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ISAE 2019

Belgrade, Serbia

31.October - 2.November 2019

Univerzitet u Beogradu - Poljoprivredni fakultet

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PREFACE

After the three successful International Symposiums on Agricultural Engineering - ISAE, that were held in Belgrade at the Faculty of Agriculture, thanks to our colleagues we are organizing The Fourth International Symposium on Agricultural Engineering – ISAE 2019. 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, Serbian Soil Tillage Research Organisation, Belgrade, Serbia, Institute of Agricultural Economics, Belgrade, Serbia and thanks to the Ministry of Education, Science and Technological Development, Republic of Serbia, support of the AMAPSEEC, RebResNet and BENA, and sponsor and donors, we have managed to organize 44 presentations (oral / poster) that were submitted as Abstracts to the Scientific Committee of the ISAE 2019 Symposium. We have arranged them in to four sections and categorized them as Original scientific papers, Scientific review papers, First (short) communications, Case studies, Professional (Expert paper) and Popular papers. Finally 30 full papers were submitted to the Scientific Committee of the ISAE 2019 and were reviewed by the members of the Scientific Committee and kind assistance of some members of other Conference bodies.

Proceedings of the ISAE 2019 International Symposium is organized in four thematic sections. Section I – Sustainable agriculture and biosystems engineering (18 papers); Section II – Soil tillage and agro-ecosystems protection (4 papers); Section III – Energy and energy efficiency in agriculture (7 papers) and Section IV – Economics in agricultural engineering (1 paper).

We wish to thank to all the authors for their contribution to the ISAE 2019 Symposium and to the all the Institutions, Associations, Universities, Sponsors and Donors for the contribution in ISAE 2019 Symposium organization.

I Section: SUSTAINABLE AGRICULTURE AND BIOSYSTEMS ENGINEERING

II Section: SOIL TILLAGE AND AGROECOSYTEM PROTECTION

III Section: ENERGY AND ENERGY EFFICIENCY IN AGRICULTURE

IV Section: ECONOMICS IN AGRICULTURAL ENGINEERING

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THE USE OF A 3D LIDAR SENSOR IN AUTONOMIC BASED NAVIGATION ON THE FIELD

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Abstract. *LIDAR sensors provide an efficient way to autonomously navigate robots through various terrain where obstacles can be used as a reference points to avoid them or use them as points that the robot needs to pass. The goal of this work was to test the advantages of using a multi-channel semi 3D LIDAR sensor (Velodyne VLP 16 a.k.a Puck) to detect this reference points and used them in autonomous navigation mode to drive the robot between two rows of maize. In order to do this two algorithms that were previously developed and were based on the data captured from a two-dimensional LIDAR sensor (Sick TIM310) are now modified to work with multichannel data. The first step is to limit the amount of data captured by the semi 3D LIDAR sensor, so the unnecessary readings are filtered out based on the height of the points in space. This way some points representing ground are removed, based on the readings of the IMU, depending on the roll and pitch of the robot that changes through the uneven real terrain. The actual points in space that do represent obstacles are then used in the second algorithm that autonomously navigates the robot. The algorithm calculates the offset from the middle of the row depending on the distances of the points on the rows relative to the middle of the row. The results prove that the use of a semi 3D LIDAR is more efficient if the terrain is not ideal, since the amount of data captured from the obstacles of different heights is higher and therefore more accurate compared to the data of a two-dimensional LIDAR, where the sensor can be tilted to the ground and can detect points on the ground, but not of the obstacles. The adaptation of the previously developed algorithms for two-dimensional LIDAR sensors is therefore possible with the correct hardware and produces a more accurate reading of the environment, needed for successful autonomous navigation.*

Key words: *multichannel LIDAR, real-time data, autonomous navigation, precise agriculture, navigation algorithm, data filtering*

1. INTRODUCTION

World hunger all across the globe is no news in the year 2019 and even with the yearly growth rate being on a decline [1], the challenge of sustainable food production is being fought daily. Beside the classical land agriculture with taking a majority of space in the rural areas of countries, the conditions for small family businesses are not getting accustomed to the standards that are growing through the years. Many protests are being held these months with farmers expressing their opinion to the regime they are working in [2,3]. With the growth of urban populations, there are other approaches in food production with the intent to be cost and space effective [4,5]. Even with the idea of vertical gardens and other urban food production solutions, there is a lot of land that must be used effectively.

One way to increase the effectiveness in land agriculture is with the use of robotics and precise agriculture. This allows the farmers to control the growth of the food produce greater than before, which results in the increase of yearly income. It also means that the farmer has to invest more in better technology. This can get quite expensive as modern tractors can cost a fortune. Usually bigger farmers can afford automation devices which can be used on agricultural vehicles with the help of high-precision real-time kinematic Global Positioning Systems or similar [6,7]. Since this solution might not be cost effective for everyone, another proposal could be using active sensing for navigating autonomously on the terrain.

In this article, an approach in navigating through field crops was presented using light detection and ranging (LIDAR) sensors. Since it was already done using a two-dimensional LIDAR sensor in a previous article [8], this was upgraded using a multichannel LIDAR sensor, testing the advantages and disadvantages of the sensors.

2. MATERIAL AND METHODS

Light detection and ranging is a method used to detect near obstacles and its properties. The used laser light is measured with a sensor after it reflects from the object to calculate distance and its other properties depending on the reflection [9]. In our case, the LIDAR sensors repeat this step for every certain angle (the number of different angles depends on the quality of the LIDAR sensor, some can measure objects at a very small difference between two neighboring points) and creates a map made out of those laser scans. Usually we get a ring of points, therefore the scanned area is only two-dimensional (figure 1). Advanced LIDAR sensors are multichannel. This means that they scan rings at different inclines, which creates a semi three-dimensional area (figure 1). The processing of the measurements requires more computing time. That can be critical for the effectiveness of the vehicle, if the computer cannot keep up with the desired rate it needs to operate on.

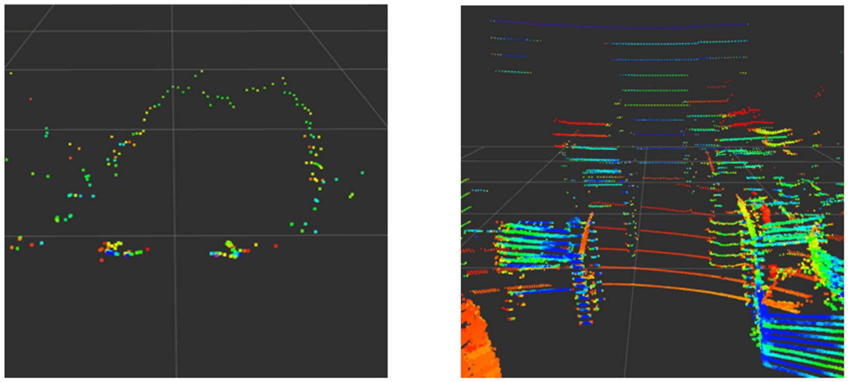

Fig. 1 Illustrated view of the scanned area of the 2D LIDAR sensor (left) and the semi 3D LIDAR sensor (right)

LIDAR sensors are used regularly nowadays, whether it is in the car industry [10] or in agriculture [11]. The sensor is no novelty and for an example, new algorithms are developed each year for the Field Robot Event competitions [12], where students compete in teams with robot vehicles that they make themselves. They compete in various tasks where the main goal is to solve them autonomically. One of the main tasks is basic navigation, where they have to autonomously drive between rows of maize. Most of the teams use LIDAR sensors to overcome that challenge [13]. Yet for the basic tasks, a two-dimensional is still the primary choice as it is cheaper than a multichannel one. That is one of the examples for the use of LIDAR sensors which what our testing field will base on.

2.1. Understanding the basics of the algorithm and filtering the data

The use of a two-dimensional LIDAR sensor (in our case Sick TIM310 [14]) has been successful in the past for basic navigation, which measures an area of 270 degrees. Its use with a refresh rate of 10Hz is enough for the competition it has been used for the past few years. Additionally, since it outputs 270 points per measurement (one point for each angle it measures), it is possible to process the reading by using Raspberry Pi 3 model B [15], which is a low-cost, low-power consuming single-board computer.

Since the measuring area is limited with the previously mentioned LIDAR sensor, the placement of it is crucial is it is because of the fact that it only scans one ring. The sensor has to be placed on a certain level to detect the area that is desired. If the LIDAR is off to a certain angle, the whole output data can become unusable as it does not scan the surrounding efficiently. For an example, the sensor could be tilted at such an angle that it could only sense the ground. In our case the area that is desired are the neighbour rows of maize through which the robot has to navigate (figure 2).

Fig. 2 The testing field

2.1.1. Writing an algorithm for the two-dimensional LIDAR sensor

The algorithm has to calculate where the robot is positioned between the rows and how it has to turn to navigate through the rows without running over the plants. This is how other agricultural vehicles have to maneuver through the fields if we don't want to damage the products.

Firstly, the measured points are divided into two sides (the left and the right row) and limited to only the certain angle that is necessary to be observed. It is important to choose only a certain angle to observe on each side, because it affects the errors of the result. This makes it easier to keep them distinct in the later processing (figure 3).

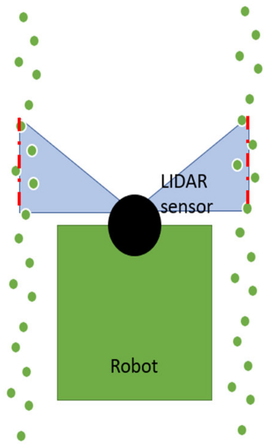

Fig. 3 Illustrated view of the scanned area of the LIDAR sensor

The measured data is output as a data structure, where each point is represented by the angle (depending on the first point it measures - from 0 to 270 degrees) and the distance from the sensor to the object it reflects from. Once the points are sorted, the following steps are used to calculate the amount the robot has to turn in a certain direction to navigate through the rows:

- linear fit each side using the least squares method,
- calculate the slope and y-intercept (of each side),
- calculate the intersection coordinates,
- translate the intersection coordinates into the angular speed for the wheels.

A detailed description of the algorithm and the robot that the algorithm is used on can be found in the book Agricultural Robots - Fundamentals and Application [8].

3. Results and Discussion

The previously mentioned algorithm must be adjusted, since the semi 3D LIDAR outputs a different data structure called a “pointcloud”. The sensor Velodyne VLP 16 a.k.a. The Puck, scans 16 rings that are measured at different inclines and scan the whole area, instead of a 270 degree scan as it was with the previous 2D LIDAR, the Puck makes a 360 degree scan [16]. That way, the sensor can be placed on different positions as it does not depend on a certain level. Because of the construction of the robot, the sensor was tilted at a certain angle, which still was not a problem.

The measured data is easily filtered with the help of an inertial measurement unit (IMU). In our case the PhidgetSpatial Precision 3/3/3 High resolution was used [17]. The IMU measures the incline of the robot and calibrates the output data of the LIDAR sensors depending on the tilt of the sensor itself and the robot. The incline is measured with the compass and gyroscope that is built in the PhidgetSpatial sensor. The measured data is transformed into roll, pitch and yaw from which we use roll and pitch to translate the measured points from the LIDAR. This is the first filtering upon the output data. This results in the data being consistent (negating all the unwanted tilts) and having no problems in using it in the further steps of the adjusted algorithm (figure 4).

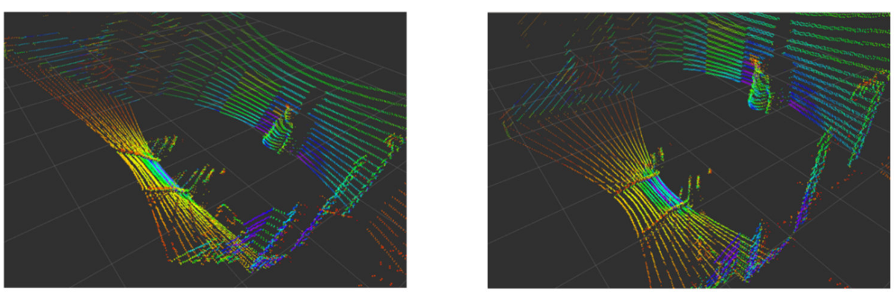

Fig. 4 Scanned data before (left) and after (right) the second filtering

The next filtering process cuts out all the unwanted points that are not needed in the further steps of the algorithm. This is done by selecting the ranges on each axis. Each range limits the scanned pointcloud to a certain area that is then used to calculate the new angular velocity for the robot. Useless points that represent ground and other parts of rows that are further away are removed as they are not needed, depicted by Fig. 5.

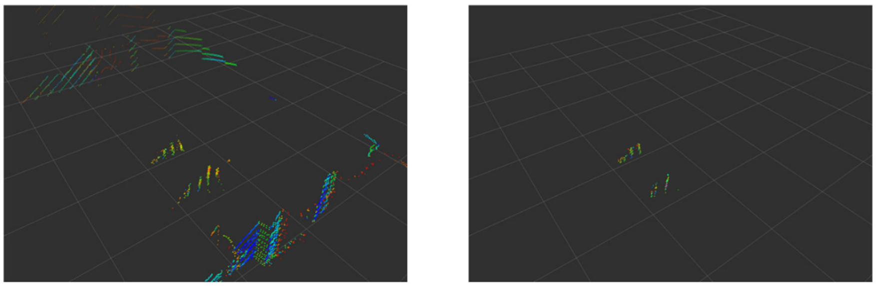

Fig. 5 Illustrated view of the scanned area of the LIDAR sensor before (left) and after (right) the filter cut

In an ideal case, the final filtered pointcloud is like the one shown in Figure 5. Thereon, the application should be trivial, since the representation of the rows looks similar to the representation shown on Figure 5. Yet, since the data structure is different, we cannot access the same properties directly. Instead of the angle of the point from a certain starting point and the distance from the sensor to the selected point, the pointcloud delivers us the x, y and z coordinates upon which the filtering has been done. This requires changes of original algorithm in a few steps, since transforming the x and y coordinates into the previously mentioned units that are needed for the old algorithm would be time consuming in a greater way than it is worth it. On the other hand, the output data of the LIDAR is still interpreted as a line for each side and the calculation of inclines is kept in the processing steps. The first step of calculating the inclines is still required, yet instead of the angle and the distance between the point and the sensor, the x and y coordinates are used. From that point on, the angular velocity can be calculated with the following equation (equation 1):

$$angular\ velocity = \frac{coeff.}{k_{Left}+k_{Right}} \tag{1}$$

Where k_{Left} is the incline calculated of the left row of maize and k_{Right} of the right row. $coeff.$ is a coefficient that depends on the speed of the robot, since the angular velocity needs to be higher to manage the same curve at a higher linear velocity of the robot. Both inclines are used to decrease the error in calculating the inclines, since the rows of maize are never planted in a perfect straight line.

3.1. Evaluation of the algorithm

The algorithm works ideally, when the robot is tilted in either way. When the robot is getting closer to being aligned with the rows, an abnormality occurs. The incline values start to jump, as the incline is undefined, when the line is parallel to the y-axis. The problem is solved by calculating the standard deviation of all the points in the chosen area of each side at the beginning and then calculating the slopes only if the standard deviation is large enough. At low values, it is assumed that the robot is aligned with the rows. It is crucial to always test at which tilt of the robot, the slope value stays consistent when the robot is idle. The use of a multichannel LIDAR sensor can only be more efficient compared to the use of a two-dimensional LIDAR sensor, if the output data is filtered at least depending on the tilt in certain direction(s). With the use of the filtered data, the vehicle can withstand a rougher terrain, since there is a high chance that at least one of the scanned rings will be measuring useful data. This also depends on the quality of the IMU sensor that is used in the process. The higher rate, at which the IMU sensor can update the data, the more accurately the data will be processed.

In our case, the use of the Puck turned out to be a success, since the position of the sensor is put higher than before, making the sensor measure more useful data. Compared to the Sick LIDAR where each frame consists of only 270 points, the Puck supplies about the same number after all the filtering is done. It has to be stated that out of the 270 points from the Sick sensor, filtering needs to be done, which leaves the useful data to consist only of less than 50 points per side.

In the next step, more output data could be used, if the sensor is put in such a position that the rows are visible all around the robot. If the robot reaches an obstacle that cannot be driven over, it can simply stop and drive backwards, using the output data of the back of the sensor. This can be useful in many cases, where there is assured that the vehicle cannot move through a row, but only to a certain point. It cannot only apply to the competition circumstances, but also to real life application, where the use of any GPS systems can fail, active sensing is the solution.

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MODELING OF TRACTOR PLATFORM FOR CROP SCOUTING

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Abstract. *This paper presents different methods for detecting changes in the condition of crops and making a special contribution through the presentation of modeling a tractor platform for crop scouting. This platform was designed in the APS LAB laboratory at the Faculty of Mechanical Engineering in Belgrade intended for the placement of spectrometric sensors. The choice of a suitable method or algorithm for the desired crop scouting is crucial for the success of further analysis of the obtained data. Four modes of spectrometry are presented. Beside handheld sensors, there are described methods of data capture via drones and satellites. Most of this paper belongs to the use of sensors in the composition of agricultural machines. This type of scouting is the most effective when it is carried out simultaneously with the distribution of mineral nutrients and crop protection. The tractor platform, on which the sensors are located, can be either a worn type or a connecting type that allows connection to a tractor in three-point in the conventional way. Except for the aforementioned ways, the sensors can be placed on the roof of the tractor or directly on the working machines. The process of constructing and modeling the front tractor platform is presented in detail in Solid Works program. Apart from the construction shown, there is a possibility of changing the platform. All foreseen and feasible variants are presented in this paper.*

Key words: *Crop scouting, modeling of platform, sensor*

1. INTRODUCTION

With the global development of industry and the growing population on Earth, there is an increasing need for spatial data. They should provide a wide range of information that is useful in different spheres of application [1]. Remote surveys are non-invasive methods of collecting information through systems that are not in direct physical contact with the investigated object. At the same time, we notice and record electromagnetic waves, process them, analyze them, and use the generated information for various applications. Field recording is done using the so-called optical color cameras (RGB - red, green, blue) and spectral sensors. Remote research used for agricultural purposes is called field scouting, and it can be routine surveying of crops, orchards, vineyards or forests [2].

Crop scouting involves an analytical process aimed at detecting spatio-temporal changes in crops from sowing to harvest. The two most prominent problems in crop monitoring during the period mentioned are: restrictions imposed by large agricultural areas or remote production parcels that need to be observed; the need for prompt, efficient and accurate observation. On the one hand, scattered or distant production lots, it is necessary to periodically visit and observe the crops on them. This “tour”, on the other hand, takes time, energy and money, and is very slow. Addressing these problems depends largely on the technical equipment and training of the farmers themselves. Since the monitoring of crops during the growing season is the most important task in agricultural production, it follows that the level of equipping one agricultural estate to properly handle this task is crucial for complete production. Surveying crops yields information on the value of many parameters of interest when monitoring plants during the growing season [3].

Special importance of crop scouting is the fact that the data generated during the surveys define the nutritional deficits of crops as well as the defective and stressful conditions of plants caused by diseases, weeds or pests, and the distribution and optimal dosing of the appropriate fertilizers and pesticides, which is followed immediately after reconnaissance or at the same time as reconnaissance, it is possible to perform not only within the optimum agrotechnical period but, more importantly, with a variable dosage rate, ie. location specific. This significantly contributes to the savings by reducing or optimizing the consumption of artificial fertilizers and pesticides. In practice, business in the field using a variable standard is only possible with the help of highly sophisticated machines and equipment that support this [4,5].

2. METHODS FOR CROP SCOUTING

The data collected through crop scouting is a good basis for geo-agronomic analyzes. However, different ways of detecting crop changes are not equally good for all analyzes, so digital change detection is affected by spatial, atmospheric, spectral and temporal constraints. Therefore, we have many techniques for detecting changes, and the choice of a suitable method or algorithm for the desired crop survey is crucial for the success of further analysis of the data obtained. The diagram in Picture 1 shows the most widespread methods and indirect means for the application of multispectral cameras - sensors for agricultural purposes for crop scouting.

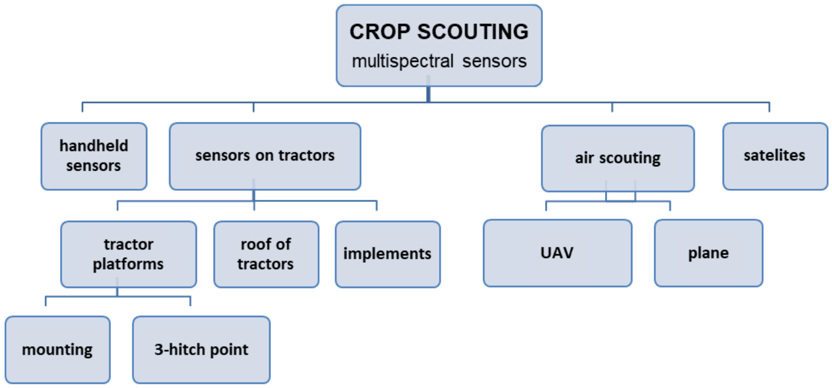

Fig. 1 Multispectral crop scouting modes and multispectral technical systems (platforms) in agriculture

Each of the mentioned crop scouting methods with the accompanying multispectral technical system consisting of a multispectral camera - sensor and adequate sensor carrier/platform, has certain advantages and recommendations for application in accordance with the desired purpose or real situation in crop scouting.

The use of manual sensors is the least effective method of scouting crops. Scouting comes down to a tour of arable parcels or fruit plantations, where visual inspection is certainly carried out, and the sensor itself is used to evaluate the condition of the crop through a measured vegetation index. Measurements of the vegetation index are made, in part, at the sole tendency of the technical persons conducting the survey, less frequently according to a pre-determined plan. The location itself may be spotty when the hand sensor is activated and held for a few seconds above a single plant entity, or may have elongated shape when walking a few tens of meters along a row with the sensor activated in the hand and directed at the crop itself. The number of measurements - sampling depends on the predicted time for measurement and the work rate of the technicians themselves, and the wet and muddy terrain can be a very limiting factor for this type of reconnaissance. Apart from the price, the advantages of these devices are the small size and weight, portability and very fast determination of the value of the vegetation index (in a few seconds) without the need for long procedures of taking and processing images. However, such devices usually have the ability to determine only one vegetation index [6].

Ground-based scouting of crops is carried out by the use of sensors within agricultural machines and tractor-machine aggregates (TMA) and falls under the so-called terrestrial photogrammetry. This type of scouting is the most cost-effective and efficient when performed simultaneously with the distribution of mineral nutrients and crop protection. Furthermore, the aggregate can then consist of a tractor and two machines. Behind the tractor is a working machine (spreader or sprayer), and in front of the tractor there is a front tractor platform of multispectral sensors, by which crop scouting and measurement of vegetation index is carried out. Based on the values of this index, the most appropriate dosage rate is calculated in accordance with the recommendations or algorithm adopted, and information on the variable and location-specific standard thus obtained is forwarded to the executing bodies of the working machines behind the tractor. The number of multispectral sensors on a platform is usually two or four, although any number of sensors can be set. The platforms can be of the carried type or mounted directly on the tractor by means of a special construction adapted to each tractor model individually or by means of a mounting type attachment that enables connection to the three-point tractor in the classic way. Sensors can also be mounted on the roof of the tractor or directly on working machines, for example on special front racks, on the wings of mounted and towed sprinklers or on the wings of self-propelled sprinklers with high clearance. The front tractor platforms of the multi-spectral sensors, as well as those mounted on the roof of the tractor, can be used, much less frequently, for the exclusive crop scouting without the simultaneous dispensing of some agent on the plot and crops [7].

Unmanned aerial vehicles (UAV), also known as drones, are also used as carriers for spectrometric sensors for agricultural purposes. These are low-flying aircraft operated by navigators / pilots with remote signal transmission from the ground or aircraft flying autonomously on given stored data. The sensor and the aircraft together make up a UAS (Unmanned aircraft system) for air crop scouting, and this type of scouting falls under the so-called aerial photogrammetry. By placing multispectral sensors on drones, it is possible to sample as many times as required by the user, even several times during the day. The scouting is usually performed by selecting in the dedicated software the region (e.g. field) to be recorded, then determining the desired flight path of the unmanned aerial vehicle and the frequency of imaging. After that, the unmanned aerial vehicle traverses the desired region by a given trajectory and performs sampling, i.e. photograph. This is how the so-called autonomous mission is accomplished. The resolution of the resulting images is several centimeters. Solid-wing and propeller drones are used for agricultural purposes, with the ,usually, four propellers. The first group of aircraft is faster and more resilient to wind, which is generally the biggest problem in the application of crop scouting drones. Rain is also an extremely adverse atmospheric phenomenon. In the context of spectrometry, these systems are typically equipped with a light sensor, so they are more independent of daylight compared to the sensors commonly used on agricultural machinery. Of course, in addition to speed, one of the biggest advantages of drones as a carrier of spectrometric sensors over agricultural machines is the independence of the soil during scouting, so in the case of crop scouting in the case of muddy terrain or the presence of water in the field, it is mandatory to apply a drone [8].

Remote rscouting using satellites, so called teledetection, is by far the fastest way to observe fields and crops, but due to the small sampling resolution that ranges from a few meters to several tens of meters, the usability of the maps and the data on them is limited. Although the great advantage of determining the reflectance index of plants using satellite imagery is the ability to obtain data for very large areas, there are a number of disadvantages to this method. If cloudy, it is not possible to obtain data on spectral reflections of plants. A disadvantage is the low frequency of sampling (depends on the frequency of satellite overflight over a certain territory and the time required for data processing). Depending on the satellites used and the area under observation, sampling periods range from one day to several weeks. Another disadvantage is that multispectral cameras mounted on satellites have fixed filters, i.e. it is not possible to change the light spectra in which the sampling is performed [9]. All these deficiencies can be a problem when it is necessary to scout crops very often (sometimes several times during the day), and for this reason satellite tracking of plants is most commonly used to monitor and influence climate change on the plant world. Satellite imagery is mainly used for the initial detection of poor soil conditions in terms of the presence of water on plots or wider areas of crop stress caused by insect infestation, severe nutritional deficiency or the spread of disease and / or weeds. When one of the above alarming conditions is identified in the satellite image, further measures of more detailed scouting shall be taken in another available and feasible manner.

3. MODELING OF PLATFORM BY SOLIDWORKS SOFTWARE

In SolidWorks, we modeled the front tractor platform of multispectral sensors. The platform is of the attachment type which enables connection to a tractor in three-point in the conventional way. The basic frame structure of the platform consists of pipes, square section, which are welded at an angle of 90 degrees (Figure 2). The lower part of the basic structure of the platform has two bottom connection points (Figure 3), while the vertical connection point (Figure 4) is positioned on the structure itself.

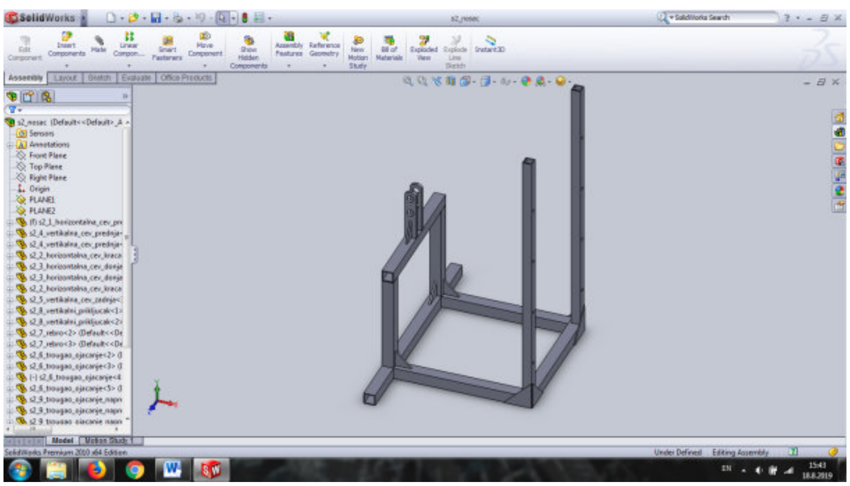

Fig. 2 View of the basic frame structure of the platform

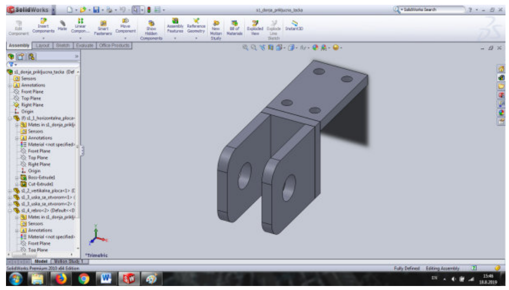

Fig. 3 Bottom connection point

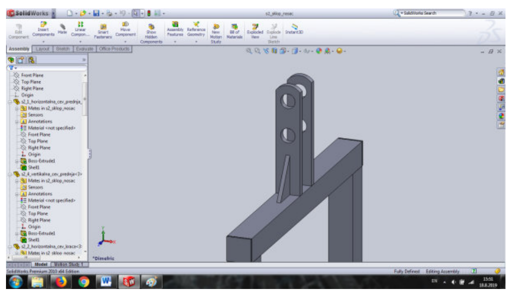

Fig. 4 Vertical connection point

The assembly of the basic structure of the platform, with connection points but also with an optional part for the sensor cables and the module, is shown in Figure 5.

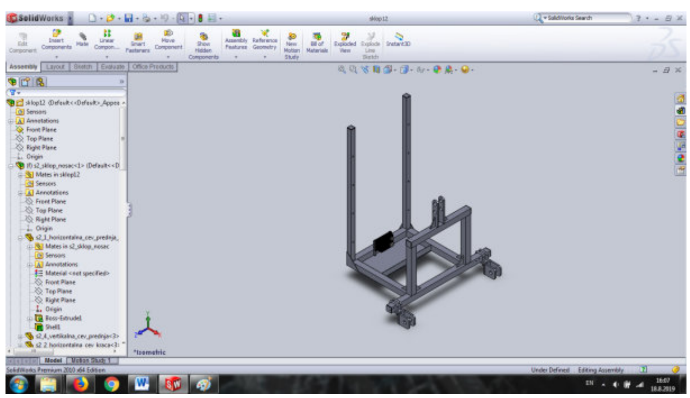

Fig. 5 Assembly of the basic structure of the platform

The wing assembly consists of two subassemblies, one of which is the central wing (with welded sliders and flaps for lateral wings) and the other subassembly is the lateral wings, where the sensors are positioned. The connection between the central wing and the lateral wings is made by screws. The limiters on the central wing serve to facilitate the positioning of the lateral wings during transport and / or working position (Figure 6).

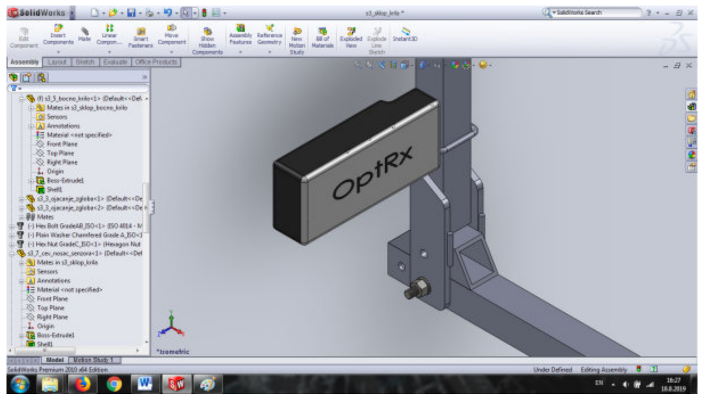

Fig. 6 Connection between central and lateral wing, with limiter

The complete front tractor platform assembly is actually a basic structure assembly and a wing assembly. The wingspan in the working position is 6.41m (Figure 7), while the height of the carrier with folded wings in transport is 2, 675 m (Figure 8).

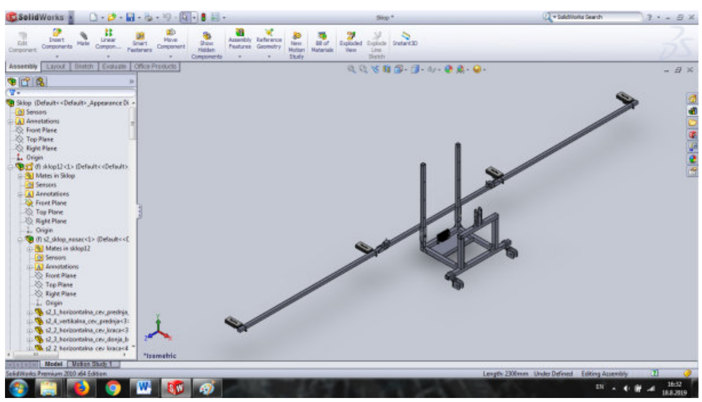

Fig. 7 Range of platform wings in working position

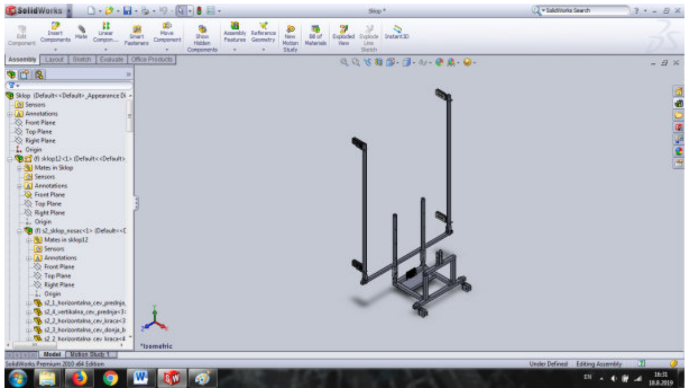

Fig. 8 Carrier with wings in transport position

While we were designing the modeled platform, care was taken to make the machine as flexible as possible. However, many possible variations of the existing solution were observed during the design and modeling process, and later during the testing of the implemented solution. Table 1 lists the possible variations of the presented and modeled platform solution

Table 1. Platform variations with description

No	**Description of variation**
1.	All three connection points are in the same plane.
2.	Fixing the bottom connection points. The bottom connection points are fixed by the welding process and not by the stirrup.
3.	On the basic structure, connect the pipes at a 45 degree angle (shown at a 90 degree angle).
4.	Fixing vertical wing guides by welding one tube at their top (crossbar).
5.	Fixing vertical wing guides by welding two pipes in an oblique position from the tips of the guides to the front of the base structure.
6.	Additional securing of lateral and center wing joints in working position. On the underside of the center wing, weld an additional pipe partially fronted through the wing itself.
7.	The tube of the central wings connect with the sliders welded at their midpoint, and drill one hole through the entire slider down and up from the wing relative to the wing. Adequately double the number of openings on the vertical slider guide.
8.	Attach each OptRx sensor to the wings by means of two stirrups.

CONCLUSIONS

Tractor plaforms for crop scouting are an excellent choice for simultaneous use in conjunction with a spreader. In this case, the site-specific distribution of mineral nutrients is technically simplest and most technologically efficient, as crop variability and consequently applied fertilizer standards are observed and determined at the same time as the fertilizer distribution itself. In addition to fertilizing soil and crops, these supports can also be used for chemical crop protection, noting that spectrometric sensors can be mounted on a working docking machine, so no platform is necessary. However, in these cases, it is easier to attach the platform than installing the sensor completely on a working machine. Finally, the platform can be used on its own, without additional work machines, for crop scouting at any time, but in that case, there are certainly faster, more efficient and less expensive ways of scouting, especially drones.

Fig. 9 Platform with wings in transport position

The modeled platform presented in this paper was successfully implemented according to the technical documentation resulting from the modeling process, Figure 9. The sensors and associated installation are systematically mounted on the platform. After this, the platform is connected to different types of tractors and then tested during transport and operation. The resulting vegetative index maps as indicators of the variable state of the surveyed crop justified the complete design and modeling process.

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FIELD USE AND CALIBRATION OF TWO DIFFERENT TIME DOMAIN REFLECTOMETRY SENSORS

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Abstract: *Time Domain Reflectometry (TDR) is a widely used device for measuring the volumetric soil water content that used irrigation management. Accurate measurement of soil water content is one of the most important factors both in making the right decision in irrigation management and in determining plant water consumption. Soil water content is affected by organic matter, soil texture, and bulk density, so calibration of TDRs in field conditions is necessary. In this study, two different TDR sensors (Buriable Waveguide-20, Waveguides-30) used in alfalfa (Medicago sativa) irrigation growing in clay soil were calibrated. Experimental data were taken from alfalfa (Medicago sativa) field irrigated with subsurface drip irrigation method in Isparta, Turkey. At the end of the study, there were clear relationships between TDR volumetric water content values and gravimetric samples, in also two probes [*$\theta v = 0.8991 \times \theta v_{TDR} + 2.9332$*, (*$R^2=0.84$*) for Waveguides-30;* $\theta v = 0.8621 \times \theta v_{TDR} + 3.7951$*, (*$R^2=0.86$*) for Buriable Waveguide-20]. Our results indicated that "Waveguides-30" and "Buriable Waveguide-20" TDR probes are dependable to measure volumetric soil moisture in subsurface drip irrigation condition and could be safely used.*

Key words : *Time Domain Reflectometry, Calibration, Volumetric soil water content, Subsurface drip irrigation*

1. INTRODUCTION

Soil moisture measurement in agriculture is carried out for different purposes such as monitoring of plant growth, evaluation of irrigation and water management. For this reason, accurate measurement of soil moisture is extremely important, especially in terms of efficient use of water resources. Soil water content is basically measured two different methods such as destructive and non-destructive (1). Destructive method is known as gravimetric methods in which soil water is removed from the soil and the amount of water removed is determined. Among the non-destructive methods are electrical conductivity method, thermal conductivity method, neutron method, tensiometer method and TDR. TDR is one of the most extensive and effective techniques used to estimate soil moisture content in a soil (2, 3). TDR has some advantages over other soil water content measurement methods. These advantages are (4, 5, 6);

(i) high-level accuracy to within 1 or 2% volumetric water content,
(ii) calibration necessity is minimum,
(iii) there is no radiation hazard as in neutron probe and gamma techniques,
(iv) simple measurements, and the method can provide continuous measurements through automation and multiplexing.

Despite these advantages, TDR measured moisture data are strongly affected by factors such as waveguide geometry, choice of waveguide, long cables, waveguide insertion, soil bulk density, soil temperature, soil texture, soil structure, soil organic matter content, and salinity (7, 8). For this reason, many researchers reported that (2, 9) TDR needs field-specific calibration to take correct data from sensors. The first study about this subject was done by Topp et al. (10). They found the relationship between the soil volumetric water content (θ) and dielectric constant (K_a) measured by TDR that have been universally as follows:

$$\theta = 4.3\times10^{-6}K_a^3 - 5.5\times10^{-4}K_a^2 + 2.92\times10^{-2}K_a - 5.3\times10^{-2}$$

The main purpose of this study is to perform field-specific calibration of two different TDR sensors used for measuring soil moisture of alfalfa irrigated by subsurface drip irrigation method.

2. MATERIAL AND METHOD

This research was carried out on experimental area of Agricultural Research Station of Agricultural Faculty in Isparta Universiy of Applied Sciences, Isparta, Turkey in 2017-2018 vegetation period (Altidute: 1020 m, Latitude: 37.83° Longitude: 30.53°). In this study, 6050X1 model Trase System-1 (Soilmoisture Equipment, USA) and its two different types waveguides were used in an experiment that was conducted in order to determine plant water consumption and irrigation scheduling of alfalfa irrigated by subsurface drip irrigation method. The 6005L2 type buriable waveguide is 20 cm long with 2 m cable (Buriable Waveguide-20) while the 6008L2 type waveguide (Waveguide-30) is 30 long cm. Buriable Waveguide-20 was inserted into three different soil depths (30-60 cm, 60-90 cm, 90-120 cm) while Waveguide-30 was inserted into one soil depth (0-30 cm). The experiment included three different alfalfa varieties and five different irrigation water levels. At the beginning of the study, 15 soil profiles were opened in the experimental area for the placement of the sensors in the soil (Fig. 1).

Fig. 1. Experimental area

In order to determine the response of the sensors at different soil moisture levels of subsurface drip irrigated alfalfa, a total of 140 soil samples were taken from different soil depths at different dates during the 2017-2018 vegetation periods. The moisture content of the soil samples taken from the field was determined based weighted (P_w), then the volumetric water content also was calculated by multiplying P_w and bulk density. Soil samples were taken according to normal procedure and volumetric water content and K_a values were measured simultaneously with TDR. Some soil properties of the site (Bulk density, Texture, EC: Electrical conductivity, FC_w: Field capacity based on weight, WP_w: Wilting point based on weight) were provided in Table 1.

Table 1 Some properties of the soil in experimental area

Soil dept, cm	Bulk density, g/cm^3	Texture	EC µs/cm	FC_w %	WP_w %
0-30	1.49	Clay	241	29.82	19.34
30-60	1.36	Clay	320	30.51	19.13
60-90	1.37	Clay	318	30.80	19.44
90-120	1.44	Clay	294	29.93	18.33

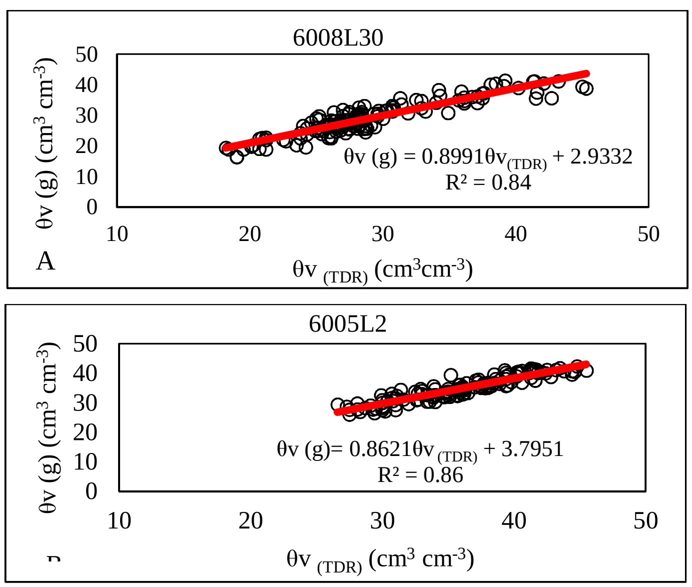
For evaluate measured (Pi) TDR data with observed soil moisture content (Oi) using gravimetric samples (n), some statistical parameters such as the coefficient of determination (R^2), mean bias error (MBE) and root mean square error (RMSE) were used. MBE and RMSE was calculated using below Equations. In addition, Paired sample t-test was used to show statistical difference between $\theta v_{(g)}$ and $\theta v_{(TDR}$ ($p<0.05$).

$$MBE = n^{-1}\sum_{i=1}^{n}(Pi - Oi)^2$$

$$RMSE = \sqrt{n^{-1}\sum_{i=1}^{n}(Pi - Oi)^2}$$

3. RESULTS AND DISCUSSION

Volumetric soil moisture values in all the depts ranged from field capacity and wilting point during the calibration procedure. Fig. 2 indicates volumetric water content measured by gravimetricaly $\theta v_{(g)}$ versus volumetric water content $\theta v_{(TDR)}$ and volumetric water content measured gravimetric method $\theta v_{(g)}$ versus dielectric constant (K_a) obtained from TDR. The calculated RMSE and MBE values for Buriable Waveguide-20 and Waveguides-30 0.145 and -0.050 and 0.097 and -0.041, respectively (Table 2). Ju et al. (6) indicated that the RMSE as 0.06 for clay loam soil while Chaves et al. (11) found the MBE and RMSE values as 0.05 and 0.025, respectively for forest soil. Kirnak and Akpinar (9) also these values reported that 1.9 and -0.16, respectively. It is thought that these differences between findings could be because of different soil temperatures, texture, management conditions and sensor type. Linear relationships were determined between measured volumetric water contend $\theta v_{(g)}$ and $\theta v_{(TDR)}$ for Buriable Waveguide-20 [$\theta v=0.8621\times\theta v_{(TDR)}+2.9332$, ($R^2=0.86$)] and Waveguide-30 [$\theta v=0.8991\times\theta v_{(TDR)}+3.7951$, ($R^2=0.84$)] (Fig. 2: A and B).



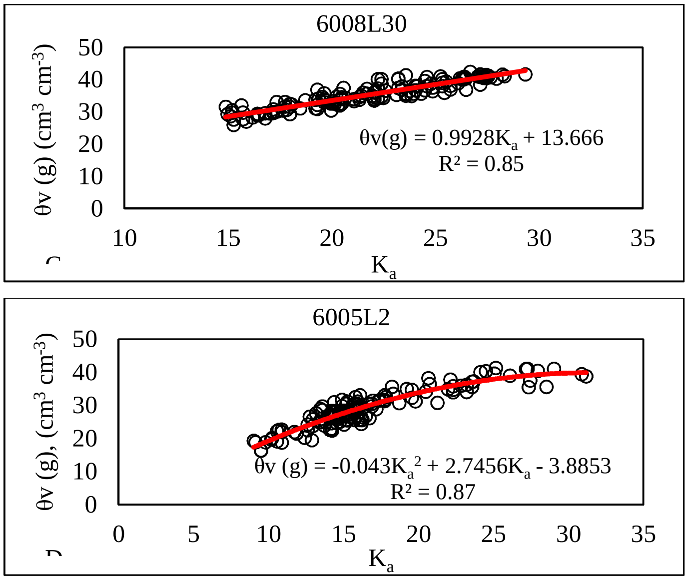


Fig 2. Comparison of obtained volumetric water content calculated gravimetric method $\theta v_{(g)}$ versus volumetric water content $\theta v_{(TDR)}$ (Fig: A and B). Comparison of measured volumetric water content calculated gravimetric method $\theta v_{(g)}$ versus measured dielectric constant (K_a) (Fig: C and D)

Table 2 Comparison of the field-based calibration of θv_{TDR} versus gravimetric measurements of θv_g

Sensors	Equation type	R^2	RMSE	MBE
Buriable Waveguide-20	Linear	0.86	0.145	-0.050
Waveguide-30	Linear	0.84	0.097	-0.041

The differences between volumetric water contents data taken from Buriable Waveguide-20 and gravimetric method and differences between volumetric water contents determined with Waveguide-30 and gravimetric method were shown in Table 3. The paired sample t-test results showed that there were no significant differences between Buriable Waveguide-20 and the gravimetric method and between Waveguide-30 and the gravimetric method ($p< 0.05$). The standard error of the mean (SEM) was found 0.366 and 0.344 for Buriable Waveguide-20 and gravimetric method and was found 0.518 and 501 for Waveguide-30 and gravimetric method, respectively.

