development is a rapidly emerging field of research with enormous potential for societal and economic benefits. In agro and food industries dimension-dependent properties or phenomena of nanomaterials may be used for various functional effects such as increased bioavailability or decreased toxicity of products, better detection of pathogens, improved food packaging materials, or improved delivery of nutrients. Since these effects may derive from altered or unique characteristics of materials in the nanoscale range that are not normally observed or expected in larger-scale materials with the same chemical composition, such changes raise questions about the safety, effectiveness, performance, quality or public health impact of nanotechnology products. In this article, we have reviewed the fabrication, properties, and selected applications of nanostructured TiO_2 based materials. Special attention has been paid to TiO_2 nanoparticles and nanotubes fabrication perspectives and applications in agriculture. We have shown that high photocatalytic disinfection and photobiological effects of nanostructured TiO_2 coupled with its low price, nontoxicity, and stable performance especially provide new approaches for solving environmental pollution and pesticide residue problems in agriculture.*

Keywords: *nanomaterials, nanoparticles, nanotubes, TiO_2*

1. INTRODUCTION

Nanotechnology and nanomaterials fabrication has great potential to positively impact the food sector through improvement of existing products and development of new ones. Agriculture may benefit from advances in nanotechnology which will not only develop new nanostructured biocatalysts in order to modify the agro-resources in the green chemistry context, but will also decrease and optimize the use of nanoparticles pesticides, increase the efficiency of nanostructure biodegradable materials, develop autonomous nanosensors for real-time monitoring and develop the smart delivery of nanosystems for prevention, improved diagnostics and treatment. One group of materials which have great potentials in this field is based on nanostructured TiO_2. Their application is closely related to their electrical, chemical and optical properties and depends on the TiO_2 crystal structure. TiO_2 crystallizes into three different polymorphs: anatase, rutile, and brookite. Rutile is generally considered to be the thermodynamically most stable bulk phase. Beside crystal structure and chemical composition, it has been established that, in order to achieve a maximum overall material's efficiency, it is crucial to maximizing the specific surface area of the material (which is, for example, obvious for any catalytic reaction). By diminishing dimensions to the nanoscale, not only the specific surface area increases significantly, but also the electronic properties may change considerably (owing for example to quantum size effects, a strong contribution of surface reconstruction, or surface curvature). These effects may also drastically improve the reaction/interaction between the material and the surrounding media, thereby making the system more effective or even allow entirely novel reaction pathways. For all nanomaterials, dimension-dependent and surface phenomena become more important compared to bulk phenomena, while quantum effects change the way how nanosystems work [1, 2]. A lot of methods were developed for fabrication nanoscale TiO_2. It has been established that by varying of processing parameters it is possible to obtain different dimensionality of TiO_2 based nanomaterials, such as 0D (nanoparticles and spheres), 1D (nanofibers, nanotubes and nanorods), 2D (sheet) and 3D (interconnected architecture). All these structural morphologies have certain advantages, for example, nanoparticles have the higher specific surface area, nanotubes and nanorods less charge carrier recombination, while sheets have a smooth surface and interconnected architectures have high carrier mobility [3]. Taking into account that 0D and 1D TiO_2 nanomaterials have great potential in agro and food industries, in this article TiO_2 nanoparticles and nanotubes fabrication perspectives and applications, have been analyzed.

2. FABRICATION OF NANOSTRUCTURED TIO_2 BASED MATERIALS

TiO_2 nanoparticles have all three dimensions under 100 nm and due to that specific surface state drastically increase, while pore volume and pore size rise up. Although a lot of techniques for synthesis of TiO_2 nanoparticles were developed, the most used are a sol-gel and hydrothermal method. In sol-gel method, in order to obtain TiO_2 nanoparticles, titanium precursor (Ti-alkoxides) and solvent with addition of water, acid or base are used to form a sol. After drying sol transfers into a gel, and the organic precursor is removed by calcination on a high temperature, forming nanoparticles at the end. By controlling composition, pH and temperature of the solution, it is possible to control size and morphology of the particles [4]. Synthesis of the monodispersed and highly homogenous TiO_2 nanoparticles is possible by using hydrothermal method in autoclave as well. Beside titanium precursor and water, in this method, it is necessary to use mineralizer such as NaOH, KOH, HNO_3, HCl, HCOOH, H_2SO_4. In order to obtain desired morphology, a lot of parameters which influence this type of synthesis: temperature, pressure, duration, pH of solution and solvent type, should be controlled [4]. Nanocrystalline TiO_2 can be also obtained by mechanical milling of Ti and CuO in a planetary ball mill with stainless steel balls. Using this process, it is possible to synthesize TiO_2 nanopowder with an average particle diameter less than 50 nm after 4 h of milling and powder with an average particle diameter under 20 nm after 12 h of milling [5]. More recently, TiO_2 nanoparticles and nanorods were prepared by using micelle templates of appropriate surfactants above their critical micelle concentration (the surfactant molecules aggregate and disperse in a liquid to give so-called spherical or rod-like micelles, which are used as a template for TiO_2 preparation). In this approach, nanotube formation is mostly carried out using water containing reverse micelles with a cylindrical exterior surface [6].

The hydrothermal method can be used to synthesize not only TiO_2 nanoparticles but nanotubes as well [7]. Because this method is template free, nanotubes form loose agglomerates and bundles. In order to obtain nanotubes on a substrate, Maiyalagan et al. [8] used alumina membrane as a template for the formation of TiO_2 nanotubes. At first, the template was dipped in a solution of Ti(IV)-isopropoxide and 2-propanol for a 2 min. For removing excess of solution, the vacuum was applied on the back side of the membrane. Then samples were dried at 30 °C and annealed at 600 °C. Finally, the template was removed by immersing each sample in 3M solution of NaOH and rising it with DI water. But one of the easiest and template-free methods for obtaining TiO_2 nanotubes (NTs) perpendicular to the substrate is electrochemical oxidative anodization. Although electrochemical anodization of the suitable metals has been conducted for almost a century for the creation of protective or decorative oxide layers on metal surfaces, self-organized oxide nanotube layers or ordered nanopore assembly have only recently been fabricated. It has been shown that TiO_2 NTAs, fabricated by anodic oxidation of Ti, have excellent biocompatibility, large surface area, good uniformity, and conformability over large areas and constitute a promising platform for protein and biomolecule immobilization and biosensing applications [9].

This process is generally carried out on a two-electrode configuration (Fig. 1). In general, the morphology and structure of the porous layers are affected by the electrochemical conditions, especially the anodizing voltage and solution parameters including the electrolyte composition, pH, and water content (Fig. 2) [10]

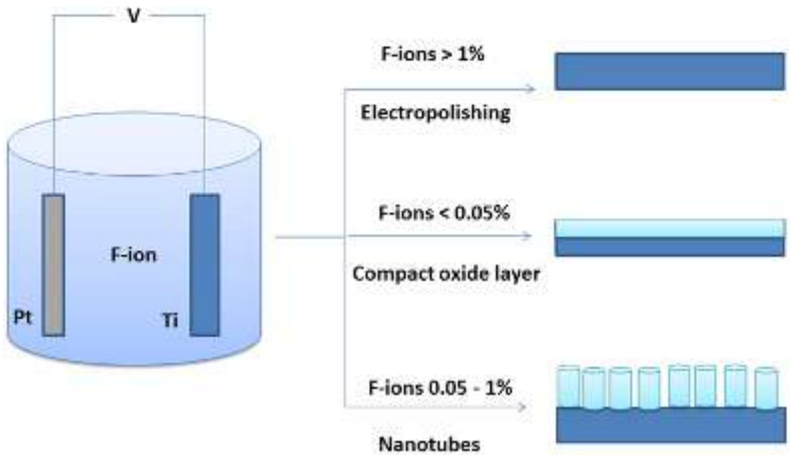

Fig. 1. Schematic illustration of set-up for anodization (left part of image) and influence of concentration F^{-}ion in electrolyte on formation oxide layer (right part of image).

It should be noticed that various advanced modifications in the tube geometry can be achieved by changing the anodization voltage during the tube growing process, and some examples are shown in Fig. 3. It has been established that the nanotubes produced in an aqueous electrolyte usually have a rough external surface and rings (ripples) on the walls because of current oscillation during anodization [11].

The as-anodized TiO_2 nanotubes are generally amorphous and the conductivity of native TiO_2 is very low, thus hampering many applications. Therefore, in recent years, many studies have focused on the modification of TiO_2 nanotubes to improve the electrical, chemical, and optical properties. The common modification methods include: (1) thermal treatment, (2) doping, (3) decoration or filling of TiO_2 NTs with other species, and (4) conversion of TiO_2 nanotubes into nanoporous $MTiO_3$ (M = Ba, Sr, Ca, Pb, Zn, etc.) or perovskite nanotubes [12].

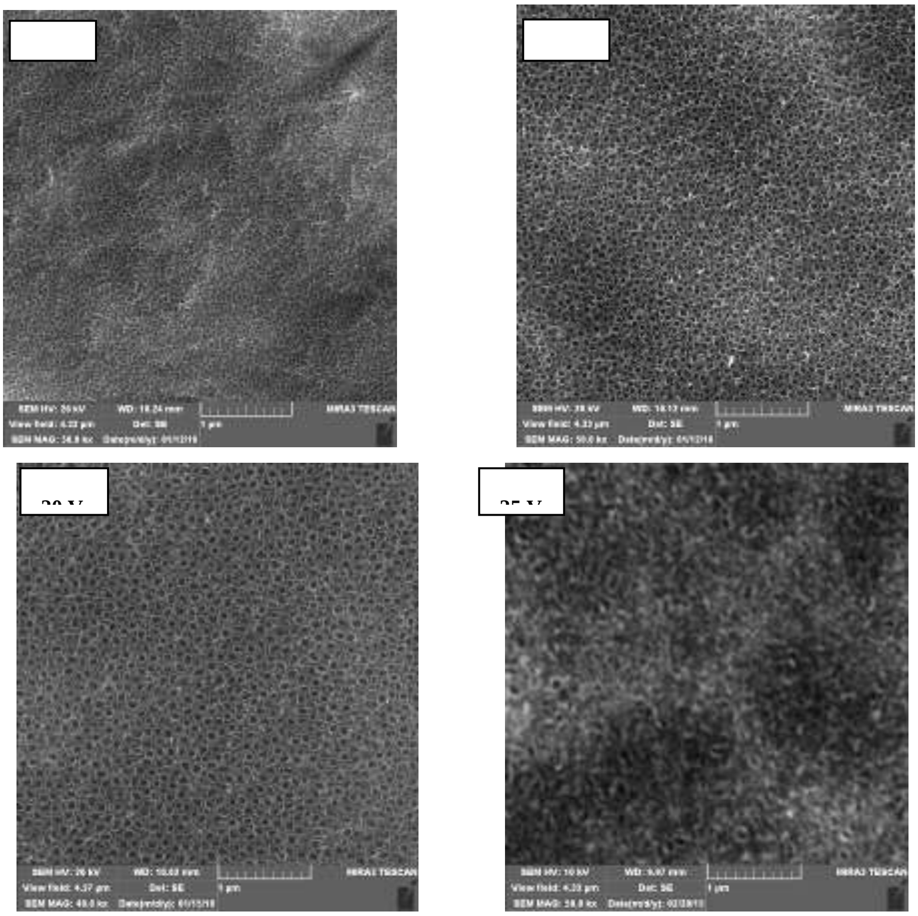

Fig. 2. SEM micrographs of influence applied voltage on diameter of nanotubes TiO_2.

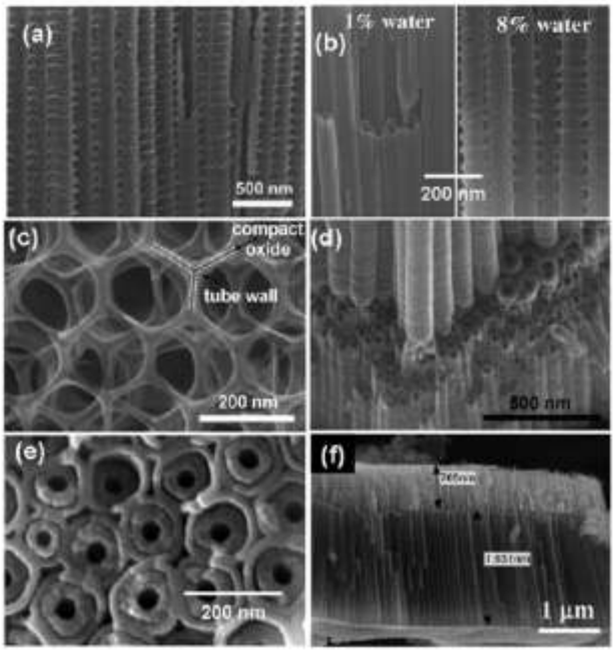

Fig. 3. Advanced TiO_2 nanotube morphologies: a) Bamboo nanotubes fabricated by alternating voltage anodization, b) smooth to bamboo-tube transition induced by variation of H_2O content in the electrolyte, c) nanolace, d) branched nanotubes by voltage stepping, e) double-walled nanotubes, f) amphiphilic double-layer tubes [11].

It is generally accepted that amorphous TiO_2 nanotubes can be fully converted into anatase TiO_2 nanotubes by using thermal treatment, at 450 °C. When the annealing temperature is higher than 500 °C, anatase and rutile phase of TiO_2 coexist. In order to improve the electrical, chemical, and optical properties of these materials, another method for modification of TiO_2 nanotubes can be used, including doping and decoration or filling of TiO_2 nanotubes with other materials. Asahi et al. reported that N-doped TiO_2 exhibited improved photoelectrochemical reactivity under visible light illumination [13]. Subsequently, other non-metals such as C, B, S, and P [14] and metals such as V, Cr, and Fe have been incorporated into TiO_2 [15]. These doped TiO_2 nanotubes usually exhibit enhanced visible light absorption and photoelectrochemical conversion efficiency or sensing performance. Typical methods for doped TiO_2 nanotubes preparation include: (1) thermal treatment of TiO_2 NTAs in a gas atmosphere containing the dopants, (2) plasma ion implantation or sputtering in an atmosphere with the doping species, and (3) Ti alloy anodization [16].

It should be mentioned that defined geometry (length and diameter) makes nanotube layers very interesting for membrane-type applications, such as filtration or microphotoreactors. The strategy to produce such membranes typically consists of the formation of a tube layer and its separation from the substrate which is followed by opening the tube bottoms. The atypical free-standing membrane is shown in Figure 4.

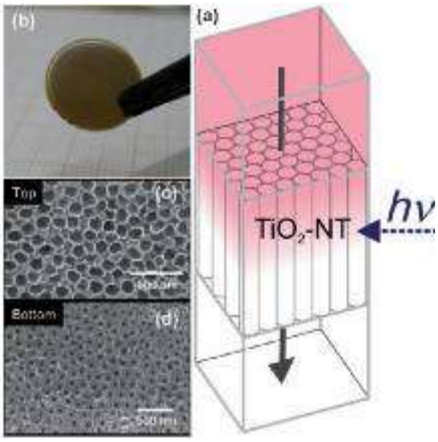

Fig. 4. TiO_2 nanotube freestanding membrane fabricated by anodization: a) flow through a membrane, b) optical image of membrane, c) SEM micrographs of membrane, top and bottom side [11].

3. NANOSTRUCTURED TiO_2 APPLICATIONS

Nanostructured TiO_2 can be used in numerous fields of agriculture, including pesticide decomposition, due to their photocatalytic properties. In the photocatalytic oxidation process, pesticides are destroyed in the presence of TiO_2 photocatalysts and a UV light source (Fig. 5).

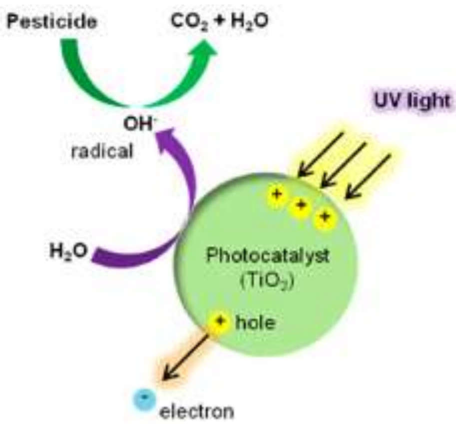

Fig. 5. Scheme of photocatalytic mechanism for pesticide degradation [19].

It was reported that a photocatalytic degradation of chlortoluron and cyproconazole pesticides on TiO_2-coated media is effective in degrading and mineralizing of pesticides

[17]. Furthermore Cedric et al. investigated the influence of TiO_2 nanotubes length on the degradation of paraquat in water. They found out that longer tubes have thinner walls and absorb on a longer distance, so pollutant has to diffuse longer, while for shorter tubes pollutant diffusion is ineffective. They reported that optimal length for photocatalysis is 7 μm [18]. Several approaches have been developed to improve the photocatalytic activity of TiO_2 nanomaterials for a wide range of applications. One effective method for improving the performance of TiO_2 nanomaterials is to increase their optical activity by shifting the response onset from the UV to the visible region by doping the TiO_2 nanomaterial with different metals or other elements.

Under light, TiO_2 nanomaterials can generate superoxide ion and hydroxyl radicals. Since it has been found that these active oxygen species are effective antimicrobial agents, the TiO_2 photocatalyst technique has a potential for crop disease control as well. Numerous investigations showed that photochemical disinfection of plant pathogens using TiO_2 thin films may offer an alternative method to conventional bactericidal methods that are used to protect plants against pathogens by applying chemical pesticides to the irrigation water. Furthermore, TiO_2 nanomaterials can be used as efficient eco-materials for water purification and heavy metal sorption. In this photocatalysis process, reactive species can be formed on the surface of a nano-TiO_2 photocatalyst that is exposed to UV radiation [19]. The complete degradation and mineralization of a large variety of organic contaminants can be achieved in most cases. TiO_2 nanoparticles have potential to be used for reducing metal uptake by agricultural crops as well. In order to minimize bioaccumulation of lead in rice, F.Cai et al. used four types of TiO_2 nanoparticles: anatase (NAnT), rutile (NRuT), rutile with a hydrophilic group (NLRuT) and hydrophobic group (NBRuT), and bulk TiO_2 (BT). Due to high sorption of NAnT, NRuT and NLRuT for Pb, it was observed that lead concentration decreases by 80% in root and by 77-97 % in the shoot, while NBRuT and BT reduce Pb for 45-61 % in roots and 11-38 % in shoots [20].