Linear relationship was found between measured volumetric water contend $\theta v_{(g)}$ and K for Waveguide-30 [$\theta v_{(g)}$= 0.9928K +13.666 (R^2=0.85)], while polynomial relationship was found between measured volumetric water contend $\theta v_{(g)}$ and K for Buriable Waveguide-20 [$\theta v_{(g)}$= 0.043K^2 + 2.7456K – 3.8853 (R^2=0.87)] (Fig. 2: C and D). It can be concluded that these two models could be used to measure volumetric water contend in clay soil types instead of Topp equation which known as universal was adequate for different soil type. This study also affirmed that the equation described by Topp et al. (1980) could be reliably used to determine volumetric water content correctly from dielectric constant (K_a) in the clay soils.

Table 3 Test of significance of the volumetric water content measured TDR sensors

Measurement methods	Means	SD	SEM	t stat	p
Buriable Waveguide-20	35.397	4.330	0.366	0.35	0.730
Gravimetric method	35.347	4.074	0.344		
Waveguide-30	29.498	6.130	0.518	0.39	0.700
Gravimetric method	29.417	5.923	0.501		

4. Conclusion

One of the main findings of this study was Buriable Waveguide-20 and Waveguide-30 can be used as a faultless soil moisture tool for determining volumetric soil water content in clay soils. Universal Topp equation for these two sensors can safely be used without a field-specific calibration. Another result of our study that Time Domain Reflectometry devices can be securely used for determining volumetric soil moisture without destructive and hazardous.

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A MODERN HARDWARE AND SOFTWARE SOLUTIONS FOR CORN IRRIGATION

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Abstract: *Increasing global climate change requires the application of modern methods in irrigation of agricultural crops. In this context, the research in this paper was based on the application of modern hardware and software solutions in determining the corn water requirements. Research was carried out at three locations: Srebrenik, Kalesija and Kakanj in Bosnia and Herzegovina. Detailed research of all climate, biological, geographical and soil characteristics was carried out during the vegetation period of 2018 in order to use the results as an input to determine corn water requirements using AquaCrop 6.1 software. In addition to using several software, certain activities were carried out by using an unmanned aerial vehicle (UAV). The corn water requirements during 2018 on three analyzed locations ranged from 405 to 530 mm, the highest value was in Kakanj, and the lowest in Kalesija. When it comes to the monthly level, during almost all month's effective rainfall was enough to cover corn needs for the water, the exception is August, when a certain water deficit (56-67 mm) was obtained for all locations.*

Key words: *corn water requirements, smart agriculture, software models, UAV*

1. INTRODUCTION

Significant increase in air temperature in Bosnia and Herzegovina (BiH), which ranges from 0.2 to 0.6°C [1-6] resulted in a changes in terms of the amount of water lost from soil by evapotranspiration [7], as well as changes in other soil water balance components [8], primarily soil moisture deficit and surplus [3, 4, 9]. As a result of climate change, the vegetation period, which refers to the period from April to September in BiH, is characterized by rainfall reduction [10] followed by increase in air temperatures [11, 12] resulting in an increase of drought frequency and magnitude.

Increased magnitude of drought and its spatial and temporal variability in BiH [9, 13-16] leads to a greater uncertainties about the future fresh water availability, as well as possible negative consequences on the social well-being and the economy in general [17].

Irrigation, which in current agronomic and socio-economic conditions has only a supplemental character in BiH [18-20], will certainly represent one of the key mechanisms for adaptation to climate change in the future. Furthermore, flood protection, drainage of water surpluses, i.e. regulation of the soil water-air regime is a priority for a future development of the agricultural sector in BiH [11].

Irrigation in BiH is currently in the process of transition from supplementary to mandatory agricultural measure under the increased exposure to drought. Due to the lack of connection with professionals and advisory services, farmers in BiH, though without experience, are forced to install irrigation systems by themselves. Thus, they are mainly installed without an adequate plan, making them very dysfunctional, uneconomical and ultimately unsustainable [21, 22]. In addition, the most common water sources used in irrigation are drinking fresh water: tap water and water from underground sources, that is often overused. Farmers do not know how much water they need to irrigate their crops, and there is no awareness of rational water consumption. This is particularly true in circumstances where they have unrestricted access to water from wells, rivers or springs located on their estates, or in their immediate vicinity, in which case it is considered as a personal inexhaustible natural resource [20].

The American National Research Council defined precision agriculture as "a management strategy that uses information technology to bring data from multiple sources to bear on decisions associated with crop production". This type of agriculture involves all of the techniques and methods available in the new Information and Communications Technology era, which can be used to retrieve useful information for managing crops while accounting for landscape heterogeneity and variability within and between fields [23, 24].

In the current uncertainty of agricultural production, the use of modern technologies should be encouraged because they represent a good basis for collecting, processing and analyzing spatial changes in a cost-effective, simple and rapid manner [25, 26]. Therefore, the future of agriculture in BiH depends directly on the implementation of sustainable production systems and the basic principles of smart agriculture, which is especially true for the water management sector.

The management of any system, therefore irrigation system as well, is impossible nowadays without the use of modern technologies to determine, analyze and process data and ultimately make decisions. Modern irrigation technologies involve the use of software models and hardware solutions to obtain comprehensive data that result in timely and quality decisions [27, 28]. If the process of determining crop irrigation water requirements (IWR) is adjusted to the atmospheric demand [29] it can result in significant improvements in the use of agricultural water [30]. Therefore, irrigation systems should be dimensioned to cover in the vegetation and, over the years, changing water needs (Vukadinović, 2017) of the specific - local conditions.

Specific crop water requirements (CWR) can be determined experimentally or by different computation methods. Experimental methods include long-term, field-based, exact research whose results are used to develop computational methods and software models, most commonly in the form of open source software, easily accessible to any researcher regardless of location [31, 32]. There are dozens of such software models operational today, some of which have been used by researchers and experts for more than 20 years. The most commonly used software models for determining CWR and IWR are: *CROPWAT* [33], *SPAW* [34], *ISAREG* [35], *GISAREG* [36], *CUP-E, WISE, CROPFLEX* [27], *AquaCrop* [37] and *SIMDualKc* [38]. Except these, there exist software models to calculate water balance components (*budget, WASIM, The Water-Balance Model, SRCLET*), evapotranspiration (*EToCalc, REF-ET*), design irrigation systems (*COPAM, HydroCalc PRO*), etc.

AquaCrop [39] developed by FAO *Land and Water Division* (http://www.fao.org/aquacrop/en/) is the most used software model today. *AquaCrop* simulates the response of yield to water availability, and it is suitable for analysis of conditions in which water is a key factor limiting agricultural production [31]. The CWR and IWR calculation procedures are based on FAO 24 [40], FAO 56 [41] and FAO 66 [32] *Irrigation and drainage paper* publication. A GIS version called *AquaCrop-GIS* was also developed recently [42], as well as *open source* platform *AquaCrop-OS* [43].

Except software, state-of-the-art hardware solutions enable accurate data collection in real time. This is made possible by using various sensors located on the ground, plants or in the different aerial vehicles (unmanned aerial vehicles or satellites) [44]. The classic way of agricultural crop monitoring usually requires fuel and it takes a lot of time. Also, in the large fields there are some zones that are completely inaccessible from the ground. This is one of the reasons that unmanned aerial vehicles (UAV) are increasingly used nowadays. By using UAV it possible to obtain a more comprehensive overview of the vegetation status in a very short period of time, as well as to obtain, through computer analysis, information that cannot be visually noticed [45, 46].

The European Parliament recently introduced the requirement to sustainably "produce more with less" in agreement with the new EU research program "*Horizon2020*" (Geoghegan-Quin, 2013), thus the key requirement of agriculture production, along with optimal product quality, is the rationalization of production processes from an economic and environmental point of view. In this regard, the use of UAVs opens up new possibilities for required efficiency of agriculture.

Possibility to have continuous monitoring of agricultural fields and crops could be a key factor in the precise planning and implementation of most agrotechnical operations. Detailed and regularly updated documentation contributes to a better planning of work operations, it saves labor, time and resources, leading to improved product quality and reduced pressure to the environment [46]. Use of UAVs has a great potential to solve some of the important problems in modern agriculture, especially when it comes to data collection and processing. Their use is especially useful for larger fields as well as inaccessible and remote areas [47]. Therefore, we can claim that use of UAVs represents one of the best possible solutions in modern agricultural production [48]. This is supported by the fact that agriculture is projected to become the second largest user of UAVs in the next 5 years [49].

All of these practices have a clear application for a large farm; however, the question is how smallholder farmers, representing the majority of farmers in BiH, can benefit from large farm technology? In this context, the main objective of this research was the analysis of possible applications of modern software and hardware solutions for the determination of real-time, non-optimal condition, corn irrigation water requirements in different agro-climatic conditions of BiH, thus creating basic conditions for usage of such solutions for more rational water resource management and the reduction of negative impact of climate change on smallholder farmers.

2. MATERIAL AND METHOD

A research plot with corn (*Zea mays*) has been selected in three agro-climatically different locations in BiH. The following municipalities were selected as research locations: Srebrenik, Kalesija and Kakanj. Detailed research of all management, climate, biological, geographical and soil characteristics was carried out during the vegetation period of 2018 in order to use these data as an input to obtain crop water (CWR) and irrigation requirements (IWR) using *AquaCrop 6.1* software model [31, 39, 50]. As a result of applied model, information was obtained on soil moisture, CWR, biomass production, yield and IWR of corn during 2018 vegetation period at each of the three selected locations.

The aim was not to set up the experimental plots where all the agronomic measures and activities would be carried out at the right time and in the right way, but to determine the IWR specific for each analyzed location and all farm-level conditions, including usual management practice. This means the farmer was not advised how to run the production, on the contrary he was given the freedom to do it in the usual way. The criteria for selecting plots was only the willingness of farmers to cooperate, accessibility of the plot and minimum of 2,000 m^2 under corn produced for the grain.

The weather characteristics for the vegetation period (01.04. – 30.09.2018) were collected using mini-meteorological stations (*IMETEOS ag – IMT 200*) installed in the immediate vicinity of the selected plots. The sensors were set at a height of 2 m from the ground and measurements were made every hour. The following data were collected: mean (T_{mean}), maximum (T_{max}) and minimum (T_{min}) air temperature, sum of precipitation (P), mean relative humidity (RH_{mean}), mean wind speed (u_2) and insolation (n). In the case of interruptions in station operation, data from the nearest public meteorological station were used.

The soil characteristics of the selected plots were determined using the *Pedological Map of BiH* (scale 1:50,000) published by the *Institute for Agropedology Sarajevo*, and by a detailed field survey conducted at the beginning of the season. After the area was surveyed, locations were selected at which soil profiles were opened (depth up to 1 m). Soil samples were taken from each horizon in disturbed and undisturbed condition, three replicates each. The soil samples were used to determine: soil texture by the hydrometric method; absolute density using air pycnometer; bulk density by gravimetric method; pH in H_2O and 1 mol dm^{-3} KCl was determined electrometrically using a pH meter, in a suspension of 1:2.5; humus content by colorimetric method using spectrophotometer while bioavailable phosphorus (P_2O_5) and potassium (K_2O) content was determined by AL method.

Soil water characteristics were determined through soil water retention at a given matrix potentials using a Sand/Kaolin box apparatus „*Eijkelkamp Agrisearch Equipment*". Following potentials (Ψ) were used: 0.33 bar (pF 2.54: field water capacity), 6.25 bar (pF 3.8: lento-capillarity point) and 15.5 bar (pF 4.2: permanent wilting point). Total (TAW) and readily (RAW) available water capacity of soil was calculated from following relation between field water capacity (FWC), lentocapillary point (LCP) and permanent wilting point (PWP): TAW = FWC – PWP; RAW = FWC – LCP.

In addition, average soil samples from a depth of 0.20 cm were taken at 10 intervals during the corn vegetation period. These samples were used to determine the actual soil moisture by the gravimetric method. Soil classification and criteria for pH, humus, phosphorus and potassium content was carried out using Resulović et al. (2008) and Resulović and Čustović (2002).

The spatial characteristics of the selected plots were determined using aerial photogrammetric images. The recording was done by a quadcopter *UAV DJI Phantom 4 PRO*, which was equipped with a standard RGB camera. The recording height was 25 m, with a 70 % overlap. The resulting resolution of each image was 5472 x 3648 pixels. A combination of *DJI Go* and *Pix4DCapture* (www.pix4d.com/) software packages was used to plan the UAV route. Individual photographs were later combined in the *DroneDeploy* software program (www.dronedeploy.com) to obtain orthomosaic photographs - maps of research plots. A total of 10 recordings were made at each location (Table 1).

Table 1 Aero-photogrammetry recording dates (09.05. – 17.09. 2018.)

Flight No.	Date	Day between flights	Srebrenik			Kalesija			Kakanj		
			Photos	Start	Dur. min.	Photos	Start	Dur. min.	Photos	Start	Dur. min.
1	09.05.	-	265	11:28	20	90	16:00	9	373	14:27	13
2	17.05.	8	314	11:31	11	149	14:27	5	380	9:46	12
3	28.05.	11	324	12:07	11	263	15:29	8	169	14:27	6
4	13.06.	16	351	11:38	12	338	13:51	14	484	14:02	16
5	03.07.	20	259	11:55	12	294	13:56	10	359	14:46	12
6	17.7.	14	260	12:09	12	224	14:13	7	362	15:45	12
7	07.08.	20	260	13:11	13	224	15:04	8	363	9:30	12
8	30.08.	22	260	13:09	13	265	14:53	9	358	10:08	12
9	10.09.	11	263	11:24	13	266	13:40	9	361	15:27	10
10	17.09.	7	260	10:42	13	260	16:15	9	358	10:33	12
Average		14	282		13	237		9	357		12
Sum		129	2,816			2,373			3,567		

Using the toolkit (distance, area, count, elevation) within the *DroneDeploy* software (pro package), the orthomosaic photographs, 10 for each research location, provided information on farm management and basic spatial characteristics such as information on land use, inclination, exposure, relief and areas under corn.

The crop (corn) characteristics were also determined using aerial photogrammetric recordings as well as field surveys and interviews with the owner of the analyzed plots. The collected images were processed in *DroneDeploy* software and using the *Agremo Plant Count & Health* online application (www.agremo.com). In this way, information was obtained on:

- number of plants per hectare – plants density,
- maximum canopy cover (CC_x) and green canopy development,
- time from sowing to start senescence,
- time from sowing to maturity,
- time from sowing to flowering and duration of flowering.

For conservative parameters such as atmospheric CO_2 concentration, harvest index (*HI*), effective rooting depth (Z_n), water productivity coefficient (WP), stress coefficients (K_s), soil moisture capillarity rise, soil water movement and infiltration, a database within the *AquaCrop* model was used.

At full maturity, corn grain yield was determined by harvesting from predefined calculation plots. A cross-method was used to select the sampling site, so 5 plots were taken at each research location. The grain was separated from the cob, adjusted to 14 % moisture and then weighed, after which the average grain yield per unit area was determined. Obtained yields as well as soil surface moisture, measured at 10 intervals during vegetation, were used to validate the *AquaCrop 6.1* software model operation.

All management, weather, soil, spatial and crop information collected from tree research plots were adjusted and in combination with conservative parameters specific for the corn crop, used in *AquaCrop 6.1*. The calculation was based on two types of conditions: the case when there is no irrigation and vegetation is carried out as it was in natural conditions and the case when there is irrigation with an adequate amount of water.

As a result, *AquaCrop* provided the data on:

- corn water requirements (CWR),
- effective rainfall (P_{ef})
- corn irrigation water requirements (IWR),
- produced biomass and yield under conditions with and without irrigation,
- surface soil layer moisture.

3. RESULTS AND DISCUSSION

3.1. Study area characteristics

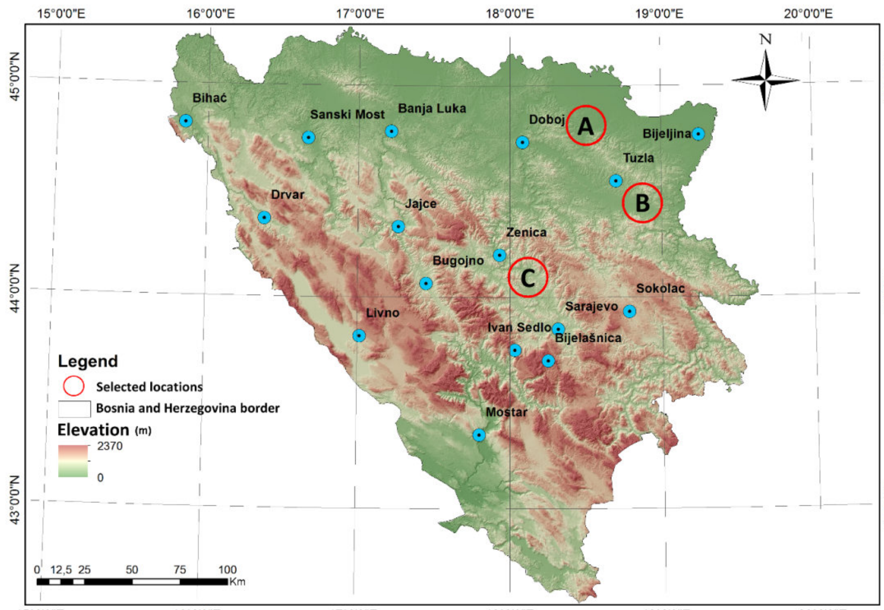
The basic information and location of three selected agro-climatically different locations (Srebrenik, Kalesija and Kakanj) where the research activities were carried out during vegetation period of 2018 are presented in Table 2 and Map 1.

Table 2 Basic spatial characteristics of research locations

Location	Mark	°*N*	°*E*	Exposure	*z*	Average inclination	Filed area
					m	%	m^2
Srebrenik	A	44°40'52.14"	18°33'8.74"	Southeast	407	8.56	3,500
Kalesija	B	44°26'12.02"	18°54'40.90"	Southwest	294	7.17	4,080
Kakanj	C	44°7'23.89"	18° 7'44.53"	Southwest	440	2.42	3,690

Note: °*N* – latitude; °*E* – longitude; *z* – elevation

All plots have southern exposure and similar surface. The plot in Srebrenik has a slightly lower slope (2.42 %) than the other two. Also, the plots in Srebrenik and Kakanj are located on similar altitude, while the plot in the Kalesija is at a slightly lower altitude (Table 2).



Map. 1 Location of selected plots: A – Srebrenik, B – Kalesija, C - Kakanj

The weather conditions as averages for the vegetation period, i.e. the 6 months period lasting from the beginning of April to the end of September 2018, are shown in Table 3.

Table 3 Average weather conditions, vegetation period, April – September 2018

Location	T_{mean} (°C)	T_{max} (°C)	T_{min} (°C)	RH_{mean} (%)	u_2 (m s^{-1})	n (h dan^{-1})	P (mm)	ET_o (mm)
Srebrenik	19.19	23.98	15.42	76	2.27	7.90	546	497
Kalesija	19.28	26.38	12.91	83	1.72	6.82	584	468
Kakanj	18.99	27.31	13.25	75	1.24	7.01	497	588

Note: T_{mean} – mean air temperature; T_{max} – maximum air temperature; T_{min} – minimum air temperature, RH_{mean} – mean relative humidity; u_2 – mean wind speed, n – solar radiation; P – sum of precipitation, ET_0 – reference evapotranspiration.

No major differences in basic weather conditions were observed between the three research locations. The highest average air temperature was recorded for Kalesija (19.28°C), but the highest average maximum was in Kakanj (27.31°C), while Srebrenik had the lowest temperature variations. In all three locations, the warmest month was August, with mean air temperatures ranging from 22.11 to 22.47 °C. The lowest RH_{mean} values were in Kakanj, while the highest wind (2.2 m s^{-1}) and insolation (7.9 h dan^{-1}) were recorded in Srebrenik. On the other hand, the amount of precipitation varied between locations. The highest amount of rainfall was recorder in Kalesija (584 mm), while it was lowest in Kakanj (497 mm). It is interesting to note that the largest amount of rainfall occurred during the summer months of June and July 2018. Also, precipitation during the 2018 vegetation period was 50 - 80 mm higher than the historical average for the same time period. During the recorded period (183 days), depending on the location, it was raining 58 - 63 days, or 31.6 - 34.9 % of the total time.

The basic physical, water and chemical soil characteristics of surface soil horizon for the tree research plots are presented in Table 4 and 5.

Table 4 Physical and water characteristics of the soil surface layer

Location	Depth cm	Soil type	Texture (%)			Texture class	Bulk density g cm^{-3}	TAW % vol.	RAW % vol.
			Send	Silt	Clay				
Srebrenik	0 – 25	Dystric Cambisol	29	55	16	Silty loam	1.23	22.62	12.71
Kalesija	0 – 30	Dystric Cambisol	19	64	17	Silty loam	1.29	25.66	13.16
Kakanj	0 – 30	Eutric Cambisol	39	40	21	Loam	1.13	21.29	11.28

Note: TAW – Totally available water in soil; RAW – Readily available water in soil

Soil type at the research plots in Srebrenik and Kalesija was Dystric Cambisol according to BiH national soil classification (Resulović et al., 2008). These soils have a higher percentage of silt (> 55 %) and therefore have a silty loam texture in the surface layer, while the clay content and density increase with depth. Based on the physical characteristics (Table 4), soils in Srebrenik and Kalesija do not differ much. The same situation is with soil water retention, the readily available water (RAW) for the 1 m soil layer at both plots is about 107 mm. The soil in Kakanj differs from the previous two. The soil type at this location was classified as Eutric Cambisol (Resulović et al., 2008), with a loamy and low density (1.13 g cm^{-3}) surface horizon. However, the clay content and consequently density, increased rapidly with depth. This soil, observed up to a depth of 1 m, has a RAW value of 70 mm, which is much lower than the usually used value when it comes to soil water balance calculation in BiH and surrounding countries (Čustović & Vlahinić, 2004; FZAP, 1994; Šimunić, 2013).

Table 5 Chemical characteristics of the soil surface layer

Location	Depth cm	pH		Humus %	Physiologically active mg 100 g^{-1} of soil	
		H_2O	KCl		P_2O_5	K_2O
Srebrenik	0 - 25	5.5	5,0	2.86	2.81	18.8
Kalesija	0 - 30	4.3	4,1	2.74	0.25	10.4
Kakanj	0 - 30	7.4	6.7	5.47	0.76	25.2

When it comes to chemical characteristics, soils in Srebrenik and Kalesija are very acidic with pH> 5.5 and have a medium humus content (2.74 – 2.85 %), while soil in Kakanj has a neutral pH reaction (pH = 7.4) and higher humus content (5.47 %). All three soils are relatively well supplied with physiologically active potassium, while phosphorus content is very low (Table 5).

3.2. Crop characteristics

Based on the interview with the farmer who owns the research plots, information on corn hybrid used and sowing dates were collected. Plot located in Srebrenik (3,500 m^2) was sown on April 22, 2018 with corn hybrid: *BC Pajdaš – FAO 400*. For plot in Kalesija (4,080 m^2), corn hybrid *BC Pajdaš - FAO 490*, was sown 9 days later, that is, May 01, 2018. A corn hybrid *P9911 - FAO 480* was sown in Kakanj (3,690 m^2) on April 23, 2018. Sowing was delayed at all three locations, due to slightly lower temperatures and higher rainfall. Vegetation period lasted depending on the location from 139 days in Kalesija to 157 days in Kakanj (Table 6).

Table 6 Length of corn growing stages in days

Location	Planting date	Days until			
		Seedling emergence	Start of flowering	Start of yield formation	Harvesting
Srebrenik	22.04.	8	70	86	146
Kalesija	01.05.	6	68	73	139
Kakanj	23.04.	11	87	107	157

Using aerial photogrammetric recordings and tools for processing them in *DroneDeploy* and *Agremo Plant Count & Health* software, the plant density, spacing between the rows and plants in the rows, number of plants and number of rows were determined for each research plot (Table 7).

Table 7 Spacing, density and number of plants

Location	Row spacing	Spacing between pants in the row	No. of plants per plot	No. of plants	No. of rows
	m	m		ha	
Srebrenik	0.71	0.32	14,635	41,813	47
Kalesija	0.74	0.35	14,178	34,749	26
Kakanj	0.64	0.28	19,562	53,133	60

The number of plants per ha was calculated based on the number of plants per plot. The largest number of plants was determined in Kakanj (53,133 per ha), then in Srebrenik (41,813 per ha), and the smallest in Kalesija (34,749 per ha). In addition to poor nutrient supply, the reasons for poor corn development in Kalesija can be found in the low level of agrotechnical measures applied. The farmer did not visit the plot in Kalesija except at the time of sowing and fertilization. Weed growth was intensive (especially *Ambrosia artemisiifolia*), a large number of corn plants did not sprout, and in addition, heavy rainfall during June and July 2018 (349 mm) formed a surface runoff in the middle of the plot, causing gully erosion. In addition to the number of plants using a combination of several photogrammetric and spatial mapping software (*DroneDeploy*, *Agremo*, *ArcGIS 9.3*), it was possible to determine canopy cover (*CC*) at 10 intervals during vegetation. *CC* represents one of the key parameters within the *AquaCrop* software model. The data obtained are shown in Figure 1.

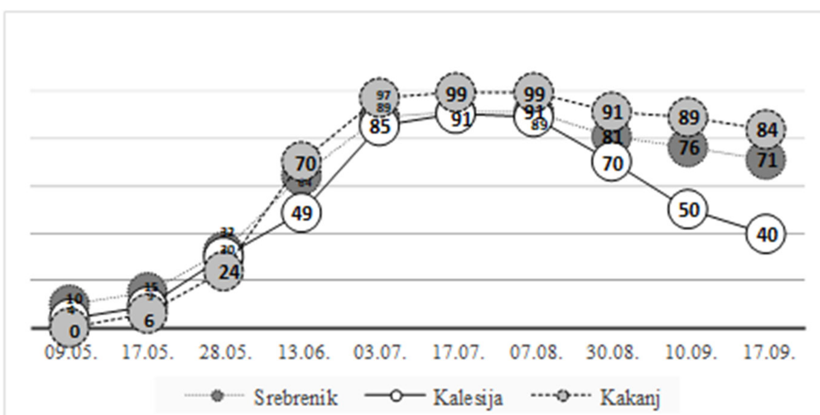


Fig. 1 Corn canopy development

Based on the corn canopy development, the differences between locations can be seen. The difference between the corn grown in Kalesija and the other two locations is particularly noticeable. During the flowering period (around June 13th) corn in Kalesija was poorly developed (CC = 49 %) compared to other two locations (CC = 64 – 70 %), which is reflected later in its development.

3.3. AquaCrop model results

After all necessary data were collected for three plots (Srebrenik, Kalesija and Kakanj), *AquaCrop 6.1* software model was applied, resulting in data on: corn water requirements (CWR), effective rainfall (P_{ef}), IWR, produced biomass and yield under conditions with and without irrigation and surface soil layer moisture. The data in Table 8 shows the relationship between monthly P_{ef} sums, that is, rainfall infiltrating the soil at each plot and the CWR, as well as the monthly IWR. The values obtained relate only to the 2018 vegetation period.

Table 8 Ratio between CWR and P_{ef}

Location	Parameter	Month						Sum	mm
		IV	V	VI	VII	VIII	IX	mm	day^{-1}
Srebrenik	P_{ef}	26	108	155	149	48	29	515	3,35
	CWR	53	72	73	105	105	24	432	2,96
	IWR	10	-	-	-	48	-	58	0,40
Kalesija	P_{ef}	-	117	148	201	43	22	531	3,82
	CWR	-	98	79	107	99	22	405	2,91
	IWR	-	-	-	-	-	-	-	-
Kakanj	P_{ef}	-	134	80	150	55	36	455	2,90
	CWR	16	110	98	134	122	51	530	3,38
	IWR	-	30	5	-	53	23	111	0,71

During 2018, CWR ranges from 405 to 530 mm, the highest value was in Kakanj and the lowest in Kalesija. Corn is a drought tolerant crop that has a low transpiration coefficient ranging from 200 to 450 mm. Its need for water depends on the length of the vegetation period, FAO ripening group, agro-climatic and soil conditions [51]. According to many studies globally, the annual CWR ranges from 238 to 964 mm [51, 52] and most often in the range of 500 to 800 mm [32]. Under the conditions prevailing in the Western Balkans (Serbia, Bosnia and Herzegovina and Croatia), according to numerous studies, CWR ranges from 418 to 642 mm [51, 53-58], which are similar to the values obtained in this research.

Previous studies in the Western Balkans found following average monthly CWR: April 20 mm, May 30 - 70 mm, June 120-130 mm, July 110 - 130 mm, August 100 - 130 mm and September 50 - 70 mm [51, 53, 54]. The values obtained in this research are slightly higher in the first two months of vegetation (April and May), while in the rest of the period (June - September) CWR is within the limits of previous research. Bošnjak (1983) found that the average daily consumption of water by corn for the entire vegetation period is about 3.0 - 3.5 mm day^{-1}. In this study, a similar value was obtained, ranging from 2.91 to 3.38 mm day^{-1} depending on the location. If we compare the annual amount of P_{ef} and CWR (Table 8), CWR (530 mm) is higher than P_{ef} only in Kakanj. On a monthly basis, in most cases monthly rainfall during 2018 was sufficient to cover CWR, the exception being the month of August, when there was a lack of moisture at all three locations. In the case of plot in Kalesija, heavy rainfall from July (201 mm) was sufficient to cover lack of rainfall in August. The highest total IWR for corn during 2018 was obtained for Kakanj (111 mm year^{-1}) while the month with the highest requirements was August (53 mm year^{-1}). On the other hand, there was no need for irrigation in Kalesija (Table 8). Furthermore, *AquaCrop* also estimated the yield achieved based on all the parameters involved (Table 9). It is interesting to note that in the estimates, yield almost did not change depending on whether it was irrigated or not. This is probably due to favorable precipitation situation in 2018 (Table 8). This also applies to plot in Kakanj where an IWR of 111 to 122 mm is determined, and where, assuming that irrigation was applied, the total estimated yield would increase by only 0.54 t ha^{-1}.

Table 9 Corn yield and biomass production at three research locations

Location	Irrigation	Total biomass	Corn grain yield					
			AquaCrop estimation		Measured yield		Difference	Average error
		t ha^{-1}	t ha^{-1}	t field^{-1}	t ha^{-1}	t field^{-1}	t filed^{-1}	%
Srebrenik	Yes	24.00	12.00	4.20				
	No	23.99	11.99	4.19	11.35	3.97	0.64	5.64
Kalesija	Yes	19.12	9.56	3.90				
	No	19.12	9.56	3.90	7.35	2.93	2.21	30.00
Kakanj	Yes	28.18	14.10	5.20				
	No	27.15	13.56	5.00	13.27	4.90	0.29	2.19

The highest corn grain yield was estimated in Kakanj, where irrigated yield was 13.56 t ha^{-1}. A much lower yield was estimated in Kalesija (9.56 t ha^{-1}).

The yields obtained are the result of a combination of all the production characteristics from the selected plots in Srebrenik, Kalesija and Kakanj. The importance of properly conducted agrotechnological measures, which, even in worse agro-climatic and soil conditions, can provide significant yields of agricultural crops, was particularly evident in this research. Although the corn crop in Kakanj received the least amount of water through rainfall and had the lowest soil RAW capacity, it had a higher estimated yield compared to the other two plots (Table 9). The reason is obvious and clearly visible on the field and on the set of photogrammetric recordings - all agrotechnical measures were implemented at the right time and in the right way.

3.4. AquaCrop validation

The *AquaCrop* model validation was performed based on two parameters, corn grain yield and surface soil layer moisture. These parameters are estimated by *AquaCrop* and measured in the field. Table 9 shows the ratio of estimated and measured yield, and Table 10 gives the estimated and measured soil moisture. At all three locations, the estimated corn grain yields are higher than those measured. A very low estimation error was obtained in Srebrenik and Kakanj, ranging from 2.19 to 5.64 %. However, the error in Kalesija is quite high and amounts to about 30 %, or 2.21 t difference in yield (Table 9).

The reason for such poor estimation may be delayed sowing (May 01, 2018), inadequate agrotechnics and soil erosion. Although designed to closely monitor all production conditions [50], *AquaCrop* does not take into account events such as poorly implemented agrotechnics, surface erosion, onset of disease, etc. Under such conditions, as is especially evident in Kalesija, *AquaCrop* overestimated corn yield. On the other hand, in conditions where agrotechnical measures were implemented at the right time (Srebrenik and Kakanj), the error in the model is very small, i.e. negligible (maximum 5.64 %). This precision of assessment has also been confirmed globally on other research sites [50, 55, 59-62].

The difference between the estimated and measured soil moisture at all three research plots does not exceed 12 % vol. (Table 10).

Table 10 Difference between measured and estimated moisture of the surface soil layer (0 – 20 cm)

Location		09.05	17.05	28.05	13.06	03.07	17.07	07.08	30.08	10.09	17.09	Aver.
Srebrenik	Measured	32.6	36.9	29.1	23.7	28.8	29.9	24.2	17.3	21.8	14.4	25.9
	Estimation	36.1	39.6	23.7	19.6	28.6	24.2	20.9	20.1	33.5	27.1	27.3
	Difference	*3.5*	*2.6*	*5.4*	*4.2*	*0.3*	*5.7*	*3.3*	*2.8*	*11.7*	*12.7*	*5.2*
	Error	*10.6*	*7.1*	*18.6*	*17.5*	*0.9*	*19.2*	*13.7*	*15.9*	*54.0*	*87.8*	*24.5*
Kalesija	Measured	27.1	29.2	22.9	27.4	28.6	30.4	21.3	16.3	19.3	19.9	24.2
	Estimation	38.0	43.9	18.6	20.5	41.5	43.6	22.8	11.7	20.3	16.9	27.8
	Difference	*10.9*	*14.7*	*4.3*	*6.9*	*12.9*	*13.2*	*1.5*	*4.6*	*1.0*	*3.0*	*7.3*
	Error	*40.0*	*50.4*	*18.8*	*25.2*	*45.0*	*43.3*	*6.8*	*28.1*	*5.1*	*15.2*	*27.8*
Kakanj	Measured		36.8	44.3	37.2	34.1	40.8	31.1	26.7	29.6	21.5	33.5
	Estimation		23.4	42.6	29.3	36.2	31.2	21.7	22.7	28.1	22.7	28.6
	Difference		*12.9*	*1.7*	*7.9*	*2.2*	*9.7*	*9.4*	*4.0*	*1.5*	*1.2*	*5.6*
	Error		*35.5*	*3.9*	*21.2*	*6.3*	*23.6*	*30.2*	*15.1*	*5.1*	*5.6*	*16.3*

An exception is Kalesija, where these differences are slightly higher (14.7 % vol.), especially in the middle of the season (July), when significant surface runoff and gully erosion occurred on this parcel due to heavy rainfall.

As in the previous case, the plots in Kalesija has the greatest estimation error due to poor corn production conditions. The average error ranges from 16.3 to 27.8 % vol. Based on the results obtained, we can conclude that the *AquaCrop 6.1* software model gives fairly accurate and reliable results when it comes to simulation of corn crop.

4. Conclusion

The obtained corn water requirements in conditions with and without irrigation indicate that, although a certain need for irrigation (max. 111 mm) was determined in 2018, it was not crucial for crop growth and development. This is especially true for the corn plantations in Srebrenik and Kalesija. In the months when corn had the highest water requirements (June and July), rainfall was more than sufficient to meet these demands. However, this research needs to be repeated over several years, as these were not the common climate conditions BiH. Furthermore, similar research needs to be carried out in other climatic and soil conditions, as well as for other significant agricultural crops in BiH.

The corn yields obtained at three research sites are the result of a combination of all the production characteristics of the selected plots, however in this research it was shown that the most important factor was the applied agrotechnical measures. Properly implemented even in worse agro-climatic and pedological conditions (Kakanj), they can ensure higher yields of agricultural crops. Verification of the obtained results on grain yield and soil moisture revealed a low estimation error, i.e. confirmed the possibility of using the *AquaCrop* and other used software and hardware tools at the territory of BiH when it comes to corn crop modeling and monitoring.

The application of modern technologies and smart agriculture certainly has advantages on both large and small-scale farms. With the use of UAVs and remote sensing, the problem is identified before it happens. Farmers can access information very quickly and whenever they need it. Through detailed orthomosaic maps, it is possible to plan and monitor production better, and make better use of available resources. All of this, in the end, ensures an increase in agricultural productivity with minimal environmental damage and an increase in income generated by farmers.

Since the use of on-farm water management software or UAVs is a relatively new practice in agriculture and it requires both financial resources and certain skills, further research into the justification of using this technology by the farmers is needed. For this reason, it is important to analyze the affordability and acceptance of these approaches among smallholder farmers in BiH, as well as to undertake focused training aimed at raising the knowledge and awareness of the benefits by application of this technology.

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FLIGHT ALTITUDE OF UAS AND OVERLAP OF IMAGES BY MULTISPECTRAL CAMERA OPTIMIZATION FOR CROP SCOUTING

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Abstract. *When preparing a crop scouting mission using UAS, two parameters are set: flight altitude and overlap of images. In practice, crop scouting is most often done at altitudes of 70 to 100 meters, and the switchover is most often between 50 and 100%. The research question that is dealt with in this paper is whether there is a significant difference in the obtained light reflection indexes and consequently postprocessed vegetation indexes, depending on height and overlap. The flight height of the UAS dictates spatial resolution, and the switching dictates the time resolution of the reconnaissance. The research was carried out on the experimental plot of barley. The missions were consecutive and performed in perfect weather conditions. The sky was clear, and the light was approximately uniform during all missions with variable heights and overlaps.*

Key words: *Crop scouting, UAS, NDVI, maps, overlap, flight height*

1. INTRODUCTION

With the global development of industry and population growth on Earth, there is a growing need for spatial data. They should provide a wide range of information that is useful in different spheres. The Unmanned Aircraft System (UAV) for air crop scouting consists of a multispectral camera and a camera carrier in the form of an unmanned aerial vehicle (UAV) - drone. Such systems are used primarily in agriculture for monitoring plant health, monitoring evapotranspiration and irrigation and for monitoring plant nutrition [1]. Farmers, agencies, agricultural research community and firms require access to tools to analyze and estimate stressed and productive regions to obtain higher yield. At present, this is performed manually using visual interpretation. Recently there has been some development in the detection and mapping of the stressed crop by use of hyperspectral analysis; but, there is an information gap between farmers and information about the location of the crop under stress in the given area[5]. The popularity of UAVs in scientific data gathering and applications, especially the use of small multi-rotor UAVs is quite widespread. These portable multi-rotor UAVs are portable, low-cost, highly maneuverable, and easy to handle. These features make such UAVs attractive to scientists and researchers worldwide. There has been a sudden spurt of UAV use in niche domains such as agriculture. Agriculturalists are choosing UAV-based field operations and remote sensing over the time-tested satellite-based ones, especially for local-scale and high spatiotemporal resolution imagery [1].

In one study, a new algorithm has been developed in accordance to the specific requirements of apple nurseries images. Algorithm composed of two key steps, i.e. a raster processing followed by a vector analyses. First step attempt to isolate apple plant pixels using spatial, spectral, and radiometric enhancements. In vector processing, filters based on the size and location of the polygons were applied to isolate the areas resulting from earlier step to represent apple plants. Algorithm was evaluated to estimate number of apple trees in an young nursery imaged with low altitude multispectral imaging system at four altitudes of 10, 25, 40, and 50 m. Multispectral imaging sensor consisted of near-infrared (NIR), green and blue as three bands. For 10- and 25-m images, algorithm performance was evaluated in individual as well as in mosaicimages. Low altitude images with≤ 25 m above ground level were ideally suited for young apple nursery tree count with 5% or less estimation error. Tree count accuracy was 97% and 95% for 10-m altitude individual and mosaic images, respectively. Similarly, those values were 92% and 88% for 25-m altitude images. Based on the results, images at 40 m are recommended only when the methodology include four extra steps added to the base algorithm to have tree count accuracies of about 88%. Images at 50 m are not recommended in any case due to the low accuracy obtained about 75% [3].

2. ADJUSTMENT OF UAS ALTITUDE PARAMETERS AND RESEARCH QUESTION

When planning a UAS flight just before crop scouting, the operator is tasked with specifying the flight altitude and switching of successive shots, Fig. The weather for field reconnaissance was ideal. Reconnaissance was first performed for an altitude of 70 m with 30%, 60% and 90% changes in recording overlap. Then, the procedure was repeated for 100 m altitude with varying overlapping images during recording. During this experiment, a Parrot Bluegrass UAV with propellers equipped with a 4-channel Parrot Seqouia multispectral camera was used. Drone management was performed through an Parrot Fields manufacturer's application installed on the remote computer.

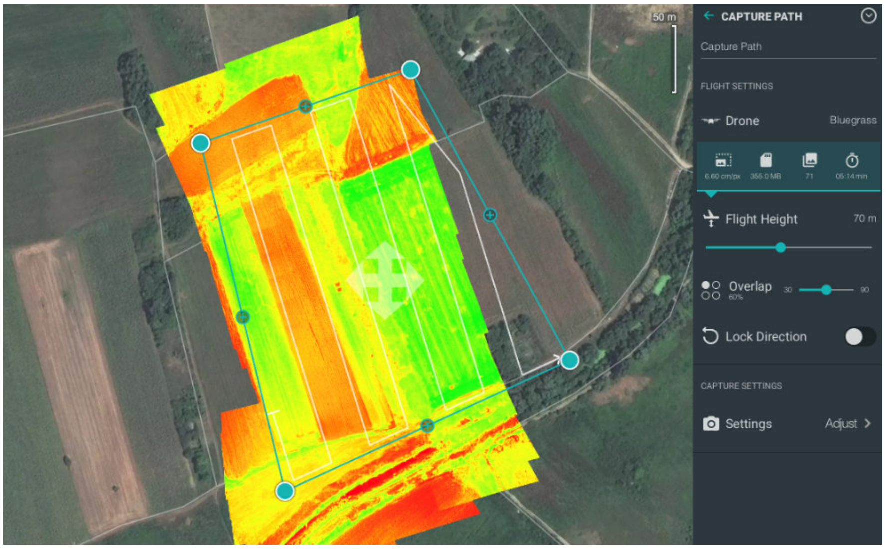

Fig. 1 Interface of computer displayfor crop scouting by Parrot Bluegrass UAV

Specified altitude and switching directly affect the number of recordings, and consequently the storage memory and flight time. Tables 1 and 2 show this dependence.

Table 1and 2 Parametars of UAS settings for flight altitude 70 m and 100m

Flight Altitude: 70 m (6.6 cm / px)			
overlap	memory	number pictutres	time duration
30	0.895	179	13:20
35	1	207	13:14
40	1.2	247	14:47
45	1.4	283	15:04
50	1.7	355	17:53
55	2.1	435	21:21
60	2.7	543	26:10
65	3.3	685	31:34
70	4.6	933	41:37
75	6.4	1316	58:37
80	10.1	2060	88:16
85	17.7	3620	147:31
90	39.3	8051	320:06

Flight Altitude: 100 m (9.42 cm / px)			
overlap	memory	number pictutres	time duration
30	0.495	99	10:08
35	0.585	117	11:38
40	0.605	121	11:38
45	0.75	150	12:01
50	0.895	179	13:32
55	1	208	13:26
60	1.3	271	15:16
65	1.7	355	18:05
70	2.2	455	22:52
75	3.2	663	31:16
80	4.9	1005	46:20
85	8.6	1770	75:30
90	19.2	3936	160:11

From the tables, there is an obvious difference in the amount of memory needed to store the data collected, the number of images, and the length of flight for different altitudes and overlaps. The research question in this paper was to identify possible differences in the quality and credibility of recordings collected with different flight parameters.

3. REVIEW OF VEGETATIVE INDEX MAPS

After software generation of orthophoto images of the field of view, NDVI and NDRE maps of the same field were generated for different image altitudes and overlaps. Figure 2 shows the folders for 30% and 90% folds, respectively.

Fig. 2 Two NDVI maps by 30% and 90% overlap

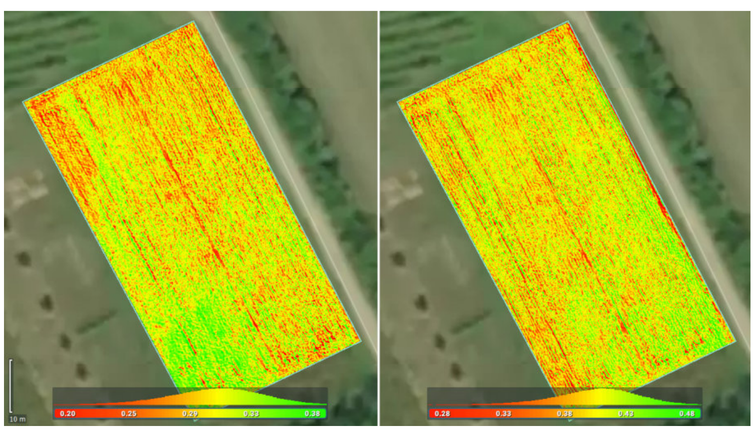

Fig. 3 Two NDRE maps by 30% and 90% overlap

The histograms show a small difference between the values of vegetation indices for different survey conditions during crop survey. The maps also give a visual impression of the similarity of the nitrogen content in the green parts of the plant. However, zoning does give a different picture of the field, but a very small sample field area (0.5 ha) should be considered. On a small surface, zoning may not be relevant.

. CONCLUSIONS

Generated maps of vegetation indexes on the basis of taken images of the experimental plot from the drone for different heights and overlaps showed no deviations between them. Therefore, for the further application of these maps as inputs during the first phase of precision agriculture, flight altitude and overlap during recording are not significant factors, especially when recording larger areas. Therefore, drone flight optimization should be carried out according to practical conditions in the field, that is, first of all, take into account the speed of recording and data acquisition and the size of the recorded areas should be adjusted to the length of each flight dictated by the durability of the battery.

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SMART MACHINES FOR PRECISION AND EFFICIENT FERTILIZING AND SPREADING

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Abstract. *Nowadays the increasing of the efficiency of agricultural production and the increasing of crop yields cannot be achieved without modern digital technology and smart machines that are a part of it. With the spread of precision agriculture and the digitalisation next to the power machines the attached equipment is becoming smarter and smarter. Through permanent technological and IT development, it became possible to thoroughly monitor and analyse operating functions and parameters not only for the most important power machines such as tractors, combines and other, but also there are existing solutions for measurement - and related to that a collection and an analyse of data - of specific utilisation parameters for other attached equipment. All of these processed data are essential for making well-considered actions related to the production technology and the machine operating.*

In our work, without completeness, we present smart solutions which are independent from the size of the machine and which are effective tools for the utilization of machines, for the precision machine work.

Key words: *smart machines, Precision Agriculture, GPS, spreading, variable rate fertilizing*

1. INTRODUCTION

Many authors have reached to the conclusion that development of digital technology and applications are regarded as an important factor in their economic growth and development in the agricultural production. The improvement of mechanization of field work, machinery and equipment is a continuous process. We are witnessing the spread and agricultural use of the more and more modern equipment, which reflects to the technical and technological level of the area. [13]

Precision Farming did become a popular research field since the 1980s. Technologies have been developed all over the world to help the farmers raise crop yields and make agricultural production processes more efficient. This new developments steadily contribute to a higher productivity and show that this technology is very important. Electronic assistance systems, such as autonomous track guidance or section control are state of the art when investing in new machines on crop farms. [3]

Precision Agriculture is just a hypernym and can be divided into three major topics [2]: “Precision Pasturing”, “Precision Lifestock Farming” and “Precision (Crop) Farming”. While Precision Pasturing focuses on methods for e.g. managing feed supply and stocking rates on pastures [20], Precision Lifestock Farming addresses all kind of systems which correspond with animals in husbandry. The last topic, Precision Farming, is defined as technology-supported cultivation of agriculturally used areas. [3, 9]

Precision Agriculture technologies are efficient tools to improve sustainability and productivity in farming. Precision Agriculture technologies offer solutions to produce more with less. It is one of the biggest revolution in agriculture. [7]

The aim of precision, or site specific agriculture is to handle within field variability [1] with input materials to achieve the highest and sustainable profit. The approach mainly benefits from the development of technologies like GPS, GIS, computer technology, automatic control, remote sensing and advanced information processing. [10] Farm field under conventional management receive uniform applications of these inputs like fertilizers, herbicides, seed or irrigation. [4, 17]

The most popular precision agricultural technologies are the grid soil sampling, the variable rate fertilizer applications, the global positioning systems and yield mapping and the variable rate seeding [5, 6, 8, 15, 18, 22].

The biggest problem with the precision farming technology is that the possible advantages and disadvantages of the technology highly depend on the professional knowledge and attitude of the farmers or of the manager and the stuff of the agricultural company. The appearance of a new technology in generally of great interest, the so co-called ‘new technology fun’ farmers try the application, invest in the new equipment – and very often without the proper knowledge, skill – they implement it into their farming. After the first experiments – if they have not got good yield and economic result – many of them give the new technology up, or did not continue the introduction and extension of the new item. The excessive expectation does not match with the reality. After the interest peak, there is almost temporary disillusionment. After the refinement of the technology, its applicability improves, instead of the risks, the benefits come to the fore, leading to its spread in production. [21]

2. MATERIAL AND METHOD

2.1. Smart Farming

“Smart Agriculture” and “Digital Farming” are based on the emergence of smart technology in agriculture. These technologies are using smart devices which consist of sensors, actuators and communication technology [13].

Digital systems, sensor techniques and technologies, remote sensing on different platforms, artificial intelligence including machine learning and deep learning, and in particular unmanned or quasi unmanned production systems are developing fast, and these are the tool for dynamic sustainability. In the future there will be the integration of these common players into smart transport, smart organisation, and smart landscape management by smart policy making. [11, 14, 19, 23]

The Smart Logistic System, integrated with the ERP (Enterprise Resource Planning), enables application of 4.0 industry approach. Its intention is to enable same application to agricultural machinery, e.g. for logging the seeding and fertilizing process (lot, operator, date, quantity) and remote diagnostic by using IoT ready systems. The advantages of own production applied utilization of digital information to trace the different materials and automate their handling, are listed following objectives:

– to reduce the material handling;

– to reduce the inventory failures;

– to implement flexibility with discipline;

– to find one place for everything and everything in its place;

– to set a FIFO (First In First Out) rule;

– to implement the material traceability. [16]

2.2. The Company INO Brezice d.o.o.

A Slovenian company INO Brežice produces a variety of mulching machines, vibrating subsoilers, fertilizer spreaders. Among the company's innovative products are so-called "Smart Solutions" which ensure a safe and efficient operating of their basic products:

- flail mowers by means of continuous measuring vibrations and detecting the outstanding ones,
- fertilizer spreaders and vibrating subsoilers by efficient specific electronic control of operating.

2. RESULTS

3.1. INO Smart Flow

INO Smart Flow ensures the quality work of the FERTI-2 type double-disc mounted fertilizer spreader **(Fig. 1**) and the VVP 115 vibrational subsoiler with deep fertilizer spreader **(Fig. 2)**. It is well known regarding versatility and an ease of use. Nowadays, site-specific nutrient application comes to the fore. Thus, accurate determination of the amount of fertilizer applied and precise dosing is essential. With this system cost savings can be achieved through efficient production and avoidance of excess nutrients.

INO Smart Flow electronic regulation of fertilizer flow on Ferti-2 is the system, which automatically regulates the position of both shutters on the bottom of the hopper. It is completely developed and designed in INO Electronic Department.

Fig. 1 Double-disc mounted fertiliser spreader FERTI-2

Fig. 2 VVP 115 vibrational subsoiler with deep fertilizer device

The machine ensures equal spreading density (kg/ha) across the spreading area, regardless of the working speed. At faster speed, the shutters must be more open than at lower speed. The optimal position of the shutters is calculated in the electronic box, based on the spreading width, speed of the tractor and fertilizer calibration.

For a proper operation the system needs to get the speed of the tractor. This information is provided by ISO 11786 connector of the tractor or GPS speed sensor. Fertilizer calibration is the procedure, which has to be done just once for specific fertilizer (NPK, Urea, KAN...) ant it takes only ca. 10 min. After this procedure is done, all necessary data are permanently stored in the electronic box and the work can begin.

The interface to the user is INO SmartAssist terminal (**Fig. 3**) placed in the cabin of the tractor, which provides all necessary data on the graphic display. User can also change all necessary parameters from tractor cab.

Before work, the user just selects the fertilizer, which is actually in the hopper and desired spread density (kg/ha). When the user starts driving, the shutters are automatically open to the correct position. If the work speed changes, the shutter position also changes to meet requirements (kg/ha). When the tractor stops, the shutter closes automatically. The user can also additionally increase or decrease the quantity of fertilizer on the area directly by pressing button on the terminal without changing basic parameters stored.

Additionally, the system provides simulation of the fertilizer quantity in the hopper (weight data in kg). To use this feature, the user must enter the quantity of the fertilizer, which is added to the hopper before work. The real quantity of the fertilizer is measured by a TRUE Weighing System attached on the spreader (optionally) and connected with INO SmartAssist.

Fig. 3 Innovations from INO's Electronic Development Laboratory - INO SmartAssist for FERTI-2 Fertilizer Spreader and for VVP 115 Vibrational Subsoiler with deep fertilizer device

The side limiter (option) is also electrically driven, so the operator just presses the button and the limiter is placed onto the working position-on and back-off. [24]

The system also provides some other useful data:

1. Battery voltage
2. RPM of the discs
3. Hectares done
4. Residual hectares
5. Working hours
6. Recommendation for greasing every 8h
7. Working speed

Using this equipment, the farmer receives necessary information about production technology and about the safe operation of the machine, such as the amount of fertilizer dispensed, the amount of fertilizer in the tank, the speed of work, the size of the cultivated area, the amount of fertilizer that can be used in the tank, the number of hours worked, the battery charge level and the alerts for the machine maintenance.

3.2. Winter Smart Flow

Winter PK Smart is a spreader for salt and sand with electronics Winter Smart Flow and terminal SmartAssist. (**Fig. 4**)

The construction of the spreader consist of plastic hopper, rigid frame, stainless components for regulation, dosing and spreading, stainless deflector consisted of changeable flaps, gearbox with slower rotations and the electronic control SMART package.

The SMART package includes:

- built in three electric actuators, used for:
  - Opening-closing of a dosing flap
  - Adjusting of the spreading width left (flaps on deflectors)
  - Adjusting of the spreading width right (flaps on deflector)
- electronic system Winter Smart Flow together with a terminal SmartAssist for operating control with the following functions:
  - Adjustment of the spreading width on the right and on the left side with lifting flaps on deflector
  - Precise adjustment of the spreading density in g/m2,
  - Automatic adjustment of dosing flap according to the working speed
  - Closing the dosing flap when stopped
  - Measuring the distance travelled
  - Showing the remaining weight of the product in the hopper - virtual weight,
  - Availability for storing 10 different sorts of the spreading product (calibration),
  - Intelligent calibration of the spreading product.

Fig. 4 *Winter PK Smart* is a spreader for salt and sand with electronics Winter Smart Flow and terminal SmartAssist

Electronics receives data regarding the tractor's speed via ISO 11786 (7-pin socket on the tractor) or GPS antenna or from the sensor on the wheel. [25]

4. CONCLUSIONS

For small, medium-sized, and for the large-scale farm machinery too, the above-mentioned Smart Solutions prove to be beneficial for efficient work, professional utilization of machines and for minimizing the production and mechanization costs.

A common feature of systems described in this article is that they can be operated with or without from the tractor's ISOBUS system. The controller can be operated autonomously, using their own system, by the control panel (assistant) which is specially designed for this purpose.

It is very important to mention that there are some advantages of IT, but some problems as well. One of specific problem is coupling the tractors and implements by using different stages of ISOBUS. [12]

The design of these electrical systems can also be realized by an individual, innovative medium-sized machine manufacturing company, as it is shown in the presented work.

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GAS EXHAUST EMISSION OF TRACTORS DIFFERENT CATEGORIES

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This paper presents studies on different categories of tractors, with different exhaust norms under real operating conditions in certain field work, where the exhaust emission of the harmful gases that they emit is observed. It will also provide an analysis how different working regime of each of tractors impact on their harmful gas exhaust emission and on which tractor categories that impact is most expessed. The gas exhaust emission will be analysed through nitrogen oxides NOx, nitrogen dioxide NO2, carbon monoxide CO, and sulphur dioxide SO_2, mesured with the portable gas analyzer Testo 350.

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

1. INTRODUCTION

Combustion in internal combustion engines is the main process in which fuel chemical energy turns into heat, and then into mechanical work. Of the total energy released in the combustion process, about 42% is used to start the machine, and the remaining 58% are losses. When regulating harmful substances in the exhaust temperature fuel is of great importance, as well as electronic regulation of fuel injection. Higher combustion temperature impact the lower amount of suspended particles in the exhaust gases, while in the case of oxides nitrogen, this proportion is the opposite [12]. Rules applicable in the European Union regarding exhaust standards gases that are divided into levels (Eng. stage) from I to V. Also in the United States certain rules are applied, that prescribes exhaust emissions, and are classified by category (Eng. Tier) from I to V [15].

If fuel in the engine would combust totally, exhaust gases would consist of nitrogen oxides NOx carbon dioxide CO_2, vapor H_2O and nitrogen N_2. But in reality fuel doesn‘t combust completely, therefore, exhaust gases can contain carbon monoxide CO, pure carbons (soot) C, hydrocarbons HnCm, aldehydes R·CHO, nitrogen oxides NOx. Combustion of sulphurous fuel creates sulphur dioxide SO_2 and SO_3, sulphur hydrogen H_2S in exhaust gases. [7]

Equipment in agricultural technological processes makes a less negative impact on the environment when it is used under reasonable and optimal conditions. Low tractor load requires more passes on the same field. This leads to higher fuel consumption for the same plot of a cultivated area. High fuel consumption leads to a higher pollution of the environment. Too big tractor load could lead to wheel slippage which damages the soil structure and increases fuel consumption for the same plot area. Besides, fuel consumption, exhaust pollutants depends on engine working conditions.[2,3,7]

A diesel engine gives more smoke in the case of a high engine speed because of unburned fuel. Also, smoke increases during engine run up. This is significant for turbocharged engines. An important thing is that the quantity of CO, HnCm and NOx in exhaust gases increases slightly. [7]

NOx make about 90% of nitrogen oxides in exhaust gases. It is generated at a high temperature of gases and enough oxygen. When the combustion process is perfect, the temperature of a cycle is higher, there is more of NO in exhaust gases. When this process is imperfect, there is more CO and HnCm in exhaust gases. [14]

Pollutants from diesel engines can be roughly divided into groups. The first one is NOx. NOx mainly consists of nitrogen oxide (NO) and nitrogen dioxide (NO2). The concentration of NO in diesel exhaust is higher than that of NO2, however, NO2 has much higher toxicity than NO does. [5]

The second element of diesel exhaust is hydrocarbons and CO. Hydrocarbons consist of thousands of species, such as alkanes, alkenes, and aromatic. Although their toxicity, carcinogenicity and impact of oxidant formation vary from species to species, they are usually treated together as total hydrocarbons (THC) [4]

The third group of pollutants are particulate matters (PM). Figs. 1, 2 present the quantity of toxic gases and its smoke dependence on engine load and speed.

How exhaust emissions depends of tractor fuel consumption, it is also a question of engine rotational frequency and load modes (figure 1. and figure 2.). A literature sources show that one of the significant fuel consumption criteria is engine speed. [8,1,10,7,4,6] The same tractor driving speed is reached at a higher gear and at a lower engine speed, and reached fuel consumption economy is of 5%. Lower fuel consumption may lead to less environmental pollution.

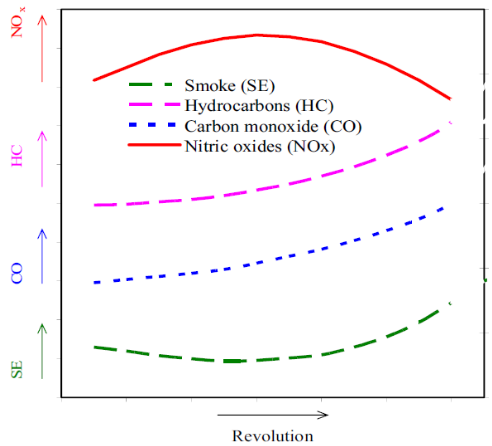


Fig. 1 Principal characteristics of diesel engine toxic gas dependence on engine speed (from idle to nominal engine speed range) [7]

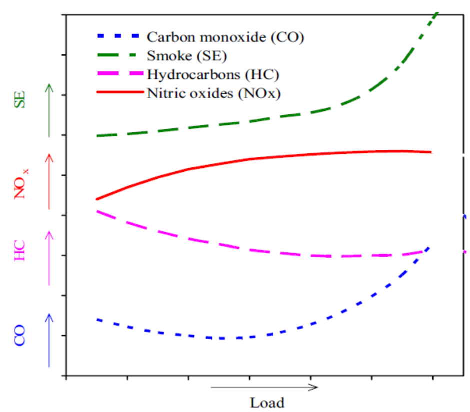


Fig. 2 Principal characteristics of diesel engine toxic gas dependence on engine load (from idle to nominal engine speed range) [7]

The aim of this paper is to find out which tractors with different exhaust emission categories will give the highest decreasing of pollution gasses by changing the different tractor working regimes.

2. Material and Methods

In this paper, the tractor exhaust emission tests were conducted on 4 tractors of different categories and different exhaust emissions, giving an overview of the tractors exhaust in Table 1. The first tractor is in Stage I emission categories and doesn't have any exhaust treatment equipment. The second tractor achieves the Stage II emission category, which, unlike the first tractor, has a turbocharger, which results in a higher oxygen concentration in the cylinder and therefore a more complete combustion. The third tractor is of the Stage IIIB emission category and has a DPF and EGR valve, in charge of reducing NOx, NO_2 and PM concentrations.

The fourth tractor has the most comprehensive exhaust treatment equipment with a combination of SCR, CUC, DOC technology, and falls into the Stage IV category.

All tractors performed soil tillage with disc harrow at the same soil type, the riparian black soil. Tests were carried on fields near Belgrade. Experiments were conducted under realistic operating conditions, in working regime in which the operators usually perform soil tillage with a given tractors and implements, which is the mostly at full engine speed in compatible gear speeds. In those tests, rated engine speed was around 2150 min^{-1} ± 50 min^{-1}, and the second engaged engine speed was at 90% of the rated engine speed - 1900 ± 50 min^{-1}. In addition to the engine speed, there were two different gears speed, lower and higher gear that are suitable for process of soil tillage, without any consequences for the working quality. Accordingly, the measurement of the exhaust emission of tractors was performed in four different working regimes.

Table 1 Specification of tested tractor

Tractor	Tractor weight (kg)	Engine rated power (kW)	Rated speed min^{-1}	Exhaust emission (Stage)	Type of fuel injection	Specific fuel consumption at rated conditions (g/kWh)	Max. Torque (Nm)@ revolving speed (rpm)	Air intake system	Equipment for exhaust treatment
I	5610	88.2	2200	I	Unit injectors	242	435@1600~ 1800	Atmosphere charged	NON
II	4400	66.2	2200	II	Unit injectors	≤248	315@1500~ 1700	Turbo charged	NON
III	6000	100.7	2200	IIIB	Common rail	247	567@1200	Turbo charged	DPF +EGR
IV	27 281	462.3	2150	IV	Common rail	240	2393@1400	Turbo charged	SCR(DEF)+ CUC+DOC

Exhaust gases: NOx, NO, NO_2, SO_2 and CO_2, was measured while tractors were working with a portable flue gas analyzer, model Testo 350 (Table 3). Duration of exhaust measuring, for every working regime, was at least five minutes, so there have been enough time for estimating stable parameters of measured gases with gas analyzer.

Table 2 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

3. RESULTS AND DISCUSSION

3.1. NOx and NO_2 Emissions

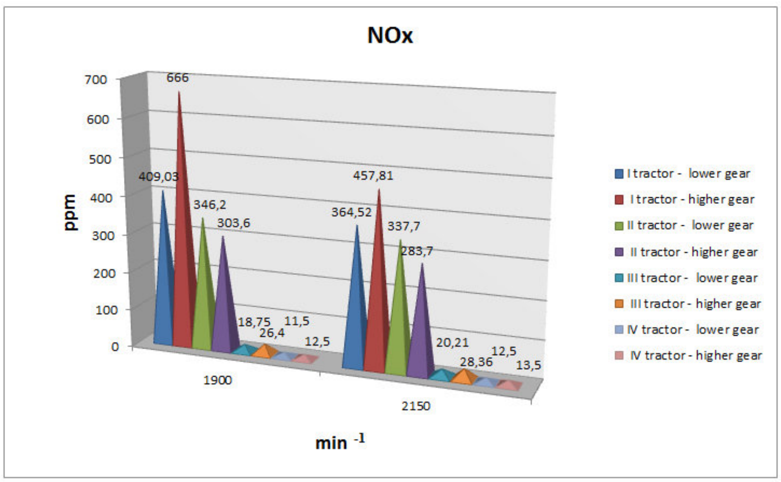
The nitrogen oxides for each of the tractors in the performed test, were in range that was specified by emission regulation, and measured value are present on graph 1. and graph 2.

For I tractor with stage I exhaust emission, NOx emissions was in range from 364.52 - 666 ppm. The lowest NOx concentration was observed in the first gear at engine speed of 2150 min^{-1}, while the unsuitable working regime was observed in the second gear at 1900 rpm. The NOx emission difference between the two modes was 45.27%.

For Stage II emission tractor, the NOx difference between the best working regime with concentration of 283.7 ppm achieved in second gear at 2150 min^{-1} and the worst working regime with concentration of 346.2 ppm achieved in second gear at 1900 min^{-1} engine speed with difference 62.6 ppm, or 18.08%.

A much lower concentration of NOx gas was observed in the third tractor due to the presence of exhaust gas treatment equipment, and thus he belongs to the Stage IIIB group. On this tractor, especially EGR valve regulate NO_x and NO_2 gasses with ratio of clean air and exhaust air in the suction line, and this part is responsible for reducing the speed and temperature of combustion of fuel and oxygen on engine cylinder. Nitrogen oxides fit a good stoichiometric relationship, so it comes to the conclusion that working regime on L.G. at 1900 min^{-1} was most favourable with 18.75 ppm of NOx. In this way, the fuel combustion reaction was firmer than other gear speed, resulting in a higher working temperature what is case in H.G. on 2150 min^{-1} with 28.36 ppm. Percentage difference between this two working regime was 33.88 %.

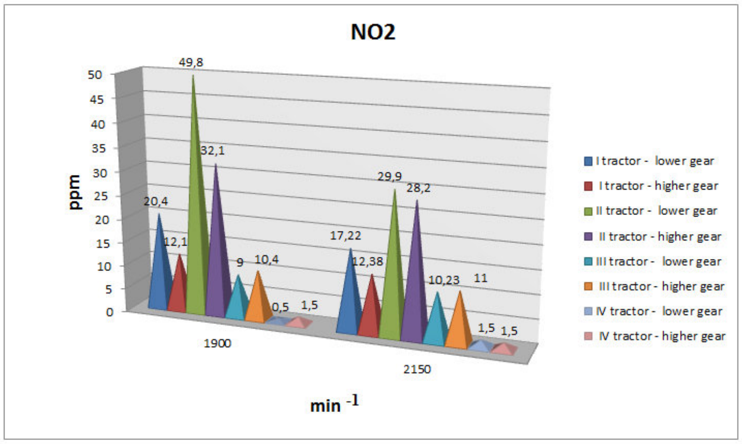
On fourth tested tractor, that has the best exhaust emission Stage IV, with equipment for treatment exhaust gases like SCR (selective catalytic reduction) together with CUC(Clean-Up Catalyst), than DOC (Diesel Oxidation Catalysts), it is measured the lowest NOx concentration. It is noticed that this kind of gas exhaust treatment, has the lowest exhaust emission. The oscillation in different working regimes of this tractor was less than in case of other tractors, so the best exhaust emission was in L.G. on 1900 min^{-1} with 11.5 ppm of NOx, and unfavorable working regime was in H.G. on 2150 min^{-1} with 13.5 ppm NOx, with difference of 14.8 %.



Graph. 1 NOx exhaust emission

NO_2 emission shows that the concentration of the first tractor was much lower than that of the II, turbocharged, tractor. The difference in the concentration of NO_2 in I tractor between the two working regimes, which was the most favorable and the most unfavorable from aspect of NO_2 emission, was 8.3 ppm, or 40.68%. For the second tractor, this difference was slightly higher and amounted to 21.6 ppm, with a percentage difference of 43.37%.

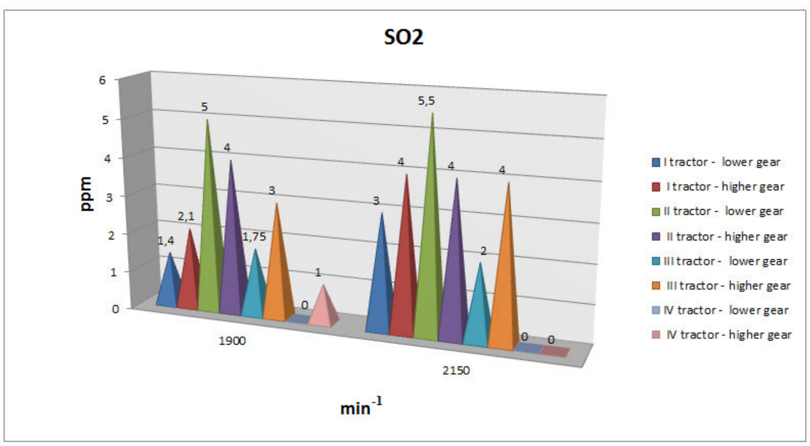
The oscillations of III and IV tractor, that have had certain equipment for the treatment of nitric oxides, were much smaller. It is observed that the concentration of NO_2 in the III tractor was not significantly lower than that of the I tractor, while in the IV tractor with more complex nitric oxide treatment equipment the NO_2 concentration was the lowest. In III tractor, the difference in NO_2 concentration is 2 ppm, while the variation in IV tractor was 1 ppm, so it can be said that the change of working regime in III and IV tractor had no major effect on the change in NO_2 emission.



Graph. 2 NO_2 exhaust emission

3.2. SO2 Emissions

The concentration of sulfur dioxide in all four tractors was most equalizing of all measured gases (Graph 3.)



Graph. 3 SO_2 exhaust emission

The most pronounced deviation of SO_2 concentration was observed in I tractor, with 2.6 ppm (65%).

In II tractor, the SO_2 concentration was low in two working regimes, at 1900 min^{-1} and 2150 min^{-1} for both in H.G.. Compared with the unfavourable working regime, the SO_2 concentration was reduced by 20%. For the tractor III, the SO_2 value ranged from 1.75 ppm in L.G. at 1900 min^{-1}, up to 4 ppm in H.G. at 2150 min^{-1}.

In IV tractor, the concentration of SO_2 is almost zero, with exception with concentration of 1 ppm that was observed in one operating mode in H.G. at 1900 min^{-1}.

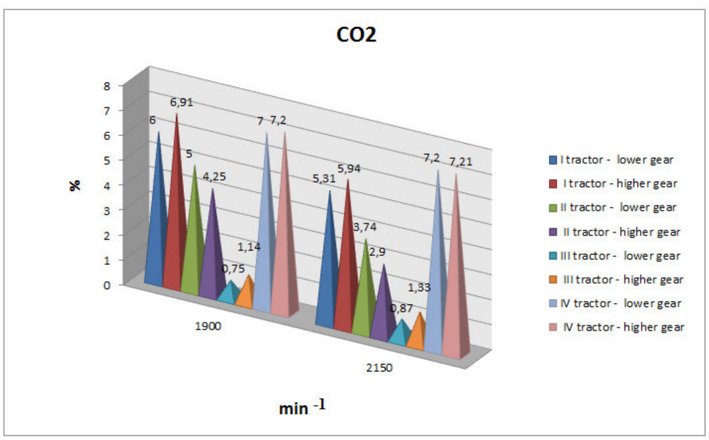
3.3. CO_2 Emissions

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. [9]

Other author claims that CO_2 emission is mostly directly linked to the fuel consumption. [11]

Changing the working regime, CO_2 concentration reduction in exhaust emission can be achieved most in II tractor, by 2.1 vol% (42%), then in I tractor 1.6 vol% (23.15%), III tractor 0.58 vol% (43.6%) and lastly in IV tractor with 0.21% vol (2.91%), and that changes can be viewed on graph. 4.

It can be found in literature that SCR catalysts selectively decompose NOx compound by an hydrolysis process after adding urea as the source of ammonia (NH3) into the exhaust mix, converting NOx contaminants into N_2, NH_3, CO_2 and H_20 [13]. In that claim we can find the reason for a slightly increase of CO_2 concentration in exhaust gasses on IV tractor.



Graph 4. CO_2 exhaust emission

In Table 3. a review of all exhaust gasses for each of four tractor is given. Favorable and unfavorable working regimes and difference between that two regimes are noticed. It can be seen that in some case there is a big percentage difference, but that difference isn't clear because of small value differences expressed in ppm. So, in conclusion it will be explain which working regime will be the most favourable from both aspects.

Table 3 Gas exhaust emission in working regimes and differences between favourable and unfavourable regime.

Tractor	Favourable working regime for observed gas	Unfavourable working regime for observed gas	Difference between two regime for observed gas	Difference between two regimes for observed gas (%)
	NOx (ppm)			
I	L.G. - 2150 min^{-1}	H.G. - 1900 min^{-1}	301.48	45.27
II	H.G. - 2150 min^{-1}	L.G. - 1900 min^{-1}	62.5	18.08
III	L.G. - 1900 min^{-1}	H.G. - 2150 min^{-1}	9.61	33.88
IV	L.G. - 1900 min^{-1}	H.G. - 2150 min^{-1}	2	14.8
	NO_2(ppm)			
I	H.G. - 1900 min^{-1}	L.G. - 1900 min^{-1}	8.3	40.68
II	H.G. - 2150 min^{-1}	L.G. - 1900 min^{-1}	21.6	43.37
III	L.G. - 1900 min^{-1}	H.G. - 2150 min^{-1}	2	18.18
IV	L.G. - 1900 min^{-1}	H.G. - 2150 min^{-1}	1	66.7
	SO_2(ppm)			
I	L.G. - 1900 min^{-1}	L.G. - 2150 min^{-1}	2.6	65
II	H.G. - 1900 min^{-1} H.G. - 2150 min^{-1}	L.G. - 1900 min^{-1}	1	20
III	L.G. - 1900 min^{-1}	H.G. - 2150 min^{-1}	2.25	56.25
IV	L.G. - 1900 min^{-1}	H.G. - 1900 min^{-1}	1	100
	CO2(vol %)			
I	L.G. - 2150 min^{-1}	H.G. - 1900 min^{-1}	1.6	23.15
II	H.G. - 2150 min^{-1}	L.G. - 1900 min^{-1}	2.1	42
III	L.G. - 1900 min^{-1}	L.G. - 2150 min^{-1}	0.58	43.6
IV	L.G. - 1900 min^{-1}	H.G. - 2150 min^{-1}	0.21	2.91

4. CONCLUSION

The processing of measured data has led to following conclusions:

1. The assumption was confirmed that tractor IV with the best exhaust emission, Stage IV, had the lowest exhaust emission, while tractor I with the Stage I exhaust emission, had the worst exhaust characteristic.

2. How there is a lot of space for reducing nitric oxide emissions, NOx and NO_2, it should be selected the working regime that is most favourable in terms of their reduction and then according to the reduction of other, SO_2 and CO_2 gases.

3. For tractors I and II with lower exhaust emission, Stage I and Stage II, the most favourable working regime was at a higher engine speed of 2150 rpm, and that for tractor I at lower gear speed, while for tractor II that is at higher gear speed.

For tractors III and IV with exhaust emission Stage III and Stage IV, the lower operating speed at 1900 rpm is more suitable, at lower gear in both cases.

4. For tractors I and II, the oscillation of the exhaust emission at different working regime is much more pronounced, than the tractors III and IV.

5. NOx can be reduced from aspect of more favourable working regime than in unfavourable working regime, by 45.27% (301.48 ppm) in tractor I and 18.08% (62.5ppm) in tractor II, while in NO_2 emissions that difference was 40.68% (8.3) for the tractor I and 43.37% (21.6 ppm) for the tractor II. In III and IV tractors, there were lower percentage differences of the exhaust emission in various working regimes. Emissions differences for tractor III and IV were from 9.61ppm and 2 ppm (33.8% and 14.8%) for NOx gas and 2ppm and 1ppm (18.18% and 66.7%) for NO_2 gas.

6. SO_2 emission can be reduced by changing the operating mode, although no large oscillations were observed in any of the tested tractors.

7. The space for reducing CO_2 emission is the largest in II tractor, where it is possible to reduce emissions by 2.1% (42%).

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INFLUENCE OF DIFFERENT MILKING SYSTEMS ON HYGIENIC AND MICROBIOLOGICAL QUALITY OF RAW COW MILK

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Abstract: *On majority of farms in Bosnia and Herzegovina milking of cows is performed on mobile and semi-stationary machines, whereas on a small number of farms it is done with stationary machines. Milking conditions in cubicles do not provide satisfactory hygienic conditions in comparison to stationary milking systems. Therefore, the focus of the research was put on establishment of influences of preparation of cow for the milking process, the milking process with different types of systems, and hygienic and microbiological quality of raw cow milk. The obtained results indicate a significantly lower number of micro-organisms in the case of a stationary system (103,166 ± 51,291) in comparison to a semi-stationary (246,200 ± 190,047) and mobile system (267,500 ± 235,732) for mechanized milking. The research also established a difference of contents of microorganisms between average morning (163,200±112,718) and evening (248,044±238,051) mil king, where the statistical significance P<0.05. The number of somatic cells with the mobile milking system totaled, 220,400±228,444, semi-stationary system 230,600±215,146 and stationary system 226,150±214,445. The experiment was done with the same cows and balanced feeding. The average number of somatic cells for all three milking systems was of E class and totaled 132,018 SCC/ml. The average number of micro-organisms was outside the E Class and totaled 159,510 CFU/ml. The obtained results lead to the conclusion that the type of milking system affects hygienic quality of raw cow milk, and that it is necessary to invest efforts in education of farmers and better technical equipping.*

Key words: *milking, milk, bacteria, somatic cells, milking system, quality*.

1. INTRODUCTION

Milk and dairy products are high-quality foods that are almost irreplaceable in human nutrition, especially for young people whose organism is still developing. In order to preserve their nutritional value and convenience for processing, it is necessary that the milk, when delivered and used, preserves its quality in the condition obtained by the milking of healthy, well-treated and properly fed cows. Antunac et al., (1997), Feldhofer et.al. (1999), Bava et al., (2009)

Considering the present problems of milk production and quality control, this research was based on examining the influence of milking appliances on the hygienic quality and the ratio of raw cow's milk classes in the most common milking systems in BiH.

Most farmers in BiH are milking their cows with mobile and semi-stationary milking systems in the area of the animal's bed, where hygienic conditions are often not satisfactory. Larger farms, due to the need for greater productivity and better hygienic milking conditions, are oriented towards stationary milking parlours. The prominent variability of different machine milking systems influenced the hypothesis that stationary farms have a higher hygienic safety of fresh cow's milk compared to mobile and semi-stationary farms where milking is performed on the animal's bed. The expected results of the research should contribute to the understanding of the hygienic state of raw cow's milk in different machine milking systems and accordingly to determine the representation of individual classes of raw cow's milk produced in real production conditions in BiH.

2. OBJECTIVES

Bearing in mind the problems of machine milking in Bosnia and Herzegovina and the high requirements issued by the Ordinance on the quality of raw cow's milk, the hypothesis is that mobile and semi-stationary agricultural systems have worse hygienic milk than stationary farms.

The intended objectives of the hypothesis will answer the following unknowns regarding the production conditions in Bosnia and Herzegovina:

- How variable is the hygienic quality of milk in mobile, semi-stationary and stationary machine milking systems.
- To what extent the hygienic quality, that is, the machine milking system used, influences the classification and the price of raw cow's milk.

3. MATERIAL AND METHOD

The study was conducted at the dairy farm ZZ “Malešićanka” in Malešići, Ilijaš Municipality. All cows during the study period had identical holding conditions, stable environment, microclimate and the same feeding ration during the experiment period. The farm selected five dairy cows for the experiment. All cows were Simental breeds from the third to fifth months of lactation. The survey period ran from the beginning of September 2014 to the end of December 2014.

The experimental dairy farm had three different milking systems, a movable, semi-stationary and stationary milking device, which allowed all three milking systems to be tested on the same milking cows.

Milk samples were taken every month at three intervals from the morning and evening milking. Three samples were taken from each cow for the milking system and control. One for testing the chemical composition of milk, the other for somatic cell content and the third for microbiological analysis. Manual milking was used as a control, where three samples were also taken.

Sampling of milk was done in accordance with the BiH Standard Milk and Milk Products - Sampling Guide (BAS EN ISO 707: 2010) and the Regulation on the Method of Sampling, Classification and Calculation of the Price of Milk.

After sampling, the milk samples with preservative for storage were deposited in the mobile cooling chambers and transported to the quality control laboratory at the Federal Institute for Agriculture Sarajevo on the same day and analyzed. The cows selected for the experiment had identical holding conditions, stable environment, microclimate and the same feeding ration during the experiment period. Cows were fed twice daily (compared to milking). For each meal, cows received: 10 kg of lucerne hay, 10 kg of corn silage and 7 kg of concentrate mixture. The ages of the selected cows ranged from 3 to 5 years, that is, they were in the second and third lactations. Farm milking was done twice - in the morning (6: 00-7: 30) and the evening (18: 00-19: 30). During the study period, milk quantity was measured using the Waikato MKV Milk Meter milk quantity meter. The mathematical and statistical analysis of the data was performed using appropriate procedures (Proc MEANS, Proc CORR, Proc GLM) in the SAS statistical software package. 9.1. The mean (x), the mean corrected value (LSM), the standard error (SE), the standard deviation (SD), and the minimum (Min.) And maximum (Max.) Values for milk fat, protein, dry matter, were calculated as well as for the total number of microorganisms and the number of somatic cells in ml of milk.

4. RESULTS AND DISCUSSION

During the experiment, the milk quality for all cows, based on the geometric mean of the number of somatic cells, was in the E class (132,018 SCC / ml). In relation to the number of micro-organisms, the total milk based on the geometric mean of the number of micro-organisms was outside the class 159.510 CFU / ml). The movement of the milk class in the trial period for all cows is shown in Graph 1. Compared to the total number of somatic cells, E-class milk prevails (62.96%), then non-class milk (28.15%) and the lowest percentage is I-class milk. (8.89%). In terms of the number of microorganisms, the highest number of milk samples is out of class (78.52%), followed by class I (11.85%), while the class E milk is the least represented (9.63%). It should be noted that milk that is out of class is mostly on the border for class I.

Table 1 . Mean ($\bar{x}$) and standard deviation (SD) of milk quantity (kg) in different milking systems

The milking system	Amount of milk, kg		
	The husband's period		
	morning	evening	Average
Semi-stationary system	11.47 ± 2.64	10.8 ± 3.95	11.13 ± 3.32
Mobile system	9.87 ± 2.42	9.13 ± 2.33	9.50 ± 2.36
Stationary system	8.53 ± 1.25	7.53 ± 1.19	8.03 ± 1.30
Average	9.96 ± 2.46	9.16 ± 2.99	9.56 ± 2.75
Statistical significance			
The milking system	0,007		
The husband's period	0,054		
The milking system x the milking period	0.915		

According to the research of Mijić (2001), milk quantity was higher (P < 0.001) during the morning milk by 2.86 kg (Holstein breed) and 1.88 kg (Simmental breed). The cause of these differences is due to the unequal time interval between these two milkings, the throat at night, etc. More milk during the morning milking is cited by Skvocsov and Kuharski (1977 and Naumann et al., (1997).

Raw milk quality depends on at least three factors, namely chemical composition (milk fat, protein, lactose), microbiological safety and udder health (mastitis, somatic cell count). The following tables present the research findings on all these factors. The analyzed results of milk quantity indicate existing statistical significance between milking systems (P ≤ 0.001). Most milk was measured in the semi-stationary system, then mobile, and the least in the stationary milking system. The results of milk analysis on milk fat have no statistical significance in different milking systems. Evening milking had a higher percentage of milk fat than morning milking, while the mobile milking system had the highest percentage of milk fat. Also, it was found that there is no statistically significant difference between the semi-stationary and stationary milking systems, while the average protein content in the mobile milking system is slightly different and is at the very limit of statistical significance (P ≤ 0.05). In relation to the milking period, no statistically significant difference was observed, which tells us that the protein content is approximately equal in milk milked during the morning and evening milking.

Table 2 Mean ($\bar{x}$) and standard deviation (SD) of somatic cell count / ml in different milking systems

The milking system	Somatic cells (SCC / ml)		
	The husband's period		average
	Morning	evening	aaverage
Semi-stationary system	182,800 ± 168,987	258,000 ± 276,612	220,400 ± 228,444
Mobile system	199,000 ± 179,908	262,200 ± 247,741	230 600 ± 215 146
Stationary system	192,400 ± 168,034	259,900 ± 254,130	226,150 ± 214,445
Average	191,400 ± 168,564	260 033 ± 253 823	225 717 ± 217 001
Statistical significance			
The milking system	0,908		
The husband's period	0,161		

Petrovska and Jonkus (2014) state in their study that the number of somatic cells was significantly higher in the classical milking system in the first (319.0 ± 90.69 thousand per ml) and second (119.0 ± 26.460 per ml, P <0.05) measurement.

Table 3. Mean ($\bar{x}$) and standard deviation (SD) of total micro-organisms (CFU / ml) in different milking systems

The milking system	Microorganisms (CFU / ml)		
	The husband's period		average
	morning	evening	Average
Semi-stationary system	234.400 ± 133.438	258,000 ± 238,142	246 200 ± 190 047
Mobile system	162,667 ± 103,644	372 333 ± 284 282	267,500 ± 235,732
Stationary system	92,533 ± 24,518	113,800 ± 67,868	103,166 ± 51,291
Average	163 200 ± 112 718	248 044 ± 238 051	205 622 ± 190 044
Statistical significance			
The milking system	0,000		
The husband's period	0,022		
The milking system x the milking period	0,344		

Bava et al., (2009) confirmed the results in different milking systems, and they will place particular emphasis on cleaning milking equipment. Namely, when it comes to semi-stationary and stationary milking system, according to the author, it is necessary to pay special attention to the water temperature when washing the system with detergent. Temperatures lower than 40ºC should increase the number of bacteria in the milk during the subsequent milking.

Feldhofer et.al. (1999) state in their original scientific work that milk fat is a highly variable and highly volatile milk component. They found that milk milk in the evening milk was slightly higher than the milk of the morning milk, but there were significant differences in the percentage of milk fat at the beginning (1,64-2,09%) and at the end of the milk (8,57-7,77%). Thoroughly limping the udder significantly affects the higher average fat of total milk.

Antunac et al., (1997) indicate in their study that, independently of the milking system, the percentage of fat in milk decreases with a somatic cell increase of 5 to 12%. The opposite results are reported by Galton et al., (2000), stating that a percentage increase in fat content in milk is caused by a decrease in daily milk production.

The results obtained indicate that there is no statistically significant difference between the individual milking systems in terms of lactose content at the $P > 0.05$ level of significance, and there is no difference in the lactose content between the different milking periods. There is no statistically significant difference in the dry matter content, both between individual milking systems and between milking periods. Regarding the dry matter content, a statistically significant difference was observed between the milking systems. The content of fat-free dry matter in milk obtained by a semi-stationary milking system is much lower. On the other hand, there is no statistically significant difference between individual milking periods. In the study, no statistically significant difference was observed in the number of somatic cells, both between individual milking systems and between morning and evening milking. The significant difference in microbial content was found between milking periods ($P < 0.05$). A significantly higher number of microorganisms was found in milk obtained in the evening milking than in the morning. Konjacic et al. (2015), in their research on the effect of year and season on the chemical composition and hygienic quality of eco-produced cow's milk, state that fat-free dry matter showed the same trend as milk fat and protein.

Table 4 . Mean (x̄) and standard deviation (SD) of milk fat (%) in different milking systems

The milking system	Milk fat,%		
	The husband's period		
	Morning	evening	Average
Semi-stationary system	3.55 ± 0.87	4.70 ± 0.89	4.13 ± 1.05
Mobile system	4.07 ± 1.21	4.82 ± 0.96	4.44 ± 1.14
Stationary system	3.88 ± 0.41	4.04 ± 0.25	3.96 ± 0.34
Average	3.83 ± 0.90	4.52 ± 0.83	4.18 ± 0.93
Statistical significance			
The milking system	0,290		
The husband's period	0,114		
The milking system x the milking period	0,102		

Table 5 . Mean (x̄) and standard deviation (SD) of protein (%) in different milking systems

The milking system	Protein,%		
	The husband's period		
	Morning	evening	Average
Semi-stationary system	3.32 ± 0.23	3.38 ± 0.26	3.35 ± 0.24
Mobile system	3.56 ± 0.23	3.61 ± 0.23	3.58 ± 0.23
Stationary system	3.47 ± 0.34	3.40 ± 0.15	3.43 ± 0.26
Average	3.45 ± 0.28	3.46 ± 0.23	3.46 ± 0.26
Statistical significance			
The milking system	0,047		
The husband's period	0,840		
The milking system x the milking period	0,222		

Antunac et al., (1997) state that the total amount of protein in milk does not depend on udder health. However, the same author states that in the event of mastitis, the amount of whey proteins (albumin and globulin) and blood proteins (serumalbumin and immunoglobulin) increase, as expected, due to the organism's reaction to the presence of microorganisms.