It has been also found that TiO_2 nanomaterials can induce active oxygen, including superoxide and hydroxide anions, in the photocatalytic process, which increases the seed stress resistance and water and oxygen intake [19]. As a result, these type of materials can be used for plant germination and growth. Hong et al. observed that after treating the spinach with rutile TiO_2, germination of the aged seeds is accelerated and its vigor increases. As a consequence, spinach grows faster and formation of chlorophyll is improved. Also, chloroplasts of spinach were treated with nanosized TiO_2 in order to protect chloroplasts from aging under light [21, 22]. It should be mentioned that although plants exposed to TiO_2 nanoparticles showed significant improvements in shoot length, root length, root area, and root nodules, they may be a possible threat to the terrestrial environment as well [23]. So far, toxicity testing of TiO_2 nanoparticles has been conducted on different levels of ecological complexity, from the cellular to the individual and the community level. Although most studies using TiO_2 nanoparticles have been performed in aqueous media, while only a few in the soil, changes in soil bacterial communities were found by Ge et al. and a reduction in total biomass and shifts in the community composition were shown [24]. Therefore, there is a great need for further investigation on how nanostructured TiO_2 based materials can be present in complex media, namely wheat roots, grains and the soil matrix.

Another important application of TiO_2 nanomaterials is their use for pesticide residue detection. In this field, there is an increasing interest in developing systems to sense, monitor, and remove pesticide residues, because they are toxic even at trace levels and because current pesticide detection methods based on liquid or gas chromatography coupled with mass spectrometric detection (HPLC-MS and GC-MS) require meticulous sample preparation and highly qualified technicians. Recently nano-TiO_2 semiconductors, which are efficient sorbents for enriching and detecting pesticides, have attracted significant attention in the photocatalytic and photoelectrochemical area, not only due to their nontoxicity, hydrophilicity, availability, and stability against photocorrosion, but also because of their high sensitivity, low detection limits and high selectivity [25, 26].

4. Conclusion

Future development of agro and food industries will benefit from advances of nanotechnology and nanomaterials development by increasing of soil fertility, improving crop quality and production and development of advanced multifunctional eco-materials for detection and degradation of various contaminants. In this review, we have shown potentials of nanostructured TiO_2 based materials for agricultural applications. The continuous breakthroughs in the fabrication and modifications of nanostructured TiO_2 have resulted in new properties and new agricultural applications including pesticide degradation, plant germination and growth, crop disease control, water purification, and pesticide residue detection.

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STATE OF THE EUROPEAN MARKET OF TOWED AGRICULTURAL VEHICLES AND MACHINERY

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Abstract. *Trailed machinery and transporters with various types of suspension account for a large proportion of the manufacture and sale of agricultural machinery in Europe. These trailed vehicles cover a wide functional range: agricultural trailers, tanker trailers, trailed fertilisers and manure spreaders, sprayers and fodder mixing wagons. They also have many different types of suspension: tandem, tridem, sprung, rigid, steered, etc. Of the product groups under examination, those with the highest levels of sales in terms of number of units were round balers, trailed sprayers and fertiliser spreaders. There is also a substantial market in large square balers, but rather than the number of units, it is the value of machines sold that is significant.*

Key words: *trailer, agricultural machinery, towed machinery, suspension, market share*

1. INTRODUCTION

Trailed machinery and transporters with various types of suspension account for a large proportion of the manufacture and sale of agricultural machinery in Europe. These trailed vehicles cover a wide functional range: agricultural trailers, tanker trailers, trailed fertilisers and manure spreaders, sprayers and fodder mixing wagons. They also have many different types of suspension: tandem, tridem, sprung, rigid, steered, etc.

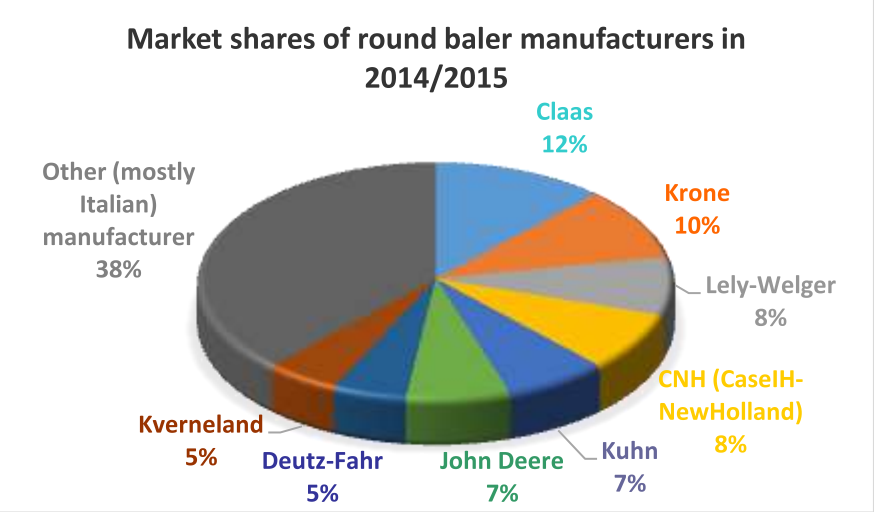
Here we present the results of systematically data collection and analysis regarding our survey of the European market of towed agricultural vehicles and machinery.

2. RESULTS AND DISCUSSION

2.1. Determination of the market shares of major manufacturers by product category

Round balers, which come in of various constructions and sizes, are made by about 40 companies worldwide. Total annual sales vary between 30,000 and 50,000 units, but have been typically between 30,000 and 35,000 in recent years. Round balers have the common feature of being towed and driven by tractor. All have either a single-axle or – the versions combined with a bale wrapper – twin or tandem axle suspensions. The latter, owing to their weight and towing speed, which is maximised at up to 40–50 km/h, generally require braked axles.

Most round baler machinery manufacturers are based in Europe, and the largest number of units are made in Germany and Italy.



Total annual number of units sold: 35,000

Fig. 1 Market shares of round baler manufacturers

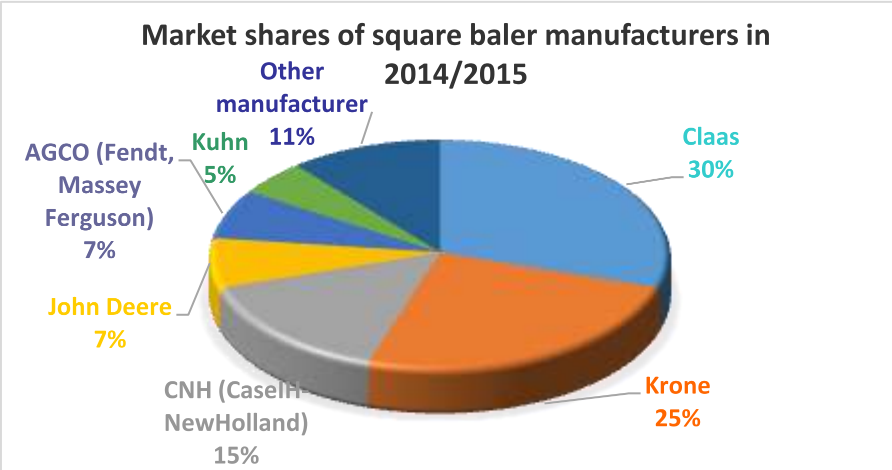
The two largest manufacturers are Claas and Krone of Germany. They produce the largest range of types and models and alternate in the position of European market leader. Other large manufacturers are the Lely-Welger (German-Dutch), the CNH Agriculture (Italian), the Kuhn (French) and the John Deere (USA). Welger filed the first patent for a fixed-chamber baler and is a dynamic manufacturer and developer within the Lely Group. CNH Agriculture engages in cooperation in the manufacture of balers. Deutz-Fahr of Germany, part of the SDF Group, also makes balers. Kverneland, owned by Kubota, sells balers from its Italian Gallignani baler manufacturing base under the names Kverneland, Vicon and Kubota. Most of the remaining manufacturers (Bergam, Ferraboli, Mascar, Maschio, Wollagri etc.) are Italian. See Figure 1.

There are considerably fewer companies – 13 or 14 worldwide – that make the more complicated **large square balers**. Europe has the greatest concentration of production, with nine manufacturers. There are about 3600 large square balers sold annually worldwide.

The design is based on a machine produced by Hesston (now part of AGCO) of the USA. The two large manufacturers, Claas and Krone, dominate the market in this product group. Claas is the outright market leader, but Krone does not lag it in the range of types and models. Another major manufacturer is CNH Agriculture, which markets several models under both of its brand names, New Holland and Case IH. John Deere recently added large square balers to its product range and is rapidly developing new models. Previously, it sold large square balers made by Krone.

Massey Ferguson has been marketing these products for some time and has recently been joined by Fendt, another AGCO brand. Kuhn also holds a 5% market share. Among the other manufacturers are Deutz-Fahr and several Italian companies, including Supertino and Cicoria. See Figure 2.

Square balers are also tractor-trailed. Depending on size, balers may have single-axle suspension or twin or tandem axle braked suspension, with balloon tyres.

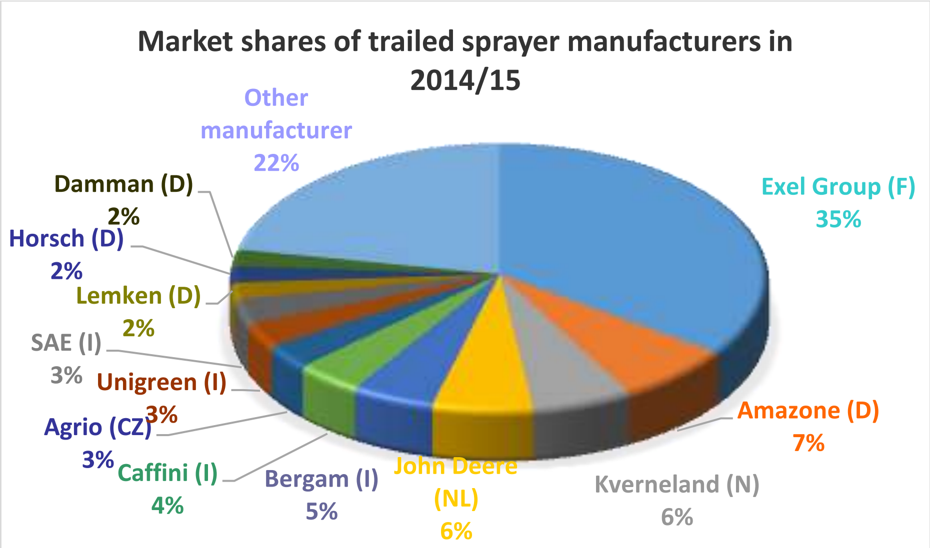


Total annual number of units sold: 3600

Fig. 2 Market shares of square baler manufacturers

Sprayers are made by more than 80 companies worldwide. They are made in a wide range of constructions (suspended, liftmounted, trailed and self-propelled) and sizes.

In Europe, some 55 manufactures make sprayers (field flat and axial fan, directed nozzle, tunnel, etc.). Most of them make trailed sprayers with single and double axle suspension, with tanks ranging in size from 1000 to 12,000 litres.

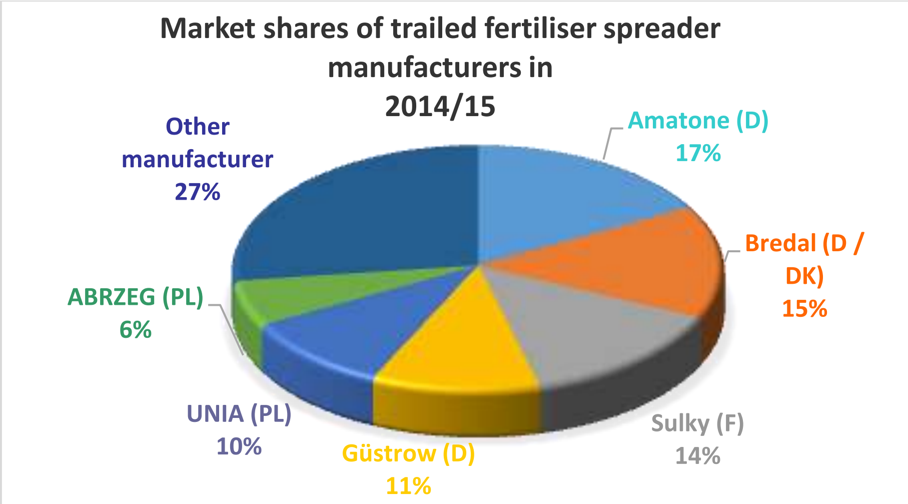


Total quantity 22,000 units/year

Fig. 3 Market shares of trailed sprayer manufacturers

Trailed and self-propelled sprayers are dominant in agriculture outside Europe (North and South America, Australia, etc.). About 22,000 trailed field and plantation sprayers are sold each year. The most widespread among European small farms are tractor-mounted sprayers of small capacities (between 400 and 1500 litres). The features of trailed sprayers are of benefit primarily to large and commercial farms and agricultural contractors. The largest worldwide manufacturer of trailed sprayers is the French Exel Group, which owns two previously independent brands, one of which – Hardi – is the clear market leader. Other large manufacturers are Amazone, the Kubota/Kverneland Group, John Deere, the Bargam Group, Caffini, Agrio, the plantation sprayer companies SAE and Unigreen, and more recently Horsch and Lemken. Damman is strong in self-propelled sprayers, but also has a presence with trailed sprayers. See Figure 3.

Fertiliser spreaders are also made in various constructions. Most widespread in Europe are tractor-mounted spinning disc types with tank capacities of between 400 and 3000 litres. Trailed spreaders, with tank capacities of between 3500 and 10,000 litres, are used mainly on large farms and are made in much smaller quantities. In large farms outside Europe, particularly in Australia, trailed fertiliser spreaders are in the majority. About 11,000 of them are sold worldwide each year. Most typically, they have a tank of between 5000 and 8000 litres capacity and single-axle braked suspension. Those with larger fertiliser tanks have braked twin or tandem axles. In Europe, Amazone of Germany is the largest manufacturer, producing trailed single-axle fertiliser spreaders of capacities between 5500 and 8200 litres. Other large manufacturers are Bredal, Güstrow and the French company Sulky, although the two Polish manufacturers UNIA and Abrzeg also have good positions on European markets. See Figure 4.



Total quantity 11,000 units/year

Fig. 4 Market shares of trailed fertiliser spreader manufacturers

2.2. Global and regional agriculture machinery market trends

There are cyclical variations in agricultural machinery manufacture. This means that the numbers of units of trailed agricultural vehicles increases in some periods and decreases in others. Agriculture is subsidised in every country of Europe. The cycles are to some extent due to the unequal effects of subsidies, but also to the periodic overproduction, cutbacks and increased demand that arise from the laws of the market.

Overall, the market in agricultural machinery contracted by 9% worldwide in 2015, as shown on Figure 5. The 91 billion-euro turnover exactly matches that of 2011. The recession is clearly perceptible.

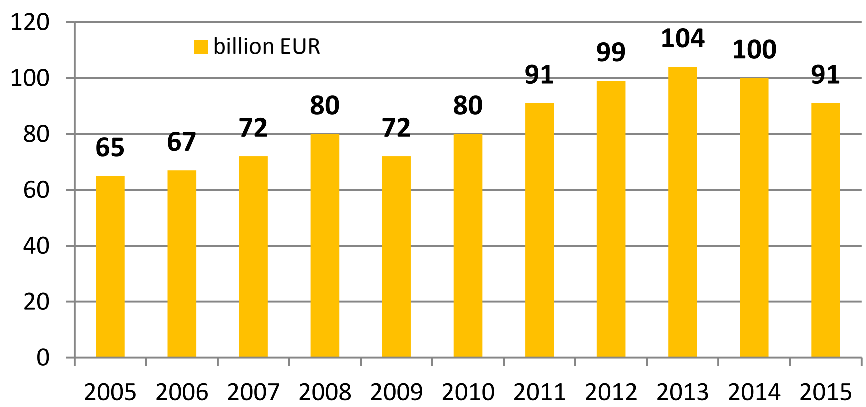


Fig. 5 World agricultural machinery turnover between 2005 and 2015. (Source: VDMA)

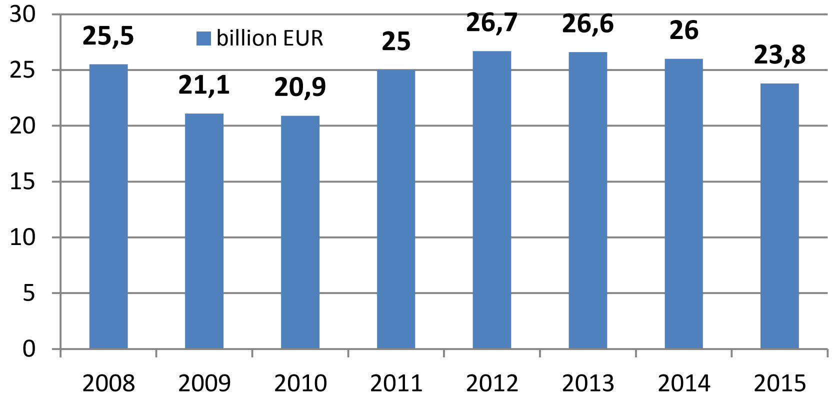


Fig. 6 Agricultural machinery turnover in EU countries between 2008 and 2015. (Source: VDMA)

There has been a steady contraction in the EU agricultural machinery market over the last two or three years. This is clear from Figure 6. In 2015, there was a decrease of 8%: the total value of agricultural machinery sales was 23.8 billion euros that year, compared with 26 billion in 2014. The peak was in the post-recession years of 2012 and 2013, when the EU agricultural machinery market swelled to 26.6 and 26.7 billion euros respectively. The figure for 2015 was the lowest for the EU in the period following the economic crisis of 2009–2010.

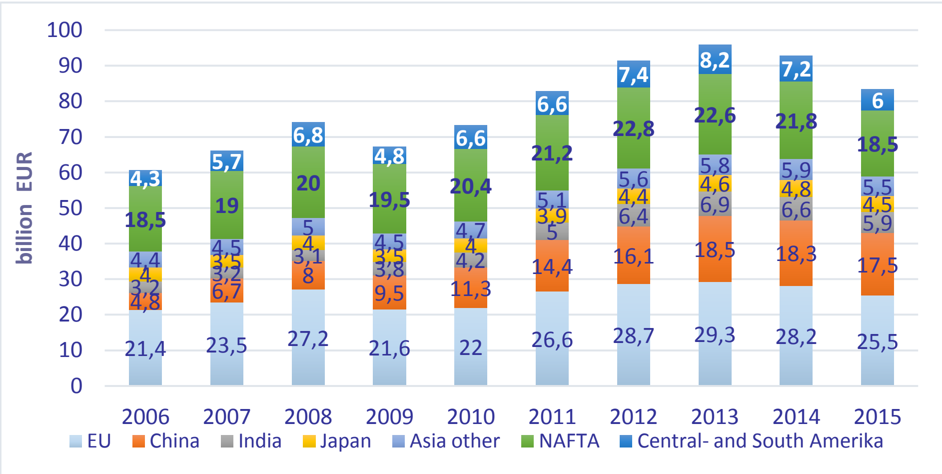


Fig. 7 Agricultural machinery manufacturing volume worldwide in billion euros (Source: German Mechanical Engineering Industry Association, VDMA, Agricultural Machinery Section)

A good illustration of global trends in the agricultural machinery market is world agricultural machinery production, shown in Figure 7. Following the crisis of 2009, output grew steeply every year until 2013, it then faltered and entered a decreasing trend. There was stagnation until 2014, but preliminary figures show a major downturn in 2015.