Table 6 . Mean (x̄) and standard deviation (SD) of lactose (%) in different milking systems

The milking system	Lactose,%		
	The husband's period		
	Morning	evening	Average
Semi-stationary system	4.42 ± 0.11	4.37 ± 0.12	4.40 ± 0.12
Mobile system	4.43 ± 0.21	4.42 ± 0.27	4.43 ± 0.24
Stationary system	4.46 ± 0.20	4.45 ± 0.25	4.45 ± 0.22
Average	4.44 ± 0.18	4.41 ± 0.22	4.43 ± 0.20
Statistical significance			
The milking system	0.828		
The husband's period	0.588		
The milking system x the milking period	0,390		

Table 7 . Mean (x̄) and standard deviation (SD) of dry matter (%) in different milking systems

The milking system	Dry matter, %		
	The husband's period		
	Morning	evening	Average
Semi-stationary system	12.20 ± 1.07	13.42 ± 0.99	12.81 ± 1.19
Mobile system	12.99 ± 1.24	13.88 ± 1.01	13,43 ± 1,20
Stationary system	13.94 ± 1.18	13,49 ± 0,80	13.71 ± 1.02
Average	13.04 ± 1.35	13.59 ± 0.94	13.32 ± 1.19
Statistical significance			
The milking system	0,098		
The husband's period	0,024		
The milking system x the milking period	0,081		

Dozet et al., (1976) examining the dry matter of six cattle breeds found that dry matter and non-fat dry matter, as well as fat, were within the range of values characteristic of good milk composition. There are differences between the breeds, however, the small number of samples of the tested milk of individual breeds does not allow a final conclusion to be reached about the dry matter as a breed trait.

Table 8 . Mean ($\overline{x}$) and standard deviation (SD) of non-fat dry matter (%) in different milking systems

The milking system	Non-fat dry matter (%)		
	The husband's period		
	Morning	evening	Average
Semi-stationary system	8.56 ± 0.23	8.60 ± 0.29	8.58 ± 0.26
Mobile system	8.85 ± 0.31	8.96 ± 0.29	9.91 ± 0.30
Stationary system	8.97 ± 0.35	8.91 ± 0.35	8.94 ± 0.34
Average	8.79 ± 0.34	8.82 ± 0.34	8.81 ± 0.34
Statistical significance			
The milking system	0,005		
The husband's period	0,720		
The milking system x the milking period	0,350		

5. Conclusions

The focus of the research was on checking whether and to what extent the variability of the hygienic quality of milk is notable, using different machine milking systems.

The defined goals were to check the extent to which the hygienic quality was met, ie whether the applied milking system affects the quality, classification and price of placement of raw cow's milk.

Based on the conducted research and the results obtained, the following conclusions can be drawn:

The transition from the old milk purchase system based on the presence of milk fat to the new concept of classification by the total number of somatic cells and micro-organisms requires conceptual changes both in terms of technical equipment and in the education of farmers in the process of machine milking.

The results of the study show that the milking system has an impact on the hygienic quality of milk and the economic indicators related to the milk classification and payment system in relation to the total number of somatic cells and micro-organisms. A significantly lower number of microorganisms was found in stationary (103,166 ± 51,291) compared to semi-stationary (246,200 ± 190,047) and mobile milking system (267,500 ± 235,732).

A significant difference in the content of microorganisms was found between the average of the morning (163,200 ± 112,718) and evening (248,044 ± 238,051) milking. Differences in the number of microorganisms between morning and evening milking can be mainly attributed to the daily activity of milking animals. The activity also causes dust and other contaminants to be raised.

The results of the somatic cell count test showed no significant differences in different milking systems. In the mobile system, the total number of somatic cells was 220,400 ± 228,444, semi-stationary 230,600 ± 215,146 and stationary 226,150 ± 214,445. The reason for the relative uniformity was the fact that all the cows during the study period had identical holding conditions, stable environment, microclimate and the same feeding ration during the experiment period.

During the experiment, the milk quality for all cows, based on the geometric mean of the number of somatic cells, was in the E class (132,018 SCC / ml). In relation to the number of micro-organisms, the total milk based on the geometric mean of the number of micro-organisms was outside the class 159.510 CFU / ml).

Based on the results obtained, we can conclude that it is necessary to work daily to improve the conditions of milk production, both by raising the level of knowledge of farmers and the technical equipment of the milking system. As part of the improvement of production conditions, it is necessary to emphasize the transition from a tie-stall to the free-stall holding system, which involves the use of a stationary milking system.

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MOVEMENT OF THE SOIL SLICE ALONG THE ROTARY TILLER KNIFE UNTIL REJECTING

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Abstract. *When the tip of the knife achieve the height of the ridge at the bottom of the furrow (h_g) the soil slice is formed, and if the conditions for its sliding with respect to the knife are met, the skating will begin. The dynamics of the soil slice motion, which was presumably located in the middle of the blade, started the relative motion from the resting state by sliding along the blade is analyzed. According to Newton's second law, the relative motion of soil slice along the blade occurs: plastic weight, normal reaction and friction force, as well as transmission and Coriolis inertia forces. The movement of the soil slice across the surface of the knife takes place until the relative coordinate reaches the value of half the width of the knife (L/2). At that moment of time when the soil slice rejecting the knife the next phase begins, a slanting shot. The impact of the setting angle of the knife γ changing, as a result of the curvature of the blade wings, the length of the relative motion time interval and the relative velocity value at the moment the soil slice is rejected from the blade, is analyzed in detail.*

Key words: *rotary tiller, knife shape construction, dynamics, soil slice*

1. INTRODUCTION

In order to determine the optimum design of the rotary tiller from the energetic and ecological aspect, the critical value of the setting knife angle was analyzed. Depending on the operating speed variation in the range from 0.43 to 1.08 m/s, the critical (maximum) value of the setting knife angle γ ranges from 74.47 ° to 65.17 ° [1]. Based on the value of the knife setting angle γ, the area of application of already existing rotary tiller can be determined. New designed rotary tillers with blades set at the optimum setting angle can achieve cutting at minimum values of the cutting angle, leading to a decrease in the energy consumption in process of soil tillage [2, 3]. In order to avoid the friction resistance from the untilled part of the soil, the optimal knife profile of the rotary tiller was determined [4]. The optimal knife shape is determined by calculating the distance of individual points on the back of the knife from the point of entry into the ground. The optimum shape of the knife is approximately the same, but the angle of inclination changes depending on the change in operating speed. When operating speed is in range from 0.43 to 1.08 m/s, the angle of inclination is 5.24–14.41 ° [5]. The critical points of the blade soil slice removing angle from the blade were determined based on the relative normal reaction F_N/m and the relative friction force F_T/m depend on the change in the coefficient of friction between the soil slice and the knife μ, and the knife setting angle γ. Based on the analysis of the change in the setting knife angle γ, the value should not have a value greater than $\gamma \leq 60$ ° [6].

The aim of this research was to determine the relative movement of the soil slices along rotary tiller knife until rejecting and to determine the moment of time and speed of soil slice when leaves the knife and starts a slanting shot.

2. MATERIAL AND METHODS

The aim of this research was to determine soil slice movement along the knife of rotary tiller until rejecting. The starting calculation values were R = 25 cm, ω = 16.038 s^{-1} L=0.06 m, v_m=0.43 m/s, z=3 i μ=0.35. [6].The equations were solved with SWP 5.5 (Scientific work place 5.5) program. The graphic solutions of differential equations were drawn in SWP 5.5 and CorelDraw X5 (Corel Corporation) programs.

3. RESULTS AND DISCUSSION

The height of the ridges (h_g) at the bottom of the furrow is determined as in ref. [7]. When the tip of the knife reaches a point at the height h_g the soil slice is formed and if the conditions for its sliding with respect to the knife are met, the sliding will begin. The area, in which the soil slice is retained, as well as when the conditions for its slipping are created, is described in detail in [6].

At first, the relationship between the height of the ridge h_g and its corresponding angle α must be determined. The assumption is that the values are known: v_m, z (number of blades oriented on the same side), R, L, γ, ω i μ.

Figure 1a shows that:

$$h_g + R\cos(\alpha + \gamma_1 - \gamma) = R \,,$$

where is:

$$\alpha = \arccos\frac{R - h_g}{R} - \gamma_1 + \gamma \,. \tag{1}$$

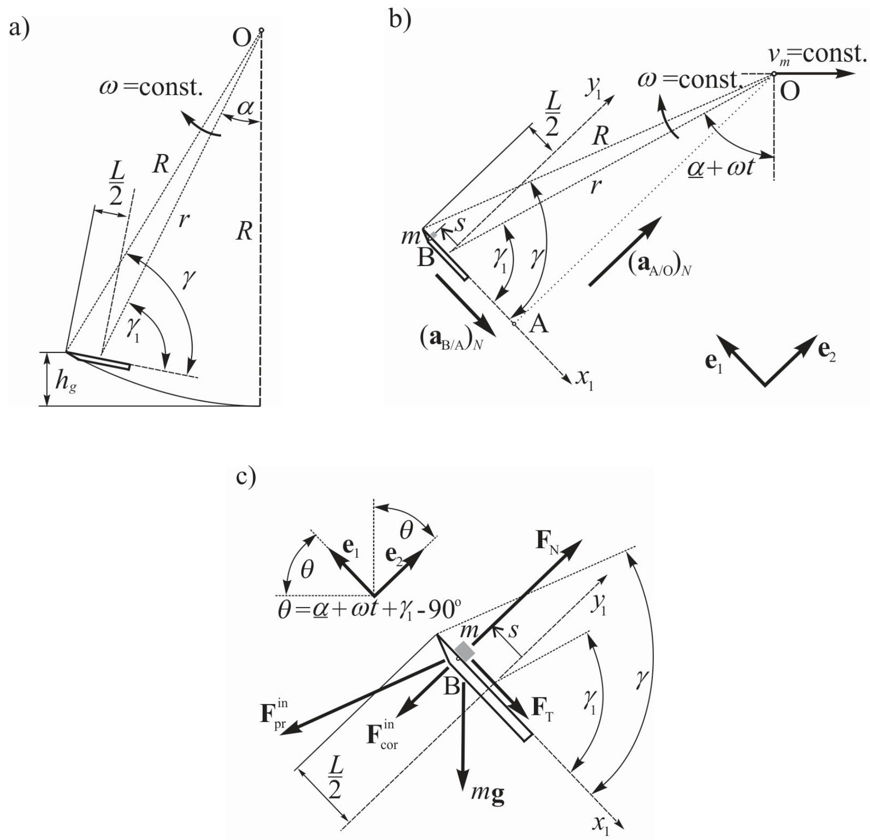

Fig. 1 The forces acting on the soil slice as it moves relative to the knife

The dynamics motion the part of a mass *m*, which was supposedly located in the middle of the blade at the moment of slip starting, is studied below. In that moment, the relative coordinate has values zero (Fig. 1), time *t* is chosen to be zero and the angle α, determined by formula (1) or in accordance with the paper [6], is denoted by $\underline{\alpha}$. Because relative movement from a state of relative rest begins, there is:

$$s(0) = 0, \quad \dot{s}(0) = 0. \tag{2}$$

The unit vector $\mathbf{e_1}$ has the route and direction of the coordinate *s* (Fig. 1) while the unit vector $\mathbf{e_2}$ is perpendicular to $\mathbf{e_1}$.

Newton's second law for the relative motion of a particle of mass *m* (soil slice) along the blade (Fig. 1c) takes the form:

$$m\mathrm{a}_{\mathrm{rel}} = m\mathrm{g} + \mathrm{F_N} + \mathrm{F_T} + \mathrm{F}_{\mathrm{pr}}^{\mathrm{in}} + \mathrm{F}_{\mathrm{cor}}^{\mathrm{in}}. \tag{3}$$

where is:

$$\mathrm{a}_{\mathrm{rel}} = \ddot{s}\mathrm{e}_1, \quad \mathrm{F}_{\mathrm{N}} = F_N \mathrm{e}_2, \quad \mathrm{F}_{\mathrm{T}} = -\mu F_N \mathrm{e}_1 . \tag{4}$$

Suitable form of the gravity force particle (soil slice) vector $m\mathbf{g}$:

$$m\mathrm{g} = -mg\sin\theta\,\mathrm{e}_1 - mg\cos\theta\,\mathrm{e}_2 \quad \Rightarrow$$
$$m\mathrm{g} = mg\cos(\underline{\alpha} + \omega t + \gamma_1)\mathrm{e}_1 - mg\sin(\underline{\alpha} + \omega t + \gamma_1)\mathrm{e}_2 \quad \Rightarrow$$
$$m\mathrm{g} = mg[\cos(\underline{\alpha}+\omega t)\cos\gamma_1 - \sin(\underline{\alpha}+\omega t)\sin\gamma_1]\mathrm{e}_1 - mg[\sin(\underline{\alpha}+\omega t)\cos\gamma_1 + \cos(\underline{\alpha}+\omega t)\sin\gamma_1]\mathrm{e}_2, \tag{5}$$

where, in accordance with the paper [2], equalities apply

$$\sin\gamma_1 = \frac{R\sin\gamma}{\sqrt{R^2 + (L/2)^2 - RL\cos\gamma}}, \quad \cos\gamma_1 = \frac{R\cos\gamma - L/2}{\sqrt{R^2 + (L/2)^2 - RL\cos\gamma}} . \tag{6}$$

Below, a suitable form for the vector record of the transfer force of inertia $\mathrm{F}_{\mathrm{pr}}^{\mathrm{in}}$ is determined. First, start with the multiplication of mass m and the transfer speed (that is the speed of point B), with a minus sign

$$\mathrm{F}_{\mathrm{pr}}^{\mathrm{in}} = -m\mathrm{a}_{\mathrm{B}} = -m\left[\underline{\mathrm{a}_{\mathrm{O}}} + (\mathrm{a}_{\mathrm{A/O}})_N + \underline{(\mathrm{a}_{\mathrm{A/O}})_T} + (\mathrm{a}_{\mathrm{B/A}})_N + \underline{(\mathrm{a}_{\mathrm{B/A}})_T}\right].$$

The acceleration vectors underlined here have intensities equal to zero since, by assumption, both the speed of the working machine v_m and the angular velocity ω are constant. It is known that the intensities of the normal accelerations of one point with respect to the other (Fig. 1a) are equal to the product of the distances of those points and squares of angular velocity, so finally have

$$\mathrm{F}_{\mathrm{pr}}^{\mathrm{in}} = -m\left[\omega^2 R\sin\gamma\,\mathrm{e}_2 - \omega^2(R\cos\gamma - L/2 + s)\mathrm{e}_1\right] = m\omega^2(R\cos\gamma - L/2 + s)\mathrm{e}_1 - m\omega^2 R\sin\gamma\,\mathrm{e}_2 . \tag{7}$$

Now determine the suitable form for the vector notation of Coriolis inertia force $\mathrm{F}_{\mathrm{cor}}^{\mathrm{in}}$. This force is obtained from the multiplication of mass m and Coriolis acceleration, with a minus sign

$$\mathrm{F}_{\mathrm{cor}}^{\mathrm{in}} = -m\mathrm{a}_{\mathrm{cor}} = -2m\omega\,\dot{s}\,\mathrm{e}_2 . \tag{8}$$

By designing the vector equality (3) in the directions $\mathbf{e_1}$ and $\mathbf{e_2}$, and with respect to (4), (5), (6), (7) and (8), is obtaining

$$\ddot{s} = \frac{g}{\sqrt{R^2 + (L/2)^2 - RL\cos\gamma}}\left[\left(R\cos\gamma - \frac{L}{2}\right)\cos(\underline{\alpha}+\omega t) - R\sin\gamma\sin(\underline{\alpha}+\omega t)\right] - \mu\frac{F_N}{m} + \omega^2\left(R\cos\gamma - \frac{L}{2} + s\right), \tag{9}$$

$$0 = -\frac{g}{\sqrt{R^2 + (L/2)^2 - RL\cos\gamma}}\left[\left(R\cos\gamma - \frac{L}{2}\right)\sin(\underline{\alpha}+\omega t) + R\sin\gamma\cos(\underline{\alpha}+\omega t)\right] + \frac{F_N}{m} - \omega^2 R\sin\gamma - 2\omega\dot{s}. \tag{10}$$

By eliminating the reaction F_N from (9) and (10), the following differential equation of relative motion is obtained

$$\ddot{s}+2\mu\omega\,\dot{s}-\omega^2 s=\omega^2\left(R\cos\gamma-L/2-\mu R\sin\gamma\right)+b_1\cos\left(\underline{\alpha}+\omega\,t\right)-b_2\sin\left(\underline{\alpha}+\omega\,t\right), \tag{11}$$

where is:

$$b_1=\frac{g}{\sqrt{R^2+\left(L/2\right)^2-RL\cos\gamma}}\left(R\cos\gamma-\frac{L}{2}-\mu R\sin\gamma\right),$$
$$b_2=\frac{g}{\sqrt{R^2+\left(L/2\right)^2-RL\cos\gamma}}\left[R\sin\gamma+\mu\left(R\cos\gamma-\frac{L}{2}\right)\right]. \tag{12}$$

The initial conditions for the obtained inhomogeneous linear differential equation with constant coefficients (9) are given by expressions (2). Solving differential equation (9) with initial conditions (2) is obtained $s(t)$ and $\dot{s}(t)$.

This phase of motion will stop in moment $t=\bar{t}$ when the relative coordinate s reaches the value of L/2. Then the relative velocity of the soil slice with respect to the knife will be $\dot{s}(\bar{t})$ and the next phase of movement will begin a slanting shot (Fig. 2).

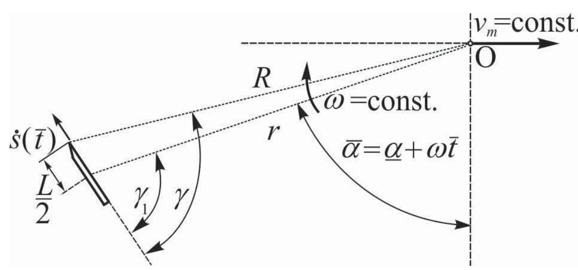

Fig. 2 Moment of rejecting the soil slice and slanting shot start

The analysis was performed for an input data: R=0.25 m, ω=16.038 s^{-1}, L=0.06 m, v_m=0.43 m/s, z=3 i μ=0.35. On the basis of the procedures described in the paper [6] for input data R, ω, v_m, z, calculated ridge height at bottom of furrow is h_g=1.9872 mm.

In previous papers [6], where the removing angle of soil slice from the blade was analyzed, it was confirmed that the optimum value of the setting angle of placement is $\gamma \leq 60°$. In order to eliminate the additional friction of the wing knife to the uncut part of the ground, the wing of the knife, depending on the operating speed, must be curved for values 5,24-14,41° [3]. For simplification of marking, the curvature of the blade wing is shown by changing the setting angle γ.

Results of relative motion for blade setting angle γ=58°.

In this case, the angle $\underline{\alpha}$ obtained from (1) and (6) is $\underline{\alpha} = 1.027^{\circ}$.

A tabular representation of the path law and speed of relative motion, that is, of the solution of differential equation (11) with initial conditions (2), is given in Table 1, and the graphical representation is given in Fig. 3. Elapsed time of relative motion obtained from the conditions

$$s(\bar{t}) = L/2\,, \tag{13}$$

amounts $\bar{t} = 0.189\,\text{s}$. The relative speed at the moment of rejection (i.e., at the end of relative movement) is $\dot{s}(\bar{t}) = 0.361\,\text{m/s}$ and the angle corresponding to that moment equals $\overline{\alpha} = 174.82^{\circ}$, determined by the formula

$$\overline{\alpha} = \underline{\alpha} + \omega\bar{t}\,, \tag{14}$$

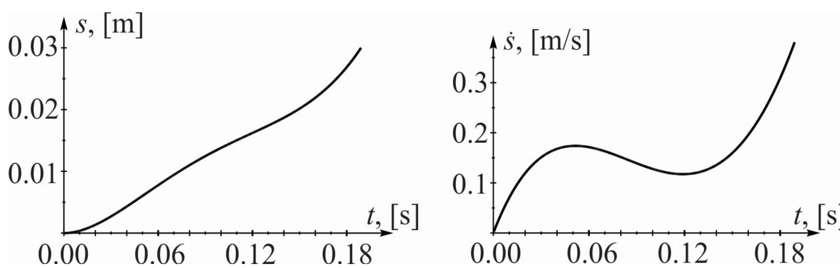

Fig. 3 Graphical representation the solution of the differential equation of relative motion and the corresponding relative speed for the given data and γ=58°.

Results of relative motion for blade setting angle γ=54°

The angle $\underline{\alpha}$ obtained from (1) and (6) is $\underline{\alpha} = 1.266^{\circ}$.

A tabular representation of the path law and speed of relative motion is given in Table 1, and the graphical representation is given in Fig. 4.

The elapsed relative time of motion obtained from condition (13) is $\bar{t} = 0.0887\,\text{s}$. The relative speed at the moment of rejection is $\dot{s}(\bar{t}) = 0.536\,\text{m/s}$ and the angle corresponding to that moment, determined by the formula (14), is $\overline{\alpha} = 82.75^{\circ}$.

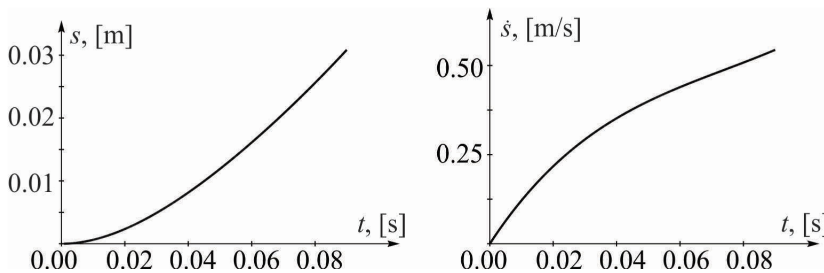

Fig. 4 Graphical representation the solution of the differential equation of relative motion and the corresponding relative speed for the given data and γ=54°.

Results of relative motion for blade setting angle γ=50°

The angle $\underline{\alpha}$ obtained from (1) and (6) is $\underline{\alpha} = 1.541^{o}$.

A tabular representation of the path law and speed of relative motion is given in Table 1, and the graphical representation is given in Fig. 5.

The elapsed relative time of motion obtained from condition (13) is $\bar{t} = 0.0680\,\mathrm{s}$. The relative speed at the moment of rejection is $\dot{s}(\bar{t}) = 0.761\,\mathrm{m/s}$ and the angle corresponding to that moment, determined by the formula (14), is $\bar{\alpha} = 63.983^{o}$.

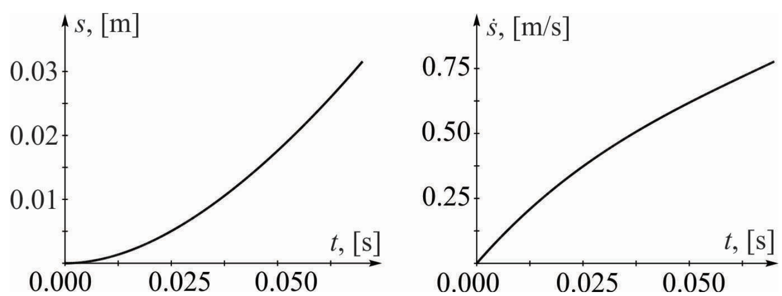

Fig. 5 Graphical representation the solution of the differential equation of relative motion and the corresponding relative speed for the given data and γ=50°.

Results of relative motion for blade setting angle γ=46º

The angle $\underline{\alpha}$ obtained from (1) and (6) is $\underline{\alpha} = 1.850^{o}$.

A tabular representation of the path law and speed of relative motion is given in Table 1, and the graphical representation is given in Fig. 6.

The elapsed relative time of motion obtained from condition (13) is $\bar{t} = 0.0577\,\text{s}$. The relative speed at the moment of rejection is $\dot{s}(\bar{t}) = 0.928\,\text{m/s}$ and the angle corresponding to that moment, determined by the formula (14), is $\bar{\alpha} = 54.869^{\circ}$.

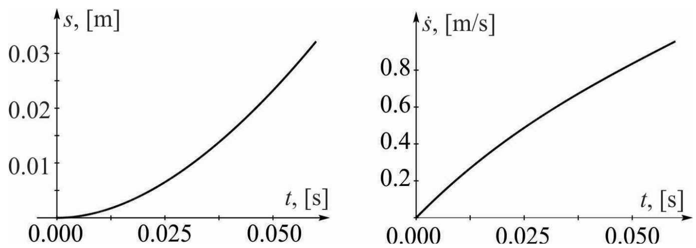

Fig. 6 Graphical representation the solution of the differential equation of relative motion and the corresponding relative speed for the given data and γ=46°.

Table 1 Solution for the relative motion of the soil slice along the knife until rejecting

	γ =58°		γ =54°		γ =50°		γ =46°	
t, [s]	s, [cm]	$\dot{s}$, [m/s]	s, [cm]	$\dot{s}$, [m/s]	s, [cm]	$\dot{s}$, [m/s]	s, [cm]	$\dot{s}$, [m/s]
0.00	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.01	0.03721	0.07049	0.06291	0.12105	0.08812	0.17067	0.11272	0.21912
0.02	0.13381	0.11947	0.23356	0.21643	0.33147	0.31166	0.42708	0.40471
0.03	0.27027	0.15080	0.48898	0.29139	0.70377	0.42956	0.91361	0.56469
0.04	0.43067	0.16789	0.81109	0.35051	1. 1849	0.53012	1. 5502	0.70593
0.05	0.60231	0.17378	1. 1861	0.39789	1. 7600	0.61846	2. 3213	0.83452
0.06	0.77543	0.17131	1. 6042	0.43728	2. 4193	0.69920	3. 2169	0.95594
0.07	0.94300	0.16309	2. 0592	0.47215	3. 1574	0.77664		
0.08	1. 1005	0.15158	2. 5482	0.50577				
0.09	1. 2458	0.13911	3. 0714	0.54127				
0.10	1. 3791	0.12790						
0.11	1. 5027	0.12003						
0.12	1. 6208	0.11749						
0.13	1. 7399	0.12213						
0.14	1. 8680	0.13569						
0.15	2. 0147	0.15976						
0.16	2. 1913	0.19581						
0.17	2. 4106	0.24518						
0.18	2. 6863	0.30904						
0.19	3. 0336	0.38848						

Higher values of relative speed will inevitably cause more intensive soil crumbling, but will also lead to greater degradation of the soil [8]. By determining the moment of rejecting of the soil slice, extremely important data were obtained regarding the determination of the optimum value of the knife setting angle γ, as well as the influence of the curvature of the blade.

The obtained resultants are valid just under approximation that compact soil slice is formed, and slipping is started at the point of the maximal height of the ridges (h_g) at the bottom of the furrow.

3. CONCLUSION

By analyzing the relative motion of the soil slice along the knife until their rejecting for the values of the knife setting angle within the limits γ= 58°–46°, the time interval for which soil slice rejection occurs, is shortened in range t=0.189–0.0577 s, and the values for the corresponding angle corresponding to the moment of rejection are also reduced $\overline{\alpha} = 174.82^{o} - 54.869^{o}$. At the same time, the value of the relative speed at the moment of rejection of soil slice increases significantly in the boundaries $\dot{s}(\overline{t}) = 0.361 - 0.928$ m/s. Higher values of relative speed will inevitably cause more intensive soil crumbling, but will also lead to greater degradation of the soil. By determining the moment of rejecting of the soil slice, extremely important data were obtained regarding the determination of the optimum value of the knife setting angle γ, as well as the influence of the curvature of the blade of the knife.

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ON THE LOOSSES OF ALFALFA DURING HAY PREPARATION

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Abstract. *This study is focused to the mass losses evaluation in the process of alfalfa mowing by machine equipped with conditioner. This way, the process can be divided in the two main stages: mowing and chopping. Following the common practice, based on the configuration of production process and machine design, the two kinds of hay losses were measured: losses caused by cutting heights over the optimal value, and those caused by chopping process imperfectness. Obviously, the total loss of hay mass was calculated by simple summation of these two kinds of losses. The minimum evidenced percentage of hay mass losses, caused by an inadequate cutting height, was 1.02% of yield, at the self-propelled machine minimum working speed of 4.76 km h^{-1}. Higher working speeds of the mowing machine increased the cutting losses up to the maximum value of 1.40% at the maximum mowing speed of 9.95 km h^{-1}. The hay mass losses, caused by the imperfectness of the crushing process, expressed an opposite behavior with respect to the mower working speed. This kind of losses ranged from the minimum value of 0.27% at the highest machine working velocity up to the maximum value of 0.39% at the minimum machine speed. The average percentage of total mass lost was 1.54% of hay yield at the average mowing speed of 7.14 km h^{-1}.*

Key words: *mowing, losses, alfalfa, cut height, chopping*

1. INTRODUCTION

Alfalfa (*Medicago Sativa*) represents one of the most widely used fodder plant varieties. Its main advantages with respect to other competitors lay in the fact that can be used in different ways: fresh, hay, haulage, silage and/or for grazing. Furthermore, the alfalfa is characterized by high nutritive values, and is highly adaptive toward different climate conditions and environments [3].

Contemporary livestock food production, produced from alfalfa plants, crucially depends on the mowing process [1]. Even more, this is the introductory operation of any production of this kind. To provide adequate quality of the final product, it is necessary to perform mowing within the optimal agro-technical period that will reduce the negative impact of environment [4]. Efficient exploitation of the biological yield of green matter demands, among others, careful control of mowing process that should result with reduced losses [2]. Thus, when produce the alfalfa seed, farmers meet the two opposing goals: maximal acquired quantity of green matter against to preventing the damage of the flap. It is usually accepted that compromise can be reached by the alfalfa cutting length in the range between 6 cm and 8 cm. More precisely, in an ideal situation, the plants should be cut neither over, nor below the optimal value of 6 cm [9]. In general, losses caused by inappropriate mowing are most commonly classified in two classes. The first kind of loses occur due to the unnecessarily high cutting height (over 6 cm in alfalfa mowing), and other losses arise due to the crushing of the mowed mass, because the chopped mass during manipulation with the hay remains on the plot. Having in mind that the largest amount of chopped mass represents the parts of the leaves that contain the largest amount of nutrients the particular attention must be paid to this type of loss [5]. Following [11], a shorter drying of the alfalfa mowed by a self-propelled mower (until the moisture content reaches 20% after 28 hours) influences the reduction of shake-off losses of the leaves.

Obviously, the increase of both kinds of losses is affected by the working speed of the mower, as it has been widely recognized a long time ago (see [8], for example). Imperfectness of the cutting process of the self-propelled mower "Fortschritt 302" has been evidenced and reported in [7]. Within the tested speed range between 3.71 km h^{-1} and 6.41 km h^{-1}, they found that cutting height deviation from the optimal value has generated an increased mass loss of alfalfa: 1.63% of the yield in average.

2. MATERIAL AND METHODS

Testing of the self-propelled mower Fortschritt 302 (Table 1) was performed at the experimental plot in the village Mačkovac, near Kruševac in 2016, located in central Serbia (43^0 33' 33"N; 21^0 12' 53"E). Without irrigation, combined with a draught, the overall conditions resulted in fairly small yield (3.65 t ha^{-1}) of alfalfa cultivar Kruševacka-28 in the third to fifth year of use. Decreasing the yield was also caused by mowing the alfalfa in the tufty phase.

Under optimal growing conditions, this cultivar has high genetic potential with respect to the yield of forage (over 80 t ha^{-1}) and dry matter (over 20 t ha^{-1}). It is suitable for intensive production, allowing 6 cuts per year with irrigation present. This cultivar provides excellent forage quality: crude protein content is 20-22 g kg^{-1} and crude fiber about 32 g kg^{-1} (Institute for Forage Crops 2011).

The yield of green mass was determined by measuring the mass of the alfalfa originating from a surface of one meter of length in width of the swath, recalculated to the square area of one hectare. Well known chronometric method was applied for the measurement of working speeds of the mower. The cutting height was determined at the loss detection site – separately for each appropriate testing part of the experimental plot, over which tests were performed at corresponding working speed of the mower.

The mowing losses were measured for each mowing speed at one meter of width of appropriate test section of experimental surface (from a surface of one meter of length) - the same place where the cutting heights were determined. Finally, the total losses were evaluated by summations losses caused by inadequate cutting cuts and losses due to crushing. Experiment comprehended six probes.

Table 1. Technical data of the self-propelled mower Fortschritt E – 302.

MOWER GENERAL DATA	
• Length	3960 *mm*
• Width	3200 *mm*
• Height	3750 *mm*
• Mass	3950 *kg*
• Axle distance	2400 *mm*
• Steering	hydraulic
WORKING SPEEDS	
• The first speed	3.3 – 8.4 $km\ h^{-1}$
• The second speed	8.4 – 21.1 $km\ h^{-1}$
• The rear moving direction	4.8 $km\ h^{-1}$
TANK VOLUME	100 *l*
CONDITIONER DATA	
• Width	1800 *mm*
• Roller diameter	241 *mm*
• Roller maximum specific pressure	35 $N\ cm^{-1}$
• Roller tread	120 *mm*
• Mass	500 kg
• Length	260 *mm*
• Height	700 *mm*
MOWING DEVICE	
• Grip	4270 *mm*
• Cut height regulation	50; 90; 150 *mm*
• Fingers distance	76.2 *mm*
• No. of fingers	55
• The mean blades speed	2.1 $m\ s^{-1}$
• The mean speed of double blades	3.6 $m\ s^{-1}$

3. RESULTS AND DISCUSSION

The mower applied is designed with grip of 4.7m. Coefficient of design grip exploitation varied from 0.90 to 0.99. The average value of this coefficient was 0.95, (Fig. 1). In general, the clear negative linear trend of reducing the value of this coefficient with increasing the operational speed of the mower is evident:

$$\beta = -0.0153 \cdot v + 1.0536 \quad (1)$$

R-square factor reached very high value of 0.9876 in this case, confirming existence of strong relationship between factor β and machine working speed.

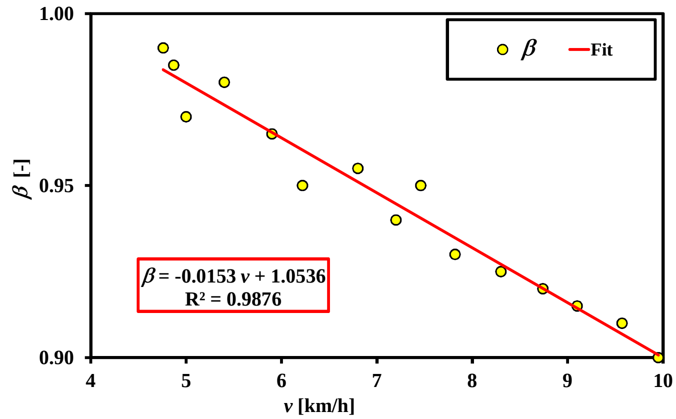

Fig. 1 Relationship between the coefficient of grip exploitation (coefficient β) and mower working speed.

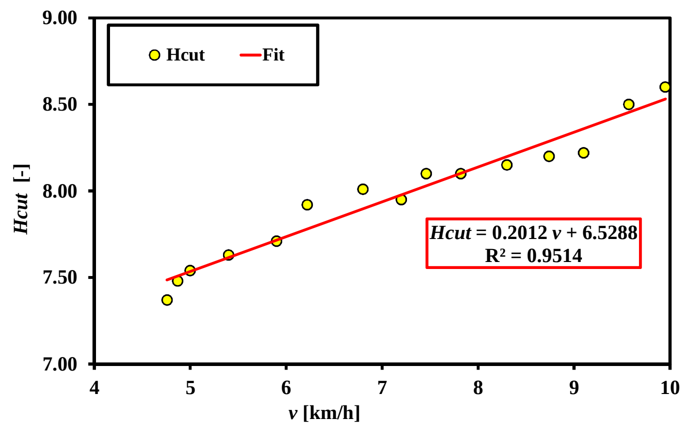

Fig. 2 Dependence of the cutting height on the working speed of the mower.

The average height of stem cut was 7.97 cm, with an average speed of self-propelled mower of 7.14 km h^{-1} (Figure 3). The smallest cutting height of 7.37 cm was evidenced at a mowing speed of 4.76 km h^{-1}, while the largest cutting height was 8.60 cm, at a speed of 9.95 km h^{-1}. Cut height also strongly depended on the mower speed – the positive linear trend defined by formula

$$H_{cut} = 0.2012 \cdot v + 6.5288 \quad (2)$$

was characterized by R-square factor of 0.951.

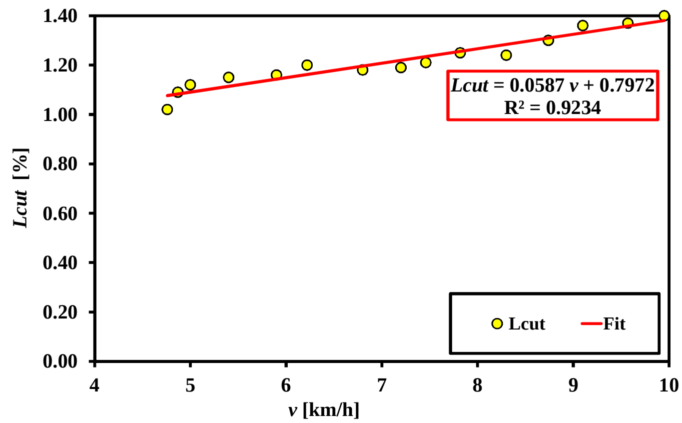

Fig. 3 Dependence of the cutting loss on the working speed of the self-propelled machine.

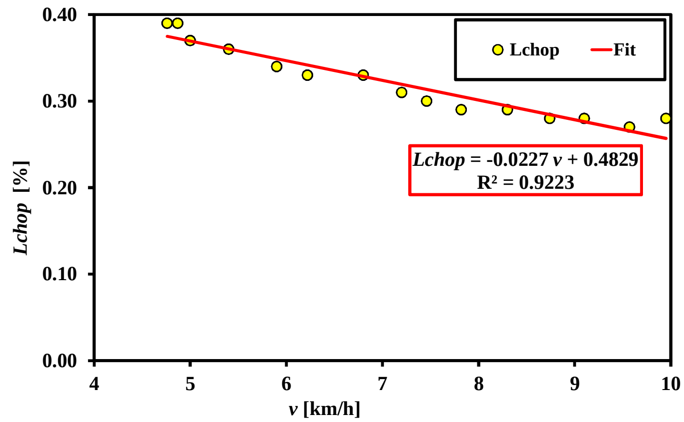

Fig. 4 Dependence of the crushing loss on the working speed of the self-propelled machine.

Figures 3, 4 and 5 illustrate relationships dependences of the cutting (*Lcut*), chopping (*Lchop*) and total (*Ltot*) losses on the working speed (*v*) of the self-propelled machine. In all cases, trend lines were linear.

$$L_{cut} = 0.0587 \cdot v + 0.7972 \quad (3)$$

$$L_{chop} = -0.0227 \cdot v + 0.4829 \quad (4)$$

$$L_{tol} = 0.0359 \cdot v + 1.2801 \quad (5)$$

and characterized by the following values of R-square factors: 0.9234, 0.9223 and 0.7924, respectively.

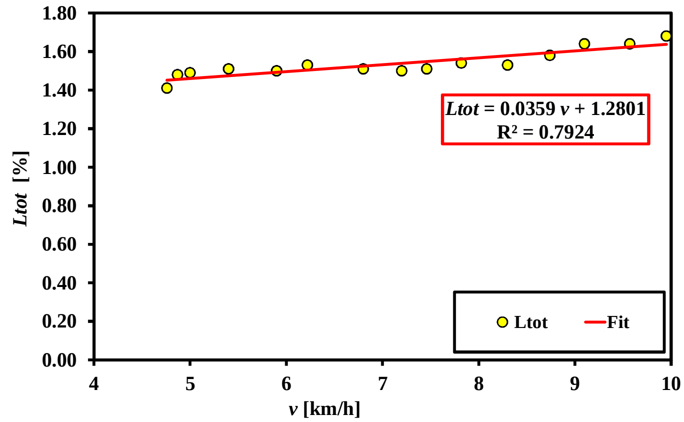

Fig. 5 Dependence of the total loss on the working speed of the self-propelled machine.

Increasing the mower speed resulted in slight increase in losses due to the cut height was observed (Figure 3). In average, losses due to the cutting height amounted to 1.22% of the yield, and they varied at the tests in the range between of 1.02% to 1.40% of the yield. In the case of chopping losses, the trend of reducing losses with increasing the speed of the mower was evident. They varied from 0.27% of the yield, and up to the value of 0.39%, having the average value 0.32% of the yield (Figure 4). Total losses represent the sum of the previous two types of losses. During the testing self-propelled mower, the average value of total losses was 1.54% of the yield. Total losses ranged from a minimum of 1.41% to a maximum of 1.68% of the yield.

4. CONCLUSION

Recommended maximum value of total (mowing + chopping) losses is 5% of the yield mass. The results of performed experiments, related to alfalfa test mowing by self-propelled mower Fortschritt 302 at various working speeds (starting from 4.76 km h^{-1} and up to the maximum value of 9.95 km h^{-1}), verified that this criterion was satisfied. Total losses were in the range between 1.41% and 1.68% (on average, 1.54% of the yield).

Dominant share in the total losses of yield mass originates from the inappropriate cutting heights of the alfalfa stems under investigation. It is widely accepted that optimal values of alfalfa cutting height should be within the range between 6 cm and 8 cm. In the present study, the average measured value of cut stems was 7.97 cm. The smallest cutting height of 7.37 cm was evidenced at a mowing speed of 4.76 km h^{-1}, while the largest cutting height was 8.60 cm, at the maximum experimental working speed of 9.95 km h^{-1}.

Concerning the other parameters, it can be concluded that the tested mowing machine achieved high values of the utilization coefficient of the design grip (known as coefficient

β). Evidenced experimental values were in the range between 0.90 and 0.99, having the average value of 0.95.

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EFFICIENCY OF MECHANISED COLLECTION OF SOYBEAN STRAW

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Abstract: *The importance of soybean (Glycine max L.) arises from the quality of its grain (high protein and oil content), so it is one of the most important protein and oil crop in the world. As biomass of agricultural origin is highly acceptable energy source from the environmental point of view, soybean takes part in the production of biofuels, where grain and straw represent raw materials for liquid and solid biofuels. The production of biofuels from grain reduces the amount of grain for food and feed and in recent years attention has been focused to the development of biofuel from the straw. Straw is also an important source of organic matter and has important influence on biological, chemical and physical properties of the soil and should not be considered as waste. The aim of this paper was to determine the actual amounts of straw that can be collected after harvesting soybean using existing mechanization on family farm, round baler with pick-up. The field experiment was set at a location in Velika Barna with three soy varieties, Lucija, Galina and Ika, represented in the crop rotation by domestic farmers. The yield of straw was in the range of 1,824 kg/ha to 2,266 kg/ha and collection efficiency differed between soybean varieties, ranging from 33.3 % to 48.9 %. The amount of collected post-harvest residues depended on the cultivar, water content of the straw at the time of baling and the construction of combine and baler.*

Key words: *biomass, harvest index, round baler*

1. INTRODUCTION

Soybean (*Glycine max* L.) is an old crop, grown for over four thousand years. The importance of soybean is derived from the quality of its grain (high protein and oil content), so it is one of the most important protein and oil crops in the world and can be fully utilized for processing for various purposes. In the world in period from 2012 to 2016 the area sown with soybeans increased 15%, from 105,350,564 to 121,532,432 hectares. In the same period, the area sown with soybeans in Europe increased by 47 %, with 3,446,289 hectares of 2012 to 5,038,132 hectares in 2016, which is 3 times higher than the increase in the world (source: faostat.org). Agro-technical significance of soybeans in the rotation is huge, because with bacteria Bradhyrhizobium japonicum at its root, it enriches the soil with nitrogen, approx. 40-60 kg/ha. It activates and moves nutrients from the less soluble forms to more accessible forms for plants, thereby improving fertility and soil structure itself (Vratarić and Sudarić 2008).

Along the grain in soybean production there is also soybean straw. The term soybean straw refers to dried soybean stalks, leaves, and empty pods that remain in the field after harvest with a combine. Soybean straw is an important source of organic matter and has important influence on the biological, chemical and physical properties of soil and should not be considered as waste. Good agricultural practice requires incorporation of harvest residues in soil by ploughing, not their burning, which has been banned in the Republic of Croatia since 2011 (Pravilnik o dobrim poljoprivrednim i okolišnim uvjetima, N.N. 89/11). Before collecting straw from the fields, consideration should be given to the fact that removing it can increase soil erosion, reduce yields and deplete soil with nitrogen and other nutrients. Straw can be taken out of the field and used in barns as litter and then be returned to the soil as manure.

Biomass of agricultural origin is a very acceptable fuel from the environmental impact point of view, especially the greenhouse gases emissions (Miller, 1992). The emission of SO_2 during the combustion of straw is less than the emission from the combustion of coal and mineral heating oil, and higher than the emission from the combustion of natural gas, while the NOx emission from the combustion of straw is much lower than in other observed fuels. Like other biomass, straw is generally considered a CO_2-neutral fuel (EC, 1997). With all the benefits of using biomass for energy production, we must bear in mind that there is a risk of soil depletion if all the crop residues are removed from the arable land, that is, the nutrient and organic matter content of the soil must not be neglected.