This global trend appears with some phase lag in countries such as Japan and the Asian countries (not including India and China). There, machinery manufacturing reached its peak in 2014 and started to go down only in 2015. Low world price levels are currently being forecast for agricultural commodities, and it can only be hoped that the machinery manufacturing output and the agricultural machinery market, now sunk to 2011 levels, will now stabilise.

4. CONCLUSIONS

The purpose of our analysis was to determine the European market shares of towed agricultural vehicles and machinery.

Of the product groups under examination, those with the highest levels of sales in terms of number of units were round balers, trailed sprayers and fertiliser spreaders. There is also a substantial market in large square balers, but rather than the number of units, it is the value of machines sold that is significant.

The market for agricultural trailers and machinery built on trailer superstructures is highly diverse and complex, posing serious difficulties for evaluation and statistical analysis of the data and for determination of actual sales figures.

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COMPARABLE VALUATION OF THE AGRI-FOOD AND OTHER MANUFACTURAL SECTORS IN N. GREECE AND S. BULGARIA - THE ENERGY CONTRIBUTION TO THE IMPROVEMENT OF THEIR ENVIRONMENTAL CONDITION AND SUSTAINABILITY

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Abstract. *For the comparable valuation of the manufactural activities between the examined regions and sectors, methods of statistical analysis are used to define significant differences in terms of competitiveness, environmental load, sustainability and eco-productivity. The data were obtained from manufacturing industries (Small and Medium Enterprises) operating in Northern Greece and South Bulgaria. The statistical analysis is based on available emergy indices produced after an emergy analysis. The results derived after the statistical analysis show that: (a) no statistical differences were found between the manufacturing sectors examined, (b) the competitiveness of the manufacturing sector in Bulgaria significantly surpass that of Northern Greece, under the current conditions in terms of labor and services compensation, (c) an elasticity of the environmental consciousness exists in Bulgaria in contrast to that of Northern Greece, (d) the low labor compensation does not lend any significant superiority to Bulgaria in terms of the sustainability of its manufacturing industry, (e) from the eco-productivity statistical analysis become clear that the three main production factors, the labor, capital and energy, are better exploited in Northern Greece than in Bulgaria Finally, proposals for further research work are suggested, since the results of this investigation are used to propose scenarios for a better management of the available energy sources, renewable and non-renewable as well as for the improvement of environmental conditions and the increase of the sustainability of the examined manufacturing sectors.*

Key words: *Emergy indices, Competitiveness, Environmental load, Sustainability, Eco-productivity*

1. INTRODUCTION

In European Union, the globalization was accompanied by a reinstallation of many productive and innovative activities in countries of low labor cost [1]. For the abovementioned reason this investigation was based on the move of several industrial and enterprising activities in Greek borderlands, such as the Central Macedonia region and East Macedonia-Thrace, in Greece as well as the nearby regions of neighboring countries, such as Bulgaria, which already belongs to the European Union. For example, the presence of the secondary sector of production in the region of Central Macedonia and especially in Thessaloniki it appears to be very beneficial, since it contributes to about 30% of the GNP (Gross National Product) and 20% of the Gross Added Value of Greece. The choice of the neighboring regions of Greece and Bulgaria appears to have a special interest for the comparable evaluation of agri-food and other manufacturing activities, due to many similarities and differences, which characterize them. The investigated industries are SMEs (Small and Medium Enterprises), which operate in two regions of Northern Greece as well as in two regions of South Bulgaria, during the year 2011. These regions are:

a. Northern Greece: i. The region of Central Macedonia: including the areas of Thessaloniki, Pieria, Kilkis and Serres. ii. The region of Eastern Macedonia-Thrace: including the areas of Drama, Kavala, Xanthi, Rodopi and Evros.

b. South Bulgaria: i. The region of Blagoevgrad. ii The region of Kardjali. These two regions are examined as one, due to the common characteristics they appear.

The above regions are characterized by the fact that (i) they include a complicated network of energy, materials and information and (ii) they depend upon the sources and services, which are offered by their biosphere similarly to natural ecosystems. For these reasons the emergy analysis produce a proper way to evaluate the total eco-productivity of each one of the regions examined [2]. The raw data referred to the examined manufacturing industries were collected from several manufacturing industries from Northern Greece and Bulgaria. All these data derived as a product of an investigation and a detailed audits analysis for the needs of a project entitled "Cross Border Implementation of Innovative Cost Cutting Technologies-CROSSINNOCUT", as a part of which the present work can be considered. The examined manufacturing industries are mainly activated in the following sectors: Food/Drinks, Metals/Wood, Chemical/Plastics, Fabric/Clothing, Electric/Electronics, Building materials & machinery. A percentage of about 90% of the total number of those industries belong to very small industries with a number of personnel below 10 persons. From the above industries, 30 belong to the region of C. Macedonia, 20 to E. Macedonia-Thrace and 16 to the regions of S. Bulgaria.

2. MATERIALS AND METHODS

Emergy analysis was introduced by H. T. Odum [3] and it is used in this investigation as a modern and holistic method (Fig. 1), to investigate the effect of renewable, non-renewable and financial inputs as well as the waste financial output produced on the sustainability of manufacturing industries. Emergy analysis offers the possibility of linking the utility that can occur in an industrial activity, since energy and environmental management are applied, in a way, which can make clear the advantage gained by "environmentally conscious enterprises", such as the food industries because these industries have interesting similarities with the natural ecosystems [4]. This is due to the fact, that both systems make use of energy and raw materials and they transform them into products and wastes [5].

The quantitative primary data were collected and classified in two ways: a. according to the region and b. according to the sector of activity, under the condition that the number of enterprises in any case is above five. The primary data used in the emergy analysis of the examined and compared industries are related to:

- The renewable inputs (R)
- The non renewable inputs (N), (electricity(N_1), Oil (N_2), LPG (N_3) and Natural Gas (N_4)
- Financial inputs (F), (labor cost (F_1), service and maintenance cost (F_2), cost of market inputs (F_3) and waste treatment cost (F_4)
- Polluting gas emissions (W_1) and waste production (W_2)
- Annual turnover (T)

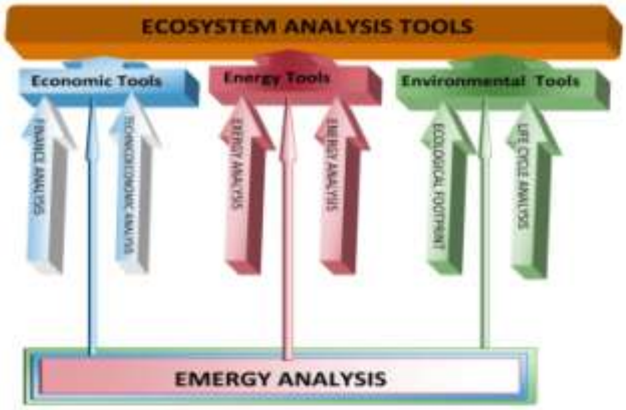


Fig. 1 Schematic diagram of the main ecosystems' analysis diagnostic tools [6].

The emergy analysis is based on the calculation of the emergy indices: (a) EYR: Emergy Yield Ratio (competitiveness), (b) ELR: Environmental Load Ratio (environmental impact), (c) EIS: Emergy Index of Sustainability (the average degree of sustainability) and the Emergy eco-Productivity Index (EPI), which expresses the influence of the monetary, non-monetary and renewable inputs, in the final economic product. The results of the above indices calculations are used as the data in this work. These emergy indices, as given by a research work of Martzopoulou, A. [4] are shown in Tables 1, 2 and 3. The comparable evaluation and the finding of significant differences of the examined sectors between and within the regions were based on the following statistical analyses:

1. Calculation of the regression equation and the coefficient of determination of the emergy indices versus the annual turnover for the industrial sectors activated in each of the regions examined.

2. Analyses of Variance (ANOVA) to define significant differences between the main five manufacturing sectors examined, in terms of competitiveness, environmental distress, Sustainability and eco-productivity, for probability value $p<0.05$.

3. Analysis of Variance (ANOVA) to define significant differences between the three regions examined, in terms of competitiveness, environmental distress, Sustainability and eco-productivity, value $p<0.05$.

4. All the above Analyses of Variance are also repeated without the influence of the services (maintenance and marketing expenses) and labor costs.

The afore-mentioned statistical analyses are used to derive conclusions referring to (a) the diversification between the regions as well the industrial sectors of the SMEs examined, and (b) the influence of the geographical regions, according to their local financial policies exercised.

Table 1 Emergy indices of Central Macedonia calculated with and without the cost of labor and services [4].

	SMEs categories	EYR	EYR_{-LS}	ELR	ELR_{-LS}	EIS	EIS_{-LS}	EPI	EPI_{LS}
1	Food/drinks1	1,193	1,553	1,233	1,691	0,918	0,918	0,784	1.732
2	Food/drinks 2	1,178	2,238	1,206	2,550	0,878	0,977	1,393	5.115
3	Food/drinks3	1,022	1,045	1,027	1,054	0,991	0,996	1,266	2.490
4	Food/drinks4	1,086	1,187	1,101	1,221	0,972	0,987	1,037	2,068
5	Food/drinks5	1,025	1,044	1,031	1,052	0,995	0,992	0,845	1,422
6	Food/drinks 6	1,057	1,074	1,064	1,084	0,993	0,991	0,953	1,225
7	Food/drinks7	1,063	1,118	1,075	1,142	0,988	0,979	1,362	2,434
8	Food/drinks 8	1,150	1,225	1,182	1,275	0,973	0,961	1,214	1,722
9	Fabric/Clothing 1	1,158	1,437	1,148	1,408	1,008	1,020	1,307	2,961
10	Fabric/Clothing 2	1,076	1,171	1,086	1,195	0,991	0,980	1,681	3,483
11	Metals/Wood 1	1,032	1,039	1,039	1,048	0,993	0,992	0,990	1,198
12	Metals/Wood 2	1,223	1,454	1,276	1,574	0,959	0,923	1,115	1,912
13	Metals/Wood 3	1,028	1,075	1,034	1,092	0,994	0,985	1,225	3,113
14	Metals/Wood 4	1,017	1,042	1,024	1,059	0,993	0,984	0,962	2,306
15	Metals/Wood 5	1,106	1,280	1,121	1,322	0,987	0,968	2,148	4,935
16	Metals/Wood 6	0,912	0,841	1,898	3,800	0,481	0,221	0,871	1,721
17	Metals/Wood 7	1,090	1,1340	1,109	1,421	0,983	0,943	0,563	1,728
18	Metals/Wood 8	1,024	1,032	1,030	1,040	0,995	0,993	0,979	1,304
19	Metals/Wood 9	1,129	1,176	1,160	1,219	0,974	0,965	0,991	1,297
20	Metals/Wood 10	1,014	1,020	1,031	1,046	0,983	0,976	1,086	1,599
21	Electric/Electronic 1	1,020	1,030	1,023	1,035	0,997	0,995	0,960	1,405
22	Electric/Electronic 2	1,091	1,753	1,110	1,985	0,982	0,883	1,323	6,845
23	Chemical/Plastics 1	1,030	1,042	1,036	1,050	0,994	0,992	0,943	1,316
24	Chemical/Plastics 2	1,473	2,129	1,542	2,345	0,995	0,908	0,780	1,322
25	Chemical/Plastics 3	1,003	1,005	1,003	1,005	1,000	1,000	1,219	1,898
26	Chemical/Plastics 4	1,003	1,003	1,003	1,004	1,000	0,999	1,123	1,253
27	Chemical/Plastics 5	1,004	1,005	1,035	1,041	0,970	0,965	1,159	1,366
28	Chemical/Plastics 6	1,022	1,079	1,010	1,034	1,012	1,043	0,883	3,076
29	Chemical/Plastics 7	1,013	1,017	1,014	1,019	0,998	0,998	1,261	1,662
30	Creative/Printing	1,141	1,468	1,174	1,598	0,972	0,918	0,809	2,083

Table 2 Emergy indices of East Macedonia-Thrace calculated with and without the cost of labor and services [4].

	SMEs categories	EYR	EYR_{-LS}	ELR	ELR_{-LS}	EIS	EIS_{-LS}	EPI	EPI_{LS}
1	Food/drinks19	1,078	1,098	1,093	1,117	0,986	0,983	1,121	1,382
2	Food/drinks110	1,009	1,012	1,036	1,047	0,974	0,966	0,914	1,187
3	Food/drinks111	1,146	1,179	1,145	1,177	1,001	1,001	0,967	1,153
4	Food/drinks112	1,081	1,118	1,096	1,139	0,981	0,981	0,881	1,233
5	Food/drinks113	1,474	1,668	1,599	1,864	0,972	0,895	0,563	0,701
6	Food/drinks114	1,205	1,362	1,253	1,454	0,962	0,936	1,831	2,857
7	Food/drinks115	1,036	1,053	1,037	1,054	0,999	0,999	1,707	2,451
8	Food/drinks116	1,045	1,073	1,047	1,077	0,998	0,997	0,748	1,180
9	Metals/Wood 11	1,132	1,438	1,152	1,514	0,983	0,950	1,069	2,874
10	Metals/Wood 12	1,062	1,092	1,076	1,113	0,987	0,981	1,049	1,515
11	Metals/Wood 13	1,001	1,001	1,424	1,514	0,703	0,661	1,265	1,478
12	Metals/Wood 14	1,038	1,068	1,042	1,076	0,996	0,993	1,031	1,809
13	Metals/Wood 15	0,972	0,947	1,104	1,214	0,881	0,780	0,777	1,542
14	Metals/Wood 16	1,528	2,045	1,622	2,279	0,942	0,897	1,784	2,639
15	Electric/Electronics	1,035	1,176	1,043	1,220	0,992	0,964	1,252	5,584
16	Electric/Electronics	1,088	1,094	1,107	1,114	0,983	0,982	0,800	0,848
17	Chemical/Plastics 8	1,897	2,971	1,923	3,050	0,987	0,974	1,625	2,281
18	Building materials	1,847	2,915	2,021	3,499	0,914	0,833	0,294	0,422
19	Car repair	0,996	0,994	1,027	1,045	0,970	0,951	0,887	1,441
20	Tire retreading	1,464	1,956	1,598	2,306	0,916	0,848	0,455	0,701

Table 3 Emergy indices of South Bulgaria calculated with and without the cost of labor and services [4].

	SMEs categories	EYR	EYR_{-LS}	ELR	ELR_{-LS}	EIS	EIS_{-LS}	EPI	EPI_{LS}
1	Food/drinks117	1,338	1,516	1,424	1,659	0,940	0,913	0,936	1,261
2	Food/drinks118	1,671	1,769	1,845	1,978	0,906	0,894	0,738	0,799
3	Food/drinks119	1,163	1,227	1,196	1,277	0,972	0,961	0,966	1,280
4	Fabric/Clothing 3	1,446	1,522	1,567	1,668	0,923	0,912	0,646	0,718
5	Fabric/Clothing 4	1,151	1,163	1,186	1,201	0,971	0,968	0,837	0,897
6	Fabric/Clothing 5	1,175	1,205	1,193	1,226	0,985	0,983	0,883	1,006
7	Fabric/Clothing 6	1,149	1,299	1,169	1,346	0,983	0,965	0,806	1,432
8	Fabric/Clothing 7	1,123	1,247	1,142	1,289	0,983	0,967	0,832	1,501
9	Fabric/Clothing 8	1,207	1,409	1,240	1,486	0,973	0,948	0,774	1,312
10	Fabric/Clothing 9	1,121	1,645	1,144	1,818	0,979	0,905	0,654	2,383
11	Metal/timber 17	1,050	1,108	1,054	1,117	0,996	0,992	0,985	2,008
12	Metal/timber 18	1,122	1,202	1,149	1,249	0,976	0,962	0,860	1,328
13	Metal/timber 19	1,029	1,058	1,342	1,795	0,767	0,589	0,838	1,603
14	Electric/Electronics	1,252	1,572	1,307	1,717	0,958	0,916	0,747	1,349
15	Building materials 2	3,280	3,596	4,721	5,446	0,695	0,660	0,364	0,378
16	Mushrooms	1,322	1,531	2,759	5,859	0,479	0,261	0,371	0,528

3. RESULTS AND DISCUSSION

3.1. The influence of the total inputs to the annual turnover of the SMEs in each region

The measurements of the non-renewable and renewable energy, labor, services, market, waste management emergy flows were compared with the gross annual income of the SMEs, separately for each region. The assessments derived after the regressions show a very close linear relation between the emergy flows and the gross annual turnover, for the three regions. The calculated high values of the coefficient of determination conclude this relation. The regression equations and the corresponding coefficients of determination are shown in Figures 2, 3 and 4. The three regressions, found to have almost same slopes, which means that inputs are almost equally exploited in the three regions.

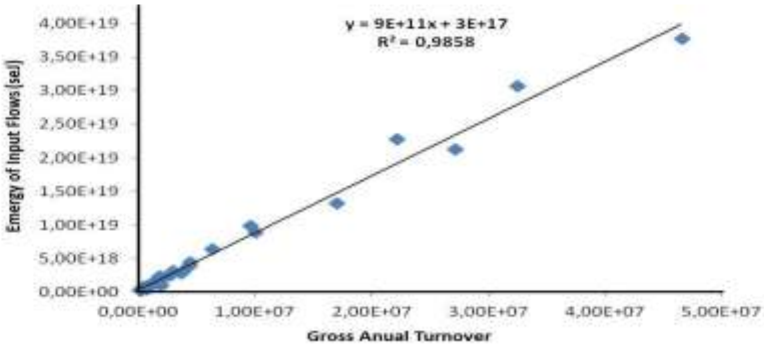


Fig. 2 Annual turnover vs. Emergy flows in the region of Cenrtal Macedonia

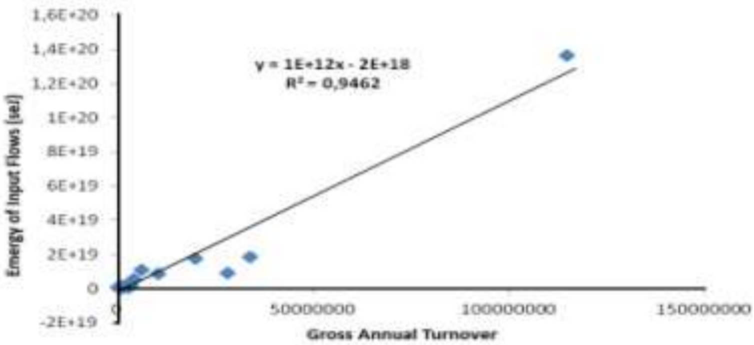


Fig. 3 Annual turnover vs. Emergy flows in the region of East Macedonia-Thrace

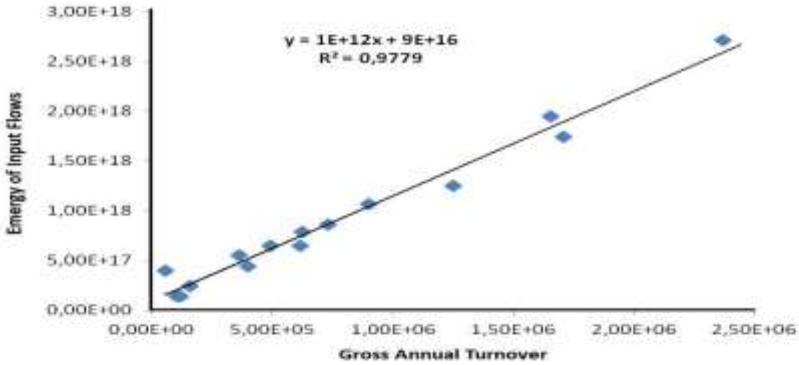


Fig. 4 Annual turnover vs. Emergy flows in the region of South Bulgaria

3.2. Comparable evaluation of the industrial groups by sector

The five more important out of the six manufacturing sectors, mentioned in the introduction and operating within the three regions, are evaluated and compared. These five sectors are the Food/Drinks, Metals/Wood, Chemical/Plastics, Fabric/Clothing, Electric/Electronics. For this reason, the ANOVA executed to find significant differences between the sectors shows the absence of any significant difference, either taking into account labor and services costs or not. However, emergy indices mean values of each for the five sectors with and without accounting the afore-mentioned costs are used for a simple comparison of the industrial groups by sector (Table 4).

Table 4 The mean emergy index values of competitiveness with (EYR) and without the services and labor costs (EYR-SL)

Index	Food/Drinks	Fabric/Cloths	Metal/Wood	Chemical/Plastics	Electric/Electronics
EYR	1.1341	1.1764	1.0794	1.1606	1.0972
EYR-LS	1.2765	1.3442	1.1715	1.4064	1.3250
ELR	1.1642	1.2063	1.1941	1.1958	1.1180
ELR-LS	1.4037	1.4041	1.4469	1.4440	1.4142
EIS	0.9776	0.9773	0.9249	0.9895	0.9824
EIS-LS	1.4233	1.3933	1.5641	1.4799	2.2220
EPI	0.9969	0.9356	1.0636	1.1241	1.0164
EPI-LS	1.7108	1.7437	1.9905	1.7718	3.2062

(a) **Competitiveness:** The above table (Tab. 4) appears a relative superiority of the chemical/plastics sector over the other four sectors and relative deficient of the metal/wood sector, in terms of competitiveness.

(b) **Environmental impact:** The environmental load indices (Tab. 4) present a settled high environmental pollution impact of the chemical/plastics and metal/wood sectors. In contrast, the sector of Electric/Electronics appears as the most environmentally clean sector.

(c) **Sustainability:** The sustainability index shows the sector of electric/electronics in a steadily high position and the sector of metal/wood in a relatively low position. The other three sectors appear to be affected by local conditions of labor and services costs.

(d) **Eco-productivity:** According to the mean value index in Table 4 the sectors of metals/wood and electric/electronics appeared to be in a steadily middle to high position, in terms of eco-productivity, while the sector of fabric/clothing is in a steadily low position. The other two sectors seem to be affected by local conditions of labor and services costs.

3.3. Comparable evaluation of the industrial groups by region

The following statistical analyses lead to the comparable evaluation of the influence of the region to the competitiveness, the environmental impact, sustainability and the eco-productivity of the manufacturing enterprises (SMEs) installed in each of the three regions, in two ways, (a) with the entry of labor, services, marketing and maintenance costs and (b) without them. The statistical analysis includes (i) an analysis of variance (ANOVA) to find out significant differences (Table 5), (ii) the means diagram of the variables (EYR, ELR, EIS and EPI) of the SMEs groups in each region and (iii) a post hoc analysis with use of least significant differences for 95% probability value, to specify the significant differences (Table 6) of each variable between the regions.

Table 5 ANOVA table of the significant differences of the SMEs variables between the three regions.

Depended Variable Between Regions	Sum of Squares(ss)	Degree of freedom (df)	Mean Square	F	Significance P
EYR	,765	2	,382	3,937	,024
ELR	2,259	2	1,129	4,495	,015
EPI	1,227	2	,614	5,609	,006
EPI-LS	11,672	2	5,836	4,611	,014

Table 6 The post hoc analysis table to point out the significant differences of each variable between the regions.

Depended Variable	(I) Region	(II) Region	Mean differences (I-II)	Std. Error	Sig.	Probability value P<0.05	
						Lower Bound	Upper Bound
EYR LSD	Central Macedonia	South Bulgaria	-,270504*	,096476	,007	-,46330	-,07771
ELR LSD	South Bulgaria	Centr. Macedonia	,462375*	,155171	,004	,15229	,77246
		E. Mac. & Thrace	,346125*	,168124	,044	,01016	,68209
EPI LSD	South Bulgaria	Centr.Macedonia	-,342921*	,102390	,001	-,54753	-,13831
EPI-LS LSD	Central Macedonia	South Bulgaria	1,029929*	,348283	,004	,33394	1,72592

(a) Competitiveness (EYR). The ANOVA shows significant differences (Table 4) between the regions with reference to competitiveness. The mean values of EYR and EYR-SL in each region is illustrated in Fig. 5. The post hoc analysis shows that the significant differences exist only between the manufacturing industries of Central Macedonia and South Bulgaria.

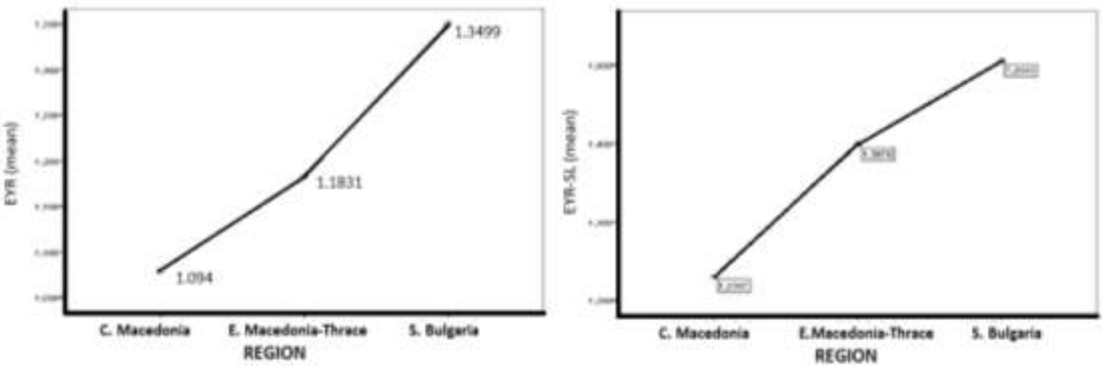


Fig. 5 Competitiveness diagram of SMEs per region with (EYR) and without the services and labor costs (EYR-SL)

However, the ANOVA in table 6 shows no significant difference in competitiveness between the regions, when the cost of labor (L) and services (S) is not accounted. The above statistical analyses show that the South Bulgarian region gains a supremacy over the Greek regions, in terms of competitiveness. Nevertheless, post hoc analysis showed significant difference only between S. Bulgaria (lowest labor-services cost) and Central Macedonia, (highest costs). On the other hand, no significant differences appear when the cost of labor (L) and services (S) is not taken into account.

(b) Environmental impact (ELR). The ANOVA shows significant differences (Table 5) between the regions with reference to environmental impact. The post hoc analysis (Table 6), showed that significant differences exist between the regions of S. Bulgaria and C. Macedonia, while a marginal existence of statistical difference appears between the S. Bulgaria and East Macedonia-Thrace, with reference to environmental impact, when labor and services are included. Also, in the ANOVA of Table 5 no significant differences appear, in the absence of services and labor costs. The mean values diagram of ELR and ELR-SL, in each region, is illustrated in Fig. 6, where it can be seen a lower environmental distress in the Greek regions compared with the S. Bulgaria.

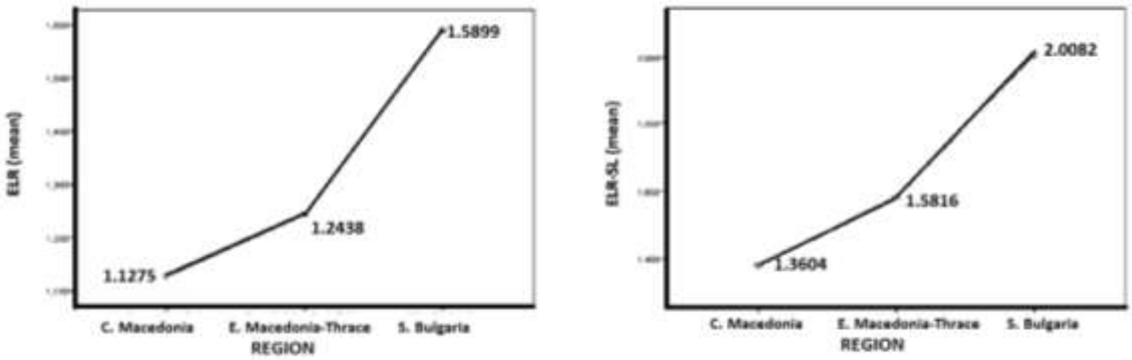


Fig. 6 Environmental load diagram of SMEs per region with (ELR) and without the services and labor costs (ELR-SL)

The above statistical analyses of ELR may conclude that a more elastic environmental consciousness exists in Bulgaria compared to Greece.

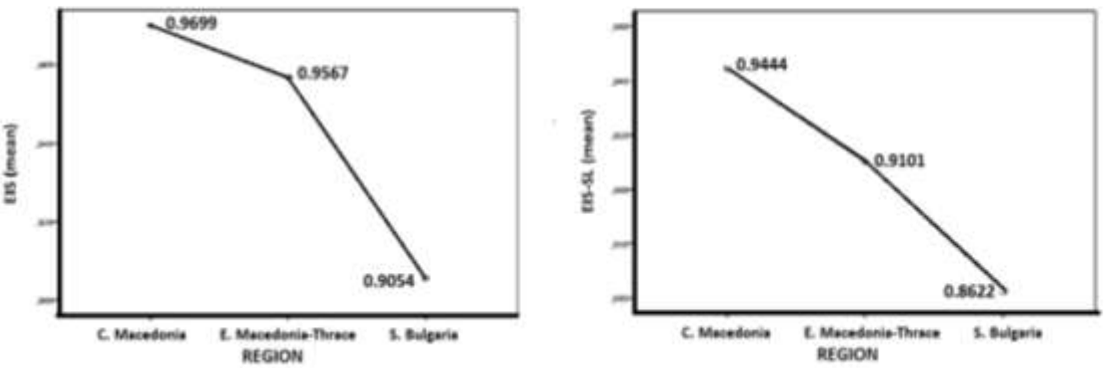
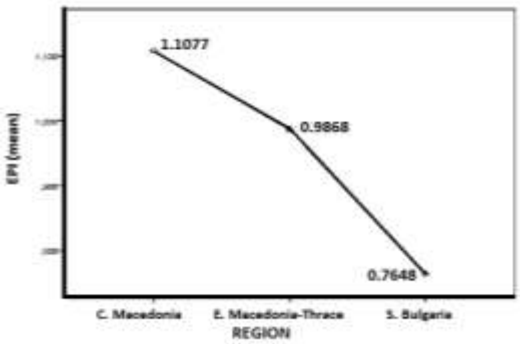


Fig. 7 Sustainability diagram of SMEs per region with (EIS) and without the services and labor costs (EIS-SL)

(c) Sustainability (EIS). The emergy index of sustainability (EIS) is a division product of the emergy index of competitiveness (EYR) by the index of environmental load (ELR). The ANOVA of the sustainability index of the three industrial groups examined, showed that no significant differences of the sustainability among the three regions exist, either accounting or not the services and labor costs (Table 5) and they are illustrated in Figure 7.

(d) Eco-productivity (EPI). The ANOVA of the emergy eco-productivity indices of the examined SMEs shows significant differences between the groups (Table 5), with and without the services and labor costs. The post hoc analysis shows that the significant differences exist only between the manufacturing industries of Central Macedonia and South Bulgaria (Table 6), either with (EPI) or without (EPI-LS) labor and services costs are accounted. The above differences are illustrated in the diagrams of Figure 8.



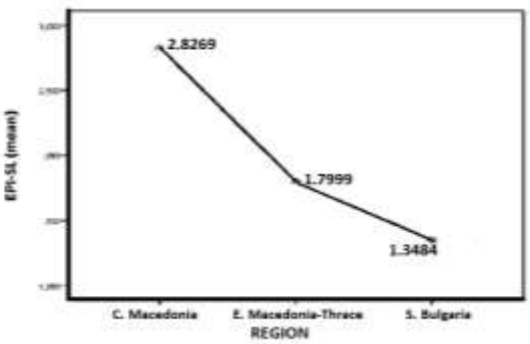


Fig. 8 Eco-productivity diagrams of SMEs per region with (EPI) and without the services and labor costs (EPI-SL).

4. CONCLUSIONS

The results of this investigation led to the following conclusions:

a. The regression analysis of the emergy index data for all the regions examined showed a similar slope and a very high coefficient of determination. These results draw the conclusion that the data used can be considered of high reliability, since the input flows proportionally affect the annual turnover.

b. The results concerning the comparison between the regions lead to the conclusion that competitivity of Bulgaria exceeds this one of Greece, mainly due to the low labor and services costs. Nevertheless, some other factors, mainly financial, related with policies exercised by each country for strengthening the industrial production, affects, also, competitiveness. For example, the percentage of the total surcharge, including taxes, fees, etc, of the operational profit in Bulgaria at 2011 was 28.10%, while in Greece was 46.80% [7] and this practice inversely affects the Greek competitiveness. On the other hand, the increasing exploitation of renewable energy sources in Greece, is expected to improve the emergy index of competitiveness (EYR). The conclusion derived from this ANOVA is absolutely aligned with the results of another investigation, according to which, a similar index of competitiveness for Bulgaria was 4.16 and for Greece 3.92, at the same year 2011 [8].

c. The results referred to the environmental distress caused by the industrial activities in the examined regions showed a significant negative picture in Bulgaria, compared with the neighboring Greek regions examined. These results were mainly due to the fact that Bulgaria, as a new member of the EU, may not fully adopted the European directives and rules for the environment. In contrast, the low environmental distress in Greece, is probably due to the severe and frequent inspections, as well as the increasing use of alternative energy sources, which contribute to the decrease of emission and environmental pollution.

d. The South Bulgarian manufacturing industries found to have no significant superiority in sustainability over the Greek ones, although the first appears with a lower labor and service cost. In contrast, the Central Macedonian manufacturing industries have the higher emergy index of sustainability, although they have the higher labor and service costs.

e. The eco-productivity statistical analysis makes clear that the three basic factors of production (labor, capital and energy) are better exploited in the two Greek regions, than in the regions of S. Bulgaria. The result of this is the achievement of higher emergy efficiency, which means higher annual turnover per emergy unit of the energy, capital and labor input, in the Greek regions, despite the Bulgarian advantage in the lower labor and services costs.

f. The comparison of the sectors examined did not show any significant difference between them in terms of competitiveness, environmental distress, sustainability and eco-productivity. However, the mean value diagrams showed a dependency of the food/drink, the fabric/cloths and the chemical/plastics sectors on local conditions, in terms of labor and services. The chemical/plastics, and metal/woods are the most pollutant sector, while the sector of electric/electronics appeared to be the most environmentally clean sector.

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Abstract. *In the present paper, the main results achieved so far by the European Project: "Skills Alliance for Sustainable Agriculture - SAGRI" are presented. SAGRI is a project financed by the Erasmus+ Programme of the European Commission aimed to give a decisive answer to the request of better trained farmers, agricultural workers and extension staff, thanks to structuring specific courses aimed to increase their knowledge, competence and skills in the field of agro-environmental technology for sustainable agriculture. Through the institution of suitable concerted and standardized study curricula and relevant teaching programmes specialized into the most recent developments of science and technology, the SAGRI Project is aimed to increase the technological level for agricultural operators. The official certification of the SAGRI courses will make agricultural operators even more employable, thanks to an enhanced mobility across EU countries, since their own competences will be recognized under the framework of the SAGRI system.*

Key words: *Sustainable agriculture; new technologies; farmer skills; study curricula; SAGRI.*

1. INTRODUCTION

In the European Union almost 50% of the territory is covered by farmland (both arable and permanent grassland), which means that agriculture plays a key role in land management, having a huge responsibility in the preservation of natural resources as well. In order to practice a sustainable agriculture, farmers responsible for the management of farmland and other agricultural operators must adopt correct and environmental-friendly practices, using appropriate technology and complying with relevant EU regulations. Recent developments in science and technology, that could be an added value for farmers' crop and land management, are still unutilized in many situations, since farmers have not been introduced to them or have not been trained to use them. "Sustainable agriculture" means therefore an integrated system of plant and animal production practices aimed to:

- Satisfy human food and fiber needs;
- Enhance environmental quality and the natural resource base for agricultural activities;
- Make an efficient use of non-renewable and on-farm resources;
- Sustain the economic viability of farm operations;
- Enhance the quality of life for farmers and society as a whole.

Recent developments in science and technology - that could be an added value for farmers' crop and land management - are however still unfortunately unutilized in many situations, since farmers have not been introduced to them or have not been trained to use them. A critical issue in the 21st century for increasing the sustainability of agricultural production is therefore constituted by the changes and adaptations required in agricultural education aimed to more effectively contribute to improve sustainable agricultural production and rural development. Poor training of agricultural extension staff has been identified as a crucial part of the problem of the relative ineffectiveness of much of extension in the field. This applies not only to extension staff, but to agricultural operators in general. Nevertheless, training of human resources in agriculture is often not a priority in the EU countries' development plans. A recent survey conducted for the European Commission revealed indeed that the majority of the farmers in Europe have received only secondary education (57%) while 15% had only primary education, 16% post-secondary (non-tertiary) education and 12% had tertiary education. Only 17% of farmers finished a basic or full training focused on agriculture-related disciplines.

In the present paper, the main results achieved so far by the European Project: "*Skills Alliance for Sustainable Agriculture* - SAGRI" [1] are presented. SAGRI is a project financed by the Erasmus+ - *Sector Skills Alliances* - Programme of the European Commission aimed to give, through a trans-national multi-actors approach, a decisive answer to the request of better trained farmers, agricultural workers and extension staff, thanks to structuring specific courses aimed to increase their knowledge, competence and skills in the field of agro-environmental technology for sustainable agriculture. Through the institution of suitable concerted and standardized study curricula and relevant teaching programmes specialized into the most recent developments of science and technology, the SAGRI Project is aimed to increase the technological level for agricultural operators. The official certification of the SAGRI courses will make agricultural operators even more employable, thanks to an enhanced mobility across EU countries, since their own competences will be recognized under the framework of the SAGRI system.