Soybean straw is one of the potentially good energy sources. With average amount of collected biomass 3,112 kg/ha and lower heating value 16.87 MJ/kg, Kiš et al. (2013) stated that energy value of soybean straw was 52.52 MJ/ha, equivalent to 998.5 kg of heavy oil. Also, soybean straw is a good source of matter for anaerobic digestion due to the high availability of biomass. Agricultural biomass such as maize and soybean straw contains complex structure lignocellulose and does not contain easily fermenting sugars. Therefore, their transformation to biofuels cannot be easily done (Hesami et al., 2015; Liu et al., 2015; Antonopoulou, 2015; Monlau et al., 2015). Matin et al. (2018) found that soybean assortment had an impact on the combustible and non-combustible properties of straw, as well as on the heating value.

Renewable sources of biomass are increasingly considered important for the development of a sustainable industrial society and for managing the reduction of greenhouse gas emissions. Biological fibers from agricultural residues such as soybean straw are widespread, cheap, recyclable, versatile, and a biodegradable renewable source of lignocellulosic matter (Liu, 2015). Some researchers have also suggested that soybean straw can be used to produce natural cellulose technical fibers whose structure and properties are similar to the cellulosic fibers currently in use (Wang and Sain, 2007;

Reddy and Yang, 2009). These tendencies should not only add to the value of soybeans as a crop, but also provide a sustainable source of fiber.

The amount of collected straw depends on the machinery and also on the condition of the harvested residues. Different strategies are used in collecting harvest residues of different crops. Petrolia (2006) found that efficiency in collecting of harvest residues was 30 % using only baling operations, while using mulcher, rakes and balers the efficiency was higher and was 40 %. Martinov et al. (2014) found that it is possible to collect about 40 % of the harvested soybean residues under average weather conditions. Increasing moisture of soybean straw during baling makes baling more difficult because the straw becomes less and less elastic.

The aim of this study was to determine the actual quantities of collected straw after harvesting soybeans, using press for round bales with a pick-up device.

2. MATERIAL AND METHODS

The field experiment was set at a location in village Velika Barna, located approx. 100 km east from Zagreb (45° 09’ N, 17° 31’ E). The climate in this area is semi-humid with a total annual precipitation of 790 mm and an average annual temperature of 11.3 °C (source: Meteorological and hydrological institute of Croatia). Soil on the site was silty loam with relatively low organic matter content (Table 1).

Table 1 Soil properties at experimental site

pH		%		AL-mg/100g	
H_2O	nKCl	humus	N	P_2O_5	K_2O
6.21	5.11	2.08	0.11	11.39	13.00

Sowing of soybean was carried out in the optimal sowing period, April 16 and 17, 2017, at a 25 cm row spacing, with a 100 kg/ha sowing rate. Three varieties of soybeans were used - Lucia, Ika and Galina. Lucia is a very early variety (00-0 ripening group), resistant to lodging, high tolerance to major soybean diseases and to shattering of pods. It has a high yield potential (up to 5 t/ha). Ika is medium early variety, 0-I ripening group. Due to extreme adaptability in different climatic and soil conditions, exceptional stability and excellent yield potential and quality, it is the most widespread variety of soybeans sown in Croatia. Galina is an early variety, ripening group 0, especially suitable for organic production. In intensive production conditions, it has an extremely high yield, above 4.5 t/ha, and is characterized by excellent resistance to various agroecological conditions.

The pre-crop on the experimental plots was maize. In the primary tillage 300 kg/ha of NPK 7:20:30 was plowed into the soil, then 250 kg/ha of NPK 15:15:15 was added in the seedbed preparation. Before sowing, soybean seeds were bacterized with Bradhyrhizobium japonicum. The protection from weeds was carried out repeatedly with herbicides Dual Gold (S-metolaklor), Harmony (tifensulfuron-metil) and Laguna 75 WG (oksasulfuron). The herbicides proved to be effective, leaving the crop free of weeds. Monitoring the growth of soybeans revealed a poorer development of nodule bacteria, and therefore two additional fertilizations were carried out. The harvest was on October

25, 2017. Deutz Fahr 1302, a conventional combine harvester with tangential threshing unit and straw walkers was used.

Prior to the mechanized harvest, plant samples (from 1 m^2) were taken from each experimental plot, from which the number of plants per m2, average plant height, average number of pods, then leaf, stem and grain weights were determined in the laboratory. After all these, the harvest index is calculated. All results were calculated with 13 % moisture content. After harvest the soybean straw was collected and pressed into round bales (125x125 cm) using a Welger RP 220 Farmer press with a pick-up device of 2.20 m working width.

Statistical analysis of data was done with computer program SAS (SAS, 2002) using analysis of variance (ANOVA). The significance of differences between the observed parameters were indicated by F-test at the level of probability p = 0.05.

3. RESULTS AND DISCUSSION

Based on the data obtained from the analysis of samples taken manually before harvest and data after harvest and baling, the baling efficiency was determined (Table 2). Baling efficiency is expressed as the amount of straw collected in relation to the total amount of straw present in the field before harvest. From the samples of plants taken manually the moisture content and the amount of straw per hectare before harvest were determined (theoretical straw yield calculated at 13 % moisture). Due to technical problems, the moisture content of straw at the time of baling was not determined, but the value of 40 % was taken as moisture at the time of baling, based on the available literature data that stated when soybean grain moisture is 13 %, the moisture content of straw is approximately 40 % (Kovačić et. al. 2017; Vratarić and Sudarić, 2008).

Table 2 Yield components and baling efficiency (Mean value ± St. Dev.)

Soybean variety	Lucija	Galina	Ika
Number of plants per hectare	346,666 ± 48,074	297,777 ± 33,555	342,222 ± 20,367
Number of pods per plant	23.5 ± 3.7	24.7 ± 2.7	20.0 ± 2.9
Grain weight (kg/ha)	2,572 ± 96,1	2,427 ± 187,7	2,043 ± 338,5
Straw weight (kg/ha)	2,266 ± 54.0	2,095 ± 121.8	1,824 ± 274.5
Total weight of plants (kg/ha)	4,839 ± 149.2	4,522 ± 292.3	3,867 ± 611.2
Harvest index	0.53 ± 0.01	0.54 ± 0.02	0.53 ± 0.01
Baling efficiency (%)	48.9 a* ± 0.80	48.0 a ± 2.85	33.3 b ± 4.21

* Different letters indicate significant ($p \leq 0.05$) differences

The number of plants and grain yield varied across varieties, but no statistically significant differences were found. Although for the Ika variety has not been determined smallest average number of plants per hectare, the lowest yield of both grains and straw has been determined. The cause of the decrease in grain and straw yields in the Ika variety is the damage caused by the wild animals during the period when the crop was already in its ripening stage. The grain yield of the Ika variety was therefore 16% lower than that of the Galina variety, and also the weight of straw was lower 20% compared to the Lucija variety.

The total plant weight of the Lucija and Galina varieties compared to the Ika variety was greater 15 to 21 %, respectively. From the obtained data it can be concluded that with the increase in the number of plants per hectare, a higher grain yield and a higher amount of straw can be expected. The resulting harvest index of 53 % to 54 % was in accordance to research conducted by Pedersen and Lauer (2004). Baling efficiency in the Ika variety was, however, 31 % lower than in the Lucija and Galina varieties.

A very strong positive correlation R = 0.9715 ($p<0.01$) was found between total straw weight and grain weight (Table 3). A very strong positive correlation was found for both total plant weight and grain weight R = 0.9944 ($p <0.01$), and also a very strong positive correlation was found for total plant weight and straw weight R = 0.9911 (p <0 .01).

Table 3 Correlations between yield components and baling efficiency

	Number of plants / ha	Grain weight	Straw weight	Total plant weight	Harvest index
Grain weight	-0,1643	-			
Straw weight	-0,1153	0,9715**	-		
Total plant weight	-0,1436	0,9944**	0,9911**	-	
Harvest index	-0,1029	0,5916	0,3919	0,5068	-
Baling efficiency	-0,1345	0,5155	0,5044	0,5142	0,3445

Fertilization value of the soybean harvest residues was estimated based on the nitrogen, phosphorus and potassium content of soybean straw taken from the research conducted by Kish et al. (2013), according to which the average nitrogen content in straw of the 5 selected soybean varieties was 3.95 g/kg, the average phosphorus content 2.95 g/kg and the average potassium content 4.50 g/kg. According to this assessment and the straw collection efficiency determined in this research, on average 3.89 kg/ha of nitrogen, 2.91 kg/ha of phosphorus and 4.43 kg/ha of potassium were taken out from the field with post-harvest residues, which should be taken into account during fertilization in the next season.

4. CONCLUSIONS

Based on the results of this research, it can be concluded that the amount of harvest residues that can be collected from the field depends on several factors. The grain yield and straw quantity differed for the varieties used in this study, and with the increase in the number of plants per hectare the total straw quantity also increased. A strong positive correlation was found between straw weight and grain weight, total plant weight and grain weight, and between total plant weight and straw weight. Mechanized collection of soybean straw has revealed that it is possible to collect, using a press for round bales with a pick-up, almost half (48.9 %) of the total available straw in the field after the harvest.

The statistically significant differences found in the efficiency of collecting soybean straw between the varieties are probably due to the condition of the crop before harvest (damaged by wild animals). The collecting efficiency of the straw is also influenced by the cutting height in harvest, the construction of the combine (threshing system), collecting strategy and the crop itself. Therefore, in order to better understand the factors affecting the efficiency of straw collection, additional research is needed in the area of collecting crop residues, which are not covered in this paper.

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FARM BUILDINGS AS DRIVERS OF THE RURAL ENVIRONMENT: A LITERATURE REVIEW

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Abstract. *Farm buildings play a central role for the sustainability of the rural environment. Conceived to host biological production, the farm building constitutes indeed a unique example in the wide epistemological sector of building construction, due to its architectural and technical issues, different from other building sectors. The originality of what happens inside the farm building corresponds to what happens outside. The role that buildings have historically played is strictly connected indeed to the surrounding context, due to the need of the farmer to live in close contact with agricultural land and animal husbandry. In this way, human activities have often strongly influenced the agricultural environment and the visual perception of its landscape. The increasing sensitivity about the concept of sustainable development of the built environment is currently stimulating the valorisation of farm buildings, as well as the assessment of their impact on the rural landscape. In the present article, a general literature review about the role that farm buildings play on the rural environment is presented, with a special focus on the wider opportunities enabled by the implementation of new technologies for the survey, analysis and planning of the interactions among farm buildings, rural environment and landscape.*

Key words: *Farm buildings; Rural environment; Cultural landscapes; Built heritage; Geographical Information System; Spatial analysis.*

1. INTRODUCTION

Rural heritage is a very important aspect of one Country's identity. Agricultural fields, orchards, natural places are landmarks that connect generations and city dwellers to their origins. Families trace their roots to rural villages, while culinary traditions begin in the countryside. The spirit of a community is a combination of many seemingly unconnected elements: buildings, objects, natural landscapes and traditions. Traditions or '*intangible heritage*' are often the strongest link between places, people and generations. Preserving a way of life and the identity of a community is more important than preserving only its physical form. Living, vibrant communities give meaning to their surroundings and create a sustainable environment for preserving culture.

Very often this intangible heritage is the most fragile and difficult to sustain. Without it, places lose their meaning, the natural environment is subjected to degradation, and connections within the community and with nearby communities sharing similar traditions are lost. Unfortunately, rural communities everywhere are currently susceptible to long slow declines, if agriculture is no longer economically viable and younger generations move to cities in search of more attractive opportunities. In rural communities this phenomenon has been accelerating in recent decades indeed, as transportation becomes easier and less expensive, urban areas offer better opportunities and globalization reaches every corner.

Most rural areas have unused or abandoned structures that could serve as places to stimulate the education and culture of their communities. The characteristic appearance of natural and cultural landscapes in rural areas is shaped by the traditional building culture of the specific region. However, the traditional building styles are often no longer respected by modern, rapid, featureless construction techniques and materials. Therefore, the characteristic appearance of rural environment and landscape is under serious threat there. The responsible building authorities at local level often lack the capacity and expert knowledge to ensure certain quality standards in planning and construction of new buildings, as well as in the reconstruction or revitalization of existing buildings. New strategies have to be found to raise the awareness of these officials and the local population, to ensure respect for traditional buildings and the landscape, as well as to advise persons requesting a building permit.

The rural built heritage is in a constant state of change. Agricultural fields are abandoned or aggregated, traditions and customs evolve or are forgotten, farm buildings are demolished or adapted to new uses, the whole tangible heritage decay. Decay starts the day after restoration. Most damages are small at first and easy to repair if noticed. However, small damages grow rapidly if no measures are taken. Consequences can be severe, such as the loss of historical value, high costs of restoration and even loss of the building. Yearly visual, non-destructive inspections and immediate repair of small-scale damage have proven to reduce restoration costs and risk of damage caused, for example, by neglect or fire. Half of the activity of the construction industry is spent on repairing and maintaining existing heritage. To successfully carry out preventive maintenance, suitable information and data are needed, while specific analysis targeted to the preservation of the rural built heritage are necessary.

In the present paper, a review on current achievements in the scientific literature about the connections between farm buildings and the rural environment is presented. Special attention has been devoted to define the main components of rural building, *i.e.*: construction materials and techniques; typological characteristics; settlement development. The relevant impact on the surrounding rural environment may be therefore assessed, even with the aim to implement new technological tools able to support policy makers and rural planners in surveying, analyzing and planning the rural landscape in all its components of the total environment.

2. FARM BUILDING FEATURES

Farm buildings, designed over the centuries to perform their primary agricultural function, have marked the surrounding environment in a distinctive way, playing a central role in the sustainability of the rural environment. Designed to house organic production, the agricultural building is truly a unique example in the vast epistemological sector of construction. The birth, growth and development of living plant and animal organisms contained in these volumes raise indeed architectural and technical problems which are deeply different, when compared to those of other building sectors. Designed to produce optimal environmental conditions for plants and animals, while protecting health and safety of workers involved in daily operations for the care of living organisms at different stages of their development, the rural building is therefore a unique technological model [1].

Furthermore, these buildings express a widespread heritage that in some cases has an irreplaceable architectural value thanks to their past, being in many Countries even more than centenary. Farm buildings are currently registering a renovated interest too, often even pushed by the recent expansion of rural tourism registered in Europe as well as in other Countries in the World [2, 3]. This makes it necessary to monitor farm buildings, both to preserve them as historical and cultural heritage and to re-develop in the perspective of sustainable tourism planning [4, 5].

According to Ruda [6], the rural environment includes three components. They are: the land for agricultural production; the natural surroundings and human settlements; the architectural area. Human, natural and architectural environment co-exist and interact among themselves, so contemporary projects should preserve and reconstruct the essence of tradition. The main characteristics of farm buildings, which make them different from other examples of constructions, have been analysed by several Authors, who have focused their analysis mostly on three main aspects, *i.e.*: building materials and techniques; typological characteristics; settlement formation.

The valorization of locally available building material, used in agriculture for the realization of constructions, both for housing purpose and for the realization of each single element within the farm, is one of the main characteristics which differentiate farm buildings from other construction typologies [1, 7]. This choice, that was at the time one of the pillars at the base of the formation of rural landscape, has its roots in the tradition left by our forefathers, since they had no choice than realize farm buildings and ancillary elements using the local material. Indeed, even if traditionally based mostly on an economic reason, this has very interesting consequences on the current perception of the rural landscape - since the colour of the building is similar to the surroundings [8, 9] - as well on the agricultural environment – this material being able to be incorporated, at the end of its useful life, in the same context.

The typological characteristics of popular architecture, mostly when applied in rural areas, have been historically influenced by the need to design buildings in close relationship to their usefulness as a barrier against the climate. This has been a fundamental parameter, since builders have had few technical resources, and the research of natural solutions has paid an enhanced attention to the interaction of form and energy, leading to a “bioclimatic” approach in vernacular rural building techniques. Bioclimatism has been therefore one of the most common way for searching solutions able to maximize the exploitation of natural sources of energy – for heating, ventilation, *etc.* – leading to the creation of a well-identified scientific sector, which has recently experienced a renewed attention by several scientists [10, 11]. In some cases [12] bioclimatic architecture was also proposed as a new model for recovery vernacular construction.

Vernacular architecture in rural areas has involved the design of traditional-functional buildings for housing owners and/or their workers [13, 14]. In figure 1 it is reported the façade of two centenary vernacular farm buildings (so-called: "*masserie*"), located in the Basilicata region (southern Italy), having a cultural interest and protected by specific regulations, surveyed through terrestrial photogrammetric techniques [15].

Fig. 1 Façades of *masserie* located in the Basilicata region (southern Italy), surveyed through terrestrial photogrammetric techniques [15].

Other different examples of vernacular farm buildings have been also analyzed with reference to their typological characteristics and architectural solutions, as those for protecting animals in stone-fenced corrals [16] or for agro-industrial production, as flour mills [17, 18], wineries [19], *etc.* In figure 2, some centenary flour mills located in the Apulia region (Southern Italy) are showed.

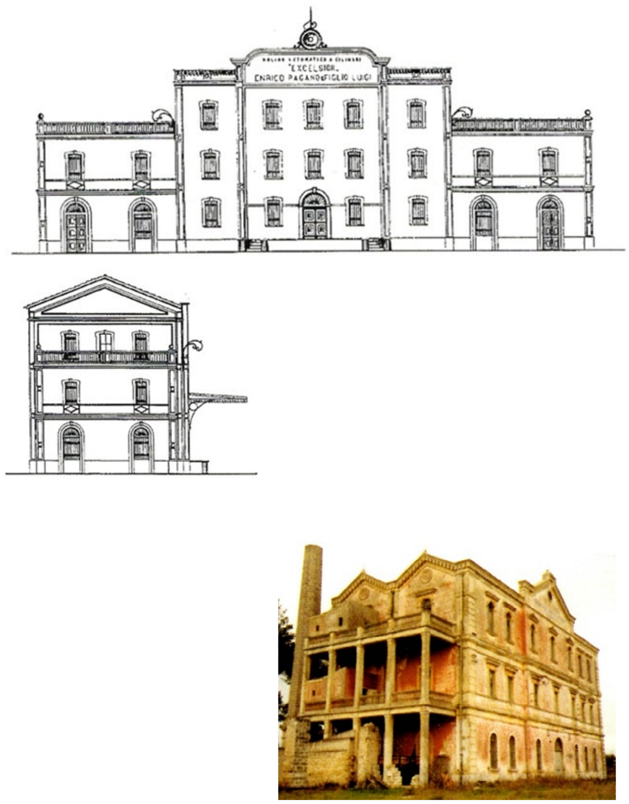

Fig. 2 Centenary flour mills located in Apulia region (Southern Italy).

The formation of human settlement in rural areas has been affected by the particular vocation of rural activities as well, including in a holistic approach the role of the surrounding environment [20, 21, 22]. The settlement dynamics are especially interesting, having played an important role. Several traces of extinct settlements and their access routes are usually still visible in many today's European landscapes. Some specific analyzes have been conducted to assess how the colonization, occurred at large scale during the past centuries, has contributed to shape the image currently perceived from a landscape, evaluating the impact on rural environment of different settlement patterns and relevant accessibility routes [23, 24].

3. FARM BUILDINGS AS DRIVERS OF THE RURAL ENVIRONMENT

The originality of what happens inside the farm building corresponds to what happens outside of it. The role that these buildings have historically played is strictly connected indeed with the surrounding context, due to the need of the farmer to live in close contact with agricultural land and animal husbandry [1]. While the organization of human beings involved in the activities of the industrial or tertiary sector allowed aggregation in urban centres, the need to live in constant contact with the agricultural production developed a synergetic function of close proximity to the extra-urban land [25, 26]. This aspect led to the spread in rural areas of many examples of buildings that served for farming, storage and processing of agricultural products, while constituting, at the same time, housing for the farmer and his family. This form of settlement has been - and still is - a unique way by which humans have populated, in harmony with the natural elements, the agricultural territory, joining the primary production needed for human nutrition with the control and care of rural land. So, the activities made by the Man have often strongly influenced the agricultural environment and the visual perception of its landscape [27, 28].

The stratification during time of the interactions among all the components of the total environment - *i.e.*: atmosphere, hydrosphere, biosphere, lithosphere and anthroposphere - is the driver of the formation of the landscape of a given territory [29]. Anthroposphere plays a pivotal role, because it strongly influences - being influenced in turn - the other natural components. The environmental changes occurred during the last decades, mainly caused by human activities and changes in land use, have been dynamic, since they "evolved" considering the needs and the socio-economic conditions, being influenced by the natural forces and continuous interactions with the surrounding context as well. Under this approach, a rural landscape may be defined as the “*System of many concurrent ecosystems, in a mutual correlation with human activities*”. It is indeed the holistic result of the evolution of free natural elements and relevant human dynamics of land use, land management practices, agricultural policies and socio-economic modifications imposed by the populations living there.

A growing interest is currently registered towards the ecological effects of the farm buildings on the rural environment, then on the importance of applying a sustainable rural development strategy to improve the protection of habitats and ecosystem services [30, 31, 32]. As reported by Haller & Bender [22], there is a strong link between biodiversity and conservation/restoration of grassland, which necessarily passes through the preservation of the rural built heritage. This is especially true for some Natura2000 priority habitats, such as the semi-natural dry grasslands code 6210 [33, 34]. Monitoring farm buildings and rural environment, considering the multidisciplinary and the spatial component of the information, requires therefore a suitable approach, now possible through the use of new geographic technologies [35, 36, 37].

4. ADVANCED ANALYSIS OF FARM BUILDINGS AND RURAL ENVIRONMENT

Several studies have analyzed the potential of advanced tools applied to the analysis of the mutual interactions between farm buildings and the surrounding rural environment. Most of them are based on the implementation of Geographical Information System

(GIS), able to include and link all the information related to the farm buildings. In this way, it has been possible to connect different datasets coming from both field survey (measuring, photographic report, field databases) and spatial analysis work (studies on land use and surrounding landscape, socio-economic analysis, viewshed analysis, index creation) so as to create a single GIS-based model of farm buildings [38, 39, 40]. This database model can be exploited for several purposes, *e.g.*: planning and management; protection and conservation of the built rural heritage; valorisation of the existing farm buildings; strategic decision on the localization of new farm buildings; implementing and monitoring concrete valorisation actions [41, 42].

The potentiality of a GIS applied to the monitoring, preservation and enhancement of the rural heritage of one southern Italian region, *i.e.*: the Basilicata region, has been recently explored [43]. After the creation of a preliminary geo-database of rural buildings and spatial data related to the rural landscape, two methodologies have been implemented: the first one was aimed to evaluate the role and impact of the rural buildings in the conservation of semi-natural environments of the surrounding context; the second one has been focused on the assessment of the safeguarding of the visual quality of the rural landscape, through an inter-visibility assessment of rural buildings.

Other studies [44] have employed a methodology combined with a *Multi-Criteria Decision Analysis* (MCDA), which borrows GIS capabilities to evaluate the suitability of one region, in order to optimally chose the locations of new agro-tourism building. More recently, a web-based Multi-Criteria Spatial Decision Support System (MC-SDSS) has been developed, validating it to assess the suitability of new rural tourism buildings integration occurred in some Spanish landscapes [45]. Other Authors have used the *Analytic Network Process and Dominance-based Rough Set Approach* for the sustainable requalification of traditional farm buildings in Southern Italy [46].

Finally, the analysis of geographical information derived from historical maps within a GIS has proved to be a very powerful tool for a better-informed decision-making and management of the farm building heritage in the context of the surrounding rural environment [29, 47]. Three-dimensional reconstruction during different time periods (figure 3) obtained through Digital Terrain Models (DTM) have so enabled to highlight the role of farm buildings, as well as to evaluate the land cover changes, demonstrating how these latter have affected the quality of the forest ecosystem in the area. The final results obtained comparing historical documents and current maps, enabled the evaluation of the multi-temporal, morphological and vegetation variations in this rural landscape [48].

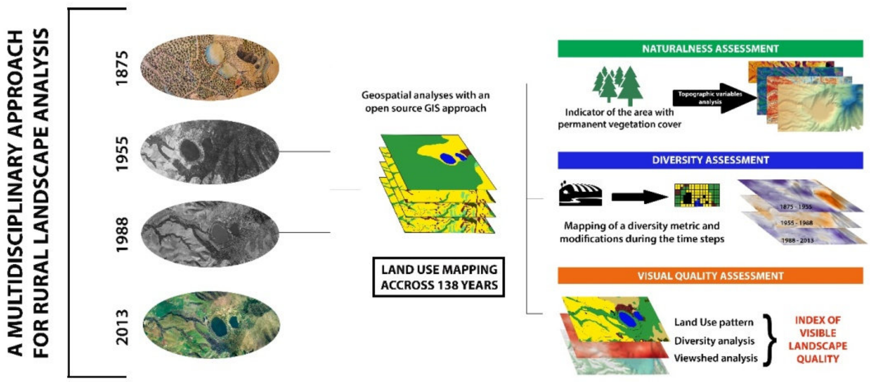

Fig. 3 Implementing historical maps into a GIS for rural landscape analysis [29].

5. Conclusions

The main results coming from the scientific analyzes which have been conducted so far would be the basis for a valorisation of farm buildings in the context of their surrounding rural environment. The relevant competences should be addressed through the development in:

-) Education: an increase in the level of scientific knowledge, competences and skills for students, expert practitioners and other stakeholders in the management of rural development, in respect of the preservation/valorisation of the rural built heritage;

-) Research: stimulation actions, aimed to support researchers in completing and deepening their knowledge and scientific activities, based on the use of cutting-edge tools (ICT; IoT; *etc.*) supporting preservation and valorisation of rural built heritage;

-) Dissemination & Exploitation: new actions aimed to valorise the results of the activities involving every kind of stakeholder belonging to the *Quadruple Helix*, *i.e.*: a) Public Institutions (Ministries; Regional/local Authorities; Development Agencies; *etc.*); b) RTD performers (Universities; Public/private research centers; Technological Parks; *etc.*); c) Private companies (Industries; SMEs; farmers; relevant associations; *etc.*); d) Civil society (NGOs; Citizen associations; *etc.*).

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FREEZE-DRYING CHARACTERISTICS FOR THE CONSERVATION OF BEE POLLEN

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Abstract: *Bee pollen is very important in the nutrition of bees since it provides them with proteins, lipids, vitamins and minerals. Bee pollen also has a significant nutritive value as a supplement to human nutrition. Fresh bee pollen contains a large quantity of moisture which favors development of various microorganisms. In order to preserve pollen from spoilage its dehydration in controlled conditions is commonly performed. In this paper, freeze-drying was proposed as a conservation method. Results showed increment in the drying rate and improve the product quality compared to traditional hot air drying. The current work provides theoretical and technical reference for applying this type of technology.*

Key words: *Bee pollen, drying, vacuum drying, freeze-drying.*

1. INTRODUCTION

Bees voluntarily collect pollen and nectar from oilseed rape and on this melliferous pasture bee keepers in Serbia prepare bees for a major black locust pasture. Due to abundance of pollen that are bees willing to collect, on this pasture, bee keepers involve the use of pollen traps and thus obtain a significant quantity of pollen. A part of oilseed rape pollen is later placed on the market for human consumption while the rest is used for making the brood food.

In the nutrition of honeybees a pollen represents a principal source of protein, fats, vitamins and minerals (Nedić et al. 2003). The number of broods in beehive and length of life of worker honeybees depend to a large degree on quantity of nutritionally available pollen (Jevtić et al., 2009; Di Pasquale et al., 2016). Pollen chemical composition varies depending on the plant from which it was collected and on the way of its keeping and storing (Campos, 1997; Campos et al., 2010). Oilseed rape pollen has a solid content of crude protein ranging from 22.8% to 26.1% and it can affect a development of bee colony (Rayner and Langridge, 1985).

Besides its extraordinary benefit for bees pollen is used also in human nutrition and in apitherapy. Due to its valuable nutritive and biological ingredients the oilseed rape pollen is used as a natural diet supplement in China. With oilseed rape pollen supercritical CO2 fluid extract the trials are conducted on its effect on benign prostatic hyperplasia (Yang et al., 2014).

Pollen brought by bees is being collected in a raw state by placing special pollen traps at the entrance of beehive populated with bees. A water content has a crucial effect on the maintenance of its quality which in fresh pollen can vary from 20 to 30 g in 100 g (Bogdanov 2004). In order to preserve valuable properties of this product a good bee keeping practice directs bee keepers to collect pollen every day and then to dry it in the temperature of 40oC. If it is not done, because of a high water content, fresh pollen becomes susceptible to fermentation, mould growth and development of mycotoxins and reduction in vitamin C content due to potential degradation of ascorbic acid in aqueous environment (Petrović et al., 2014; Kostić, 2015). In dry pollen the water content should be in the range of 4 to 8% (Mustaers, 2005; the Official Gazette of the Republic of Serbia, 101/2015).

Freeze drying is a process whereby water or other solvent is removed from frozen material by converting the frozen water directly into vapor without the intermediate formation of liquid water. Of the various methods of dehydration, lyophilization is especially suited for substances that are heat sensitive. Also, freeze drying has been extensively used in the preservation of biologicals, nutrients and food properties due to the nondestructive nature of this process. (Cinkmanis et al., 2019)

2. MATERIAL AND METHOD

For the purpose of pollen drying a fresh sample of pollen was used in the experiments collected with pollen traps placed at the entrance of beehive on oilseed rape melliferous pasture (Brassica napus L.). Up to the moment of drying a fresh oilseed rape pollen has been vacuum packed and stored in a deep-freezer.

This research used oven-dry method as one of the commonest methods of determining sample moisture content. It consists of taking a pollen sample, determining its exact weight, and dry the sample in an oven at a temperature of 105 centigrade for 3 hours, then weighing the sample and determining the moisture loss by subtracting the oven-dry weight from the moist weight. (Shreve et al., 2006) The obtained resultes showed 23.48% of water content at dry basis in fresh pollen sample.

Moisture analyzers (MA) type BTS110D was used for fast and precise moisture determination of a sample based on mass loss during heating process. Drying proces parameters (40°C and 50°C) were set on the basis of law norms and available chemical-physics data of pollen samples. Moisture analyzers are designed to work in food industry, construction materials industry, biotechnology, pharmacy, environment protection and others. Main field of use is quality control. Moisture analyzer use 2x100W halogen radiators for the material heating. Density redout precision was 0.1%.

Labconco FreeZone® 18 freeze dry (FD) system was used for laboratory lyophilization procedures. The pollen samples were kept in deep freezer at -70°C before freeze drying process. During the lyophilization, the collector temperature were maintained at -40°C and the chamber pressure condition was vacuum less than 0.133 mBar.

3. DISCUSSION ON THE RESULTS

Bee pollen samples were dried in thin layer without significant overlapping of the pollen layers (Fig. 1). All experimental measurements were performed with the initial mass of the pollen between 10 and 30 grams for one experiment. The results were obtained as average from several measurements per experimental setup.

Fig. 1 a) Fresh pollen sample; b) freeze-drying of pollen

Moisture content of the material during time (Fig. 2) is shown by various temperatures and drying methods. Moisture analyzer was used for moisture determination of a sample at 40, 50 and 60°C temperatures within approx. 3 hours period. Similar drying parameters were used by other authors (Ayla et al. 2018; Kanar and Mazi, 2019). Freeze dryer was used for the determination of drying characteristics of pollen twice. First sample was frozen at -70°C and then dried within lyophilization process in absolute vacuum. Second sample was exposed fresh to an absolute vacuum at room temperature of 25°C without any thermal pretreatment.

Results showed that moisture content decreased significantly during the first hour (approx. during first 4000 seconds), and decreased slowly afterwards. As expected, the increase in drying air temperature will speed up drying process. Drying temperature of 40°C that is commonly used in commercial bee pollen dryers caused the lowest moisture losses of the material, i.e. longest drying process. Consequently, the temperatures of 50 and 60°C provided significantly higher moisture losses and faster drying, especially during the first hour.

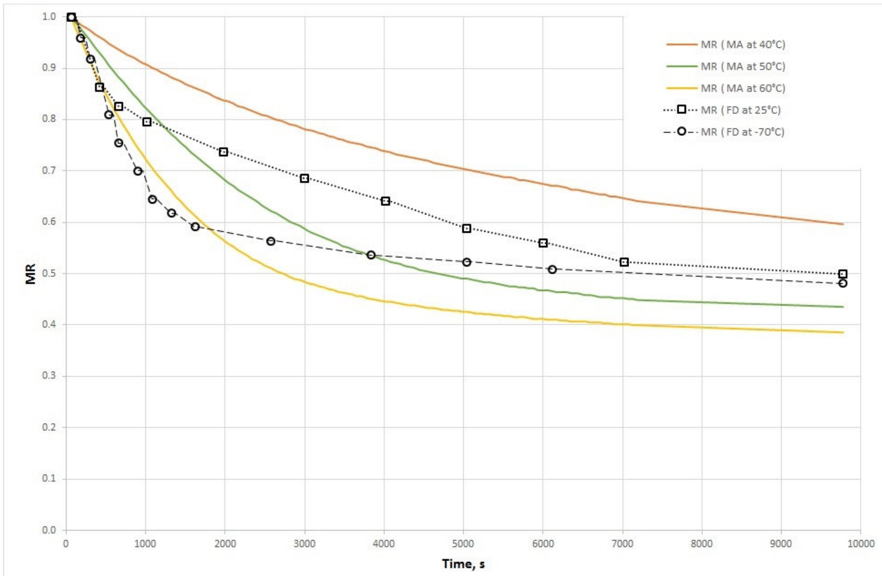

Fig. 2 Experimental moisture ratio (MR) vs. drying time (MA – moisture analyzer, FD – freeze dryer)

However, these temperatures cannot be applied commercially because of the negative effect on bee pollen chemistry. Vacuum regimes showed that initial moisture losses were significantly higher than losses from conventional drying regimes. The best drying kinetics was achieved in lyophilization processes with almost 50% moisture losses within first half an hour of drying process. This effect was almost concurrence with conventional 60°C regime during this period.

4. Conclusion

Moisture content of the material during time by various temperatures and drying methods were analyzed in this paper. Three types of drying procedures were analyzed: conventional sample heating (drying temperatures (40, 50 and 60°C), vacuum drying at room temperature and freeze-drying of samples at -70°C temperature (lyophilization). The higher moisture loss was achieved with lyophilization process, especially at the beginning of the drying process, i.e. first hour period. The conventional drying off bee pollen at 60°C showed similar drying rate at initial stages of the drying period. Pollen lyophilization can be recommended from the point of view of the efficiency of the drying process.

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DEVELOPMENT AND APPLICATION OF MACHINE VISION FOR INSPECTION OF AGRICULTURAL PRODUCTS

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Abstract. *The inspection and sorting of agricultural products is a necessary technological operation in the agricultural and food industries. Research in this area shows significant potential in improving the inspection and evaluation of fruits, vegetables, the quality of cereals and other agricultural products, as well as the evaluation of the quality of prepared food products by non-destructive methods. As an integrated system, machine vision has been widely used to test, monitor and control various industrial processes. The increasing and complex performance requirements of modern machine vision systems require their further improvement through the development of new, intelligent solutions. Automatic non-destructive recognition of the qualitative characteristics of different types of bio products is a constant challenge for researchers, where the imperative is on product and method which is applicable in industrial conditions. In this regard, there is a large number of works with experimental and numerical data collected for different construction solutions and operating conditions. This paper will analyze the development of machine vision as well as its application in agriculture over the last five years. A special part will be guidelines for the direction of further research in the field of optical recognition of agricultural products.*

Key words: *machine vision, sorting, fruit, vegetable, machine learning*

1. INTRODUCTION

Agricultural and food products are different from other industrial products in that all human senses are included in the purchase: sight, smell, taste, touch, and even hearing. For the last two decades, the importance of consumer emotions has been given importance, various studies have been conducted and the product has been created in accordance with the results. It can be said that the 'experience' of this product is being sold. In all research, visual experience plays a dominant role by buying products and later in other periods, e.g. during consumption, some senses such as taste and smell are as important as the appearance of the product itself [1]. But the imperative is that appearance is one of the main parameters that characterizes a product from purchase to consumption. When referring to the visual effect, it also includes the packaging of the product itself (images on the packaging, colors, texture of the packaging material, etc.) [2, 3]. Or, if fresh produce is concerned, the very way the product is packaged in the so-called counters, the combination of colors with other exposed products, or even the different possible shape of the product influence the choice of the product purchased or provoke a reaction of expectation of a certain price of the product. All of the above shows the importance of the technological operation of selecting, inspecting and sorting agricultural products in industrial processing plants. In general, the external quality of fruits and vegetables is judged mainly by physical characteristics: color, visual texture of the surface, size, shape and visual defects [4, 5]. Descriptive parameters can be created through color parameters, and in most cases the statistical measures are the mean and standard deviation. In addition to color, texture is another significant sensory qualitative characteristic most commonly used in external quality inspection and sorting of agricultural products. Texture analysis can play an important role in identifying and segmenting defective objects when selecting agricultural products [6]. Visual texture of the surface can be said to be one of the widely used indicators that a consumer uses when purchasing to evaluate the quality of an agricultural product. The aforementioned characteristics (features, attributes) of agricultural products can be represented by numerous values, while statistical methods represent the basis for predicting and classifying sets of these values data.

Industrial processing of fruits and vegetables requires mechanical inspection where a machine vision system is used. Machine vision is an optical, non-destructive method of screening bio products and the system or machine used in industrial plants is generally called the color sorter. The color sorter subsystem consists mainly of multiple optical devices (cameras, lasers) that capture the product and, based on the output signal and parameters, the central control system generates further processing data using different decision-making approaches. A schematic representation of one of the possible solutions of the recording subsystem is shown in Fig. 1. The classification is most often encountered when using machine vision in the inspection of agricultural products, which has the task of separating non-conforming products from those that are in conformity. Agricultural products are classified by class (degree of maturity, size ...) or by variety, where machine learning algorithms have shown enviable results in the recent period. Research in the field of agricultural product quality assessment can go in several directions: improvement of existing classical methods of statistical indicators of organoleptic properties of bio products, development of mobile online applications and finally the application of artificial intelligence, ie machine learning algorithms for the detection, localization and classification of objects of interest.

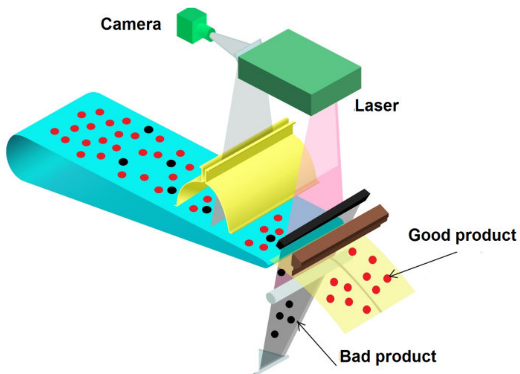

Fig. 1 Schematic representation of machine inspection

2. MACHINE VISION – A BRIEF OVERVIEW

The need for the usage of automatic sorting and quality assessment of fruits and vegetables is becoming increasingly apparent worldwide. To this end, various non-destructive methods of inspection of agricultural products in technological lines have been developed, and machine vision is a promising tool for quality control. This type of inspection is based on image analysis and processing with multiple implementation types in the agricultural industry. Probably the first PhD thesis related to machine vision, written by Larry Roberts in 1963. called "Block World," where the visual world was simplified into simple geometric shapes, where the goal was to recognize them and later reconstruct them to their original shape. Nearly 60 years later, some of the fundamental problems of machine vision are still being studied and it is one of the most important and fastest growing areas of artificial intelligence. Various physical systems have been developed to avoid subjectivity when analyzing organoleptic characteristics of agricultural products that can be evaluated visually and / or with specific instruments. Conventional instruments that analyze e.g. color of the product, they do so on a small part of the sample and are not always adequate for products that usually have a heterogeneous surface. In order to overcome these problems, artificial visual systems have been developed in recent years to make the analysis more comprehensive and accurate, including the total product areas during processing [7]. The need for an accurate, fast and objective way of determining these characteristics of the tested products is constantly growing.

Algorithms that are still in widespread use today began to evolve mainly in the 1990s or a little earlier. Sonka [8] stated in his work that more than 1000 papers are published every year in the field of computer vision and image processing. The trend of progress in image processing continues. However, the current situation shows that classical methods for classifying fruits and vegetables have been developed for a limited number of classes of fruits and small sets of products. By applying artificial intelligence algorithms to inspection problems and evaluating the quality of bio products, the field of agriculture is brought to a new higher level. Machine learning algorithms in agriculture are used for: classification, clustering, segmentation, regression and as recommendation systems. The general machine learning cycle is shown schematically in Figure 2. Considerable research has been done to design and analyze the classifiers for hyperdimensional features that require high computational power to optimize the model. Machine learning can also be used to automate repetitive tasks in this field. The Support Vector Machine (SVM) method [9] is one of the most widely used in many fields, as is the Backpropagation algorithm [10] that allows neural network weights to be adjusted to fit minimized the error on the set of vectors belonging to the pattern recognition problem. The great progress that began in the 2000s can be attributed to better image quality that has been improving rapidly. Therefore, it has better quality of data to process, in addition to all the known features of the Internet and greater processing power of computers. Matlab software is used in many studies to analyze the image. It is necessary to note the development of mobile applications in assessing the quality and quantity of agricultural products that has been gaining in importance in recent years [11].

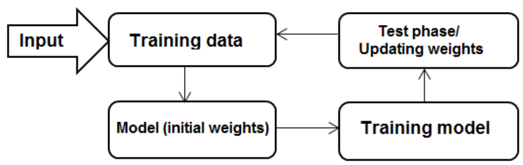

Fig. 2 Machine learning cycle

3. DISCUSSION OF POSSIBLE SOLUTIONS OF A NON-DESTRUCTIVE SORTING

After analyzing the available scientific literature, it was concluded that the problems lie in the following items: The previous classical statistical methods used characteristics that were mainly designed by researchers and not applicable to all products; classifiers are in most cases simpler structures, so there may be a mapping failure for more complex features until the final identification result. As industrial machinery inspection systems generally use multiple optical devices such as cameras (color cameras, IR, spectral and hyperspectral cameras, lasers, etc.), many studies over the last five years have raised the idea that color camera cameras are used to detect and classify agricultural products sufficient. This is where machine learning algorithms and the latest developed field of deep learning and convolutional neural networks come into play. Although there are no scientific papers directly related to the application of machine learning algorithms to color sorting and inspection machines in industrial production, considerable research has shown the potential of machine learning in fruit inspection and evaluation [12, 13], vegetables, cereal quality [14], legumes, bruise detection and disease [15, 16] as well as evaluation of the quality of finished food products [17, 18], meat products [19] and in combination with machine vision [20, 21]. In addition to this application, machine learning algorithms have been successfully implemented in combining menus, recipes, diet recommendations [22], in predicting customer behavior, and similarly. Machine learning is also an attractive approach to canopy fruit detection. In the paper [23] an SVM algorithm was used to identify objects in an orchard when harvesting. The texture parameters of the products from the selected regions of interest were used. On the test, accuracy was more than 86%, even on products that did not reach their full maturity and under different lighting conditions, which is one of the leading problems of image analysis in this area. So the result is satisfactory for real-time and conditions needs with respect to the four previously proposed work methods that do not involve machine learning. The combination of machine vision and neural network for real-time classification of poultry parts is described in the paper [19]. The machine has a capacity of ∽0.85 t/h which corresponds to the real industrial capacity of the meat industry. The accuracy of the proposed method was 94% at a maximum conveyor speed of 0.2 m/s. The authors agreed that deep neural networks would give far better results when it comes to this issue.

The advancement of machine vision has been largely contributed by deep learning algorithms. As this area is relatively young, agricultural applications are best described in a review paper [24]. These networks are widely used in primary agricultural production and a detailed analysis of the application of deep learning for fruit detection is presented in [25]. Compared to the highly represented models of classical neural networks, the application of deep neural networks in the industrial processing of agricultural products has not been found in recent literature. One of the main directions for the entire field of agriculture is the detection of plant diseases in the farm / field itself. It could in some future research be linked to disease detection in machine inspection of agricultural products in industrial plants. The quality of the final product depends on pre-harvesting factors that play a far greater role. It is estimated that 80% of the quality of the harvested fruit and vegetables is defined before the crop is removed from the field, and only 20% of the quality is influenced after the harvesting factors [26]. A large number of studies on the application of machine vision are related to the detection and evaluation of plant diseases on the crop orchard itself. The detailed application of image processing techniques for the detection and classification of citrus plant diseases is described in [27]. In crop disease detection, the first research with the use of high-performance convolutional neural network was presented in the paper [28]. The paper [29] used deep neural networks to recognize and classify maize images, detect disease, and determine plant growth rates, all to optimize production. The simple model is capable of accurately identifying healthy leaves, backgrounds, unhealthy plants, as well as mapping problem areas on the farm. The average accuracy of the results on the developed model was 99.58%. The paper [30] gives an overview of 23 scientific papers, which include different approaches of convolutional neural network and architecture in the challenges of agricultural production, as well as practical results of application of these. The application of a convolutional neural network in the identification of missing sugar beet vegetation in the field using drone imagery has been specifically demonstrated in the paper [30]. With such good classification results, plant treatment plans can be easily formulated as soon as possible, send a signal to the automated machine to implement appropriate measures, or map the required plant treatments with GPS coordinates. These results are far better than previously used image analysis techniques, and demonstrate the ability of the model to accurately predict the treatment solution, to make the soil equally fertile, and therefore to optimize production.