2. MATERIALS AND METHODS

The contents and relevant Learning Outcomes of the SAGRI courses result from a cross-linking approach, which connects the expectations coming from the primary sector with the most recent developments in science and technology. The first information is coming from the farmer associations which are participating into this Project, on the basis of the awareness of farmers, agricultural workers and extension staff in terms of green and digital/technological skills, while the second information is detected and focused by the Universities belonging to the SAGRI Partnership Consortium. The course contents concern:

-) Green skills. Skilled agricultural workers increasingly need to have a holistic awareness of sustainability, *i.e.*: understanding climate changing, the need for carbon emission reduction, renewable energy, biomass valorisation and biofuels, water resources and ecosystems management, integrated pest management, to be updated with new regulations and legislation.

-) Digital or technological skills. Skilled agricultural workers will need to be able to understand and apply new technologies related to: primary production for both food and non-food uses, soil science, crop and livestock genetics, agri-chemicals, precision technology and general purpose technologies such as remote sensors, satellites and robotics.

Framework conditions under which the SAGRI courses are conceived consider that:

- Technology itself is not sufficient and a well trained team is also required. Investing solely in technology will not ensure successful implementation of ICT applications; it is necessary to invest in a team that can effectively perform tasks, investing in capacity development of end users who can ensure the sustainability of the project.
- Complex ICT or complex platforms are not necessarily essential: technologies already being used by farmers are anyway taken into consideration.
- Contextual factors: local factors such as the lack of adequate resources must be taken into account beforehand (*e.g.* electricity, gender issues, limited network coverage and low bandwidth, local languages). Implementation approaches need to identify the specific needs of the intended users by working in collaboration with them. There is not one single solution that fits all projects: context, policies, marketing efforts and incentives are all essential factors to ensure participation from community members.
- Data integrity and security must be ensured throughout the project and when using ICT applications. Experts agreed that leveraging location data and other metadata with individual records helps maintain integrity.
- Agricultural worker or farmer would have a minimum education level of high school and a basic knowledge and experience in agriculture, at a practical level.

Of course, not all agricultural workers or farmers have sufficient knowledge to understand all the new developments in agriculture applied research, since some of them require a minimum education level. Therefore, prior to identifying the skills, it is mandatory to define the agricultural worker profile to whom are destined. In the SAGRI project the skills needs of an agricultural worker or farmer were analysed considering that he or she would have a minimum education level of high school and a basic knowledge and experience in agriculture, at a practical level. Seven major areas were therefore identified in significant technological developments that can help farmers for a more sustainable agriculture:

1) Precision technology.
2) Remote sensing to assess land capability.

3) Integrated pest management in plant protection.
4) Agricultural reuse of organic residuals.
5) Drip irrigation and water-conserving technologies.
6) Renewable energy and its application as green agricultural energy source.
7) Bioenergy and energy crops.

These skills are the basis for the developing of new innovative curricula integrating the latest advancements of the “agri-tech” sector, and training courses for agricultural workers according to the EQF/ECVET framework.

3. RESULTS AND DISCUSSION

3.1. Transversal skills

Although the analysis was mainly focused about the job-specific skills for agricultural workers, there are some generic and transversal skills that agricultural workers need to have in order to adapt to changing production processes, and to other sector-specific changes and challenges [2]. Agricultural workers are the women and men who labour in the crop fields, orchards, glasshouses, livestock units, and primary processing facilities to produce the world's food and fibres. They are employed on small- and medium-sized farms as well as large industrialized farms and plantations. In an integrated farming approach, a correct management and a balanced approach of every farm decision is needed and some specific points cover essential elements of a whole farm management approach:

- Organisation & planning: Planning and evaluation of practices is essential to ensure environmentally responsible production and continuous improvement.
- Human & Social Capital: Standards of employment practice, health and safety at work, and occupational training need to embrace EU standards of employment practice as minimum standard. Using local markets will help to maintain both local business and livelihoods and can also improve efficiency. Besides, open and active involvement of the farmer in local community’s life can help generate transparency and trust. This can also include hosting farm visits or holding open days for the public.
- Energy Efficiency: Awareness of sustainable development and the responsible management of natural resources are central. More careful and selective use of inputs, conservation tillage practices, reducing fossil fuel needs where possible and striving for optimum instead of maximum yields are just some strategies to increase the input-output-ratio and hence energy efficiency.
- Water Use & Protection: Use of water resources should be balanced and programmes which determine crop needs should be used. Protecting natural ground and surface water bodies is a key for maintaining and enhancing the environment, wildlife and biodiversity.
- Climate Change & Air Quality: By working in the open, using fossil fuels, keeping livestock, storing and spreading manure and by other agricultural practices, the

emission of greenhouse gases and other air pollutants is unavoidable. Farmers' decisions may help to keep carbon stocks in soils by allocating land to annual or perennial crops, to grassland, woods or buffer zones (such as hedges, grass strips, *etc.*). Some practices on reduced tillage or cover crops or incorporation of crop residues to soil may even increase the carbon sequestration to a certain extent and also help to improve air quality.

- Soil Management: Soil is fundamental to agricultural systems and a rich soil ecosystem contributes to crop and livestock performance: "The quality of life below ground determines productivity above". Good soil husbandry ensures the long-term fertility of soil aids yield and profitability and reduces the risk of soil damage such as erosion, compaction and associated environmental concerns.

- Crop Nutrition: Knowledge of the soil nutrient status is a decisive tool for ensuring that only the necessary and recommended amount is applied. The decision-making process involves crop demands, the supply that is in the soil and available nutrients from farm manure and crop residues. A balanced approach to fertilisation should be adopted, practices should be adapted to local situations, thereby reducing risks of environmental pollution by fertilisation.

- Animal Husbandry, Health & Welfare: Health and welfare of farm animals are linked with performance. Farmers employ and demonstrate techniques directed towards meeting the needs of the livestock and maintaining the animals in good health, comfort and low stress, allowing for natural behaviour to the greatest possible extent.

- Landscape & Nature Conservation: Protecting and enhancing wildlife and biodiversity of the landscape is of great importance within the concept of Integrated Farming. Management practices should consider biodiversity effects such as the thread to larches during mechanical weeding. The structural diversity of land and landscape features will create floral and faunal abundance and diversity.

- Waste Management & Pollution control: Wastes, including farm manure, must be seen as a valuable resource in terms of saving money and reducing pollution. Farming effluents should be managed to optimise recycling and re-use, thereby minimising effects on the environment. Recycling of external materials such as sewage sludge should only be considered if there will be no hazard to soil and environment due to critical ingredients such as heavy metals etc.

3.2. Specific skills

3.2.1. Precision agriculture

Precision Agriculture (PA) may improve agricultural yield and reduce potential environmental risks. The main benefits are [3]:

- Monitor the soil and plant physicochemical parameters: by placing sensors (electrical conductivity, nitrates, temperature, evapotranspiration, radiation, leaf and soil moisture, *etc.*) the optimal conditions for plant growth can be achieved.

- Obtain data in real time: the application of sensing devices in the fields will allow a continuous monitoring of the chosen parameters and will offer real time data ensuring an updated status of the field and plant parameters at all time.

- Automate field management: by incorporating a Decision Support System (DSS) in Precision Agriculture environment, the best conditions for the specific soil and plant species will be automatically optimised based on the data obtained by the sensors. The DSS will suggest the best moment for watering (or whether there is need or not), the need to irrigate to wash the salt content due to an excess in the radicular area, the need to fertilise, *etc.*

- Save time and costs: by introducing a PA system in the daily operation of an agricultural exploitation, time is saved due to the on-line measurement methods. Data from the sensors are automatically transmitted to a central server and this can be consulted using a Smartphone or Laptop. Or even, e-mail or SMS alerts can be programmed to notify the field owner when there is a need to irrigate, fertilise or address any issue in their properties. Moreover, costs in terms of water, pesticides and others are optimised and can easily be reduced.

- Improve the farmers' image: by using PA technology, not only the yield and profits will be increased but also the perception of the general public and Public Administration (through Smart Agriculture and environmental care) towards agricultural activity will be enhanced.

So, Precision Agriculture seems to bring many benefits to farmers and land owners who decide to use technology to manage their fields.

3.2.2. Applications of remote sensing to assess land capability

The applications of remote sensing to assess land capability in agriculture are designed to provide the farmer with timely information about crop progress. Here follow just some of the benefits that can be gained from the use of remote sensing:

- Early identification of crop health and stress.
- Ability to use this information to do remediation work on the problem.
- Improve crop yield.
- Crop yield predictions.
- Reduce costs.
- Reduce environmental impact.
- Crop management to maximise returns through the season.
- Crop management to maximise returns during harvest time.

Remote sensing data, used appropriately and at the right times of the season, has the ability to provide benefits to crop health and hence improve production [4].

3.2.3. Integrated Pest Management in plant protection

Integrated Pest Management (IPM) in plant protection focuses in the long term application of ecologically-friendly biological methods such as natural predators, resistant plant strains, sterile male technique, and so on. IPM aims to slowly reduce the use of pesticides via biological control methods. The main benefits of IPM are [5]:

- Slower development of resistance to pesticides: pests can develop a resistance to pesticides over time. When the applications of the chemicals are used repeatedly, the pests can develop a resistance to the pesticides via natural selection, where the pests that survive the application of the chemicals will pass on their genes to their offspring.

- Maintaining a balanced ecosystem: the use of pesticides may eradicate the pest population. However, there is a risk that non-target organisms are also affected, which can result in species loss. IPM can eradicate pests while maintaining the balance of the ecosystem.

- Better cost vs. value margin: The reduced usage of pesticides is more cost effective in the long term, as IPM controls pests when there are surges, as opposed to the regularly timed application of pesticides.

3.2.4. Agricultural reuse of organic residuals

The agricultural reuse of organic residuals may provide agronomic and environmental benefits that were either not previously well understood and/or that are critical to addressing emerging environmental issues associated with climate change. Environmental benefits are possible from manure application if manure and manure management are applied and timing and placement follows best management practices. When compared to more conventional fertilizer, manure properly applied to land has the potential to provide environmental benefits including:

- Increased soil carbon and reduced atmospheric carbon levels.
- Reduced soil erosion and runoff.
- Reduced nitrate leaching.
- Reduced energy demands for natural gas-intensive nitrogen (N) fertilizers.

Several long-term manure application studies have illustrated its ability to slow or reverse declining soil organic levels of cropland. The ability of manure to maintain or build soil organic matter levels has a direct impact on enhancing the amount of carbon sequestration in cropped soils. Manure organic matter contributes to improved soil structure, resulting in improved water infiltration and greater water-holding capacity leading to decreased crop water stress, soil erosion, and increased nutrient retention [6].

3.2.5. Drip irrigation and water-conserving technologies

Drip irrigation is a type of micro-irrigation that has the potential to save water and nutrients by allowing water to drip slowly to the roots of plants, either from above the soil surface or buried below the surface. The goal is to place water directly into the root zone and minimize evaporation.

The advantages of drip irrigation and water-conserving technologies are [7]:

- Optimum use of available water.
- No water being available to weeds.
- Maximum crop yield.
- High efficiency in the use of fertilizers.
- Less weed growth and restricts population of potential hosts.

- Low labour and relatively low operation cost.
- No soil erosion.
- Improved infiltration in soil of low intake.
- Ready adjustment to sophisticated automatic control.
- No runoff of fertilizers into ground water.
- Less evaporation losses of water as compared to surface irrigation.
- Improves seed germination.
- Decreased to tillage operations.

3.2.6. Renewable energy and its application as green agricultural energy source

Renewable Energy of all sizes has become a familiar sight around the world for a wide variety of reasons, including economic, environmental, and social benefits. Main advantages coming from renewable energy and its application as green agricultural energy source are [8]:

- Clean water: Turbines and solar panels produce no particulate emissions that contribute to mercury contamination in lakes and streams. Renewable energy also conserves water resources. For example, producing the same amount of electricity can take about 600 times more water with nuclear power, and about 500 times more water with coal.
- Clean air: Other sources of electricity produce harmful particulate emissions, which contribute to global climate change and acid rain. Wind and solar energy is pollution free.
- Mining & transportation: Harvesting the wind and sun preserves our resources because there is no need for destructive resource mining or fuel transportation to a processing facility.
- Land preservation: Wind farms are spaced over a large geographic area, but their actual “footprint” covers only a small portion of the land resulting in a minimum impact on crop production or livestock grazing. Large buildings cannot be built near the turbine, thus wind farms preserve open space.

3.2.7. Bioenergy and energy crops

Energy crops are unique because they don’t just produce renewable energy – they also provide other environmental and economic benefits [9], since they may lead to both new feed and energy from harvesting, in the framework of a circular economy. Other than creating renewable energy, bioenergy and energy crops also provide:

- Rural & regional benefits.
- Distributed base load power.
- Competitive cost proven renewable energy generation.

Energy crops provide therefore great economic and social opportunities for rural and regional communities. Farmers, truck drivers, contractors, suppliers, as well as local restaurants and shops are all provided with an economic boost. This provides a source of permanent fulltime employment unique from the seasonal workforce in many rural and regional areas.

Energy crops also encourage the development of new and innovative farming techniques and can provide economic returns on land and crop residue with no other identifiable market or environmental value. As these communities deal with the impacts of climate change, energy crops provide rural and regional areas with a more self-reliant labour force less vulnerable to the impacts of drought and flood.

4. CONCLUSIONS

Traditionally, pen and paper have been used to collect data in the field and for monitoring and evaluation of projects in rural areas. However, this approach is time consuming and susceptible to human error that may affect productivity and accuracy. Information and communication technologies are now being used widely with remarkable positive results to perform these tasks in agricultural development projects.

In a recent global discussion organised by the World Bank to point out the benefits of the new tools and methods with respect to the traditional ones, experts from various fields and organisations around the world shared their experiences and discussed the ways in which they were using ICT – mobile phones, tablets, applications, software, *etc.* – to collect data in the field. The same have also considered how to perform Monitoring and Evaluation (M&E) in development projects, while also working closely with rural communities and taking their feedback. The discussion has been summarised in a policy brief and outlines the benefits of using ICT for data collection.

The advancements in the agricultural technologies sector, and in particular new technologies for the above mention skills, will be transferred to agricultural workers in the frame of the SAGRI project. Particular focus will be put on environmental technologies that are of direct interest for the participant end-users, but also for European farmers in general. The study is focused on novel practices and methods for applying advancements in environmental technologies to an agricultural and environmentally challenged society and to facilitate the farmers everyday activities. The information will be applied in order to facilitate the transfer of the most critical points of it to the agricultural workers.

The acquisition of these skills is an important step to achieve a more technologically advanced and social, economic and environmentally sustainable agriculture. At the present, it is evident the role of the farmer who knows not only the traditional cultivation to produce different crops but that has to take into account the new techniques and technologies to reach a sustainable agriculture.

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SELECTED ANGLICISMS IN SERBIAN REGISTER OF AGRICULTURAL MECHANISATION IN FRUIT GROWING AND VITICULTURE

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Abstract. *The current paper focuses on an empirical study of selected anglicisms found in the language register of agriculture mechanisation in fruit growing and viticulture. The aims of the study are to explore, classify and determine the frequency of their use in several glossaries according to the classification given by Prćić (2004). The results show that this register contains a considerable number of anglicisms, fully or partially assimilated. The most common ones used in this specific language field, according to the figures, are calques and obvious anglicisms, which are more or less integrated in Serbian linguistic system with minor modifications. The number of hidden and raw anglicisms is significantly smaller. The agricultural machines and the capital allowances are vehicles and tools used worldwide, therefore the most pragmatic move in their nomenclature, especially when dealing with complex expressions, is to translate the original term in order to be recognisable in different languages.*

Keywords: *anglicisms, agriculture, mechanisation, fruit growing, viticulture, calques.*

1. INTRODUCTION

Agriculture is essential for human's survival. Agriculture represents the cultivation and breeding of animals, plants and fungi for food, fibre, biofuel, medical plants and other products used to sustain and improve human life. Agriculture has made great progress in feeding the increasing world population, but it is still dealing with serious problems and challenges. Food production is constantly increasing and the predictions are indicating that gap between demand and production will grow with the growth of the population, urbanisation and income growth in developing countries, which consequently are fuelling a massive global increase in demand for food. In order to solve these problems and challenges modern agriculture is constantly improving technical processes and mechanisation [3]. Besides improving production efficiency, mechanisation encourages large scale production and sometimes can improve the quality of farm production.

Mechanised agriculture is the process of using agricultural machinery to mechanise the work, greatly increasing farm worker productivity. Mechanisation enables farmers to increase farm productivity via production intensification and expansion. In its broadest sense it can contribute significantly to the development of food systems. The machines and the implements are used for various agricultural processes such as irrigation, drainage, conservation, soil cultivation, transportation of goods or harvesting. The machines are elements that are used to direct the action of forces based energy work, and motor mechanisms used in this work lighten the production and improve farming techniques. Agricultural or farm equipment, such as ploughs, drags, sprayers, planters, fertilizers, are devices designed for various works in the field.

The application of farm power to appropriate tools, implements and machines – "farm mechanisation" – is an essential agricultural input with the potential to transform rural families' livelihoods by facilitating increased output of higher value product while eliminating the drudgery associated with human muscle-powered agricultural production [6].

Despite the fact that the Serbian language has its own vocabulary and register of words in agriculture, mechanisation, fruit growing and viticulture, many words and expressions with obvious English origin are used in the discourse, written and oral. The impact of these words is evident and considerable.

In order to determine the type of anglicisms, we have used the corpus analysis. The aim of the paper is to determine, present and classify anglicisms found in the linguistic corpus of agricultural mechanisation in fruit growing and viticulture, according to the different level of their assimilation in Serbian. The examples found in *Englesko-srpski i srpsko-engleski poljoprivredni rečnik* (Institut za kukuruz "Zemun Polje"), *Englesko-srpski*, *srpsko-engleski poljoprivredni rečnik* (Poslovni system "Grmeč"), *Glossary of biotechnology and genetic engineering*, *Glossary of agri-environmental terms* (University of Reading), *Glossary of definitions of agricultural terms* (Inter-American Institute for Cooperation on Agriculture) and *Mašine u voćarstvu i vinogradarstvu* are classified and put into the tables which represent different types of anglicisms - *obvious*, *hidden*, *raw*, and, *calques* as a subcategory.

Having in mind the fact that we encounter anglicisms on a daily basis in all aspects of life, we presume that words of English origin can also be found in the names of agricultural machinery.

The Serbian language contains words of English origin (anglicisms) in agricultural (mechanisation in fruit growing and viticulture) language register and they are in use along with their Serbian equivalents (translations).