The use of convolutional neural networks as a nondestructive technique for classifying objects of interest in many agricultural products has greatly beat the results of traditional techniques [31]. Most authors agree that the successful implementation of a convolutional neural network depends largely on the size of the set and the quality of the input data used to train the model, in terms of variability between classes and labeling accuracy. Also, a small number of training samples can lead to an underfitting model [32]. However, recent research has shown enviable results on the smaller data sets available. Emphasis has also been placed on online real-time detection applications, which are one of the leading machine vision problems. Combining multiple machine and deep learning algorithms, some of the leading algorithms have been developed, such as R-CNN [33, 34, 35] and Yolo [36, 37, 38] algorithms, which have three versions each. Yolo is most commonly used for real-time applications and unifies object localization and classification into a regression problem. Yolo v3 is good enough to detect small objects too, but much research has yet to be done to detect agricultural products in industrial processing plants. Previous research on the application of these algorithms has focused directly on fields and orchards, with the aim of tracking the growth of yields and quantities of vegetables and fruits. Analyzing the papers that applied convolutional neural networks and Yolo algorithms, it can be concluded that the same models give satisfactory results while considering different problems, and that there is a possibility of modifying the models in order to improve the results. Although the main ideas of these algorithms were devised relatively long ago, in the 1990s, they have been increasingly used over the last five years, due to the far greater computing power of collecting and processing data. The full implementation of this type of detection and classification is only expected when quantum computers for widespread use are emerging.

The following Tab. 1, presents a brief chronological overview of the above methods for digital image processing.

Table 1 Chronological representation of digital image processing methods

Color and color space	RGB, CIE L*a*b*, HSV, HSI…
Statistical approach	Anova, PCA, PLSR...
NN (1943), (1981)	Neural Networks
SVM (1995)	Support Vector Machine
CNN (1990), (2012)	Convolutional Neural Network
R-CNN (2014)	Regions with CNN features
FAST R-CNN (2015)	Fast Regions with CNN features
FASTER R-CNN (2016)	Faster R-CNN: Towards Real-Time Object Detection with Region Proposal Networks
Yolo (2015)	You Only Look Once: Unified, Real-Time Object Detection
Yolo 9000 (2016)	YOLO9000: Better, Faster, Stronger
Yolo v3 (2018)	YOLOv3: An Incremental Improvement

CONCLUSIONS

A system, such as machine inspection of agricultural products in industrial production, requires a new approach to the objective decision-making on the acceptability of compliant products. The future goal is to create "smart factories" where autonomous systems monitor physical processes and make decisions, and the ultimate goal is to increase productivity and efficiency through competitiveness in the global market. The development of efficient algorithms, models and software for non-destructive inspection of agricultural products is imperative in the creation of new technologies in the field of agriculture and food industry.

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DETERMING THE OPTIMAL OPERATIONAL PARAMETERS OF KNAPSACK SPRAYER FOR RASPBERRY PROTECTION

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Abstract*: Export of raspberries to the European Market requires controlled application of agro-technology. Winter raspberry protection is of major importance for high and quality yield, which is why proper and quality protection is necessary. On small raspberry fields, application of phytopharmaceuticals is applied with motorized knapsack sprayers. The high-level of use of motorized knapsack sprayers results from its affordable price in comparison to tractor sprayers, bigger range than non-motorized knapsack sprayers, as well as bigger efficiency and effectiveness of work. Farmers on the ground are not familiar with proper handling of this tool, which can result in various unwanted consequences. The aim of the research was to establish optimum parameters of treatment which include speed of movement of the applicator, the position of flow-rate dosing element, which is reflected in the quality of protection and loss phytopharmaceuticals in form of drift. The measurements encompassed various speeds of movement of applicator and various positions of flow-rate dosing element. The testing of protection quality was done with water-sensitive papers, which were subsequently analyzed in the GIMP software. The loss of phytopharmaceuticals (drift) was analyzed by using paper towels. The average flow-rate of the nozzle had significant statistical deviations with respect to defined factory norms. The processed measuring results indicate that optimum parameters of setting of motorized knapsack sprayers are 1.20 km/h for the speed of movement of the applicator and position 3 for the flow-rate regulator. Sprayers with such set parameters provided optimum plant coverage and recommended consumption of phytopharmaceuticals. The loss of phytopharmaceuticals (drift) amounted to 84.48 % of the overall amount used.*

Key words: *Motorized knapsack sprayer, raspberry, phytopharmaceuticals, plant protection, water sensitive paper.*

1. INTRODUCTION

In Bosnia and Herzegovina is a great representation of small agricultural raspberry producers, which raise the plantations on the surface of 1000-2000 m^2. For raspberry protection, the most represented are motorized knapsack sprayers. Their representation increases due to a more acceptable price, concerning to other machines for application of phytopharmaceuticals (in future text FFS), increased range compared to back sprayers, faster and more efficient work. The advantage of knapsack sprayers compared to normal sprinklers is that it reduces the expenditure of FFS to five times compared to the normal sprinklers, reduced fuel consumption, higher speed of treatment, knapsack sprayers are lighter than normal sprayers and less compacted and have simpler pumps, because the distribution of FFS is made by air current [1]. Winter raspberry protection is of major importance for high and quality yield and it is applied with preparations based on copper and mineral oil. Winter raspberry protection is applied before bud swelling for extermination *Byturus tomentosus, Agrilus rubicola, Aphis idaei Goot, Didymella applanata Sacc*. etc [2]. To make the protection successful, it is necessary to pay attention to the proper settings, correctness, use compatible and modern devices for application of FFS. Allowing the production of health food, environmental protection and to reduce production costs, it is necessary to provide a controlled application of FFS, and that is only possible with properly working and adjustable sprinklers [3]. The properly performed calibration is one of the most important prerequisites for an effective FFS application [4]. Often agricultural producers in the ground aren't familiar with the proper device handling, which could result in different unwanted consequences. The consequences are reflected in the application of higher or lower doses than the recommended, higher concentrations of active substances, harmful influence on the environment and the health of the applicator (the sprayer operator). Also, improper handling of the device results in higher monetary expenses, which can significantly increase costs of raspberry production. For the properly settings of knapsack sprayer farmers needs to adhere to certain rules. Those are: to understand potential dangers for environment and personal health, to use proper protective equipment, to use the correct and configured device for the FFS application and to possess the necessary knowledge to treat different plant species. The huge savings in protection could be achieved by short training of farmers in the field and thus avoiding the unnecessary scattering of FFS [5]. Considering the listed problems, the aim of the research was to establish optimum parameters of treatment which include speed of movement of the applicator, the position of flow-rate dosing element, which is reflected in the quality of protection and loss FFS in form of drift.

2. MATERIAL AND METHODS

The experimental part of the research worked on experimental polygon at Butmir within Faculty of Agriculture and Food Sciences in Sarajevo, where are located multiple plots of different raspberry cultivars. Raspberry cultivar named *Willamette* selected for the experiment. The application of FFS performed with a motorized knapsack sprayer, model *Stihl SR 420*. Analysis of the quality of protection and plant coverage with FFS performed with water-sensitive papers. The amount of FFS which are holding back on the plant was determined by the mass method of kept FFS on paper towel. The test conducted in three separate parts. In the first part, the deviation of the nozzle flow checked against the factory standard, which ranges from 0.12 l/min to 1.81 l/min. The second part included testing the application of the FFS in three different speed modes of applicator movement (0.72 km/h, 1.20 km/h and 1.66 km/h) and three different positions of the flow-rate element (positions 2, 3 and 4). During the research strictly adhered to a constant distance from the treatment object of 1 meter an attack angle of treatment of 45 degrees. The third part consisted of data processing in which water-sensitive papers processed by a digital method of recording, format of water-sensitive papers were 26x76 mm, an then analyzed by a computer image analysis software named *GIMP* on an *ASUS VivoBook S15* notebook model. Digital recording performed at artificial lighting and distance of 10 cm from the subject. The photos taken with a professional digital camera, using a camera tripod. The digital photos had a resolution of 3968x2976 pixels and saved in JPEG format. For analysis in *GIMP* software, each photo cut into a 2400x700 pixels image. In the applied mass method, used dry towel paper, dimensions 92x119 mm, which weighed before and after the FFS treatment and the obtained results converted into exact indicators of the retained FFS, which kept on the plant surface. Besides the mass and digital methods, still used: treatment area determination method, calculation and statistical methods. Because of the need to determine the total area of treatment, the used method included measuring the height, width and number of last year's raspberry shoots. The results processed by *IBM SPSS Statistics v20*, which intended for statistical analyses, and as part of that used T-test, two-factors ANOVA and Tukey test. *Microsoft Office 2019* used for the spreadsheet view and graphical presentation of the results. During research used equipment like: motorized knapsack sprayer model Stihl SR 420, complete protective equipment, digital scale, professional digital camera, tripod, caliper, meter, stopwatch and markers.

3. RESULTS AND DISCUSSION

The first step was to check deviation the flow-rate of the nozzle against the factory standards. All 6 flow-rate dosing element positions tested and the results shown in Table 1.

Table 1 Flow of six different positions of the flow-rate dosing element (ml/min)

	Position 1	Position 2	Position 3	Position 4	Position 5	Position 6
$\overline{x}$ ± Sd	200±7.9	600±15.8	1300±93.5	1850±68.9	2122±53.1	2216±77.6
Factory standards	120	440	860	1270	1580	1810
Deviation of factory standards	80*	160*	440*	580*	542*	406*
Percentage deviation	40%	27%	34%	31%	26%	18%

***** statistically significant deviation with significance level of 0.05

Sd – standard deviation $\overline{x}$ - average value

Table 1. shows that the flow ranged from 200 to 2216 ml/min. Compared to factory standards, deviations observed from 80 to 580 ml/min, which is from 18 to 40 %. The smallest deviation observed at position 6 of the flow-rate dosing element (18 %), while the largest deviation observed at position 1 (40 %). The deviations at all 6 positions of the flow-rate dosing element were statistically significant relative to the factory standards (sig<0.05). According to European Standard EN 13790, the nozzle considered correct until the flow-rate increased by more than 15 % compared to the factory standard [6]. When checking the nozzle flow deviation, all six positions of the flow-rate dosing element had a deviation of more than 15 % from the factory standards, which considered a significant deviation for the correct nozzles.

In winter raspberry protection, it should be considered that it is often done before tying the raspberry shoots. This means that the shoots were still laid and free standing. Based on this, it is very important to determine the actual amount of FFS that will retain at the raspberry shoots and achieve its goal. For this reason, accessed to raspberry treatment with all combinations of applicator speed of movement and positions of flow-rate dosing element, with paper towels placed inside the rows. Paper towels weighed before and after treatment and the results shown in Table 2.

Table 2 The amount of FFS retained on the surface of a paper towel of 109,25 cm^2 (g)

Positions of flow-rate dosing element/Speed of movement	0.72 km/h		1.20 km/h		1.66 km/h	
	Moistened paper (g)	Only FFS (g)	Moistened paper (g)	Only FFS (g)	Moistened paper (g)	Only FFS (g)
Position 2	1.54±0.05	0.38	1.44±0.05	0.28	1.38±0.08	0.22
Position 3	1.70±0.07	0.54	1.60±0.07	0.44	1.54±0.05	0.38
Position 4	1.98±0.05	0.82	1.88±0.08	0.72	1.78±0.04	0.62
Mass of blank paper towel	1.16±0,05					

From Table 2., it can conclude that the amount of retained FFS on paper towel is in interval 0.22-0.82 g per surface of a paper towel. The smallest amount spent at applicator speed of movement of 1.66 km/h and at position 2 of the flow-rate dosing element (0.22 g or 0.22 ml), while the largest amount spent at applicator speed of movement of 0.72 km/h and at position 4 of the flow-rate dosing element (0.82 g or 0.82 ml). The results form tab 2. are graphically represented by Figure 1.

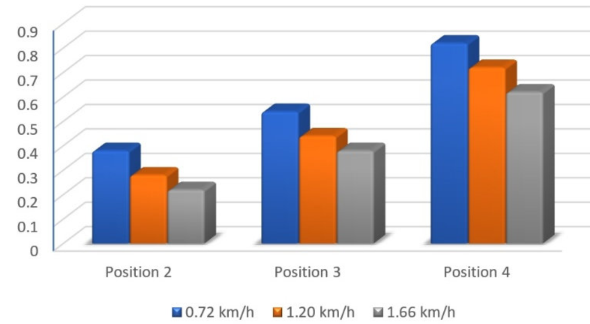

Fig. 1 Graphic presentation of the amount *of* FS per surface of paper towel of 109,25 cm^2

Two-factors analysis of variance (ANOVA) did not show statistically significant effect of the interaction of applicator speed of movement and position of the flow-rate dosing element on amount of FFS retained on treated surface (sig=0.958). However, mentioned test showed a statistically significant effect of separate factors, applicator speed of movement and position of the flow-rate dosing element (sig<0.05). The mention impacts can be clearly seen in Figure 1., where by reducing applicator speed of movement, the amount of retained FFS increased and conversely. Also, by reducing the position of the flow-rate dosing element, the amount of retained FFS reduced and conversely. According to obtained results, it is also possible to obtain the amount of FFS spent to treat 1 meter of row length. The average FFS consumption per 1 meter of row length, relative to applicator speed of movement and position of the flow-rate dosing element, shown in Table 3.

Table 3 Average consumption of FFS per 1 meter of raspberry row length (ml)

Positions of flow-rate dosing element/Speed of movement	0.72 km/h	1.20 km/h	1.66 km/h
Position 2	69.57	51.26	40.27
Position 3	98.86	80.55	69.57
Position 4	150.11	131.81	113.50

From Table 3., it can see that the consumption of FFS per 1 meter of row length ranges from 40.27 to 150.11 ml/m. The lowest consumption achieved at applicator speed of movement of 1.66 km/h and at position 2 of the flow-rate dosing element (40.27 ml/m), while at applicator speed of movement of 0.72 km/h and at position 4 of the flow-rate dosing element results in the highest consumption of FFS (150.11 ml). Based on obtained results, it can clearly conclude that the applicator speed of movement and position of the flow-rate dosing element, play a significant role in the consumption of FFS. The difference in consumption of FFS at the lowest speed and the lowest tested position of flow-rate dosing element, versus the highest speed and the highest tested position of flow-rate dosing element, is over 110 ml/m of FFS. Based on these parameters, farmers can significantly save on FFS and at the same time preserving the environment. If these results linked to the total consumption of FFS per unit area, then it is very important to take care of planting distance and about the height of raspberry shoots. The raspberry plantations are usually based on 2.5 and 2.8 meters planting distances. Accordingly, the total treated area of plants has changed, so at planting distance of 2.5 m treated area is larger than 2.8 m. Table 4., shows the total consumption of FFS per 1000 m^2 of planting area at both planting distances.

Table 4 Total consumption of FFS per 1000 m^2 of planting area at planting distance of 2.5 and 2.8 m (l)

Positions of flow-rate dosing element/Speed of movement	0.72km/h		1.20 km/h		1.66 km/h	
Planting distance (m)	*2.5 m*	*2.8 m*	*2.5 m*	*2.8 m*	*2.5 m*	*2.8 m*
Position 2	36.513	31.949	26.906	23.541	21.139	18.496
Position 3	51.887	45.401	42.278	36.993	36.513	31.949
Position 4	78.792	68.943	69.183	60.535	59.574	52.127

From Table 4., the smallest amount of FFS for treatment of raspberry plantations area of 1000 m2 consumed at the highest applicator speed of movement (1.66 km/h) and at position 2 of flow-rate dosing element (12.139 liters used for planting distance of 2.5 m and for 2.8 m spent 18.496 liters). The highest amount of FFS for treating same plantations area, consumed at the slowest applicator speed of movement (0.72 km/h) and at position 4 of flow-rate dosing element (78.792 liters used for planting distance of 2.5 m and for 2.8 m spent 68.943 liters). Depending on planting distances, variations in the amount of FFS consumed range from 2.643 to 9.849 liters. From this, it can conclude that at a smaller planting distance, a larger amount of FFS consumed, and deviations from a lager planting distance can be up to 9.849 l/1000 m2. Often, the recommended dose for winter raspberry treatment is between 40 and 50 liters/1000 m^2. From Tab 4., it can conclude that optimal applicator speed of movement is 0.72 km/h or 1.20 km/h and using position 3 of flow-rate dosing element. At these values of parameters, the recommended dose for winter raspberry treatment achieved.

To determine the actual amount of FFS retained on raspberry shoots, it is necessary to determine total area of raspberry shoots in the total treated area. Counting, measuring the height, width and surface of last year's raspberry shoots performed for these purposes. Table 5., shows the results of the mentioned parameters with the average values, standard deviations, minimum and maximum values.

Table 5 Average height, width, surface and number of raspberry shoots

	Height of shoots (cm)	Width of shoots (cm)	Surface of shoots (cm^2)	Number of shoots (1m row length)
$\overline{x}$ ± Sd	131.22±27.54	1.012±0.20	135.792±49.78	15.03±3.89
Minimum	15	0.60	16.50	10
Maximum	179	1.50	243	27

At the time of research this problem and from Table 5., average height of raspberry shoots was 131.22 ± 27.54 cm, average width was 1.012 ± 0.20 cm, average surface of a shoot was 135.792 ± 49.78 cm2 and average number of shoots per 1 meter row length was 15.03 ± 3.89. The height of shoots ranged from 15 to 179 cm, width from 0.60 to 1.50 cm, surface from 16.5 to 243 cm^2 and shoots number from 10 to 27. According to research by many authors, average shoot height is usually to 2 meters, but it should in mind that the study included treatment immediately after the hibernation of plants, so average shoots height is much lower than indicated height. The presence of shoots based on the surface was also examined, where results showed that the largest distribution of raspberry shoots had a surface between 100-150 cm^2, which is 40 % of the total tested, while only 2 % of shoots had a surface below 50 cm^2. The average number of shoots per 1 meter of row length is 7 to 8 for Willamette raspberry cultivar [7]. However, it should in mind that winter raspberry treatment done before shoots tied up and before winter pruning done. Considering this information, such a large number of shoots per meter (15.03) is nevertheless relevant information and real condition of raspberry plantations. Based on these results, at a planting distance of 2.5 m between rows, the plantation area of 1000 m^2 represents 800 m of length of treated raspberry rows because the treatment carried out on both sides of the row. At planting distance of 2.8 m between rows, the plantation area of 1000 m^2 represents 700 m of length of treated raspberry rows. Based on length of the treated row in the total planting area and average height of raspberry shoots, information of total treated area can be obtained. At a planting distance of 2.5 m, total treated raspberry area is 1049.76 m^2 and at a planting distance of 2.8 m, it is 918 m^2. Based on mentioned values, it can conclude that at a smaller planting distance, the total treated area is larger than at larger planting distance by average value of 131.22 cm^2, which results in a higher amount of FFS total spent. Based on results presented earlier, Table 6. shows the amount of FFS that reaches its target and holds on raspberry shoots and loss of FFS during the drift.

Table 6 Amount of FFS retained on treated raspberry shoots and loss during the drift

Planting distance (m)	Total treated area (m^2)	Area occupied by raspberry shoots (m^2)	The amount of FFS retained on the plant (%)	The amount of FFS lost during the drift (%)
2.5	1049.76	162.95	15.52	84.48
2.8	918.54	142.58	15.52	84.48

From Table 6., it can see that area occupied by raspberry shoots in total treated area, at planting distance of 2.5 m is 162.95 m^2 and at planting distance of 2.8 m is 142.58 m^2. Obtained results show that only 15.52 % of the total treated area occupied by raspberry shoots and others 84.48 % is empty space. Based on this, only 15.52 % of the total spent FFS reaches its target and hold on raspberry shoots, while the rest of FFS lost in the drift. This information calls into question the use of motorized knapsack sprayer for winter raspberry protection because it achieves enormous FFS loses. This information is very important for all farmers because they must take care of the amount of FFS which they will spend to provide the best quality protection. According to conclusion that only a certain amount of FFS retained on raspberry shoots and a large part lost, there is a need to test the mentioned quantities depending on planting distances. Table 7. shows quantities of FFS retained on raspberry shoots in relation to planting distances, applicator speed of movement and positions of flow-rate dosing element.

Table 7 The amount of FFS retained on raspberry shoots per 1000 m^2 of plantation area at both planting distances (liters)

Positions of flow-rate dosing element/Speed of movement	0.72km/h		1.20 km/h		1.66 km/h	
Planting distance (m)	*2.5 m*	*2.8 m*	*2.5 m*	*2.8 m*	*2.5 m*	*2.8 m*
Position 2	5.678	4.968	4.184	3.661	3.287	2.876
Position 3	8.068	7.060	6.574	5.752	5.678	4.968
Position 4	12.252	10.721	10.758	9.413	9.234	8.106

Based on Table 7., it can conclude that the smallest amount of FFS retained on raspberry shoots at the highest applicator speed of movement (1.66 km/h) and at the position 2 of flow-rate dosing element (for a planting distance of 2.5 m it is 3.287 liters of the total spent of 21.139 liters, and for a planting distance of 2.8 m is 2.876 liters of the total spent of 18.496 liters). The maximum amount of FFS retained on raspberry shoots at the slowest applicator speed of movement (0.2 km/h) and at the position 4 of flow-rate dosing element (for a planting distance of 2.5 m it is 12.252 liters of the total spent of 78.792 liters, and for a planting distance of 2.8 m it is 10.721 liters of the total spent of 68,943 liters). Drift is one of the biggest problems in plant protection because it reduces the amount of FFS which needs to reach the plant and at the same time it pollutes the human environment [3]. Considering the important role of drift in application of FFS, Table 8. shows the quantities of FFS lost in the treatment of raspberries in relation to the planting distance, applicator speed of movement and position of flow-rate dosing element.

Table 8 The amount of FFS lost on raspberry shoots per 1000 m^2 of plantation area at both planting distances (liters)

Positions of flow-rate dosing element/Speed of movement	0.72km/h		1.20 km/h		1.66 km/h	
Planting distance (m)	*2.5 m*	*2.8 m*	*2.5 m*	*2.8 m*	*2.5 m*	*2.8 m*
Position 2	30.835	26.981	22.720	19.880	17.852	15.620
Position 3	43.819	38.341	35.703	31.241	30.835	26.981
Position 4	66.540	58.222	58.425	51.122	50.310	44.021

Based on Table 8., it can conclude that the smallest amount of FFS lost at the highest applicator speed of movement (1.66 km/h) and at position 2 of flow-rate dosing element (for planting distance of 2.5 m is 17.852 liters of 21.139 liters total consumption, and for planting distance 2.8 m is 15,620 liters of 18,496 liters total consumption). The highest amount of FFS lost at the slowest applicator speed of movement (0.72 km/h) and at position 4 of flow-rate dosing element (for planting distance of 2.5 m is 66.540 liters of 78.792 liters total consumption, and for planting distance 2.8 m is 58.222 liters of 68.943 liters total consumption). The protection quality of fruit crops depends largely on size of droplets and their distribution per plant. Knapsack sprayers are machines that additionally break down droplets by air current to make them small as possible, unlike normal sprayers, where droplets size conditioned by the choice of the nozzle. This feature is very important for the protection quality of plants. Used knapsack sprayer has a flow-rate dosing element with six different positions. At different positions of flow-rate dosing element, different sized droplets should come out. To check it out, we used positions 2, 3 and 4 on flow-rate dosing element and three different applicator speeds of movement. Water-sensitive papers placed in the rows of raspberries and droplets diameter measured using GIMP software by analyzing digital photos of water-sensitive papers. The digital measurement method can consider a reliable and can use in measuring the FFS application [8]. According to their research, there was no statistically significant difference in results of droplet size measurements by the digital method opposite the microscopic method. Accordingly to the importance of droplets sizes, is necessary to give a representation of droplets distribution at different positions of flow-rate dosing element and applicator speed of movement. For these purposes, droplets classified according to their diameter into: very small (I), small (II), medium (III), large (IV) and very large (V) droplets. Based on this classification, Table 9. gives an overview of droplets representation in relation to two tested factors.

Table 9 Droplets representation in regard to the position of flow-rate dosing element and applicator speed of movement

	Position 2		Position 3		Position 4	
	Size	*Representation (%)*	*Size*	*Representation (%)*	*Size*	*Representation (%)*
0,72 km/h	**I**	30	**I**	0	**I**	0
	II	37	**II**	17	**II**	3
	III	23	**III**	50	**III**	33
	IV	3	**IV**	27	**IV**	40
	V	7	**V**	6	**V**	24
1,20 km/h	**I**	20	**I**	0	**I**	0
	II	77	**II**	37	**II**	3
	III	3	**III**	40	**III**	24
	IV	0	**IV**	23	**IV**	33
	V	0	**V**	0	**V**	40
1,66 km/h	**I**	33	**I**	0	**I**	0
	II	33	**II**	40	**II**	23
	III	4	**III**	60	**III**	63
	IV	0	**IV**	0	**IV**	14
	V	0	**V**	0	**V**	0

From the attached Table 9., it can conclude that at position 2 of flow-rate dosing element the most represented are very small and small droplets, at position 3 the most represented are small and medium droplets, while at position 4 the most represented are medium and large droplets. Based on this, it recommended to use positions 2 and 3 on flow-rate dosing element and position 4 only for specific FFS. When applying contact FFS, it is important to cover the largest possible surface of plant and use fine and medium droplets and for application systemic FFS, do not require complete plant cover and it recommended medium and large droplets to use [9]. According to the results of this study, it recommended to use position 3 for contact FFS and position 4 on flow-rate dosing element for systemic FFS. One of the most important features of good crop protection is coverage of the treated surface of FFS. With small droplets and good distribution throughout plant, achieved optimal plant coverage and best quality protection. Practice has shown that the use of knapsack sprayers results in better coverage and smaller droplets, which is not case with using normal sprayers. For the purpose of coverage analyzing surface coverage by FFS, analyzed digital photos of water-sensitive papers by *GIMP* software and coverage results expressed as a percentage, which shown in Table 10.

Table 10 Coverage of water-sensitive papers at different positions of the flow-rate dosing element and applicator speed of movement (%)

Speed	Position 2 (%)	Position 3 (%)	Position 4 (%)
0.72 km/h	16.45	46.37	50.80
1.20 km/h	15.83	32.28	54.40
1.66 km/h	9.81	38.94	43.03

From Table 10., it can see that the lowest percentage coverage of water-sensitive papers, is when using position 2 of flow-rate dosing element and it ranges from 9.81 to 16.45 % depending on applicator speed of movement. The percentage of the highest coverage of water-sensitive papers is when using position 4 and it ranges from 43.03 to 54.40 %. When it uses position 3 of the flow-rate dosing element, coverage ranges from 32.28 to 46.37 %. A coverage of 20 % of plant surface is the minimum for effective protection, and a coverage of over 70 % is the optimum protection [10]. However, for good protection, it can not only look at percentage coverage, but it must look at the size of droplets and compare the water-sensitive papers with standard for protection quality. By comparing digital photos of water-sensitive papers with pictures of standard for protection quality, and based on recommended dose for winter protection, the water-sensitive paper, which results from use of position 3 of flow-rate dosing element and applicator speed of movement of 1.20 km/h gives the best coverage. Also, percentage coverage was 32.28 % at mentioned conditions. Based on all analyzed parameters, which determines coverage of water-sensitive papers and quality of protection in general, it can conclude that optimal applicator speed of movement is 1.20 km/h and optimal position 3 of flow-rate dosing element. In this way, it will apply the recommended dose of FFS for winter raspberry protection and small and medium droplets and will achieve optimal plant coverage.

4. CONCLUSIONS

Testing the optimal parameters of setting of motorized knapsack sprayer, analyzing and comparing results with literature data, the following conclusions have been reached:

- The average flow deviation, at all six positions of flow-rate dosing element from factory standards, ranges from 80 ml/min to 580 ml/min, which is in range of 18-40 %. This indicates mandatory testing and adjustment of both, new and used sprayers.
- Applicator speed of movement adjusts to the flow-rate of the nozzle. The flow-rate of the nozzle should accord by type of crop, weather and climatic factors and type of phytopharmaceuticals. For winter raspberry protection, the optimum applicator speed of movement was 1.20 km/h, with nozzle flow-rate of 860 ml/min. This adjustment is optimal for raspberry height up to 2m, with 80.55 ml phytopharmaceuticals consumed per meter of raspberry row. The optimum consumption of phytopharmaceuticals for a 2.5 m planting distance was 42.28 l/1000 m^2, and for a planting distance of 2.8 m was 36.99 l/1000 m^2.
- Optimal consumption of phytopharmaceuticals per 1000 m^2 of the surface requires calculation of treatment area. The total area of raspberry shoots in plantation, at a planting distance of 2.5 m, was 162.95 m^2, on plantation area of 1000 m^2. The surface of shoots at planting distance of 2.8 m was 142.85 m^2. Tested raspberry shoots occupy only 15.52 % of the treated area.
- Phytopharmaceuticals consumption is correlated with applicator speed of movement and position of flow-rate dosing element. Increasing speed by 0.46 km/h reduces phytopharmaceuticals consumption by 5.76 l/1000 m^2 and reducing the phytopharmaceuticals rate by 0.48 km/h increases the consumption by 9.61 l/1000 m^2. Reducing position of flow-rate dosing element (with same speed) to position 2, the consumption is reduced by 13.37 l/1000 m^2. Increasing position of flow-rate dosing element to position 4, consumption of phytopharmaceuticals is increased by 26.9 l/1000 m^2.
- A nozzle flow of 860 ml/min (position 3) and applicator speed of movement of 1.20 km/h gave the optimal relationship of droplets size and plant coverage.

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APPLICATION OF MACHINES IN THE GRAPEVINE DEFOLIATION

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Abstract: *Modern grapevine production technology involves the implementation of various technological operations, among which grapevine defoliation has an important place. Defoliation is an ampelotechnical measure of removing a certain number of leaves from the cluster zone. Removing the leaves changes the microclimate conditions of the grapevine (light intensity, temperature, humidity, ventilation), which affects the yield, structure of the clusters and the quality of the grapes. Leaves removal can be done manually, with chemical agents (defoliants) and with the use of machines. With development of different technical solutions and different designs of defoliation machines, the productivity of work today is significantly increased compared to the manual removal of leaves, which is still dominant in Serbia region. The technological parameters of grapevine plantations necessary for efficient and rational application of defoliation machines will be presented in this paper. Modern technical solutions and basic operating parameters of machines commonly used in practice will also be presented in this paper.*

Key words*: grapevine, defoliation, technical solutions, working parameters.*

1. INTRODUCTION

The main goal of viticultural production is the production of high quality grapes with the optimal amount and ratio of chemical components responsible for the quality of wine (Sabbatini, 2015). Modern grape production technology involves the application of various ampelotechnical measures which are more and more often implemented using modern technical systems intended for certain operations (Lanari, at al., 2013; Clingeleffer, 2013; Morris, 2000; Morris, 2007). Defoliation represents one of the measures that occupies an important place in the grape production technology (Bešlić, at al., 2016). With mature pruning, leaving a certain number of winter buds on the vine, it is not possible to fully balance the formation of vegetative and generative organs (2), the operations of green pruning and defoliation are applied as supplementary measures. Defoliation represents the removal of a certain number of leaves from the zone of bunches. The removal of leaves changes the microclimate conditions of the grapevine (light intensity, temperature, moisture, ventilation) which influences the yield, bunch structure and grape quality (Noyce et al., 2016; Kotseridis at al., 2012; Bešlić, at al., 2018; Almanza, at al., 2011).

The removal of leaves can be done manually, with chemical agents (defoliants) and with the use of machines. Thanks to the development and refinement of different technical solutions, various constructions of defoliation machines are increasingly used in practice today, which significantly increases the work productivity in relation to manual removal of leaves, which is still dominant in our regions. Modern defoliation device constructions can be applied from the phase of vine flowering until just before grape harvesting without the risk of damage to the plant and fruit. Given that modern technology of grape production involves defoliation as obligatory ampelotechnical measure, the procurement and use of machines for performing this operation is increasingly economically justified.

2. Technical Systems Applied in Vine Defoliation

Today, in practice, one can encounter various constructions of devices intended to perform vine defoliation. These devices appear as attachments that are aggregated on standard tractors from which they are driven for the work of working elements. The devices for removal of leaves can be aggregated from the front (figure 1a) or from the rear side of the tractor (figure 1b). There are also technical solutions which can be installed on self-propelled machines which are applied in pruning, protection, harvesting and other operations in grape production (figure 1c).

Mechanical removal of leaves from the zone of bunches, by applying modern technical systems, can be performed in various manners. One group of technical systems uses low-pressure compressed air which is precisely directed to the zone where the leaf mass is to be removed. The device is aggregated on standard tractor which, through hydraulic system and connecting shaft, enables working and control of the working organs of the device. Connecting shaft of tractor drives the compressor which enables the compression of air intended for the removal of leaf mass. The compressor is mounted on the rear of tractor and through elastic lines compressed air reaches working head which can be mounted on the front or rear part fig. 2b. Hydraulic system of tractor, performs positioning and control (adjusting) of the working head during the procedure of defoliation. The device can have one, two or a larger number of working heads thus simultaneously performing defoliation in two rows fig. 2a.

Fig. 1 a) defoliation device aggregated from the front of tractor; b) defoliation device aggregated from the rear of tractor; c) defoliation device aggregated on self-propelled machine

Fig. 2 a) device with a larger number of working heads; b) position of compressor and working head mounted on the front of tractor.

During the process of removal of leaf mass, working head slides across the surface of the rank in the zone in which defoliation is performed. Inside the working head, there are two rotors that carry nozzles through which compressed air is passed through (fig. 3). The outer side of working head is covered by stainless steel sheet with slits to protect the rotors with nozzles from leaf mass and to enable unobstructed work of the rotors. By alternating rapid pulsation of compressed air through rotating nozzles, short and sharp air currents are generated. The action of alternating air currents causes the leaves to be twisted and separated (removed) in the desired zone.

Fig. 3 Working head of defoliation device

The carrier is designed to allow the rotation of the working head and adaptation to different growing forms and required technologies of vine production. By rotation of the working head as shown in figure 4. the width of the working zone in which defoliation is performed can be adjusted. Changing the angle of the working head as shown in figure 5. enables the removal of leaf mass from the desired zone which is the most suitable for the given growing form and ampelotechnical measures that are applied.

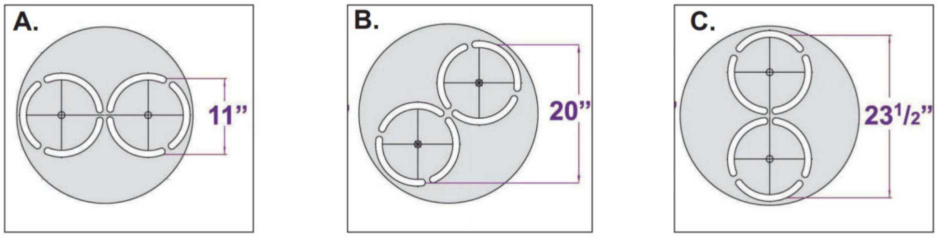

Fig. 4 Positions of the working head depending on the width of the working zone

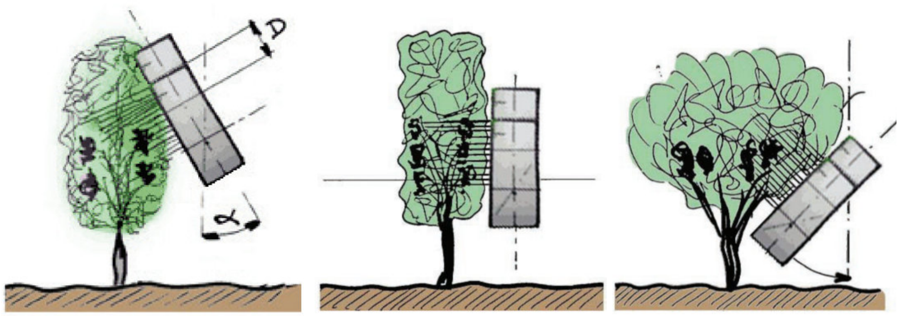

Fig. 5 Position of the working head in relation to the growing form

The newer technical solution is a defoliation device with vertically mounted pair of rollers fig. 6. During operation, the rollers rotate in opposite directions whereby leaves come into the space between rollers which grip them and cut them. One roller is made of PVC material with embossed surface in order to enhance the effect of gripping the leaves. The other roller is made of elastic material with the goal of increasing the friction on the spot where the roller touches the vine leaf. During work, the elastic roller vibrates and enhances the procedure of cutting the leaves. The fan (figure 7) is mounted on the inside of the rollers. During operation, the fan creates a suction air stream which is directed into the space between rollers. The task of the suction air stream is attracting vine leaves and bringing them into the interspace between rollers which grip them and cut them. After cutting, the fan air current blows the leaves out of the device. The drive of the rollers and fan is made through hydro motor driven by hydraulic system of the tractor on which the device is aggregated. The joint frame of telescopic type enables the adjustment of the device to the form of rank and the zone in which defoliation is performed.

Fig. 6 Device for defoliation with vertical pair of rollers

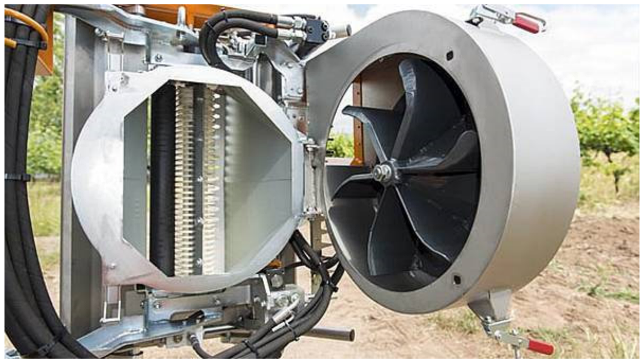

Fig. 7 The fan of defoliation device

The construction of defoliation device shown in figure 8 consists of vertically mounted perforated drum and a rubber roller which during operation rotate in opposite directions. The central part of the drum is connected with the fan which inside the drum creates suction air current. Around the edge of the drum there are openings through which suction air current attracts leaves and glues them to the surface of the drum. Due to the rotation of the drum, the attracted leaves are brought into the interspace with rubber roller which rotates in the direction opposite to that of the drum. The rotation and gripping of leaves by rubber roller result in cutting leaves. By further rotation, the edge of the perforated drum enters the zone in which the activity of the suction air current ceases, which causes the removal and falling of separated leaves from the surface of the drum to the ground. The fan, perforated drum and rubber roller are driven through hydro motor driven by hydraulic system of tractor. The device is mounted on the joint carrier of telescopic type which allows for the freedom of movement of the working part in all directions and the application in different growing forms of grapevine. This device has the possibility of installation and application in standard tractors and self-propelled machines.

Fig. 8 Device for defoliation with perforated drum

Fig. 9 Device for defoliation with perforated drum aggregated on the tractor from the rear side

3. Conclusion

The removal of leaves from the zone of bunches has become an increasingly popular ampelotechnical measure which is regularly applied in practice. The removal of certain leaves significantly improves the brightness and aeration of bunches, which contributes to the better and higher quality ripening, lesser development of diseases and easier performance of the operation of manual or machine grape harvesting. In our country, the procedure of defoliation is mostly done manually, which is the consequence of the lack of monetary funds for procurement of defoliation devices. The original technical solutions of these devices did not satisfy necessary requirements related to possible damage to the very plant, which was another important reason that slowed down the introduction and application of mechanical procedure of defoliation in the technology of grape production. Recently, due to the lack and high price of workforce, manufacturers increasingly opt for procurement and application of various construction solutions that can perform mechanical removal of leaves from desired zone. Another reason for the introduction of mechanical procedure of defoliation to practice is that modern technical systems can realize great performance with satisfactory quality of work and minimal possibility of damage to the fruit and vine tree.

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PREDICTION OF FRUIT FIRMNESS INVOLVING MODERN COMPUTATIONAL TECHNIQUES

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Abstract: *Firmness is an important component for determining the quality of any fruit. In this study, the data obtained for different apple categories were used. Once these experimental data were validated, they were used as dependent variables for the construction of a high predictive power model using the QSPR (Quantitative Structure Properties Relationships) technique. In order to obtain the specified model, the firmness values for the different categories of apples were correlated with the firmness values for other fruit categories and with the Young modulus values. The obtained model was statistically validated, obtaining data in accordance with the experimental data.*

Key words: *firmness, apple, fruits, QSPR technique, Young modulus*

1. INTRODUCTION

The firmness is one of the most important indices regarding the ripening and the quality of the fruits and is used in various researches in the field [1]. Maturity at harvest can affect the firmness of some categories of apples. Golden Delicious apples show a decrease in firmness at a later harvest [2] while other cultures (Starking Delicious) are not affected by harvest time [3].

The maturity at harvest can also affect the speed with which apples are softened during storage. For example, previously harvested Orange Pippin apples from Cox have a higher retention during storage than apples harvested later [4]. Although the ethylene production of apples is associated with increased maturity, fruit firmness is not necessarily linked to ethylene production [5].

Fruit firmness can be determined by destructive and non-destructive methods. In the destructive method, the amount of force required to penetrate the apple flesh (skin and pericarp) and the deformation value can be recorded. Another way is to determine the force required to deform the tissue at a certain distance or by determining the degree of deformation for a given applied force [6]. This was called a destructive method.

Techniques for nondestructive firmness and maturity sensing of fruits and vegetables have received much attention due to consumer expectations for better quality and the increased competition brought on by the globalization of the fresh fruit and vegetable trade [7].

2. MATERIALS AND METHODS

Firmness (peak force in N) was determined on four opposite sides of the surface of each fruit (equatorial region), using a TA-XT2i texture analyzer (Stable Micro System Ltd; Godalming, Surrey, England). After that, two slices (2 mm thick) were obtained from opposite sides of each fruit and dried (105 °C for 3 h) in order to gravimetrically determine the moisture content. Finally, the remainder tissue from the 20 apples was individually juiced using a commercial juice extractor and TSS% was directly measured in the obtained juice using a Pal-1 hand refractometer (ATAGO, Co. Ltd., Osaka, Japan) [8].

The data obtained by J. J. Ornelas-Paz [8] were used for this study. The firmness of the apples from the Golden Delicious variety was determined after several days, obtaining the data presented in Table 1.

Table 1 Determining the firmness of Golden Delicious apples after 167 DAFB [8]

Days after bloom (DAFB)	Firmness (N)
107	89.6
122	82.4
137	70.2
152	66.1
167	63.0

For the same category of apples, the values of Young's modulus of elasticity were determined [9]. These values are presented in table 2.

Table 2 Determining the Young module of Golden Delicious apples after 167 DAFB [9]

Days after bloom (DAFB)	Young modulus (MPa)
107	2.33
122	2.28
137	2.25
152	2.10
167	2.09

The values obtained in tables 1 and 2 were correlated using computer techniques [10] and in particular the QSPR (Quantitative Structure-Property Relationships) technique [11]. The following correlational model is obtained:

$$Y=94.87(\pm 24.41)X - 135.4\ (\pm 54.01) \qquad (1)$$

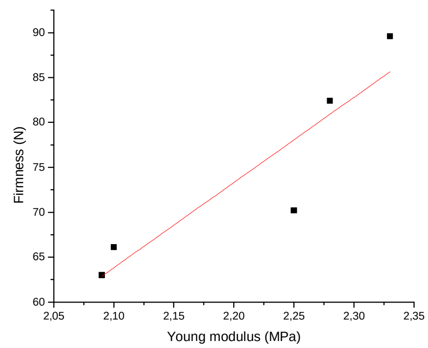

Fig. 1 The correlation Firmness vs. Young modulus

In order to validate the model presented in equation 1, the following statistical parameters presented in Table 3 were obtained.

Tabelul 3 Statistical parameters for the validation of the model presented in equation 1

R-Square	Residual Sum of Squares	F Values
0.778	84.78	15.09

3. CONCLUSIONS

The values of firmness of the Golden Delicious apples and the values determined experimentally for the Young module were used to obtain a statistically validated correlational model that can be used to determine other parameters for various vegetables as well as fruits. Because the obtained model has statistical significance, the experimental data for obtaining the model have been taken from the specialized literature according to the quotations presented.

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TECHNICAL ACCURACY OF ORCHARD SPRAYER USED IN INTENSIVE FRUIT AND VINEYARD PRODUCTION IN REPUBLIC OF SERBIA

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Abstract: *The technical accuracy of the machine is a prerequisite for the effective implementation of chemical protection in fruit and grapevine production. The paper presents the results obtained during the control testing of 50 different models of orchard sprayers, with different period of exploitation in growers throughout Serbia that are used in intensive fruit and grapevine production. During the control testing, a large number of parameters were monitored, using standardized methods and test procedures. Comparison of the obtained data was applied to four groups of orchard sprayers (defined by the period of the exploitation). The technical accuracy of the individual orchard sprayer is expressed by the coefficient of the technical correctness (C_{ta}) according to individual marks of the tested parameters of orchard sprayers.*

Out of the total number of investigated orchard sprayers, 12% of the orchard sprayers are in exploitation for less than three years, while the largest number of orchard sprayers, and 42% is in exploitation for seven years or more. The technical accuracy of Group 1 orchard sprayers was sufficiently high, except for the parameters related to the Measuring regulatory system (C_{ta} = 0.80) and the Nozzles (C_{ta} = 0.86). In Group 2, a decrease in the coefficient of technical accuracy in all parameters was observed with respect to the sprayers from Group 1, which was particularly pronounced for Agitators (C_{ta} = 0.50) and Nozzles (C_{ta} = 0.68). The orchard sprayers from Group 3 are characterized by a low coefficient of technical accuracy for the Nozzles (C_{ta} = 0.37), while Group 4 orchard sprayers have a very low coefficient of technical accuracy in all tested parameters. The level of technical accuracy of the orchard sprayers used in intensive fruit and grapevine production is directly dependent on the period of their exploitation.