Methodological approach to this investigation of anglicisms involved the following objectives:

- Selection of glossaries used as corpora,
- Identification of anglicisms in agriculture, agriculture mechanisation, fruit growing and viticulture,
- Assessment of frequency of the selected anglicisms.

2. THEORETICAL FRAMEWORK

Anglicisms in Agriculture

An anglicism, according to Filipović [2], is any word borrowed from the English language denoting an object or a concept which is at the moment of borrowing an integral part of English culture and civilization; it need not be of English origin, but it must have been adapted to the linguistic system of English and integrated into the vocabulary of English.

According to the criterion of their form and integration into the borrowing language, Prćić [5] classifies anglicisms into *obvious*, *hidden* and *raw* anglicisms. *Obvious* anglicisms are all lexical units (lexemes and affixes) that are taken from the English language and are more or less integrated into the Serbian orthographic, phonological, morphological, syntactic, semantic and pragmatic system. *Hidden* anglicisms are the ones in which English language forms and meanings are 'hidden' inside Serbian forms [5] and easily integrated into the Serbian language system. They are created either by means of translation or by remodelling and adaptation of English words to Serbian language system. *Raw* Anglicisms are directly taken from the English language without any adaptation to the Serbian orthographic system [5].

A word is borrowed from English when there is a need to fill empty spaces in the vocabulary of the receiving language. Since in languages which are in contact with English there do not exist equivalent words for the transferred objects and concepts which have to be named, the simplest way of naming them is to borrow their names from the donor language. It is the case in the language register of agriculture as well. There are many types of machinery, from hand tools to countless kinds of farm implements. Modern mechanisation includes the names of tractors, trucks, combine harvesters, countless types of farm implements and tools, aeroplanes and helicopters (for aerial application) and other vehicles. The transfer of their names from English into the receiving languages belongs to the process of borrowing, which is regulated by the laws and rules of the theory of languages in contact. Table 1 shows some of the anglicisms found in agriculture jargon in general.

Table 1 contains three columns – 1) *English term*, original term in English, 2) *Adapted Serbian Anglicism*, a counterpart used in Serbian, an obvious anglicism which is adapted to comply with the orthographic system of the Serbian language, 3) *Serbian translation*, hidden anglicism which is a Serbian original word, a counterpart of the translation.

As it can be seen in the table, not all the terms have dual translation, as an adapted anglicism, and the Serbian counterpart.

There are cases when anglicisms appear as the output words of the process of blending. One of these characteristic terms found in the processed corpus is *fertirrigation.* It consists of source words *fertigation* (or *fertilization*)and *irrigation*. According to Agropedia, fertigation is a process in which fertilizer is dissolved and distributed along with water in a drip or spray irrigation system, while Merriam-Webster online dictionary defines irrigation as the watering of land by artificial means to foster plant growth. These two terms, combined, give a complete picture of this process in agriculture.

Table 1 General agricultural terms

ENGLISH TERM	ADAPTED SERBIAN TERM	SERBIAN TERM
Agriculture	Agrikultura	Poljoprivreda
Agronomy	Agronomija	
Accumulation	Akumulacija	Nagomilavanje
Biodiversity	Biodiverzitet	
Biomass	Biomasa	
Compost	Kompost	
Clon	Klon	
Ecosystem	Ekosistem	
Farm	Farma	Poljoprivredno gazdinstvo
Farmer	Farmer	Poljoprivrednik
Fermentation	Fermentacija	Vrenje
Fertilization		Đubrenje
Fertirrigation (Fertilization + Irrigation)		Navodnjavanje sa đubrenjem
Horticulture	Hortikultura	
Hybrid	Hibrid	
Incubation	Inkubacija	Veštačko leženje pilića
Irrigation	Irigacija	Navodnjavanje
Lactation period	Period laktacije	
Pollen	Polen	
Pollination	Polinacija	Oprašivanje
Viticulture	Vitikultura	Vinogradarstvo

3. CASE STUDIES

3.1. *Identification and analysis of obvious anglicisms*

Obvious anglicisms comprise lexical units (including affixes) which are taken over from the English languge but which quickly adapted within the system of the Serbian language (on orthographic, phonological, morpho-syntactic, semantic and pragmatic level) where over time they receive the status of the native words. *Table 2* shows selected obvious anglicisms in Serbian, and original terms in English.

Table 2. Obvious anglicisms

ENGLISH TERM	SERBIAN TERM (OBVIOUS ANGLICISM)
Aerosols	Aerosoli
Tractor	Traktor
Cultivator	Kultivator
Types of cultivators: grabers, extirpators, scarifiers	Tipovi kultivatora: gruberi, ekstipatori, skarifikatori
Motocultivator	Motokultivator
Chisel (plow)	Čizel plug (plug podrivač)
Mulching	Malčiranje (pokrivanje zemljišta ili korena stable biljnim ostacima i drugim u svrhu zaštite)
Bulldozer	Buldozer
Angledozer	Angldozer
Scraper	Skreper
Grader	Grejder
Grader elevator	Grejder sa elevatorom
Pump	Pumpa
Impeller and centrifugal pump	Impeler i centrifugalna pumpa
Atomiser	Atomizer (raspršivač za tečnost)
Reservoir	Rezervoar

Given the circumstances, these lexical units are not necessarily of English origins. Source of borrowings, which marks the language from which the word was taken, is English, but the origin of borrowings, which marks the language to which the word may be ultimately traced, may be:

- Latin (tractor, cultivator, scarifier, motocultivator, impeller, centrifugal, reservoir (taken from French, but originally from Latin),
- Greek (aerosols)
- French (chisel, reservoir)
- Middle Dutch (pump)

3.2. *Identification and analysis of hidden anglicisms*

The Serbian form of an adapted anglicism conceals its true identity, and this is the reason why they are called hidden. They are often made through the process of translation.

In the process of borrowing, two semantically identical forms appear – adapted anglicism, which is a copy of an English expression (works as a minimal pair), and hidden anglicism, which is the translation of the original term. A Serbian word *zamagljivač*, for example, and the original English term *fogger* or adapted Serbian anglicism*foger* do not share common ground in terms of linguistic adjustment. Nevertheless, both terms were accepted in the linguistic system of Serbian, hence they can be found in the corpora (selected dictionaries). The level of the acceptence of the newly created (borrowed) term largely depends on the attitude of lexicographers towards giving the new English senses the benefit of trust. However, many inovative uses are treated as a reflection of linguistic fashion and therefore perceived as short-lived[7]. Regarding etymology, *fogger* is an original English term.

Table 3. Hidden anglicisms

ENGLISH TERM	ADAPTED SERBIAN ANGLICISM	HIDDEN ANGLICISM
Fogger	Foger	Zamagljivač

Calque (loan expression) is a word or expression which is a result of literal translation; the input parts are English, but the word-formation pattern of the Serbian language. Many of such English-derived expressions are used internationally.Table 4 contains calques or literal translations of some agricultural terms used in fruit growing and viticulture.

Table 4. Calques – Serbian translations

ENGLISH TERM	SERBIAN TRANSLATION
Crane tractor loader	Kranski traktorski utovarač
Manure distributor	Rasipač stajnjaka
Mineral fertilizer distributor	Rasipač mineralnog đubriva
Mobile platforms for fruit harvesting	Mobilne plaforme za berbu voća
Fruit shaker (machine)	Tresači voća
Hand-held fruit shakers	Ručni vibracioni tresači
Machines for collecting and loading of stones in the lines	Sakupljači i utovarači kamenja iz redova
Single axle and double axle tractor	Jednoosovinski i dvoosovinski traktor
Sprayers (hand-held, trailed)	Prskalice (nošene, vučene)
Contour cut	Konturna rezidba
Stone crushers	Drobilice kamena
Stone digging and collecting machines	Mašine za vađenje i sakupljanje kamenja
Stone collecting –clearing machines	Sakupljači-odlagači kamenja
Stone loading machines from the lines	Sakupljači utovarači kamenja iz redova
Machines for pipe laying and mole drainage	Mašine za postavljanje cevne i krtične drenaže
Pipe drainage laying machine	Drenopolagači
Machines for mole drainage	Mašine za izvođenje krtične drenaže
Self-propelled elevating scraper	Samohodni skreper sa elevatorom
Trailed elevating grader	Vučeni grejder sa elevatorom
Vineyard rakes	Vinogradske grablje

Approximately half of the examples from the table are borrowed from English, mostly word-for-word or root-for-root translations. Expressions such as *crane tractor loader*, *mobile platforms for fruit harvesting*, *single axle and double axle tractor*, *sprayers*, *contour cut*, *machines for pipe laying and mole drainage*, and *vineyard rakes* share the same linguistic pattern with the Serbian counterparts *kranski traktorski utovarač, mobilne platforme za berbu voća, jednoosovinski i dvoosovinski traktor, prskalice, konturna rezidba, mašine za postavljanje cevne i krtične drenaže, mašine za izvođenje kritične drenaže i vinogradske grablje.*

The rest (*manure distritubutor/rasipač stajnjaka, mineral fertiliser distributor/rasipač mineralnog đubriva, fruit shaker/tresač voća, hend-held fruit shakers/ručni vibracioni tresači, machines for collecting and loading of stones in the lines/sakupljači i utovarači kamenja iz redova, stone crushers/drobilice kamena, stone digging and collecting machines/mašine za vađenje i sakupljanje kamenja, stone collecting-clearing machines/sakupljači-odlagači kamenja, stone loading machines from the lines/sakupljači utovarači kamenja iz redova, Pipe drainage layingA machines/drenopolagači, self-propelled elevating scraper/samohodni skreper sa elevatorom, trailed elevating grader/vučeni grejder sa elevatorom*)are adapted to fit in Serbian.

3.3. *Identification and analysis of raw anglicisms*

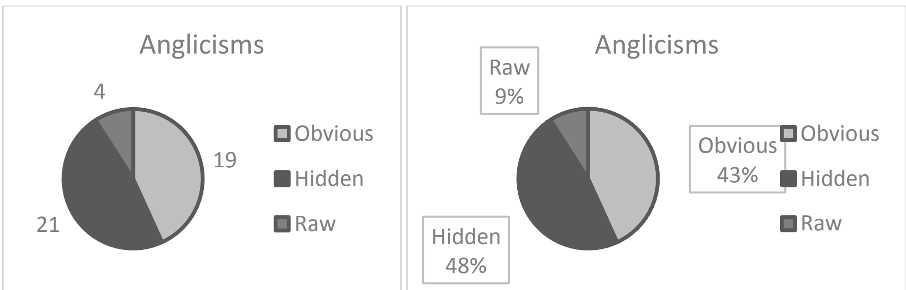
Raw anglicisms are words and phrases used in their original form, as they are found in the English language, without undergoing any adaptation. They are considered to be partially assimilated – on one hand they are fully adapted on the semantic level, partially adapted on the phonological level, and are not adapted on orthographical, morphological and morphosyntaxical level to the system of the Serbian language[4]. Table 5 presents raw anglicisms and their English counterparts.

Table 5. Raw anglicisms

ENGLISH TERM	RAW ANGLICISM
Tiltdozer	Tiltdozer
Atomizer	Atomizer
Dozer	Dozer
Drift	Drift

A raw anglicism *drift* presents the process of application of the pesticides in the open field everything that turns away drops of the jets from the ideal trajectory that should reach the object of treatment.

Graphic 1 and 2 show the distribution of anglicisms according to the classification. Graphic 1 shows their final number in various classes, and Graphic 2 shows the percentage of their use.



Graph. 1 Distribution of anglicisms

4. CONCLUSION

Lexical borrowing is a common moment in expanding vocabulary; due to difficulties of finding Serbian equivalents for agricultural terms and problems in their translation (especially when it comes to technical vocabularyin mechanisation),words and expressions which describe devices designed and produced in foreign countries, are borrowed, with or without adaptation.

Comparing the agricultural terms in both Serbian and English we have come to the conclusion that besides *partial equivalency* of expressions in both English and Serbian (terms hidden inside Serbian equivalents, e.g. *fogger-foger-zamagljivač*), there is also the *absolute equivalency* which includes terms borrowed without any adaptation to the Serbian orthographic system (*raw* expressions, e.g. *tiltdozer-tiltdozer*). There are cases when anglicisms appear as the output word or expression of the process of blending (e.g. *fertirrigation*= *fertigation* (or *fertilization*)and *irrigation.*

The findings in the paper confirm that the most common anglicisms in the Serbian register of agricultural mechanisation in fruit growing and viticulture is *calque*since the agricultural machines and the capital allowances are vehicles and tools used worldwide. The most pragmatic move in their nomenclature, especially when dealing with complex expressions, is to translate the original term in order to be recognisable in different languages. Calque is a reflection of the need for one's own word and, ultimately, the result of tendences for language clarity, but not the clarity in the negative sense that is usually attached to it, but an active relation towards cherishing the foreign heritage in its own culture. These words and expressions are more comprehensible then those of foreign origin. It is a compromise by which the Serbian language is enriched following the Engish model retaining expressive originality.

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TRACTOR ACCIDENTS IN RELATION TO THE CHARACTERISTICS OF THE AREAS IN AGRICULTURE OF SERBIA

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Abstract. *This article shows the profile of Serbia's agricultural production and documents important trends in fatalities and injuries that occur in its realization. Some of the dangers that occur in agriculture are related to plants, chemicals, noise, dust, exposure to the sun and working with animals, and a combination of these hazards that are found in agriculture, as well as the circumstances in which agricultural jobs are done, makes agriculture one of the most dangerous industries. By analyzing the types of accidents that occurred in the study period, outside the public transport of the Republic of Serbia, it can be concluded that the type of accident with the largest percent in the total number of accidents, is overturning tractor or aggregated implements and other power machines. Falling of persons from the tractors, aggregated implements or other power machines on the move, is the second most common type of accident. The third in terms of the total number of accidents with tractors and other power machines, outside public transport areas, in agricultural production processes, are accidents with run over of tractor's wheels, other power machines and trailers. The following in terms of representation, in the processes of agricultural production, are accidents that occurred during interventions at the operation of machines (interventions on the connection-cardan shaft, moving parts of connecting machines and combines. It can be concluded that during the research period, which lasted from 2005 to 2009, there were 7,528 accidents with tractors and other power machines, of which 6,625 accidents or 88% in public transport in the Republic of Serbia, and 903 accidents or 12% in the exploitation of tractors and other power machines outside public transport areas, that is, in the processes of agricultural production. The highest number of accidents was recorded in Zlatibor, Moravica and Belgrade areas.*

Key words: *accidents in agriculture, power machines, agricultural operations, maintenance, areas in Serbia.*

1. INTRODUCTION

Agriculture is the oldest economic branch, the earliest target-oriented human activity. From this, the first attempts to replace the human labor with tools, and later the replacement of working animals with machines, is also in line with the general definition of mechanization of agriculture. Mechanization of agriculture is a key component of modern agricultural production. By introducing complex machinery, agricultural production takes on an industrial character, with all its characteristics.

SOURCES OF RISKS IN AGRICULTURE

Soil is slowly forming in nature, but in the process of destruction it quickly destroys, and man with his activity can increase or decrease the natural resistance of the soil to various aspects of its degradation. Human activities that endanger the achievement of high, stable yields of the appropriate quality are: reduction of humus stocks, soil compaction, structural deterioration, deterioration of water-air and thermal regime, reduction of biological activity, disorder in number and representation of microorganisms, insufficiently controlled use of pesticides, pollution by heavy metals, nitrates, radionuclides, shading, alkalisation and acidification of soil, erosion, disregard of agro-technical requirements, and deadlines, loss due to changes in the purpose of using agricultural land, etc. In the results of the research (Mačvanin et al., 1999), it was concluded that the soils, except for certain sites in the vicinity of industrial facilities, the waste dumps, etc., is still suitable for the production of quality and health-safe food, since it possesses favorable properties and the content of heavy metals, pesticides and other harmful substances is below the allowed limits. The increasing needs of man for energy, food, agricultural products and other material goods increase the need for water, which in the hydrological cycle does not regenerate sufficiently. By introducing into the open flows of wastewater from economic and other human activities, as well as swelling of water from agricultural land, with various types of harmful and dangerous substances, as well as excess pollution reduces the use water value. The problems of contamination of agricultural resources have long been known. Knowing that apart from industry and agriculture can cause harmful effects and various disorders in the biosphere, it can lead to deterioration in the quality of agricultural products, causing insecurity and discomfort among consumers. One of the obvious ecological problems is waste oils, in which toxic substances, toxic, carcinogenic and mutagenic, are produced during use. According to the degree of toxicity and the potential of carcinogenicity, motor oil and metal oils are the most dangerous ones, and the other, less dangerous, group consists of hydraulic oils and gear oils. For these reasons, in most of the developed world, waste oils are classified as hazardous or special waste, which requires special treatment. Uncontrolled dismantling of waste oils, their improper combustion or unintentional use very dangerously endangers the environment. Waste oils have poor biodegradation, destroy the microflora and make the soil inoperable for many years. For these reasons, organized collection and further treatment of waste oils (processing or controlled burning) have significant ecological and economic effects.

Sources of air pollution can be thermo energetic, industrial, craft, utility plants, landfills, transport vehicles with internal combustion engines, as well as activities that generate gases and aerosols (cleaning, smoking of inhabited places, agricultural areas, forests, etc.) operations in agriculture (seedbed preparation, dusting, spraying, spraying, burning of plant materials etc.). The polluted air contains C, SO_2, CO, NOx, CO_2, metals (As, Be, Cd, Pb, Ni, Se) which can cause adverse effects in the environment as well as organic matter. Almost all pollutants can be separated from the air by certain procedures, the achievement of which is limited by their economics. The use of conventional fuel types for diesel engines is increasingly polluting the environment, with the acceleration of the greenhouse effect. Components of incomplete combustion of fuel are mostly toxic and carcinogenic, and their quantity can be reduced: rational fuel consumption, better technology and work organization, the improvement of internal combustion engines design, purification of exhaust gases, the use of additives and the search for new types of ecological fuels. Studies show that in combustion products, biodiesel fuel has less harmful substances than diesel fuel, which can be used as a blend of diesel and fuel biodiesel, as additives in up to 20%, in order to reduce air pollution.

RISKS IN THE AGRICULTURAL MECHANIZATION

Tractors are the most commonly used machinery on farms (Oljaca et al., 2000), and they cause the most injuries, more than any other agricultural machinery. The lack of a protective frame on tractors is the most common case of fatal injuries. The presence of "blind passengers" on the tractor is very common in the number of injuries. Workers, tractors are exposed to difficult working conditions, conditioned by the seasonal nature of jobs. They are exposed to difficult physical tasks, the operation of unfavorable microclimate factors, extended daily work in the season, increased noise levels, vibrations, dust, pesticides, easily flammable and explosive agents, gases and vapors. The result is tiredness, reducing the resistance of the organism, exacerbating existing diseases, losing health and work ability, and a shortened working life. It is necessary to train workers in the field of occupational safety with certain chemicals, in order to prevent injuries due to improper use. These injuries are not identified as injuries at work, because the cause is detected late. For all this, it is necessary to determine the criteria for workplaces with special working conditions in terms of increasing the risks to the health of workers, the specifics of the workplace and the technological process. Tractor implements and tools are the cause of many fatal and serious injuries. The greatest risks are from the moving parts, including the PTO (power takeoff). Absence of drive shutdown during maintenance operations is also associated with a large number of injuries, as well as the presence of "blind passengers" on machines and devices during transport. Hydraulic lines due to high pressure are frequent sources of injuries, as well as uncontrolled lowering of hydraulic hitches. In cattle breeding, in outdated cattle breeding systems, workers are exposed to chemical influences, of which the most pronounced ammonia is. Keeping all this in mind and the protection at work of workers is specific and complex, since workers at the same time protect the employees from the adverse effects of several different factors.

Large farm animals can hurt workers, especially in the case of cow with calves, as well as in ordinary operations in buildings for breeding domestic animals. Storage capacities for grain, silage, and storage for legumes can cause significant risks. The height of individual objects is the cause of fatal falls, as well as the failure of the conveyor drive during the repair of the fault. The lack of air in the silo and the presence of force-gas cause frequent injuries. Electrical installations such as high voltage and low voltage networks are a risk when working with high machines. Off-road vehicles used on farms, due to insufficient preparation and insufficient training of drivers, lead to an accident.

Chemical agents. Many different chemicals are used on farms, depending on the type of operation. A very important instruction manual, with an emphasized degree of risk. Acute and chronic exposure to pesticides without the necessary protective equipment must be prevented. Work with pesticides is exposed to: warehouse workers, workers preparing pesticides for treating cultures, pesticide workers and workers working on the maintenance of machinery and plant protection products. Chemical products, used in agriculture, through products represent a threat to the health of the population and pollute the environment. Respiratory risks, the problem of organic dust and chronic allergies are present when using the means of mechanization. Appropriate ventilation must reduce the risk to the smallest extent.

Noise. Repeated exposure of the pump can often result in hearing loss. Ear protectors should be used if the noise is above 85 dB. Older tractors without sound protection exceed a significant level of noise in the cabin. Fans in dryers and chain saw can exceed the permissible noise level.

Heavy manual physical work. Back pains are very common among household workers, due to heavy physical work with high repetition, and inadequate body position.

Maintenance and repair. Serious injuries can occur due to the lack of proper maintenance and repair, and protective equipment, especially in the field.

Children are often asserted on farms, due to the inadequate place to play, as well as the unprofessional work of adults with machines. Children may receive jobs in proportion to their psycho-physical potential, and after certain training.

Older workers. Aging results in impaired vision, mobility, and ability to function fast, which are characteristics that are necessary for safe work, without risk.

2. MATERIAL AND METHODS

The collection of materials for this research refers to the collection of documentation on accidental cases with tractors and other mobile agricultural machinery, which during the period of testing occurred in the agricultural production processes themselves, or outside the public transport of the Republic of Serbia. The most of this material necessary for research was collected by a field method that included the collection and analysis of the records from the location of accidents taken from the Basic Courts by the areas of the Republic of Serbia, as well as going to the places of the event of the accident. This field meditation has collected relevant data that have been studied for accidents documented from the aspect of records and documents (official records, photographs of events) of official institutions and persons accompanying such events (records of the Ministry of Interior, records of investigative judges and other documents).

The research involves analyzing the collected data related to accidents involving tractors and other mobile machines outside the public transport of the Republic of Serbia, or in the agricultural production itself. Collected relevant indicators of tractor operation as a traction-drive unit, in different conditions of field operations, with the recording of the consequences of accidents and types of accidents will be systematized. Data on these accidents have been systematized for certain administrative areas of the Republic of Serbia. The impact of the administrative areas of the Republic of Serbia in which the research is conducted will be investigated, the total number of accidents / the number of casualties, and the results will be processed and presented in an appropriate manner.

The results of the investigation of accidents that occurred outside the public areas (fields, meadows, forests, unclassified roads, land roads, etc.) will be presented in the administrative areas of the Republic of Serbia characterized by a certain intensity of agricultural production, agricultural land, number of inhabitants, etc. All these factors will be taken into account when making final conclusions.

Territorial organisation of the Republic of Serbia

In terms of administrative and territorial division, the Republic of Serbia is divided into provinces, regions, administrative areas, the City of Belgrade, cities and municipalities.

The territorial organisation of Serbia includes five regions (Belgrade region, Vojvodina region, Sumadija and western Serbia region, eastern and southern Serbia region and Kosovo-Metohija region). They include the City of Belgrade as a separate territorial unit established by the Constitution and law, and 30 administrative areas, 24 cities, 30 urban municipalities, 150 municipalities, 6,158 villages and 193 urban settlements (http://www.srbija.gov.rs/pages/article.php?id=20617).

The Republic of Serbia is divided into 25 administrative areas, without taking into account the area of the AP of Kosovo and Metohija. Out of the above 25 administrative areas, 7 administrative areas belong to the Vojvodina region, while the other 18 areas, including the Belgrade region (the city of Belgrade), include the rest of the Republic of Serbia (Belgrade region, Sumadija and Western Serbia and the region of South and East Serbia). Studies are related to accidents involving tractors and other mobile machines outside public transport, covered the 18 administrative areas (Fig. 1).

Fig. 1. Administrative areas of the Republics of Serbia that were included in the research, (Facts about the Republic of Serbia, 2012)

Data on accidents with tractors and other mobile agricultural machinery outside public transport (agricultural production) for administrative areas have been collected, systematized and analyzed to review the seriousness of the problem in order to reduce the identified number of accidents and their consequences for the population and the country itself.

Research was analyzed traces of accidents with tractors and other mobile agricultural machines in agricultural production (outside public transport) of the Republic of Serbia were conducted in the period from 2005 to 2009. In the mentioned period, data on accidents involving tractors and other mobile agricultural machines were collected.

REGIONAL DEVELOPMENT OF THE ADMINISTRATIVE AREAS OF THE REPUBLIC OF SERBIA

The positioning of areas (as mesoregional units), according to the values of the selected features, points to their role in the existing regional reality, that is, the spatial and developmental differentiation of Serbia. Regional disproportions are interactively linked to unbalanced population structures, material constraints and structural disparities over many years.

The degree of development of the area, measured by per capita income, varies in the ratio of 4:1, most notably in the area of the City of Belgrade (74% above the national average), while, in contrast, the lowest wages are recorded on the area of Toplica and Jablanica (about 60% below the average). The lowest earnings per capita were realized in the insufficiently developed area, that is, in the areas of Toplica, Jablanica and Pcinja, where besides administrative centers (Nis, Pirot and Vranje), all other municipalities recorded a multi-annual status of underdeveloped area.

As a result of insufficient economic activity and the lack of adequate human resources, the highest unemployment rates were recorded in the regions of Jablanica and Toplica, which almost double the average of Serbia. The rates of regional unemployment in districts vary in size over 4:1 (Republican Institute for Development, 2009).

The regional educational structure of the Serbian population is still unfavorable, that is, almost 50% of the adult population is at the elementary educational level or below it. In general, in the education structure of the population, secondary school is the most common type of education in both sexes (41%), while with a high professional education only 6% of the population. Economically poor areas (Pčinja, Bor, Braničevo and Raška) due to their low level of education are on a critical level regarding the quality of labor supply.

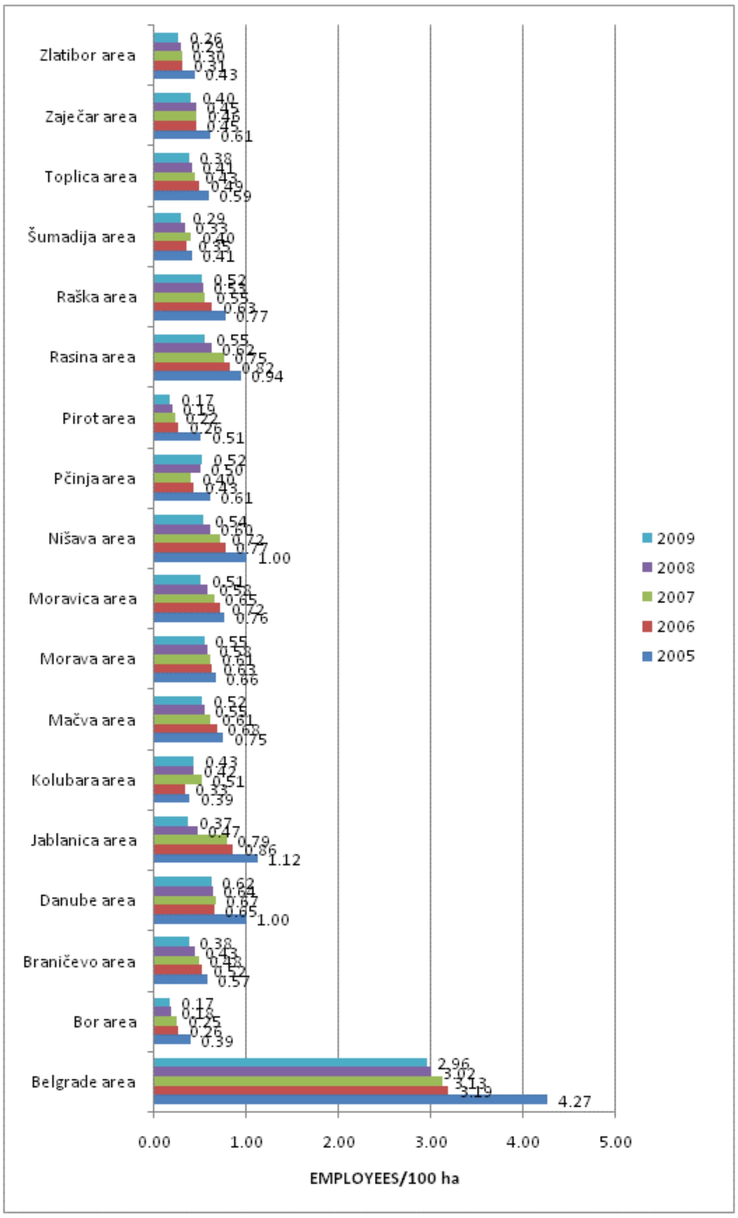

Fig.2 Number of employees in agriculture per 100 ha agricultural land for administrative areas of the Republic of Serbia

3. RESULTS AND DISCUSSION

In this research, when analyzing accidents outside public transport, under the total number of accidents, the total number of accidents with the injured persons is considered.

Table 1. The consequences of accidents with tractors and other mobile agricultural machines in agricultural production (Gligorević, 2014).

Year	In total accident	With the dead persons	With the injured persons	In total the injured	Fatal injured	Injured	Seriously injured	Easily injured
2005	155	25	130	190	26	164	60	104
2006	161	30	131	206	30	176	69	107
2007	211	42	169	242	40	202	66	136
2008	202	36	166	228	37	191	80	111
2009	174	28	146	204	31	173	69	104
Total	903	161	742	1070	164	906	344	562
Average	180.6	32.2	148.4	214	32.8	181.2	68.8	112.4
%	100	17.83	82.17	100	15.33	84.67		

Based on the results presented in Table 1, during the research period, outside the public transport of the Republic of Serbia, there were a total of 903 registered accidents involving tractors and other mobile agricultural machines, or 180.6 accidents annually per year in the research period. In 161 accidents or 17.38% of the total number of accidents, there were dead and tragically injured persons, while in 742 accidents or 82.17% of cases of accidents were injured. An average of 32.2 accidents per year with tragic casualties and 148.4 accidents with injured persons, with tractors and other mobile agricultural machines in the process of agricultural production, are annually average.

Analyzed the number of persons who were died in the aforementioned accidents, it was noted that in 903 accidents that occurred during the research period, a total of 1070 persons or 214 persons per year per year in the research period were killed. Out of this number, 164 persons or 15.33% were fatal injured (died), while 906 persons or 84.76% were heavily and lightly injured. A total of 32.8 people died annually, i.e. 181.2 persons a year were injured annually in the research period.

The aforementioned data on accidents involving tractors and other mobile agricultural machinery outside public transport were analyzed, it was noted that the participation of accidents with deadly, tragically injured persons in the total number of accidents is very high (17.83%), as well as the participation of tragically victims in the total the number of victims (15.33%).

It should be noted that in the same period, when it comes to road accidents on the public roads of the Republic of Serbia, the share of tragically injured in the total number of injured persons was 4,19%.

Based on this, it has been established that accidents with tractors and other mobile machines in agriculture (out of public transport) are extremely risky from the point of view of the tragic consequences for the operators.

ANALYSIS OF THE OCCURRENCE OF ACCIDENTS IN THE ADMINISTRATIVE AREAS OF THE REPUBLIC OF SERBIA

The consequences of accidents with tractors and other mobile agricultural machinery outside public transport were analyzed. The analysis was carried out for the following categories of consequences:

• Number of dead, fatal injured persons;

• Number of injured persons.

Table 2 Total number of accidents with tractors and other mobile agricultural machinery in agricultural production (outside public transport), for the territory of the Republic of Serbia (Gligorević, 2014).

Area	2005	2006	2007	2008	2009	**Total**	Average	%
Belgrade area	24	42	44	22	28	**160**	32	17.72
Bor area	8	9	15	10	11	**53**	10.6	5.87
Braničevo area	6	6	10	9	7	**38**	7.6	4.21
Danube area	3	2	7	5	5	**22**	4.4	2.44
Jablanica area	3	2	0	5	4	**14**	2.8	1.55
Kolubara area	5	4	0	3	2	**14**	2.8	1.55
Mačva area	4	4	14	16	12	**50**	10	5.54
Morava area	3	5	3	5	4	**20**	4	2.21
Moravica area	32	19	24	33	25	**133**	26.6	14.73
Nišava area	4	6	5	7	7	**29**	5.8	3.21
Pčinja area	0	1	2	1	2	**6**	1.2	0.66
Pirot area	1	1	4	4	2	**12**	2.4	1.33
Rasina area	3	0	2	3	3	**11**	2.2	1.22
Raška area	7	6	3	7	5	**28**	5.6	3.10
Šumadija area	4	6	3	6	4	**23**	4.6	2.55
Toplica area	4	4	7	5	3	**23**	4.6	2.55
Zaječar area	7	10	18	11	12	**58**	11.6	6.42
Zlatibor area	37	34	50	50	38	**209**	41.8	23.15
Total	**155**	**161**	**211**	**202**	**174**	**903**	180.6	100
Average	8.61	8.94	11.72	11.22	9.67	50.17		
%	17.17	17.83	23.37	22.37	19.27	100		

The total number of accidents with tractors and other mobile agricultural machinery, which occurred outside public transport in the aforementioned areas of the Republic of Serbia, was analyzed (Table 2). It was noted that during the research period, a total of 903 accidents or 180.6 accidents occurred annually on average. The schedule of accidents after years of research in this doctoral dissertation was the following: in 2005, a total of 155 accidents occurred in the mentioned areas of the Republic of Serbia, or 17.17% of the total number of accidents. In 2006, 161 accidents or 17.83% were recorded, in 2007 there were 211 accidents, or 23.37% of the total number of accidents, in 2008 there were 202 accidents or 22.37%, and in the last year of the research, there were 174 accidents or 19.27% of the total number of these accidents.

The previously presented data on the number of accidents with tractors and other mobile agricultural machinery, which occurred outside public transport in the administrative areas of the Republic of Serbia, were analyzed, and it was concluded that during the first two years of the research the number of accidents increased. The largest number of accidents happened in 2007, and the smallest was recorded at the beginning of the 2005 research. The trend line of the total number of accidents for the research period had a growing character.

The total number of accidents in the areas of the Republic of Serbia in which the investigations were conducted was observed, and it was concluded that the most of the mentioned accidents happened in the Zlatibor area, as many as 209 accidents or 23.15% of the total number of accidents. An average of 41.8 accidents occurred annually during the period of research in this area.

The second area in terms of the number of accidents involving tractors and other mobile agricultural machinery outside public transport was the Belgrade area, where 160 accidents or 17.72% of the total number of accidents occurred during the research period, with an average of 30 accidents annually.

The third area with the most pronounced number of mentioned accidents was the Moravica area, where 133 accidents occurred, or 14.73% of accidents or 26.6 accidents a year on average.

The mentioned three areas in the total number of accidents with tractors and other mobile agricultural machines that occurred outside public transport in the administrative areas of the Republic of Serbia participated with 55.6%, so it can be stated that they are most influential on the total number of accidents.

Of the other areas, Zajecar area had a share of 6.42%, with more than 5% of shares being allocated in the Macva and Bor areas. Other areas participated with less than 5% in the total number of crashes.

The least involved area was the Pcinja area with 0.66% or only 6 accidents during the research period.

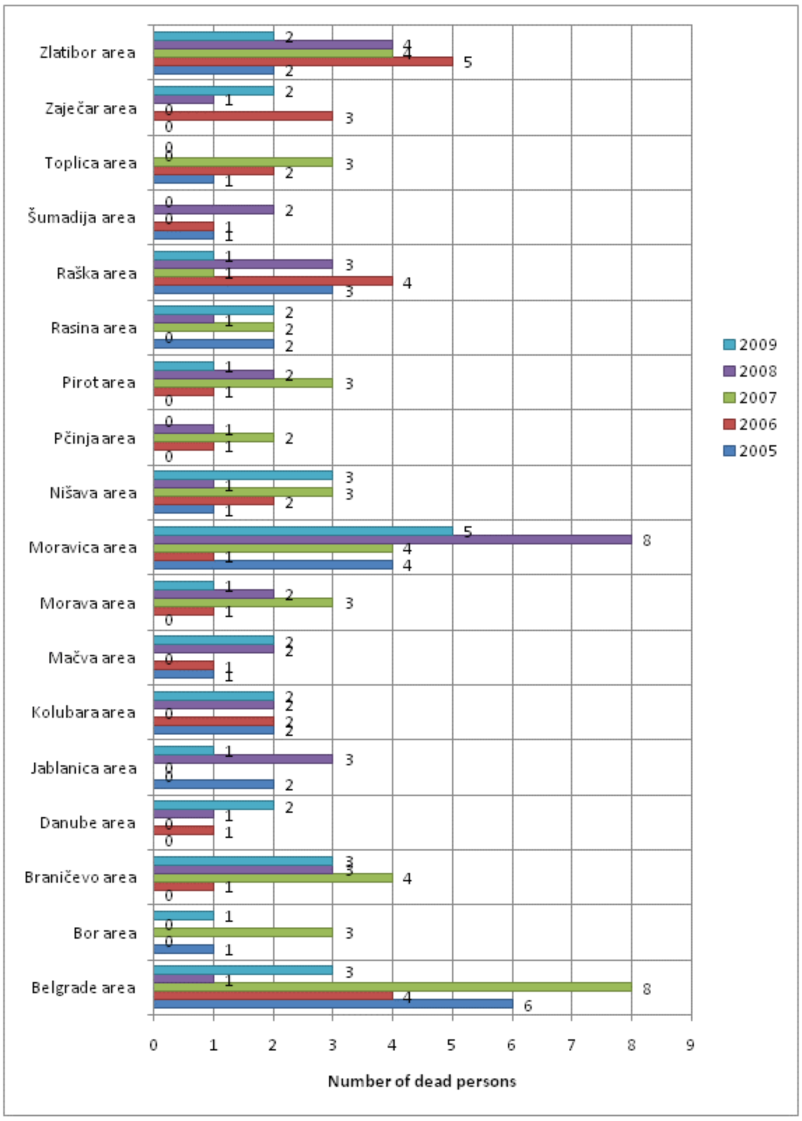

Fig. 3 Number of dead, fatal injured persons in accidents with tractors and other mobile agricultural machinery in agricultural production for the territory of the Republic of Serbia

The number of dead, tragically injured persons in accidents with tractors and other mobile agricultural machinery, which occurred outside the public transport in the administrative areas of the Republic of Serbia (Fig. 3), was observed, and it was noted that in the period of the investigation a total of 164 persons were tragically died, 32.8 persons a year on average. The number of tragically injured persons in the mentioned accidents, according to the years of research, was as follows: In 2005, 26 persons were traumatically died in the administrative areas of the Republic of Serbia, or 15.85% of the total number of tragically injured persons. In 2006, 30 persons or 18.29% were traumatized, in 2007 there were 40 tragically died persons, or 24.39% of the total number of tragically injured persons, in 2008 there were 37 tragically injured persons or 22.56%, and in the last year of the research, 31 persons were tragically died or 18.9% of the total number of tragically injured persons.