Keywords: *control testing, coefficient of technical accuracy, period of exploitation, maintenance of the orchard sprayers, application quality*

1. INTRODUCRION

Proper technical functionality of plant protection machines is a prerequisite for carrying out efficient operations, achieve financial savings and increase safety among the employees. In order to provide the production of healthy food, as well to protect the environment, controlled use of pesticides should be ensured. To ensure this kind of pesticide application, proper machinery is needed during the exploitation period.

Modern agricultural production involves the increased use of pesticides as plant protection products, as well as the use of pesticide application machines [8]. The proper setting of the device for the application and the adequate use of the treatment aggregate have a significant impact on the quality and efficiency of the application of the pesticides. The amount of costs depends on the choice of the machine and its performance, and the amount of costs directly affects the cost of production. The use of modern machinery combined with the optimum technique for the application, which has significantly advanced, increases the efficiency, cost-effectiveness and the safety of the environment. For all the above reasons, the pesticide application technique is nowadays a major plant protection issue.

The introduction of the mandatory "HACCP" standard in the food industry, as well as the "GLOBALGAP" standard in primary agricultural production ensure, to some extent, production of health-safe food and the absence of pesticide residues. Farmers cannot obtain the certificates for the "HACCP" and GLOBALGAP" if there is no information showing how the application of pesticides was carried out during the entire production process. The aforementioned standards require periodic monitoring of the proper technical functionality of the plant protection machinery. The testing of the machines is carried out according to the European standard EN13790, which has been in force since 2003 and is divided into prEN 13790 - 1 related to field sprayers and prEN 13790 - 2 standard for orchard sprayers (atomizers) [5]. These standards contain a set of rules and guidelines for determining the safety and technical functionality of plant protection machinery.

The first testing of plant protection machines in the Republic of Serbia was carried out in 2006 and at the time very poor results of the flow of the nozzles were obtained due to inadequate maintenance [6]. There are more and more agricultural areas in Serbia and therefore the usage of plant protection machines is bigger. Control testing of plant protection machines in Serbia is not regulated by law yet, but all larger companies and agricultural holdings are conducting these tests in order to get a technical functionality certificate of the machines, as well as to identify malfunctions that are not noticeable. Regular control of a plant protection machinery condition is a necessary measure in modern agricultural production, which uses pesticides over a large area [6].

In our field research we found that the defective nozzles were the biggest problem for the proper operation of plant protection machines. In the field, nozzles are often clogged with mechanical impurities, poor water quality or deterioration due to a long period of exploitation, which significantly affects the quality of pesticide application. In addition to regular maintenance and cleaning, it is also necessary to perform regular checks of the proper operation of the nozzles on the tested plant protection machines. The flow rate of the spray liquid depends on the condition of the nozzle, the pump flow, the condition and the methods of maintaining the nozzle [4].

2. MATERIAL AND METHOD

The survey was conducted on five agricultural holdings in the Republic of Serbia, where the data collected were obtained by controlling technical equipment of the orchard sprayer. The holdings on which the survey was conducted have an average of 50 ha of fruit and wine production. In order to perform correctly control of technical functionality, the equipment for control testing of plant protection machines, owned by the Faculty of Agriculture in Belgrade, was used. The pump capacity was measured using the "AAMS Pump tester", while the pressure gauge functionality was checked with the "AAMS Manometer tester". Testing the flow rate of each individual nozzle was performed using an "AAMS Flow rate device". During the functionality check of the working parts of the orchard sprayer the questionnaire was filled in, which consisted of four parts. The first part was related to the general information about the orchard sprayers (type, model, date and year of production). The second part of the questionnaire included information on the condition of the protective lining (safety), filters, fans, agitators, tanks, leakage (dynamic and static), condition of conduits and hoses. The third part of the questionnaire consisted of pressure gauge and pump flow data. Also, the third part of the questionnaire contained the data of the declared pump flow, which are read from the plate carved on the pump. The fourth part of the questionnaire referred to the data on the established flow of the nozzles, as well as the data on their factory declared flows which are read from the nozzle manufacturers catalog.

After collecting the data and completing the questionnaire, the processing of the data was carried out. A form consisted of controlled elements of the orchard sprayer and the coefficients of technical functionality was created. The assessment of the technical functionality of the tested elements was made on the basis of the questionnaire data, where the score values have the following meaning:

- C_{ta} = 0 – 0,2 - completely out of order orchard sprayer parts, it is necessary to replace the tested elements with new ones;
- C_{ta} = 0,2 – 0,4 - the orchard sprayer elements are out of order but they can be repaired;
- C_{ta} = 0,4 – 0,6 - the elements of the orchard sprayer are within acceptable functionality limits;
- C_{ta} = 0,6 – 0,8 - the elements of the orchard sprayer are functional, but there are some slight irregularities in the operation of the orchard sprayer, which are easily repaired;

41 orchard sprayers with different models and technical characteristics were tested. In order to facilitate the processing of the data and organize them, the tested orchard sprayers were divided into four groups according to the influence of the exploitation period:

- Group 1: 0 to 1,99 years;

- Group 2: 2 to 3,99 years;
- Group 3: 4 to 6,99 years old;
- Group 4: 7 years and older.

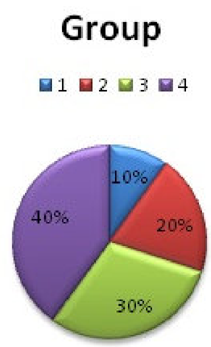

Fig. 1 Division of tested orchard sprayers according to the impact of the exploitation period

3. RESEARCH RESULTS AND DISCUSSION

The technical functionality of the orchard sprayer has a decisive influence on the proper distribution of the protective liquid, as well as on the chemical protection of orchards and vineyards. During the testing of the technical functionality of the orchard sprayer it was found that, despite the calibration, there was a change in the functionality of the elements of the orchard sprayer during the exploitation period. The obtained results show that irregularities in the operation of the elements of the orchard sprayer were caused during the exploitation period. It was found that Group 4 had a lower coefficient of technical functionality of the tested orchard sprayer elements compared to Group 1.

Table 1 Display of technical functionality score coefficients according to tested elements of the orchard sprayer

Group	Period of exploitation	Power take-off	Leaks	Pumps	The agitator	Tank	Pressure gauges	Hoses	Filters	Nozzles	Fans
1	1	1.00	1.00	1.00	1.00	1.00	0.80	1.00	1.00	0.86	0.96
2	2.2	0.66	0.78	0.76	0.50	0.69	0.66	0.95	0.86	0.68	1.00
3	4	0.42	0.76	0.76	0.61	0.82	0.68	1.00	0.96	0.37	0.94
4	12.24	0.12	0.39	0.49	0.50	0.61	0.38	0.75	0.71	0.34	0.61

The tested elements of the orchard sprayer Group 1 have a score coefficient of technical functionality from C_{ta}=0.86 to C_{ta}=1.00. Average ratings for Group 1 of technical functionality of tested orchard sprayer elements show that all elements are in order (Table 1). The good results of the technical functionality of tested orchard sprayer elements of Group 1 result from their average period of exploitation of one year.

Group 2 whose average period of exploitation is 2.2 years, has oscillations in the evaluation of the technical functionality of the tested orchard sprayer elements. In Group 2 the coefficient of technical functionality for fans is C_{ta}=1 and for conduits and hoses C_{ta}=0.95 which makes these elements operational and functional. The agitator, as one of the essential elements of the orchard sprayer, within the Group 2 have a coefficient of technical functionality C_{ta}=0.50. Operational functionality of the agitator in Group 2 decreases by 50% compared to Group 1.

The tested orchard sprayers within Group 3 have an average exploitation period of 4 years. Orchard sprayer elements with the lowest technical functionality score within Group 3 are nozzles (C_{ta}=0.37) and power take off (protective lining on power take off C_{ta}=0.42). Such a low technical functionality coefficient stems from the length of the exploitation period.

The fans (C_{ta}=0,94), conduits (C_{ta}=1) and filters (C_{ta}=0,96) have a significantly higher technical functionality coefficient score. Fans, conduits and filters are made of more durable materials, so an average operating life of 4 years does not affect their functionality and operationality. Fans, conduits and filters are made of more durable materials so an average exploitation period of 4 years does not affect their functionality and operationality.

Orchard sprayer elements from Group 4 that have been subjected to control testing have an average exploitation period of 12.24 years. In Group 4, all tested orchard sprayer elements have a decreasing coefficient of technical functionality. Power take off (C_{ta}=0.12), nozzles (C_{ta}=0.34) and leaks (C_{ta}=0.39) have the lowest technical functionality score. Slightly better technical functionality scores were recorded for conduits and hoses (Cta=0,75) and filters (Cta=0,71). The assessment of technical functionality of orchard sprayer elements which has not been changed during the 4 years of exploitation begins to change in Group 4.

The elements of the orchard sprayer on which depends proper application of the protective fluid are the pump, pressure gauges, nozzles and the agitators. In this study, it was observed that agitators during the exploitation period had a decrease in technical functionality coefficient score. For an average exploitation period of 12.24 years, the agitator technical functionality coefficient is Cta = 0.50.

It is this decline of technical functionality coefficient that shows the significance of the influence of the period of exploitation on the functionality of the agitator. Also, a decrease in the technical functionality coefficient during the period of exploitation was also noted with pumps (C_{ta} ranges from 1.00 in Group 1 to 0.49 in Group 4). The flow rate of the tested nozzles during the exploitation period changes from the one declared at the factory, as can be seen in Figure 2. The nozzle technical functionality coefficient ranges from C_{ta} = 0.86 in the first year of exploitation and C_{ta} = 0.34 in the average exploitation period of 12.24 years. A decrease in the pressure gauges technical functionality coefficient was noted. The pressure gauge in the first year of exploitation has C_{ta}=0.80 and C_{ta} = 0.36 with an average exploitation period of 12.24 years. The displayed values of the pressure gauges technical functionality coefficient shows that during the exploitation period pressure is displayed, which is bigger or smaller than the given one.

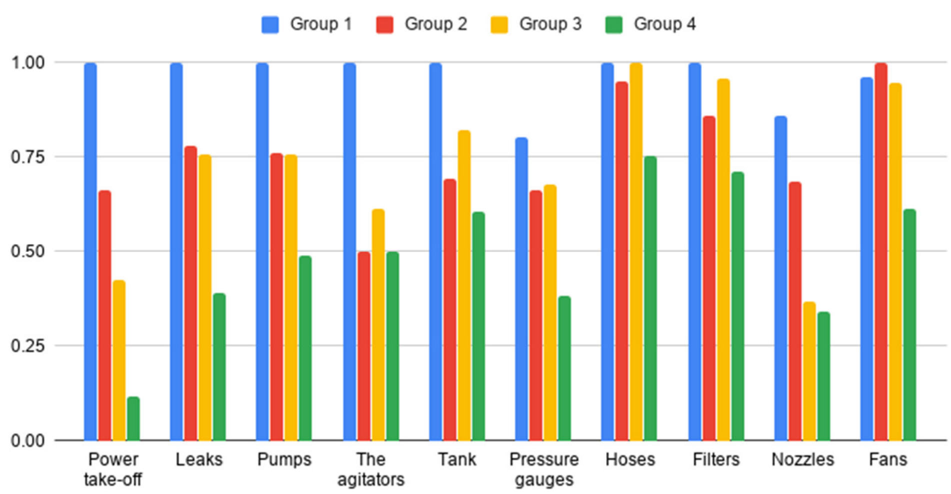

Fig. 2 Display of assessment of tested orchard sprayer elements technical functionality by groups

The orchard sprayer elements that have the biggest changes in the assessment of technical functionality during the period of exploitation are power take offs (C_{ta} from 1.00 in Group 1 to 0.12 in Group 4). The protective lining on power take off has extensive damage during the period of use. Damage on the power take off protection is the consequence due to the length of exploitation. The material of which the protective lining for the power take off is made, begins to wear out during the period of exploitation, so it is necessary to check its entirety regularly. Leakage occurring on the orchard sprayers increases during the exploitation period (at the beginning of exploitation the value is Cta = 1.00, and then decreases to Cta = 0.39), (Figure 2).

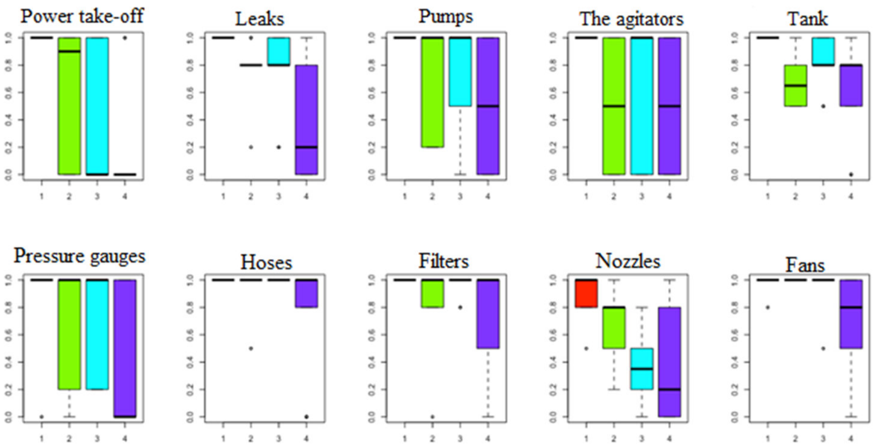

Fig. 3 Effect of exploitation period on the tested orchard sprayer elements technical functionality

The tested orchard sprayer elements showed that there is an influence of the exploitation period on their technical functionality. The functionality of the tested elements decreases with the period of exploitation (from year to year coefficient of technical functionality is lower). However, there are those orchard sprayer elements that have started to break down in Group 4 (average exploitation period of 12.24 years). Fans, filters and conduits during testing showed changes in functionality and operation only in Group 4 (Figure 3). The fans have been fully operational for 4 years of exploitation (C_{ta} of 1.00 for Group 1, while for Group 3 C_{ta} it is 0.94), while for Group 4 (average period of exploitation of 12.24 years) the coefficient score decreases to C_{ta} = 0.61.

In the case of conduits and hoses, we also have a decrease in the technical functionality coefficient score only in Group 4 (average exploitation period of 12.24 years) to Cta = 0.75. Figure 3 shows that fans, conduits and filters require regular annual controls to maintain them throughout the period of exploitation.

4. CONCLUSION

Republic of Serbia has not yet adopted the law EN 13790, which obliges all agricultural producers to regularly check plant protection machinery so that they can market their products. However, in the Republic of Serbia there are stations that control plant protection machinery and there are already a large number of producers that have tested their plant protection machinery. However, there are also producers who have not yet heard of this type of testing.

This research has shown that the exploitation period has an impact on 72% of the tested orchard sprayer elements. During this research major irregularities were noted with the pumps, agitators, nozzles and pressure gauges in Group 4, that is, for the orchard sprayers with the longest period of exploitation. During the exploitation of the orchard sprayers, material from which the elements are made wears out. Significant wear out of the orchard sprayers elements was noted with nozzles and pumps. The flow of the nozzles deviates from the factory declared flow, because blockages are created in the body of nozzles or there is an expansion of the protective fluid leakage hole. The tested pumps had a flow deviation from the factory declared flow due to the wear out of the membrane during the exploitation period which led to its bursting. The aforementioned facts show a great need for regular orchard sprayer technical functionality control during exploitation.

With the introduction of mandatory plant protection machinery control testing, all producers would have to test plant protection machinery once a year by authorized persons, if this were supplemented by the introduction of other laws on the use of pesticides, irregularities in their use would drastically decrease, thereby this would increase environmental protection from the harmful effects of pesticides, which directly affects human health. This law would, in addition to all of the above, have the effect of reducing malfunctions of plant protection machinery during exploitation and, consequently, reducing the cost to producers.

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THE INFLUENCE OF THE MOTION MECHANISM OF TRACTOR AND MOBILE SYSTEMS ON SOIL COMPACTION

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Abstract. *Moving tractors and mobile systems around the soil results in excessive compaction, causing multiple negative consequences. The results of the influence of the running mechanism of tractors and mobile systems on changes in soil compaction and cone resistance at penetration at a depth of 0-35 cm in sunflower production are presented in the paper. The resistance to cone penetration into the soil was measured on the track and between the tracks of the tractor wheels and the mobile systems in the inner part of the parcel and at headlands in the germinating and harvest stages of sunflower, by the Eijkelkamp pentrologer. Combining the possibilities according to given criteria, the results were obtained based on which we used numerical interpolation and created eight topographic maps showing penetration resistance in eight characteristic cases. The obtained results indicate that at a depth of 0-5 cm in the sunflower germinating phase by 32.86% the soil compaction was less between the tracks than in the track of the tractor wheels, while at a depth of 30-35 cm the compaction was less by 22.53%. In the harvest phase at 0-5 cm of depth between the wheels the compaction was less by 14% than in the track of the wheels of tractors and mobile systems, while at 30-35 cm the difference was 21.53%. Similar differences in soil compaction were observed in the other variants tested.*

Key words: *soil, penetration resistance, agricultural mechanization, sunflower.*

1. INTRODUCTION

Beside of benefits that tractors and mobile systems bring to plant production, pressing soil leads to the forming the unfavorable conditions for the normal development and fruition of plants, with permanent damage to the soil, reduced yields and increased production costs. Agricultural machinery has the greatest impact on intensive soil compaction, with harvesting due to firefighting by moving mechanism and transport being 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 ha of arable land [1, 10]. Soil is a three-phase system whose compaction changes the ratio of solid, liquid and gaseous phase to the detriment of gaseous and liquid phase [13]. When designing a mathematical model of soil compaction by a moving mechanism, a constant change in soil moisture, which has a significant impact on compaction, must be taken into consideration [21]. Movement of tractors and other mobile systems on the ground, especially in wet conditions, results in permanent soil compaction, which, though difficult, can only be resolved by basic tillage [17]. The negative consequences of compaction are multiple, with an increase in the volume of the soil, which leads to greater resistance of the machines to cultivation and resistance to the growth of the root system, which adopts less water and food, which negatively affects the yield [5, 6, 11, 20]. Due to the lower turning speeds and the large number of passages, soil compaction is more expressed at headlands than the interior of the plots [9, 15]. Soil compaction due to field machine wheel or track action causes undesirable soil changes. This is especially the case with the soil containing a higher amount of clay. Soil compaction causes pore volume decreasing, that deteriorates internal air-water transfer and consequently plant growth and development [8]. Up to a depth of 50 cm, soil compaction is more intense and water and nutrient uptake difficult, with an increased risk of erosion and energy consumption for cultivation [2, 3, 4, 16, 23]. Compaction is particularly expressed after the first passage of mechanization along the wheel track so that at a depth of 24 cm, soil compaction is higher by over 39% compared to a depth of 34 cm [7, 22]. Applying lighter mechanization can significantly reduce soil compaction and reduce energy consumption [12]. At the beginning of the sunflower stem elongation phase, the average soil compaction at a depth of 7-28 cm in the inner part of the plot was 1.29 MPa (max. 1.57 MPa), and at headlands 2.12 MPa cm (max. 2.39 MPa), an increase of 63.96% [14]. The same authors emphasize that in the sunflower harvesting phase, the average compaction in the interior of the plot was 2.27 MPa (maximum 2.95 MPa), and at gaps 2.95 MPa (maximum 3.35 MPa), which is a difference of 30.03%. During 5 years of research, it has been shown that in sunflowers the average increase of soil compaction at headlands in relation to the inner part of the plot is 23.01% in the germination phase and 28.43% in the harvesting phase, and the decrease in yield at the headlands by about 26% compared to the inner part of the plot [18]. According to the results reported by [19], soil compaction at a depth of 7-28 cm after sunflower germination in the inner part of the plot was 1.22 MPa, and at headlands 2.05 MPa, an increase of 67.70%. The aim of the study was to determine the influence of soil treading on changes in cone resistance at penetration at 0-35 cm depth in the production of sunflower.

2. MATERIAL AND METHODS

The impact of the moving mechanism of tractors and mobile systems on soil compaction was examined during 2018. in the agro-ecological conditions of central Serbia (44°07'08.2 "N 20°50'25.1" E) on vertisol soil type during the production of NS Ronin sunflower hybrids. The technological maps define the classic tillage with plowing as the basic tillage, bearing in mind that it is the most represented tillage system under the given conditions. Mobile systems were formed using agricultural machines represented in the test conditions. During the compaction measurement, tire load was not considered as a particular consideration, having in mind that the contact surface between the tire and the wheel increases slightly with the load increase at normal soil humidity. In the production of sunflower, conventional agro technique was applied, and all the aggregates used were aggregated with a tractor of 36.9 kW, weighing 2475 kg, with tires 7.50-20 (front) and 13.60-28 (rear). The rotation of tractors and mobile systems was carried out on a 10 m wide recess on the plot adjacent by the road. Sunflower harvest was done with ZMAJ 142 combine, weighing 6250 kg, with tires 18.40-26 (front) and 7.50-16 (rear).

Fig. 1 The satellite snapshot of the field of the research

Soil compaction was measured with an Eijkelkamp 6.0 pentrologer, 11.28 mm diameter cone with an angle of 60°, in accordance with NEN 5140, a penetration rate of 2 cm sec^{-1}, according to ASAE S313.1. The actual soil moisture was measured by Theta probe and was expressed in % vol of air-dry soil. Resistance recording was performed at a depth of 0-35 cm in the interior of the plot and at headlands (first criterion), between and along the tracks of tractor wheels and mobile systems (second criterion), as well as in the germination and harvest phase of sunflower (third criterion). This way, by combining two possibilities within each of the three possible criteria, $2^3 = 8$ typical cases were examined. In each of these cases, the compaction measurement was performed at depths of 5, 10, 15, 20, 25, 30 and 35 cm at 11 measuring points 1 m distanced, so that 616 compaction values were obtained (7 x 11 x 8) , on the basis of which, using numerical interpolation, eight topographic maps were created showing penetration resistance in the above eight characteristic cases. Measurement was conducted in the direction tractor and mobile systems was movement. During the germination phase of sunflower, the average soil moisture in the interior of the plot was 24.82% of air-dry, at a headland 26.14%, while at the harvesting phase in the interior of the plot, the moisture was 17.80% and at a headland 16.43% of air-dry soil. The data obtained were processed using Penetroviewer 6.03 software and R-Statistics.

3. RESULTS AND DISCUSSION

Figures 2-9 show the values of cone resistance when penetrating the soil during sunflower production according to the variants tested. The obtained results show that different values of cone resistance were measured, and soil compaction generally increased along the depths of the measurements, which clearly show brighter surfaces at greater depths. Darker colored surfaces show lower and brighter higher penetration resistance values.

In the sunflower germination phase, less soil compaction values were measured between the tractor wheels and the mobile systems than in the wheel track, both in the interior of the plot and in the headlands. Based on the obtained results, it is observed that the lowest soil compaction was measured between the tractor wheels and the mobile systems, at a depth of 0-5 cm and amounted to 0.70 MPa, while the average compaction of 0.93 MPa was measured on the track of the tractor wheels at the same depth, which expressed higher compaction by 32.86%.

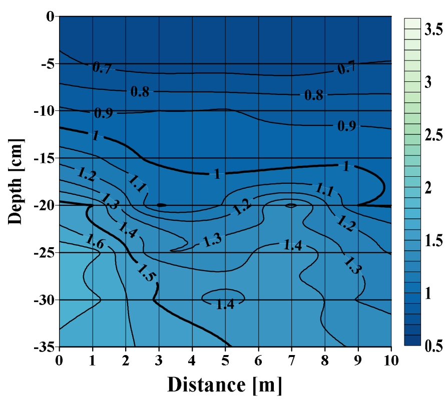

Fig. 2 Compaction of soil in the interior between the wheel tracks in phase sunflower germination [MPa]

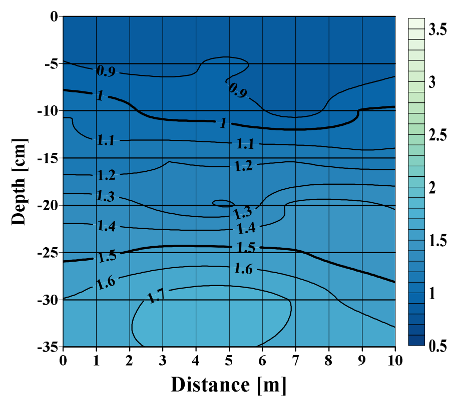

Fig. 3 Compaction of soil in the inner part by tracks of wheels in the phase of germination the sunflower [MPa]

Compactness of 1.42 MPa was measured between the tractor wheels in the interior of the plot during the sunflower germination phase at a depth of 30-35 cm, while the soil compaction was 22.53% higher along the wheel track and averaged 1.74 MPa, which is the highest value in this test variant. Similar differences in soil compaction were observed at other depths of measurement in the sunflower germination phase in the interior of the plot for both variants examined (Figs. 2 and 3).

Higher values of soil compaction were measured at headlands compared to the interior of the plots, which was expected considering the lower speed at turning and the large number of passages caused the compaction of the soil to be more expressed. The lowest values of soil compaction in the sunflower germination phase at gaps of 1.05 MPa were measured between the wheels tracks of the tractors at a depth of 0-5 cm, while the track compaction was higher by 33.33% and amounted to 1.40 MPa. At a depth of 30-35 cm in this test variant, the highest compaction was measured along the track of the tractor wheels and averaged 2.84 MPa, while the compaction between the wheel tracks was 2.40 MPa, which is a difference of 18.33% (Figs. 4 and 5).

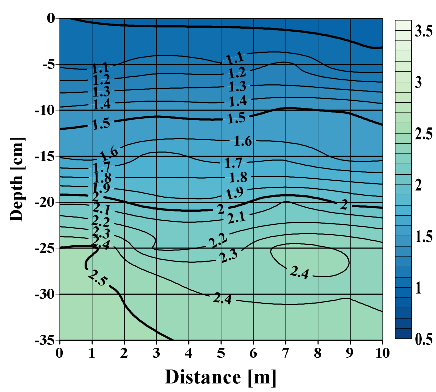

Fig. 4 Compaction of soil at headlands between wheel tracks in the germination phase of sunflower [MPa]

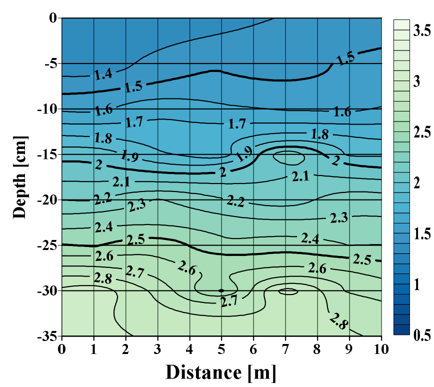

Fig. 5 Compaction of land on headlands by track of wheels in the germination phase of sunflower [MPa]

Similar differences in soil compaction were observed at other depths of measurement at this stage of testing.

Comparing the soil compaction in the interior of the plot and at headlands in the germination phase of sunflower, it is observed that in the interior of the plot at a depth of 0-5 cm the compaction of the soil between the tractor wheels was reduced by 50% (0.70 MPa interior, or 1.05 MPa headlands), while at a depth of 30-35 cm the difference was 69.01% (1.42 MPa inside the plot, or 2.40 MPa-headland). In terms of the wheel track, the compaction in the interior of the plot was 50.54% (0.93 and 1.40MPa) less in relation to the headland, while it was 63.21% (1.74 interior, or 2.84 MPa-headland) at 35 cm (Figs. 2-5).

The results of cone resistance measurements show an increase in soil penetration resistance in the sunflower harvesting phase compared to the germination phase in all the variants tested.

At a depth of 0-5 cm in the interior of the plot at this measurement stage, the lowest compaction was measured between the tractor wheels track and amounted to 1 MPa while along the wheel tracks was 1.14 MPa, which makes a difference of 14%. Between the tractor wheels at a depth of 30-35 cm, lower soil compaction was also measured and amounted to 2.09 MPa, while along the tractor wheel track compaction amounted to 2.54 MPa, which is a difference of 21.53% (Figs. 6-7).

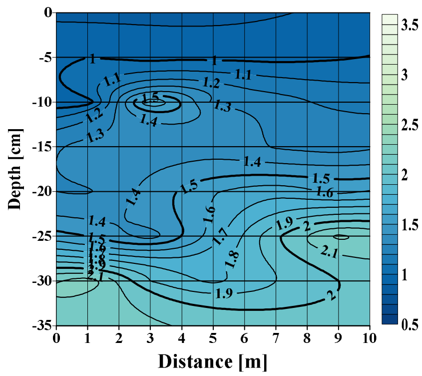

Fig. 6 Compaction of soil in the interior between the wheel tracks in sunflower harvesting phase [MPa]

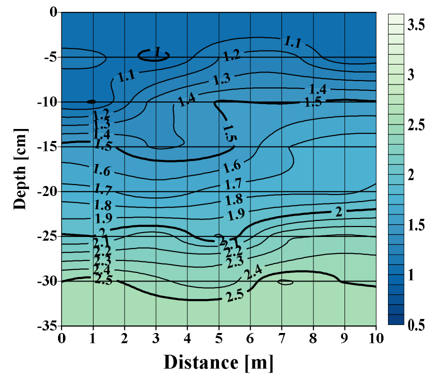

Fig. 7 Compaction of soil in the interior along the trace of wheels in sunflower harvesting phase [MPa]

In the sunflower harvesting phase, higher soil compaction values were measured at the headlands related to the interior of the plot. Between the wheels of tractors and mobile systems at a depth of 0-5 cm, soil compaction of 1.30 MPa or 1.64 MPa per wheel track was measured, which represents a difference of 26.15%. At a depth of 30-35 cm between the wheels, an average soil compaction of 2.75 MPa was measured, while the track of the wheels at this depth measured the highest soil compaction at all and averaged 3.54 MPa, which is a difference of 28.72% (Figs. 8-9).

Comparing soil compaction in the interior of the plot and at headlands during the harvest phase of sunflower, it is observed that in the interior of the plot at a depth of 0-5 cm the soil compaction between the tractor wheels was reduced by 30% (1 MPa interior of the plot, or 1.30 MPa-headlands), while at a depth of 30-35 cm, the difference was 33.50% (2.09 MPa inland and 2.75 MPa-headland). Along to the trace of the tractor wheels, the compaction in the interior of the parcel was 46.42% (1.14 and 1.64 MPa) lower in relation to the headland, while it was 39.37% (2.54 and 3.54 MPa) while at 30-35 cm was lower by 39.37% (2.54 and 3.54 MPa) (Figs. 6-9).

During the harvest phase of sunflower, the average soil moisture in the inland was 17.80% and at the headland 16.43%.

The results obtained show that the running mechanism of tractors and mobile systems significantly influences soil compaction and adverse changes, with compaction being more pronounced in trace than between trace wheels of tractors and mobile systems, which coincides with results reported by other authors [7, 8, 17, 22].

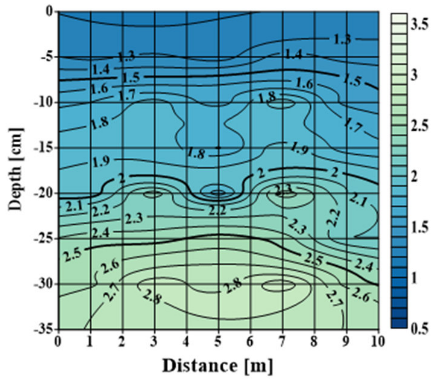

Fig. 8 Soil compaction at headlands between the wheel tracks in the sunflower harvest phase [MPa]

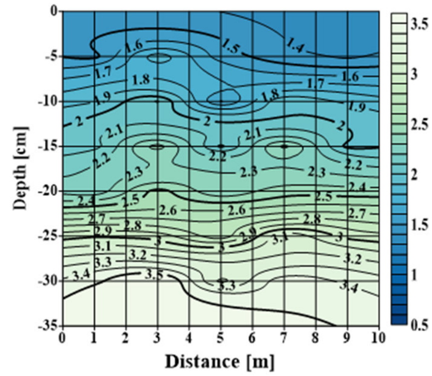

Fig. 9 Soil compaction at headlands along the track of the wheels at the sunflower harvesting phase [MPa].

Due to the slower turning speeds and the large number of passages, soil compaction is more pronounced at headlands than the interior of the parcels, both between the track of the tractor wheels and the mobile systems at all stages of testing. Soil compaction increases with depth of measurement. Similar results are reported by other authors in their studies [2, 3, 4, 9, 14, 15, 16, 18].

4. CONCLUSION

Based on the results obtained, it can be concluded that soil compaction generally increased with depths of measurement across all variants tested during sunflower production. Lower soil compaction values were measured between tractor wheels and mobile systems than compaction along wheel track. Higher values of soil compaction were measured at headlands compared to the interior of the parcel, which was expected given that due to the lower turning speeds and due to the large number of passages, soil compaction was more expressed.

In the sunflower germination phase between tractor wheels and mobile systems, soil compaction in the interior of the plot at a depth of 0-5 cm was reduced by 32.86% compared to compaction along the wheel track, while at a depth of 30-35 cm it was reduced by 22.53%. At the headland, the compaction between the tractor wheels at a depth of 0-5 cm in the sunflower germination phase decreased by 33.33% compared to the compaction along the wheel track, while at 30-35 cm the difference was 18.33%.

Comparing soil compaction in the interior of the parcel and at the headlands in the emergence phase of sunflower, it can be concluded that between the tractor wheels at a depth of 0-5 cm it was 50% lower in the interior compared to the headlands, while at a depth of 30- 35cm, the difference was 69.01%. Along the wheel tracks, the compaction in the interior of the plot was 50.54% lower than in the headland, while it was 63.21% lower at 30-35 cm.

In the sunflower harvest phase, higher resistance to cone penetration at soil penetration was measured related to the emergence phase of all variants tested, and differences in soil compaction were reduced. At 0-5 cm of depth between the wheels, the compaction in the interior of the plot was 14% lower than the compaction per track, while at 30-35 cm the difference was 21.53%. At recesses between the wheels of tractors and mobile systems at a depth of 0-5 cm in the sunflower harvesting phase, soil compaction was reduced by 26.15% compared to compaction by the wheel track, while at 30-35 cm compaction was reduced by 28.72%.

The soil compaction between the wheels of the mobile systems in the interior of the plot in relation to the headland in the phase of sunflower harvest at the depth of 0-5 cm was reduced by 30%, while at the depth of 30-35 cm the difference was 33.50%. Along the track of the wheels of tractors and mobile systems, the compaction in the interior of the plot was reduced by 46.42% in relation to the headland, and by 39.37% at the depth of 30-35 cm..

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DETERMINATION OF WEED PROBLEMS OF CORN GROWING AREAS (ZEA MAYS L.) IN ADANA/TURKEY

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Abstract: *The aim of this study was to determine the actual extent of weed damage in corn fields and to suggest the most efficient control methods for corn producers in the Adana region. A total of 36 growers in the Adana corn producing districts (Imamoglu, Kozan and Ceyhan) were individually interviewed in the year of 2018. The survey included 30 questions aimed to determine the extent of weed damage and their control methods. Results of the survey exhibited that, i) the majority of growers have been using certified seed, ii) less fertilizer usage in corn production areas, iii) in general, the growers care the cleaning of tillage equipment, iii) at least, the half of the growers do not recognize the weeds in corn areas, iv) the yield loose due to weeds is moderate, and the weeds are more damaging when they are in early stages in corn areas, v) the majority of the growers have been preferred chemical control methods against weeds. The present findings represent important findings regarding the infestation of weeds in corn areas due to lack of knowledge and phytosanitary measures.*

Key Words: *Corn, weeds, Zea mays, survey, Turkey.*

1.INTRODUCTION

The corn (*Zea mays* L.) a member of the Poaceae family, is a cereal grain originating from southern America. Maize is widely cultivated throughout the world, and a greater weight of maize is produced each year than any other grain (Anonymous, 2013). Corn is the third main food after wheat and rice. The reasons for this are related to the cultural and social preferences of some countries and in some countries corn is grown as animal feed (Secchi et al., 2011; Wallington et al., 2012). In recent years, corn plant has been used as biofuel. For these reasons, the economic value of this plant has increased. Corn production has greatly contributed to the production of animal protein in Turkey. In recent years, along with aris of irrigated agricultural land in Turkey it has gained importance in corn production. In addition, corn starch, glucose and corn oil obtained from the grain of grain is of great importance in terms of raw materials in the economy (Süzer, 2007). Water is an important factor in obtaining maximum corn yield. The corn is mainly grown in summer seasons and the irrigation is essential for higher yields. Worldwide, among the countries that are most commonly made of corn production it ranks seventh in Turkey (Anonymous, 2016). Corn growing areas and production quantities by years in Turkey are given in Table 1.

Table 1. According to the year in Turkey corn growing areas and production quantities (Anonymous, 2018).

Years	Area (da)	Production (tons)
2001	5 500 000	2 200 000
2006	5 360 000	3 811 000
2010	5 940 000	4 310 000
2014	6 586 450	5 950 000
2017	6 390 844	5 900 000

Weeds in agricultural lands are harmful to the development of crops. They cause developmental disorders such as fine roots, short seedling formation and yellow plant leaves in cultivated plants. In addition, they result in a reduction in grain yield by about 10% each year (Qiang, 2009). Crops and weeds compete for plant growth resources including light, nutrients and especially water (Zimdahl, 1999).

The aim of this study, was to determine the actual extent of weed damage in corn fields and to suggest the most efficient control methods for corn producers in the Adana (Imamoglu, Kozan and Ceyhan).

2. MATERIAL AND METHODS

This study was conducted during 2018 at Adana province (located at the South Turkey) and in Kozan (12), Imamoğlu (12) and Ceyhan (12) with a total of 32 face to face interviews with the farmers (Fig. 1, 2). The survey included 30 questions aimed to determine the extent of weeds damage and their control methods. In this areas, in order to identify the problem of weeds; fertilizers, irrigation water supply focused on questions etc. The data were analyzed using the general linear model of SPSS statistical software (SPSS, 2009).

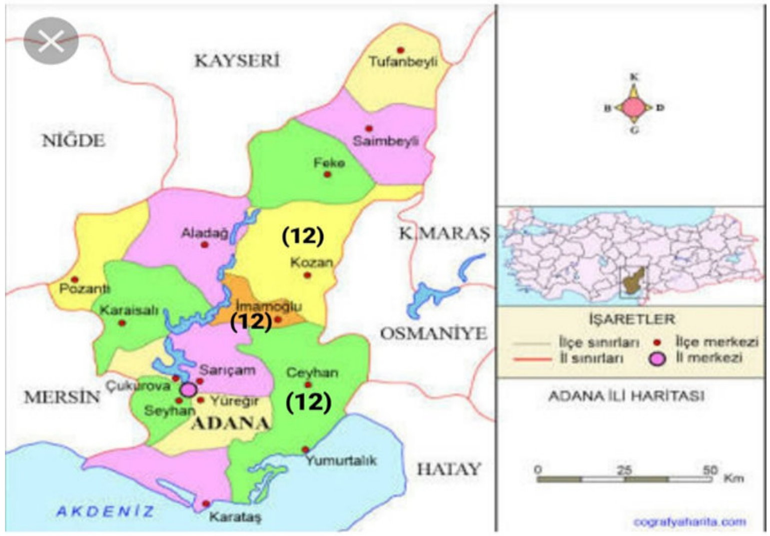

Fig. 1. The districts where the study is carried out in Adana

Fig. 2. Corn production areas and interviews with farmers in Adana (Imamoğlu, Kozan and Ceyhan)

3.RESULTS AND DISCUSSION

This study focuses on problems in corn production such as the used seeds, fertilizer, irrigation source, weeds control etc., which are related to weeds problem in corn growing areas.

Imamoğlu, Kozan and Ceyhan districts of Adana are important questions asked to farmers in corn production areas;

A. Producers' Perspective on Corn Breeding

The reason for corn production of producers

In Adana (İmamoğlu, Kozan and Ceyhan), 33.33% of the farmers stated that they produce corn because the land conditions are suitable for corn cultivation (Fig. 3).

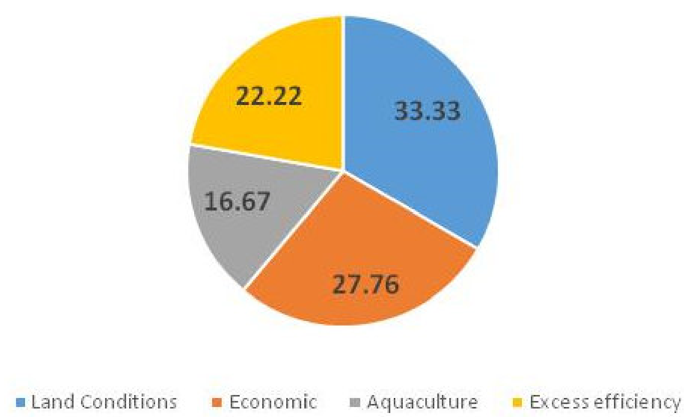

Fig. 3. The reason for corn production of producers

The preferred irrigation method in corn

In Adana (Imamoglu, Kozan and Ceyhan), 61.11% of the producers stated that they prefer sprinkler irrigation method (Fig.4).

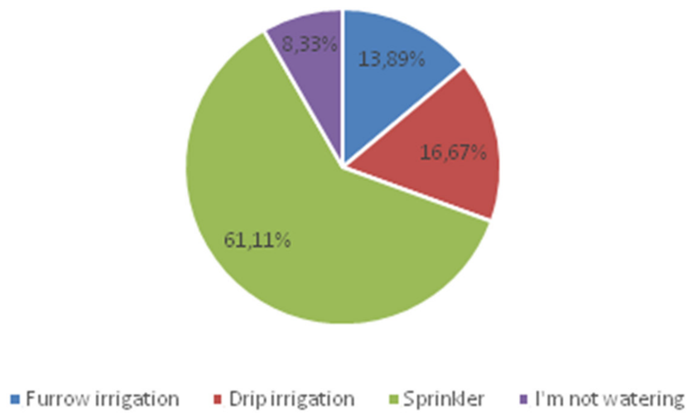

Fig. 4. The preferred irrigation method in corn

Corn sowing time

In Adana, usually 2 or 3 sowing is done annually. In the study area, 44.44% of the corn producers stated that they planted in February and March (Fig. 5). The weeds that germinated before or at the same period with corn are more competitive than the ones that germinated after the corn, which causes higher yield losses (Swanton et al., 1999).

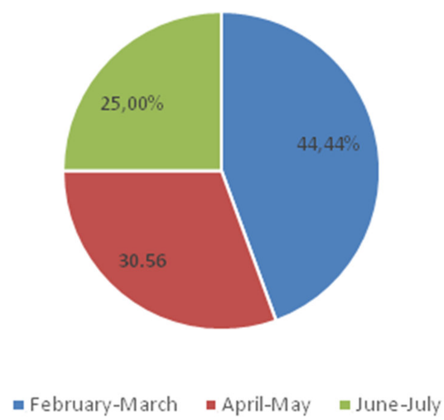

Fig. 5. Corn sowing time

Where corn seeds are obtained

It was determined that the producers of the region were conscious about seed production conditions and the use of clean seeds. Half of the farmers stated that they bought corn seeds from drug dealers and half of them from cooperatives (Fig.6).

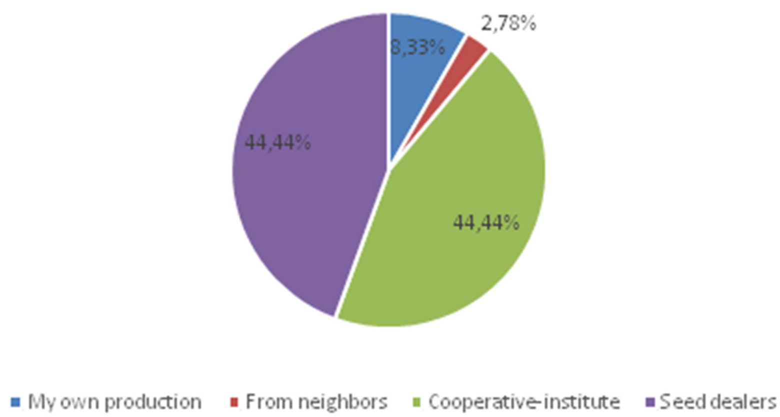

Fig. 6. Where corn seeds are obtained

Amount of products received per 1000 m^2

In the study area, it was stated that the highest amount of product taken by the producers was 1400 kg / da and the lowest amount of product was 650 kg / da. Almost half of the producers reported that they got 1300-1500 kg / da yield from corn (Fig. 7).