Preliminary data on the number of tragically affected persons in accidents with tractors and other mobile agricultural machinery, which occurred outside the public transport in the administrative areas of the Republic of Serbia, were analyzed, and it was concluded that in the first two years of the research, the number of tragically injured persons increased in order to After that, the end of the study was a constant decline. The highest number of tragically injured persons was in 2007, and the smallest was recorded at the beginning of the research in 2005. The trend line of the total number of tragically injured persons for the research period had a growing character.

Based on the analysis of data on tragically injured persons, according to the areas of the Republic of Serbia in which the research was conducted, it was concluded that the most tragically injured persons were in the Moravica and Belgrade areas where 22 persons were tragically died or 13.41% of the total number of tragically injured persons in these accidents. An average of 4.4 tragically injured persons per year in the period of research in these areas averaged annually.

The following area according to the number of tragically injured persons in accidents involving tractors and other mobile agricultural machinery outside public transport was Zlatibor area, where 17 persons or 10.37% of the total number of tragically injured persons were tragically died during the research period, with an average annual 3.4 were tragically died.

The above three areas in the total number of tragically injured persons in accidents involving tractors and other mobile agricultural machines that occurred outside public transport in the mentioned areas of the Republic of Serbia participated with 37.19% and they have the highest share in the total number of tragically injured persons in research period.

In other areas, the Raska area had a share of 7.32%, the Branicevo area had a share of 6.71% and the Nišava area with a share of 6.1% in the total number of tragically injured persons, while the other areas had a significantly smaller share.

The areas with the smallest share in the total number of tragically injured persons were Pčinja and Sumadija areas with 2.44% or only 0.8 tragically injured persons per year during the research period.

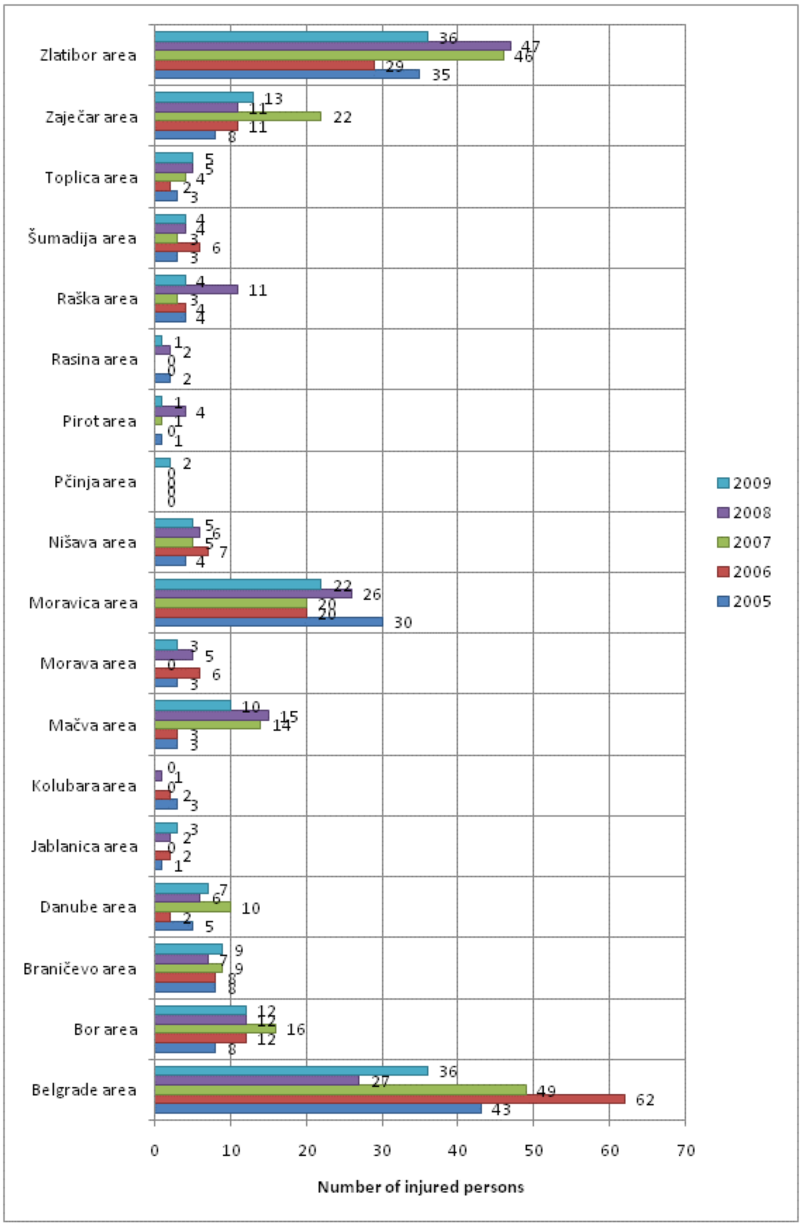

Fig.4 Number of non-fatal injured persons in accidents with tractors and other mobile agricultural machinery in agricultural production for areas of the Republic of Serbia

Analyzed the data associated with the number of injured persons in accidents with tractors and other mobile agricultural machinery, which occurred outside public transport in the administrative areas of the Republic of Serbia (Fig. 4), it was concluded that during the research period a total of 906 persons were injured or 181, 2 persons annually per year. The number of injured persons in the aforementioned accidents, following the years of research was the following: in 2005, 164 persons were injured in the administrative areas of the Republic of Serbia, or 18.1% of the total number of injured persons. In 2006, 176 persons were injured or 19.43%, in 2007 there were 202 injuries, or 22.3% of the total number of injured persons, in 2008 there were 191 injured persons or 21.08%, and in the last year 173 persons or 19.09% of the total number of injured persons were injured.

During the first two years of the study the number of injured people increased, and after that, until the end of the study period was recorded constant decline. The highest number of injured persons was in 2007, and the smallest was recorded at the beginning of the research in 2005. The trend line for the total number of injured persons for the research period has a growing character.

Based on the analysis of data on injuries, according to the areas of the Republic of Serbia in which the research was conducted, it was found that the highest number of injured persons was in the Belgrade area, 217 persons or 23.95% of the total number of injured persons in these accidents. Annually, 43.4 injuries were reported during the period of the study.

The following area according to the number of injured persons in accidents involving tractors and other mobile agricultural machinery outside public transport was Zlatibor area, where 193 persons were injured during the research period, or 21.37% of the total number of injured persons, or 38.6 persons on average annually.

The third area according to the number of people injured in the mentioned accidents was the Moravica area, where 118 people were injured during the research period, or 13.02% or 23.6 persons were injured annually on average.

The mentioned three areas in the total number of injured persons in accidents with tractors and other mobile agricultural machines that occurred outside public transport in the mentioned areas of the Republic of Serbia participated with 58.27% and they have the highest share in the total number of injured persons during the research period.

Of the other areas, the Zajecar region had a share of 7.17% (65 injuries or 13 injured persons per year) and the Bor area with 6.62% (60 injuries or 12 injured persons per year), the total number of injured persons, while the rest the areas had a significantly smaller share.

The area with the smallest share in the total number of tragically injured persons was Pčinjska with 0.22% (2 injuries during the research period) or only 0.4 injured on average annually during the research period.

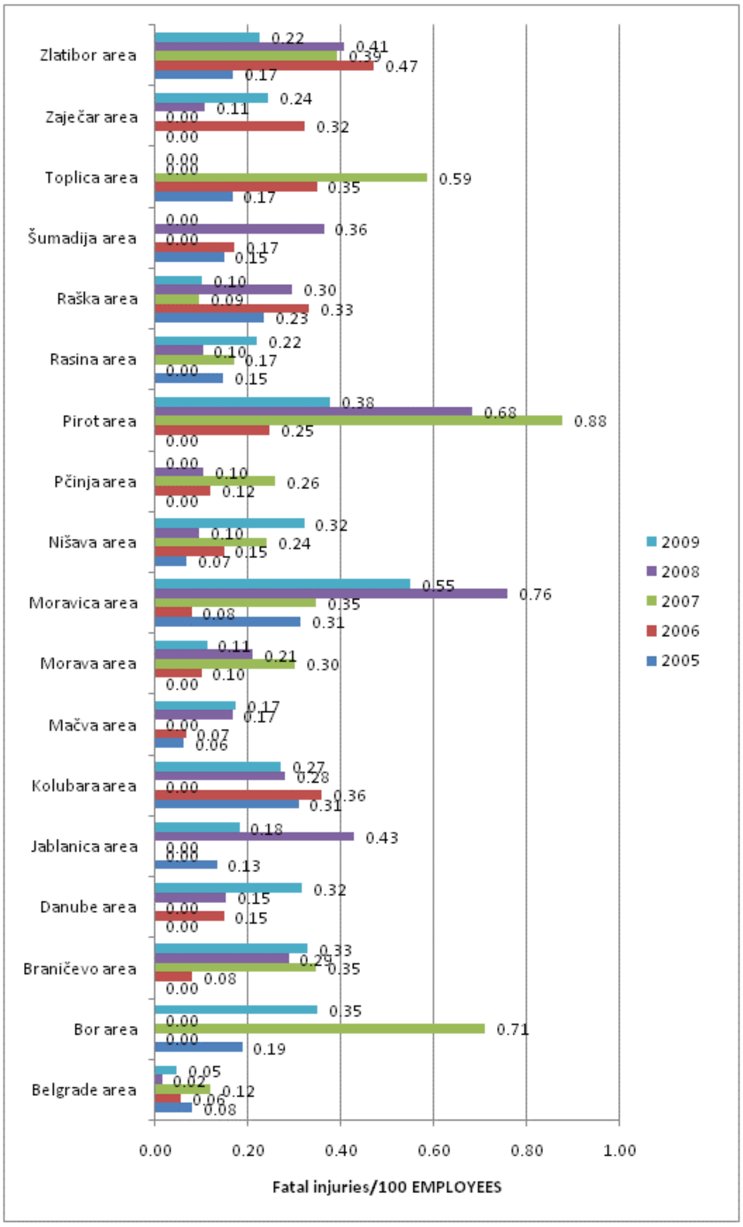

Fig.5 Number of fatal injured persons per 100 employees in accidents with tractors and other mobile agricultural machinery in agricultural production for areas of the Republic of Serbia

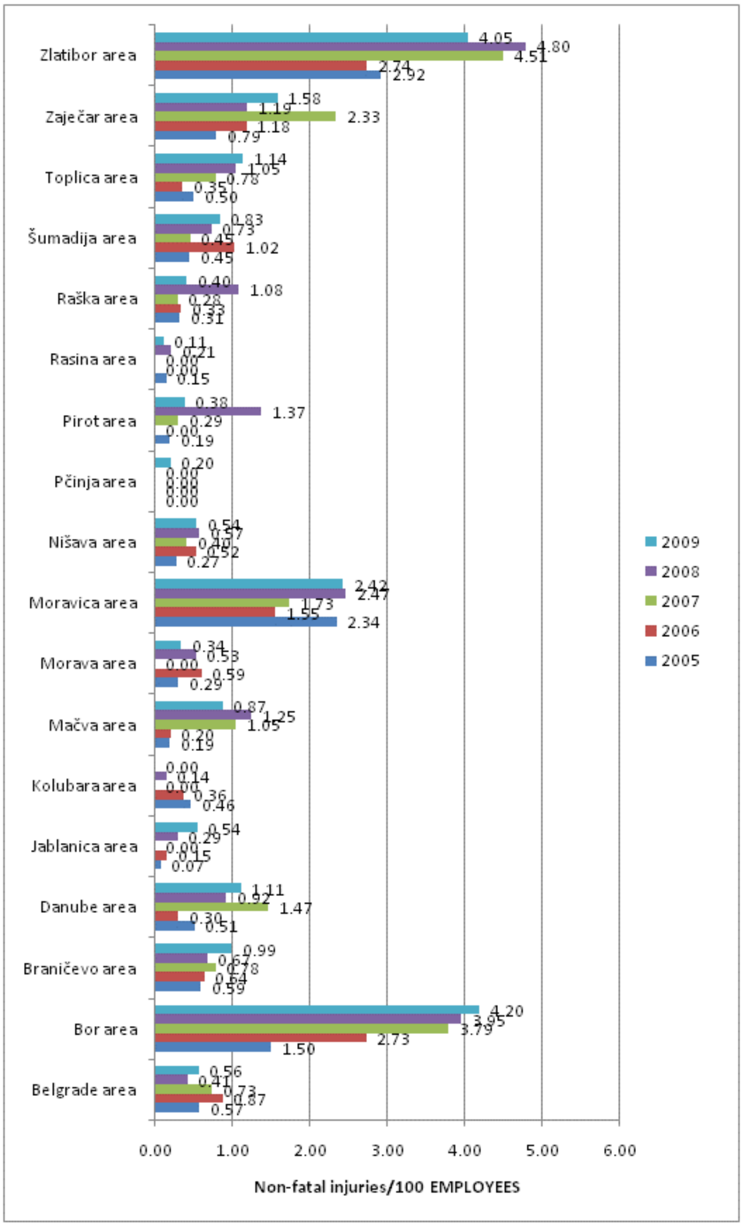

Fig.6 Number of non-fatal injured persons per 100 employees in accidents with tractors and other mobile agricultural machinery in agricultural production for areas of the Republic of Serbia

The number of dead, tragically injured persons per 100 employees in accidents with tractors and other mobile agricultural machinery, which occurred outside the public transport in the administrative areas of the Republic of Serbia (Fig. 5), was observed, and it was noted that in the period of the investigation a total of 164 persons were tragically died, whose value has varied considerably, both by the years of research and by administrative areas separately.

In 2005, the highest values were in areas Moravica and Kolubara (0.31); in 2006, the highest values were in areas Zlatibor (0.47) and Kolubara (0.36); in 2007, the highest values were in areas Pirot (0.88) and Bor (0.71); in 2008, the highest values were in areas Moravica (0.76) and Pirot (0.68); and in 2009, the highest values were in areas Moravica (0.55) and Pirot (0.38).

In general, the areas of Moravica and Pirot had the highest values of the number of dead, tragically injured persons per 100 employees in accidents with tractors and other mobile agricultural machinery, which occurred outside the public transport in the administrative areas of the Republic of Serbia, during the research period. The lowest values of this parameter had the areas Belgrade, Macva and Pcinja.

The number of non-fatal injured persons per 100 employees in accidents with tractors and other mobile agricultural machinery, which occurred outside the public transport in the administrative areas of the Republic of Serbia (Fig. 6), was observed, and it was noted that in the period of the investigation a total of 906 persons were injured, whose value has varied considerably, both by the years of research and by administrative areas separately.

In 2005, the highest values were in areas Zlatibor (2.92) and Moravica (2.34); in 2006, the highest values were in areas Zlatibor (2.74) and Bor (2.73); in 2007, the highest values were in areas Zlatibor (4.51) and Bor (3.79); in 2008, the highest values were in areas Zlatibor (4.80) and Bor (3.95); and in 2009, the highest values were in areas Bor (4.20) and Zlatibor (4.05).

In general, the areas of Zlatibor and Bor had the highest values of the number of dead, tragically injured persons per 100 employees in accidents with tractors and other mobile agricultural machinery, which occurred outside the public transport in the administrative areas of the Republic of Serbia, during the research period. The lowest values of this parameter had the areas Pcinja, Rasina and Kolubara.

4. CONCLUSIONS

Due to certain characteristics of agriculture - such as work: in the open, in greenhouses, with heavy machinery, and because of isolation at the workplace, poorer training of workers, use of chemicals and plant protection products - workers faced with greater risks, which is reflected in the rate an accident that is higher than the average rate for other sectors.

Agriculture and forestry, as a profession, are systematically occupying the third or fourth place among the most dangerous occupations in the European Union.

During the research period and when collecting data on accidents with tractors and other mobile agricultural machines in the processes of agricultural production, no accidents were recorded which resulted in only material damage. Precise data on the number of these accidents can not be reached, because such accidents are not usually registered by the competent authorities, and thus there are no traces of their records. The consequences of such accidents are usually not reported to anyone, but the owners of machines are concerned about remedy of damages.

It was generally concluded that during the research period that lasted from 2005 to 2009, it happened 903 accidents or 12% in the exploitation of tractors and other mobile agricultural machines outside public transport areas, that is, in the processes of agricultural production, and 1,070 persons or 22.15% in agricultural production, while 164 persons or 32.22% were died by performing works in agricultural production.

The analysis of the consequences of accidents with tractors and other mobile agricultural machinery outside public transport, according to the areas of the Republic of Serbia in which the research was conducted, showed that Zlatibor, Moravica and Belgrade, the areas with the largest share in the total number of accidents / casualties for all categories are consequences.

The occurrence of accidents with mobile agricultural machinery, primarily tractors, in the Republic of Serbia is a very common occurrence today, as there is no permanent training, follow-up professional courses for proper use and maintenance of these machines.

In the following period, it is necessary to reduce the number of accidents during the operation of agricultural machinery and tractors, to the smallest possible number. This primarily means ensuring the working process in agricultural production, with the utmost respect for all prescribed measures and laws in the field of machine safety.

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