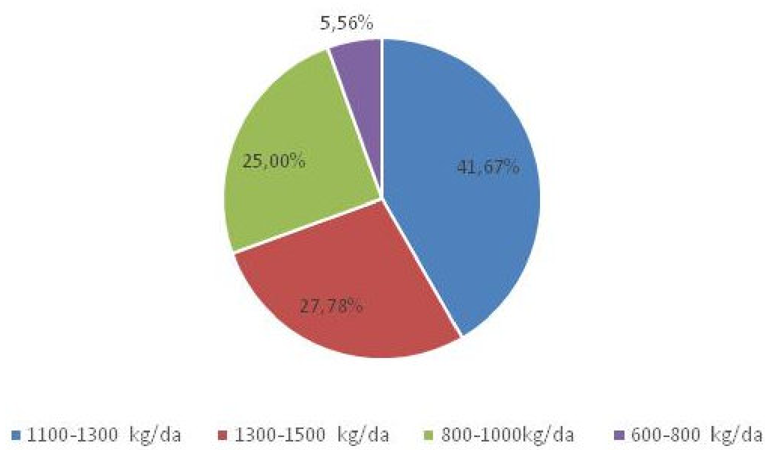

Fig. 7. Amount of products received per 1000 m^2

Important problems in corn production

Farmers reported that 52.78% of the most important problems encountered in corn cultivation were agricultural struggle problems (Fig. 8). Successful maize production depends on the correct application of production inputs that will sustain the environment as well as agricultural production (Jean du Plessis, 2003).

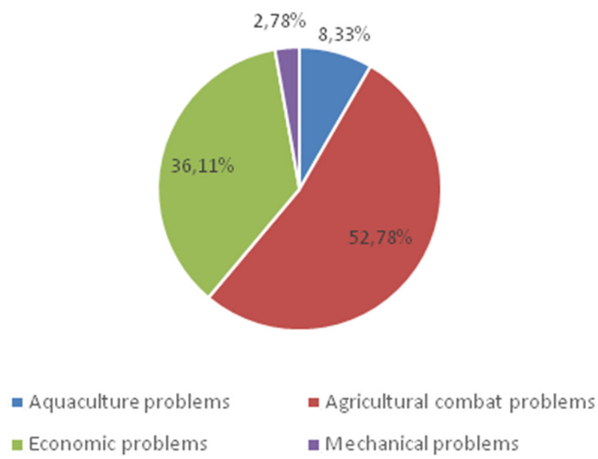

Fig. 8. Important problems in corn production

Use of fertilizer in corn

In the study area, 52.78% of the farmers stated that they use low levels of fertilizer. Farmers reported that Adana's land is fertile and does not require much fertilizer (Fig 9).

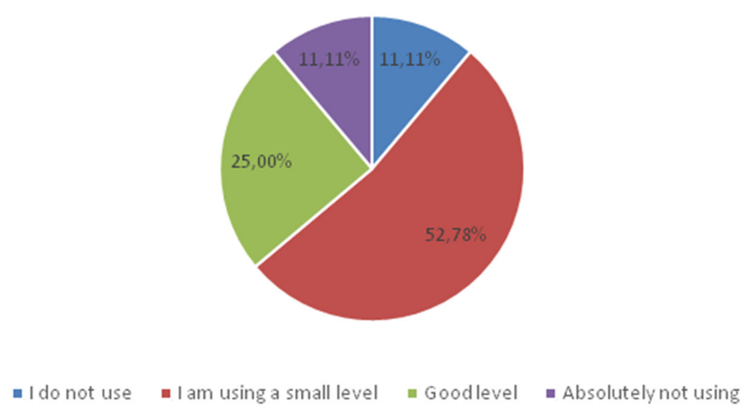

Fig. 9. Use of fertilizer in corn

B. Perspective of producers against weeds that are problematic in corn production areas

The level of recognition of weeds by producers in corn production areas

In the question posed to determine the recognition levels of weeds seen in corn production areas, 8.33% of the producers stated that they did not recognize at all. 47.22% of the producers reported that I know little, 36.11% of them know medium level, and 8.33% of them said I definitely know (Fig. 10).

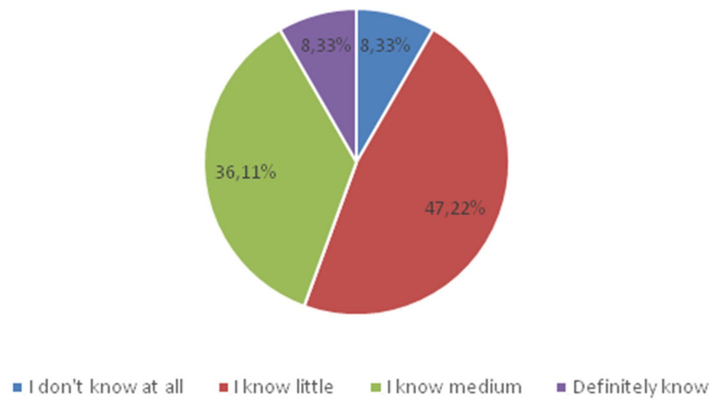

Fig. 10. The level of recognition of weeds by producers in corn production areas

Loss of yield caused by weeds

In the question directed to producers about how much yield loss caused by weeds in maize plant, 44.44% of the producers stated that weeds cause moderate yield loss in maize plant (Fig. 11).

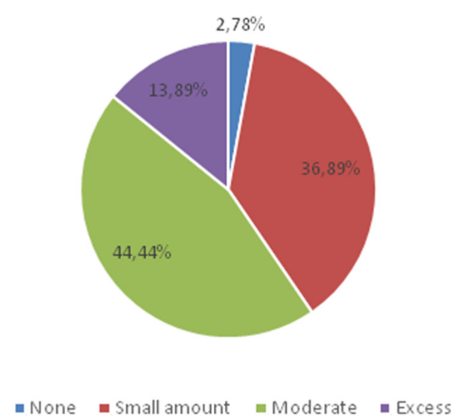

Fig.11. Loss of yield caused by weeds

Weed control methods

To the question of how do you fight weeds in your field, 69.44% of the producers stated that they prefer chemical control (Fig. 12).

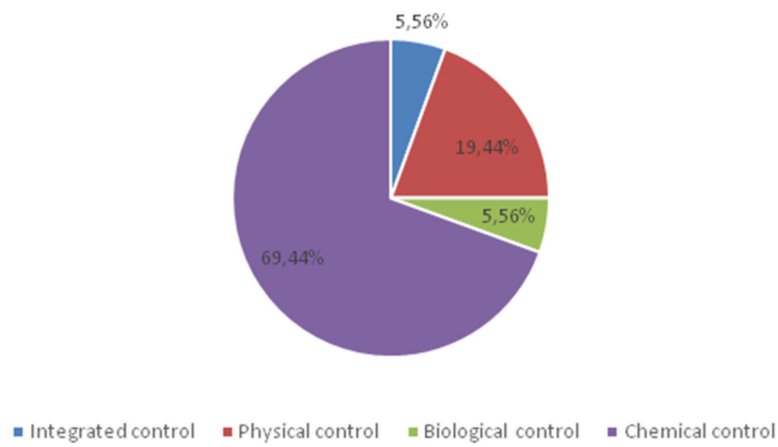

Fig. 12. Weed control methods

Spraying according to weed density

If you see how many weeds per m^2 in the field, you can apply the spray, almost half of the producers stated that they are fighting in 5 weeds (Fig. 13).

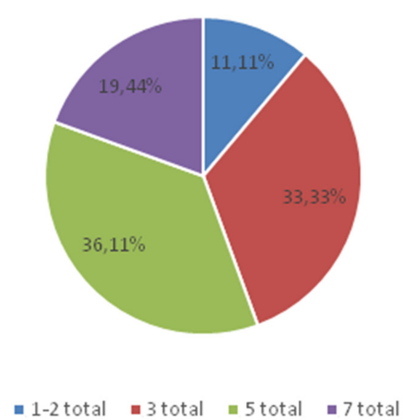

Fig. 13. Spraying according to weed density

Weed status after chemical control

The question was asked whether the producers could understand that weed was damaged after the chemical struggle and almost half of the producers replied that weeds were damaged at a low level. Some of the producers stated that weeds were definitely damaged (Fig. 14).

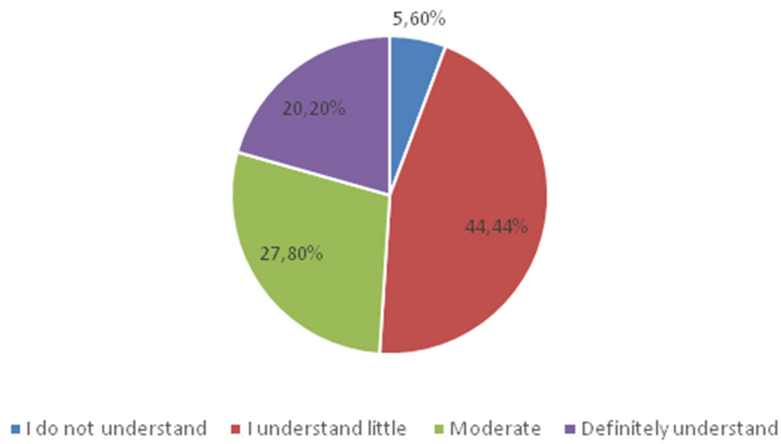

Fig. 14. Weed status after chemical control

Do you know the resistance to herbicide?

To the question of did you hear the word resistance to herbicides, 30.56% of the farmers know yes, 30.56% of them heard, but I do not know, 19.44% did not know anything and 19.44% emphasized that they do not remember the word resistance (Fig. 15).

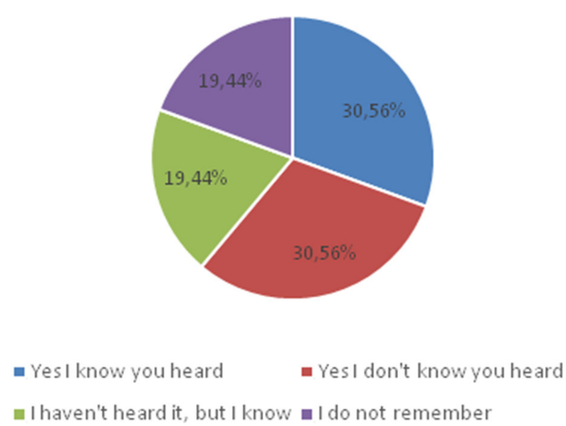

Fig. 15. Do you know the resisherbicide resistance?

Frequency of using the same herbicide

66.67% of the producers stated that they used the same herbicide 1-2 times in one year, 22.22% 3-4 times, and 11.11% 5-6 times (Fig. 16).

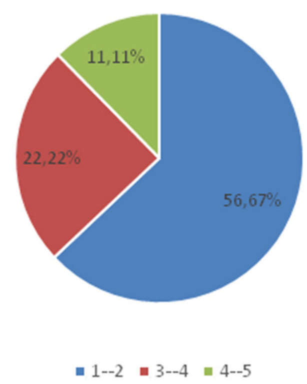

Fig. 16. Frequency of using the same herbicide

What do you do if the drug is ineffective at the appropriate dose and at the appropriate time?

If the herbicide used in corn production areas is ineffective, the question of what do you do is asked to the producers and 2.78% of the producers apply to the technical organization, 58.33% consult the dealers where I supply the herbicide, 36.11% ask the pharmaceutical company, 2.78%'i have given the answer to change where I get the herbicide (Fig. 17).

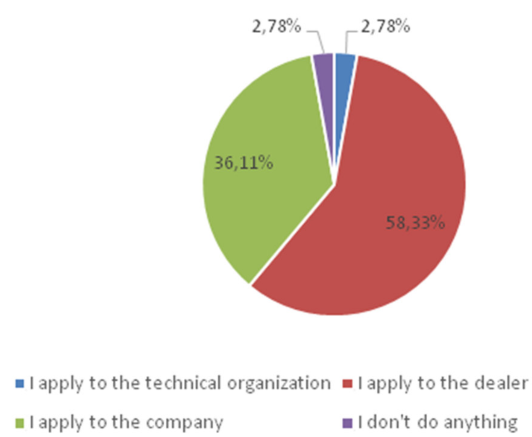

Fig. 17**.** What do you do if the drug is ineffective at the appropriate dose and at the appropriate time?

4.CONCLUSION

Results of the survey exhibited that, i) Farmers realize that some varieties of corn are due to the presence of a sales market, ii) Used corn seeds is certified iii) Seed frequency and irrigation method increased yield iv) There is a problem in agricultural production in the areas of production v) Fertilizer is useful when used at low levels, vi) Pay attention to the cleanliness of the machines used, vii) Producers recognize that weeds at a low rate, viii) Weed yield loss is moderate, ix) Chemical control against weeds is generally preferred, x) It was concluded that the farmers participated in the seminars moderately.

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PATHOGENICITY METHODOLOGY OF *RHIZOCTONIA SOLANI* FROM CARROT

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Abstract: *Carrot (Daucus carota* var. *sativus Rohl.) is one of the most popular and commonly consumed vegetables and it is widely planted in the Central Anatolia and Eastern Mediterranean Region of Turkey. Root diseases are among the most important factors limiting carrot production in Turkey. Crown rot causing by Rhizoctonia solani is one of the important root diseases. Sometimes, root rot agents are not found to be single on root. In this situation, it is necessary to find the main causal agent of it. In this case, pathogenicity test must be performed on all isolates and, practical and safe methods should be choosen.For this aim, carrot samples showing root disease symptoms were collected from culture growing areas located in Ankara provinces in Central Anatolia Region,Turkey. Rhizoctonia fungus had been isolated from necrotic lesions of the carrot roots.and the above mentioned fungal isolates had been identified on the basis of hyphal and colony morphology along with anastomosis reaction with known tester isolates of the same pathogen.Pathogenicity tests such as hypocotyl test and carrot disc method,were conducted on three isolates of Rhizoctonia solani AG4 and one isolate of binucleat Rhizoctonia. The disease severity values of R. solani AG-4 isolates and binucleat Rhizoctonia were found between 73,00 to 48,00% and 43,50%, respectively in carrot disc pathogenicity tests. Disease values were determined as 67,00 to 84.50 % and 55.50% in hypocotyl test, respectively. In conclusion, the results of these two methods were almost similar and thus, both methods from the present work proved to be very effective and efficient methods for pathogenicity test.*

Key words: *Carrot, crown rot, Rhizoctonia, pathogenicity test, methodology.*

1. INTRODUCTION

Carrot (*Daucus carota* var. *sativus* Röhl.) is one of the most popular and commonly consumed vegetables becauses it is rich in vitamins, minerals and fibers. The marketable portion of the crop, the carrot root, is subjected to a wide range of field stresses which include diseases, nematodes and variations in soil conditions. Many biotic stresses hamper carrot production and specifically, fungal diseases cause huge economic losses [7]. In Turkey, carrot cultivation occupies about 10,849 hectares with a production of 569,533 tonnes.It is widely planted in the Anatolia region that includes Ankara province producing nearly 40 % of Turkey's carrots [1]. Root and foliar diseases, are one of the most important factors limiting carrot production worldwide. Among them, *Rhizoctonia* spp. leading to significant root and crown diseases can cause yield losses in carrot. Besides, *Rhizoctonia* fungi are responsible for three important carrot root diseases: crown rot (*Rhizoctonia solani* J.G. Kühn 1858), violet root rot (*Rhizoctonia crocorum* (Pers.) DC. 1815) and crater rot (*Rhizoctonia carotae* Rader 1948). Crown rot of carrot, caused by *R.solani*, was firstly reported by White in 1926 in [17]. *Rhizoctonia solani* Kuhn (telemorph: *Thanatephorus cucumeris* (Frank) Donk) is an economically important fungus that causes diseases on a great variety of plants worlwide. The pathogen is a soil inhabitant and can persist in the soil for long periods as sclerotia or mycelium in infested crop residues [6]. *R.solani* isolates are divided into distrinct groups, called anastomosis groups (AGs), that have different virulence levels and in some cases preferred host ranges.The groups affecting carrots are mainly AG2-2 and AG-4, occasionally AG-1[10]. Crown rot is caused by the same *Rhizoctonia* fungus which causes damping-off when seedlings are small. On carrot roots, early symptoms are horizontal dark brown lesions and as the crop matures the tops may die in patches in the field [5].

To study the seed and soil borne pathogens different methods have been tried. Establishment of disease by artificial inoculation is essential for plant pathology studies, including epidemiology, etiology, disease resistance, host-parasite interaction and disease control.

The aim of the present work was to develop a low cost, rapid screening method for disease phenotyping and identification of resistance traits. For this porpose, a comparison was carried out among two different artificial inoculation methods: 1) seed hypocotyl test and 2) carrot disc test for pathogenesis studies of *R.solani* from carrot.

2. MATERIALS AND METHODS

2.1 Survey and fungal isolation

In order to identify species of *Rhizoctonia* causing diseases on carrot root, surveys were carried out in carrot production areas in Ankara province,Turkey (Fig. 1). Samples were taken from carrot fields in Ayaş and Beypazarı districts of Ankara.The infected carrot crown and root pieces were initially surface-sterilized with sodium hypochlorite [1,0% (w/v)] for 2-3 min then rinsed in sterile water three times before they were placed onto potato dextrose agar (PDA, Merck,Germany) Petri plates containing streptomycin (50mg/L). The Petri plates were incubated at 24±1°C with a 12-h photoperiod for 7-10 days. Fungal isolates were stored on PDA slant tubes at 4°C.

Fig.1 Geographic location of the survey performed for *Rhizoctonia* species identification from carrot in Central Anatolia Region-Turkey.

2.2 Identification of fungus

Fungal cultures (12-15 day-old) grown on PDA (with 50 mg/L streptomycin) were used for fungus identification based on both culture morphology and growth rate[4]. In order to determine hyphal diameter and the number of nuclei per cell, *Rhizoctonia* isolates were maintained on PDA at 25 °C and in darkness. Developing mycelia were stained with safranin O (Sigma, USA) and 3% KOH [2] and observed under phase contrast microscopy at x 400 magnification. Hyphal diameter was determined by measuring 10 cells. Nuclei were counted in 15 cells.

Anastomosis was tested by pairing isolates with representative testers of *Rhizoctonia* isolates. Tester isolates were activated on PDA at 25 °C in the dark. Coverslips, sterilized by dipping in 95% ethyl alcohol and flaming, were coated with a thin layer of 0.5% PDA and placed on water agar plates. Agar plugs with mycelia of *Rhizoctonia* isolates and the tester isolates were cut from the margins of a growing colony and transfered to water agar plates on the opposite sides of the coverslip. After incubation at 25 °C for 24-48 h in the dark, when overlapping mycelia of two isolates were observed, the coverslip was removed from the plate and placed on a slide in the mixture of one drop of safranin O and one drop of 3% KOH. Stained hyphae were observed microscopically. Anastomosing hyphae were traced back to their source in order to confirm the anastomosis between our isolates and the tester isolates [12, 4]. For the anastomosis testing, all pairs were examined twice. At least 15 cells were identified. Based on the cultural and morphological characteristics of the isolates, their properties were compared with those reported in the literature and their diagnoses were made according to Sneh et al. [15].

2.3 Pathogenicity Test

Two different methods were used for pathogenicity test in order to select the one which may be standardized for pathogenicity and pathogen variability/ aggressiveness analysis: a) seed hypocotyl test and b) carrot disc test.

2.3.1.Seed hypocotyl test

To determine pathogenicity of *Rhizoctonia* isolates the "Nantes" variety of carrot was used. For seed hypocotyl test, 4 mm diameter discs taken from 2 day old PDA pure cultures of *Rhizoctonia* were placed in the centre of 2% water agar plates and incubated at 24±2°C with a 12-h photoperiod for 10 days. At the same time, 10 sterilized seeds were placed around 3 cm away from discs (Fig. 2). Control Petri plates contained only agar discs. After 10 days incubation,the hypocotyls of the plants were examined and evaluated for disease severity by using a 0-5 scale [9]. Four plates were used for each isolate and the experiments were repeated 3 times.

Fig. 2 Petri plates containing PDA and germinated sterilized carrot seeds used in seed hypocotyl pathogenicity tests..

2.3.2.Carrot disc pathogenicity test

Mature cv. "Nantes" carrots were assessed for pathogenicity of Rhizoctonia spp..Roots were first washed with tap water and then sliced into discs (approximately 5 mm thick). Successively, the discs were surface-disinfested by soaking them in 0,1% sodium hypochlorite for 5 min then triple rinsed with sterile water and placed on a paper towel for 1hr to dry. Finally, the carrot discs were placed in Petri dishes (20x100 mm) containing two Whatman No.1 filter papers moistened with 2 ml of an antibiotic solution (50mg/L). Carrot discs were inoculated with mycelial plugs (4 mm diameter) cut from the margins of an actively growing culture (Fig. 3). Controls were treated similarly using same sized pieces of water agar. The Petri plates containing inoculated discs were incubated on wire racks in clear plastic trays for 10 days at 24±2^{0}C, 12h light with 12-hour dark cycle. Pathogenicity test was evaluated after 10 days incubation according to a

0-3 scale [11]. A total of four Rhizoctonia isolates was tested, and each test was replicated four times.

2.3.3.Disease assessment

Isolates of *Rhizoctonia* spp. were assessed for their pathogenicity in hypocotyl test using a 0-5 scale [9], based on the relative size of a necrotic area present on the hypocotyl as follows: 0= no disease, 1= 1-10%, 2= 11-30%, 3= 31-50%, 4= 51-80% and 5= the entire surface of the hypocotyl was infected.

In the carrot disc method, the severity of the disease symptoms was assessed using a modified 0–4 scale [11] based on the extent of mycelial colonization and rot lesions observed on the surface of carrot discs (0= 0%; 1= 1%; 2= 2-25%; 3= 26–50%; 4= 51–100%) as shown in Fig. 3.

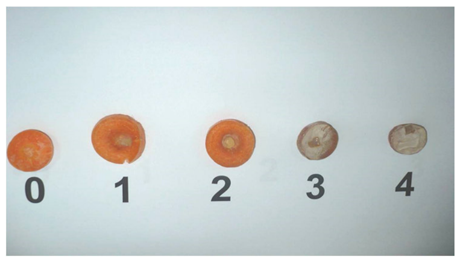

Fig. 3 Carrot discs displaying disease symptoms and the 0-4 scale used in the disease assessment.

The disease severity was evaluated using the Townsend-Heuberger's Formula [16]. The data were statistically analyzed using Minitab Statistic Programme (version 16.1.1)

3. RESULTS AND DISCUSSIONS

3.1.Survey and Identification of Fungus

Surveys done in carrot production areas in Ayaş and Beypazarı districts of Ankara province showed that root and crown diseases were more prevalent (8,78%) than foliage diseases in Beypazarı and also the disease ratio value of root diseases was higher (13,88%).

Fungal siolates belonging to *Rhizoctonia* spp.have been obtained from necrotic lesions of carrot roots and identified on the basis of their hyphal, colony morphology and anastomosis reaction with known *Rhizoctonia* tester isolates.

3.1.1 Rhizoctonia solani AG- 4

It has been determined that four isolates obtained from Beypazarı and Ayaş districts belong to the AG-4 group of *R. solani*. *Rhizoctonia solani* developed at 25 ± 1 ° C and in dark conditions with colony colors ranging from yellowish brown to brown at the end of the 10 day incubation period in the PDA medium (Fig.4).

Fig.4 Colony morphology and sclerotial characteristics of *Rhizoctonia solani* on PDA.

Sclerotia were formed flat irregularly shaped and of dark chestnut color on PDA. Multinucleate hyphal cells were clearly stained by safranin O. The average number of nuclei was 3.1 observed under phase contrast microscopy. According to the number of nuclei per cell with of the main runner hyphae isolates were identified as *R. solani*. As a result of anastomosis testing, three isolates anostomosed high fusion freguency with tester isolates belonging to *R. solani* AG 4 (Fig. 5).

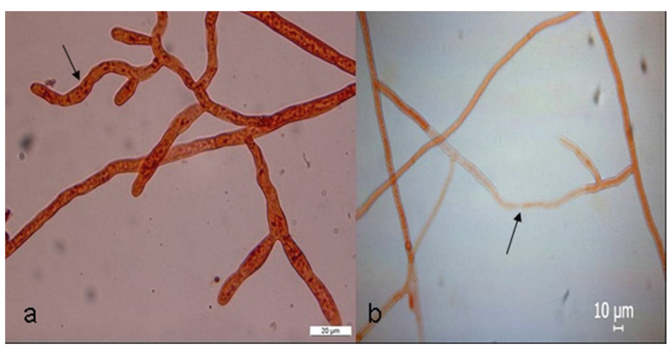

Fig. 5 Nuclear structure in *Rhizoctonia solani* hyphae (a) and anostomosis between hyphae (b).

3.1.2 Binucleat Rhizoctonia sp.

As a result of nuclei staining, one of the *Rhizoctonia* isolates obtained from carrot cultivation areas (Ayaş) was determined as being a binucleat *Rhizoctonia* sp. Furthermore, this isolate growth on PDA was whitish yellow and sclerotia formed in a more obscure yellowish color. It were found that the average number of nuclei was 2 at between two septa (Fig. 6).

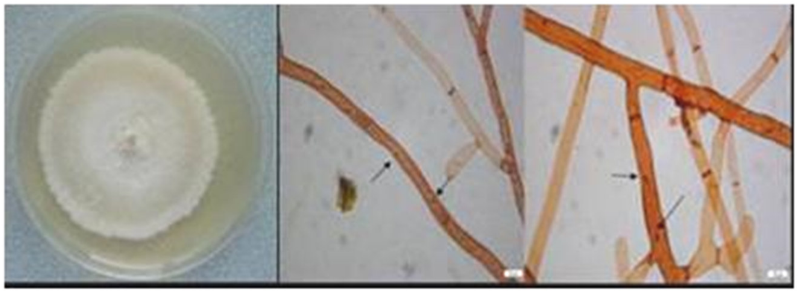

Fig. 6 Colony morphology of binucleat *Rhizoctonia* sp. on PDA (left) and nucleus number in hypha cell (right).

3.2 Pathogenicity Test

Pathogenicity test such as hypocotly test and carrot disc method, were conducted on two isolates of *Rhizoctonia solani* AG4 and one isolate of binucleat *Rhizoctonia*. The binucleate *Rhizoctonia* isolate showed low disease severity values (55.50 % and 43,50%) in both tests compared to other isolates investigated. Whereas, *R. solani* AG-4 isolates exhibited high pathogenicity (Table 1). Some studies in the world have similar results to our study [13,14]. On carrot plant, AG-4 and AG–2-2 IV isolates killed all seedlings and caused extensive rot on mature root tissue whereas isolates of binucleate *Rhizoctonia* sp. damaged neither seedling nor mature root tissue [14]. In another study conducted with *R. solani* (AG-4) in carrots, it was stated that the agent causes damping of carrot seedling [13].

Table 1. Disease severity values of *Rhizoctonia solani* AG-4 and Binucleat *Rhizoctonia* isolates obtained from Ankara province.

District	Pathogen	Isolate No.	Seed Hypocotyl Test	Carrot Disc Method
			Disease Severity (%)*	Disease Severity (%)*
Beypazarı	*R. solani AG-4*	1-1-6	84,50±6,18	66,75± 8,35
Beypazarı	*R. solani AG-4*	1-1-5	81,00±7,68	73,00± 9,21
Ayaş	*R. solani AG-4*	300	67,00±5,20	48,00±12,00
Ayaş	Binucleat *Rhizoctonia*	301	55,50±1,71	43,50± 5,11
LSD (P≤0,05)			12.17	15.30

*Each value represents mean±SD of four replications per treatment.

Results of carrot disc pathogenicity tests showed that disease severity values of *R. solani* AG-4 isolates and binucleat *Rhizoctonia* ranged from 43,50% to 73,00%. Whereas, disease values in seed hypocotyl test, were slightly higher than in the other method and ranged from 55.50% to 84.50%. Overall, the outcomes of both methods were almost similar. However, usually the virulence of *Rhizoctonia* isolates was found to be higher in the hypocotyl test than in the carrots disc method. Non-inoculated seeds and carrot discs remained healthy. The pathogen was always re-isolated from diseased hyphocotyl and carrots and confirmed to be *R. solani.*

Generally, for *Rhizoctonia* spp. several inoculation methods have been used such as seed inoculation, root dip and spore suspension methods. In addition to, agar methods, seedling test, hypocotly test were used depending on host, *Rhizoctonia* species, and host-pathogen interaction [8,13,14]. Baskar et al. [3] studied five different methods of inoculation for sheath blight on rice and, among these, the grain inoculation and covering with polythene bags was found to be the best in plant infection.

Both methods employed in present work showed to be the most effective and efficient methods for pathogenicity test and to check the aggressiveness of the pathogen. In conclusion, these two methods proved to be more easy, rapid, practical and reliable compared to the seed inoculation and the root dip method.

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THE USE OF CHIA SEED (SALVIA HISPANICA L.) ON FOOD INDUSTRY

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Abstract: *Chia seed is a prehistoric seed variety that has become popular in recent years due to its high content of fat, protein and dietary fiber. Chia seeds are seen as a healthy food product that is added to foods in different proportions or found in foods as a component. What attracts the attention of consumers are its beneficial properties to health. In this review, chia seeds, bioactive components of chia seeds, health effects, musilage properties and application areas in food industry are briefly given.*

Key words: *Chia, Salvia hispanica L., seed, composition, bioactive properties, human health*

1. INTRODUCTION

Chia seed (*Salvia hispanica* L.) is a one-year herbaceous plant that belongs to the Lamiaceae family and extends from southern Mexico to northern Guatemala. It can be cultivated in tropical and subtropical regions. Seeds are grown commercially in Mexico, Bolivia, Argentina, Ecuador and Guatemala (Ixtaina et al., 2008). The annual production of chia seeds, dating back to the Aztec and Maya, is around 30 000 tonnes worldwide (Goh et al., 2016; Timilsena et al., 2016a).

Chia seed is a prehistoric seed variety that has become popular as super food in recent years due to its high content of fat, protein and dietary fiber (Cassiday, 2017). Chia seeds contain approximately 15-24% protein, 26-41% carbohydrate and 25-40% fat. It has been the subject of many studies mainly with high quality fat content, it has almost 55-60% linolenic acid (ω-3), 18-20% linoleic acid (ω-6), 6% monounsaturated ω-9 and 10% saturated fat content (Orona-Tamayo et al., 2017). In chia seed which is a good source of unsaturated fatty acids, n-6 / n-3 ratio was found to be 0.30. The low n-6 / n-3 fatty acid ratio has been associated with a reduced risk of cardiovascular disease (Biçer et al., 2017). Oil content and fatty acid composition of Chia seed are affected by seasonal conditions, growing conditions, genotype and geographical characteristics (Ayerza, 1995; Timilsena et al., 2016a).

Chia seeds are a promising source of antioxidants due to the presence of polyphenols, chlorogenic and caffeic acids, myricetin, quercetin and kaempferol, which protect consumers against adverse conditions such as cardiovascular diseases and certain cancers (Ayerza and Coates, 2001; Craig and Sons, 2004; Reyes-Caudillo and et al., 2008; Ixtaina et al., 2011). On the other hand, the seed contains more than 35% of the total weight of soluble and insoluble dietary fiber and is a rich source of B vitamins and minerals (Orona-Tamayo et al., 2017). In addition to magnesium, iron, zinc and copper, it has 6 times more calcium, 11 times more phosphorus and 4 times more potassium than 100 g milk (Ayerza and Coates, 2009).

Chia seeds have properties such as gel forming, emulsifier and stabilizer in foods. With its high omega-3 and omega-6 content, it is an important source in enriching nutrients in terms of functionality (Erdoğdu & Geçgel, 2019).

Chia seed is considered as a functional food due to its essential nutrients (Ergene & Bingöl, 2019). Functional foods have attracted considerable attention in recent years as components of healthy life. The term functional is used to refer to a regularly consumed food for physiological benefits, or to reduce the risk of chronic disease in addition to essential nutritional functions. Functional foods provide health benefits in addition to nutritional values contained in their chemical composition, and they play a potential role in reducing the risk of chronic degenerative disease (Pacheco and Sgarbieri, 2001; Al-Sheraji et al., 2013). It has protective effects against cardiovascular diseases, nervous system diseases, inflammatory and diabetes (Ergene & Bingöl, 2019).

2. HISTORY

2.1. Chia Seed in General

Chia seed (Salvia hispanica L.) is a one-year herbaceous plant belonging to the Lamiaceae family, extending from its native Mexico to southern Guatemala (Ergene and Bingöl, 2019). It is known that it was used by Aztecs and Mayans since 3500 BC (Ulbricht et al., 2009). Traditionally, chia seeds have been used by the Aztecs and the Maya people in the preparation of folk remedies, food and canvas (Armstrong, 2004). Chia seed was not only used as a food, but also offered to the Aztec gods (De Meester and Watson, 2008).

In Mesoamerican societies, chia seeds were added to water and cooked by mixing with flours from different cereals (Valdivia-López and Tecante, 2015). It is known that the Aztec and Mayans used chia seeds as a part of traditional medicine for medicine making, dyeing and increasing the strength and endurance of warriors. Chia seed was defined as running food by Aztecians because it is a nutrient that the messengers carrying messages at that time frequently consumed in order to give energy (Muñoz et al., 2013).

The word Chia comes from Nahuatl, an ancient Aztec language which means that the word ian Chian ”is“ fatty “. When the Chia plant blooms, it blooms purple or white. The seeds of the Chia plant typically have very small and oval shapes. Chia seeds generally have an irregular color combination that can include black, brown, white or gray tones (Koç, 2018). Chia seeds have an oval shape with a diameter of approximately 1.9-2 mm in length, 1-1.4 mm in width and 0.8-1 mm in thickness (Imran et al., 2016).

The polysaccharide structure that can form musilage in the shell as a result of the contact of the seed with water forms a gelatin structure like a capsule around the seed by holding water (Moreira et al., 2012). Mucilage is concentrated in the outer part of the seed shell and constitutes 5-6% of the dry weight of the seed. Mucilage structure is easily soluble in water (Ergene and Bingöl, 2019). This gelatinous musilage structure contains components such as xylose, glucose and 4-methyl glucuronic acid (Yurt & Gezer, 2018). The mucilage structure consisting of 2:1 xylose: glucose has a molecular weight of 800-2000 kDa (Timilsena et al., 2016a).

Chia seeds have the ability to hold up to 27 times its own weight and quickly form mucilage when it meets water (Muñoz et al., 2013). With this feature, chia seed stands out as a potential natural thickener that can replace commercial thickeners used in the food industry (Özbek and Yeşilçubuk, 2018). In addition, the gel formed is also a suspending agent, emulsifier, adhesive and binder capable of water retention (Alfredo et al., 2009). It is thought that chia seeds can be used instead of fat, eggs and sugar in the food industry (Muñoz et al., 2012).

2.2. Cultivation Place and Climate Conditions

Worldwide, countries that produce food products containing chia seeds and chia seed production in Mexico, Argentina, Australia, Bolivia, Colombia, Ecuador, Nicaragua and Paraguay (Ramos et al., 2017). Chia seed is a perennial and hermaphrodite plant that grows in tropical or temperate climates. Chia seeds bloom in summer and the length of this plant is approximately one meter, the length of the leaves is 4-8 cm and the width is 3-5 cm (Yurt and Gezer, 2018). Seeds are oval, smooth and bright and their colors are black, gray and black to white. Their size is between 1 mm and 2 mm (Ayerza and Coates, 2005).

Agriculturally, chia plants require temperatures of 11-36 °C for growth and development, while optimum growth conditions are described 16-26 °C by Bochicchio et al. (2015). It was reported that it grows on sandy and well-drained soils with pH 6.0-8.5 and can adapt to low nutritional concentrations (Yeboah et al., 2014). Chia plant is resistant to salt concentrations, seed oil of plants grown in saline soils significantly reduced (Heuer et al., 2002). The plant can grow on very well drained clay and sand soils with a reasonable salt and acid tolerance (Ullah et al., 2016).

While chia production is carried out in certain areas such as Bolivia and Paraguay, other countries such as Mexico, Australia and Argentina have started to grow chia plants in the last decade (Orona-Tamayo et al., 2017). A value of $ 8,000-12,000 per ton was reached in 2013 and then demand for production increased in 2014 (Orona-Tamayo et al. (2017). They reported chia production worldwide and it is clear that there was an increase in production in 2014. Bolivia is one of the largest producers of chia that exports this seed in large quantities. At the same time, Bolivia was the largest producer in 2013, while Argentina's production was the highest in 2014 (Koç, 2018).

There are many factors that can cause changes in the components of Chia seed. Depending on the planting area, climate change, harvest year, soil conditions, total oil content of chia seeds may vary between 25-40% (Mohd Ali et al., 2012). Ayerza and Coates (2011) examined the changes in chia seed components grown in different countries and different conditions. They observed that protein content decreased with increasing elevation and polyunsaturated fatty acids decreased with increasing temperature. In addition, it is reported that chia seed oils grown at low altitude contain more saturated fatty acids compared to those at high altitude (Ayerza, 2010). Early harvesting of Chia seeds resulted in a 23% loss of α-linolenic acid content and an increase in linoleic acid and lignin levels (Peiretti and Gai, 2009).

3. BIOACTIVE COMPONENTS OF CHIA SEED

100 g of Chia seed contains 42.1 g of carbohydrate, 30.7 g of fat and 16.5 g of protein, giving about 486 kcal of energy. The seed contains high amounts of α-linolenic acid (ALA, n-3) which is one of the essential fatty acids. Although calcium, phosphorus, potassium and magnesium content is high, sodium, iron and zinc content is low. In addition, niacin, vitamin A and dietary fiber content is rich and vitamin C is insufficient (Yurt & Gezer, 2018). Chia seeds were found to have safe levels of heavy metal content, did not exceed the maximum metal levels in terms of food safety and the seeds were found to be free of mycotoxins (Bresson et al., 2009). Another important feature of Chia seed is that it does not contain gluten. With this feature, it is an alternative food for individuals with gluten allergy (Bueno et al., 2010). Chia seed has a higher vitamin and mineral content compared to other cereals. There are 6 times more calcium, 11 times more phosphorus and 4 times more potassium than milk. Iron content is higher than spinach. Calcium, phosphorus and potassium content is higher than wheat, rice, oats and corn (Muñoz et al., 2013).

In literature studies, it was observed that chia seeds contain approximately 25-40% fat, 15-20% protein and 26-41% carbohydrate (Orona-Tamayo et al., 2017). Some of the average nutrient components of chia seeds in the US Department of Agriculture database are shown in Table 1. The energy value of 100 g chia seed was reported to be about 486 kcal. It is reported that calcium, phosphorus, potassium and magnesium are 335-860 mg in 100 g chia seeds and 4.58-16 mg in sodium, iron and zinc (Erdoğdu and Geçgel, 2019).

Chia was once considered to be the main source of grain for the people of Mexico and Guatamala, but now has a large proportion of consumers (Jamboonsri et al., 2012). Because of its nutrient content, chia seeds are seen as a functional food to maintain and improve health (Marcinek and Krejpcio, 2017). Often as seeds, flour can be obtained and added to various foods, oil can be consumed as a nutritional support. For example, chia seeds and flour may be added to breakfast cereal, bread, cakes, sweets and various beverages. Chia seed has become a popular functional food due to its health effects, particularly in relation to its prominent fatty acid pattern and antioxidant capacity (Oliveira-Alves et al., 2017).

Table 1: Chia seed energy and nutrient composition (Yurt and Gezer, 2018).

Component	Quantıty (100g)
Energy (kcal)	486
Carbohydrate (g)	42.1
Protein (g)	16.5
Leucine (g)	1,378
Phenylalanine (g)	1.016
Lysine (g)	0.970
Valine (g)	0.950
Isoleucine (g)	0.801
Threonine (g)	0.709
Methionine (g)	0.588
Histidine (g)	0.531
Tryptophan (g)	0.436
Oil (g)	30.7
Saturated fatty acids (g)	3.3
Monounsaturated fatty acids (g)	2.3
Polyunsaturated fatty acids (g)	23.6
Linoleic acid (18: 2)	5.8
Alpha linolenic acid (18: 3)	17.8
Dietary fiber (g)	34.4
Calcium (mg)	631
Iron (mg)	7.7
Magnesium (mg)	335
Phosphorus (mg)	860
Potassium (mg)	407
Sodium (mg)	16
Zinc (mg)	4.5
Vitamin C (mg)	1.6
Thiamine (mg)	0.62
Riboflavin (mg)	0.2
Niacin (mg)	8.8
Vitamin A (IU)	54
Vitamin E (α tocopherol)	0.5

3.1. Protein Content

The protein content of Chia seed varies between 15% and 23% (Yurt & Gezer, 2018). With a protein content of 20%, chia has great potential to correct and prevent protein energy deficiency. The protein content of the seed depends largely on environmental and agronomic factors. The protein content of Chia seed is greater than the protein content of most grains (Ullah et al., 2016). Therefore, corn (14%), wheat (14%), rice (8.5%), barley (9.2%), oat (15.3%) and amaranth (14.8%) cereals were higher compared to the protein content (EFSA, 2009). The seed contains all essential amino acids in an appropriate amount. It is also a source of food that celiac patients can consume because it does not contain gluten (Marcinek and Krejpcio, 2017).

The amino acid profile does not constitute a restriction for the adult diet, but may be found to be insufficient for preschool children due to the limited content of lysine, leucine and threonine (Capitani et al., 2012). Chia seed contains all essential amino acids, but also contains high amounts of non-essential amino acids such as glutamic acid, arginine and aspartic acid (Timilsena et al., 2016b; Timilsena et al., 2016c). Protein structure consists of 4 different fractions and the most important component is globulin. Along with globulin, albumin, glutelin and prolamine are among the fractions that make up the structure. 52% of the total protein fraction was composed of globulin and the remaining fraction was equal to other fractions (Timilsena et al., 2016c).

Chia seed contains globulin (52%), albumin (17.3%), gliadin (14.5%) and prolamine (12.7%) proteins (Sandoval-Oliveros and Paredes-López, 2012). The highest globulin protein; glutamic acid, aspartic acid, threonine and histidine. Glutamic acid is an important amino acid for metabolic activities as well as stimulates the central nervous system, increases immune functions and increases endurance for athletes (Brosnan and Brosnan, 2013; McCormack et al., 2015). Chia seed meal contains sulfurous amino acids (cystine and methionine; 2.7 g), arginine (4.2 g), aspartic acid (4.7 g) and glutamic acid (7.0 g). Aspartic acid helps regulate nervous system functions, and arginine may have protective effects against cardiovascular diseases (Sandoval-Oliveros and Paredes-López, 2012; Boger, 2014).

3.2. Oil Components

Recent assessments of Chia's properties and possible uses have shown that it has a high fat content (32%), and that 60% is linoleic acid, which is associated with a fatty acid type omega 3, which has various benefits to consumer health (Rosamond, 2002).

Chia seeds are a rich source of unsaturated fatty acids. Chia seed oil is unique in that it contains a higher proportion of omega 3 than all known natural sources (Ayerza, 1995; Coates, 1996). Chia oil contains quite unsaturation. The content of polyunsaturated fatty acids is about 83%. The linoleic acid content (LA) is approximately 18% and the α-linolenic acid content (ALA) is about 64%, which is unique among general vegetable oils such as sunflower, rapeseed, olive and soy. Chia oil is also qualitatively different from the less common vegetable oils such as flax with a ALA content of 53.3% with a high content of PUFA (Bhatty, 1993).

Chia seeds contain 30-35% oil on average (Muñoz et al., 2013). The location, temperature and time of harvesting of Chia seed affect the amount of fat and the fatty acid pattern. Decrease in height of the chia plant from the sea and increase in ambient temperature may cause an increase in saturated fatty acid levels. The rate of polyunsaturated fatty acid may decrease due to the increase in air temperature of seeds growing in April-May (Ayerza, 2009).

The n-6/n-3 ratio of fat was determined to be 0.3, which may reduce the risk of cardiovascular disease due to its low rate (Timilsena et al., 2017). The ratio of n-6/n-3 in chia seeds is quite low compared to other vegetable oils such as corn (76.5), canola (2.2), soy (6.7) and olive oil (17.8) (Álvarez-Chávez et al., 2008).

3.3. Dietary Fiber Content

Chia seed contains 34–40 g dietary fiber per 100 g and the contribution of an adult person to the amount of dietary fiber required per day is high. Dietary pulp fraction of Chia seed consists of soluble dietary pulp which can be used in 53–56% metabolism. The emulsifying activity of corn gluten, which is used as a commercial emulsifier in the food industry, is 49.3%, the stability of the resulting emulsion is 39.7%, whereas the emulsifying activity of the chia seed dietary fiber is 53.3%, the stability of the resulting emulsion is 94.8% (Alfredo et al., 2009).

Dietary fiber found in foods and especially whole grains is an important biocomponent due to its potential health benefit. Numerous research studies have shown that fiber consumption has an effect on reducing the risk of coronary heart disease, type 2 risk of diabetes mellitus and various types of cancer (Reyes-Caudillo et al., 2008). Dietary fiber consumption is associated with increased post-meal saturation and reduces subsequent hunger. According to the American Dietetic Association, dietary fiber has provided benefits for health care and disease prevention (Ullah et al., 2016).

3.4. Phenolic Compounds and Antioxidant Effects

Chia seeds contain phenolic compounds with high antioxidant capacity. (Uzbek and Green Sticks, 2018). Chia seeds and oils extracted from chia seeds are rich in point of various natural antioxidants such as tocopherol, phytosterol and carotene (Álvarez-Chávez et al., 2008; Ixtaina et al., 2011). It also contains chlorogenic and caffeic acid-containing phenolic compounds that protect consumers from various diseases and promote human health (Capitani et al., 2012).

An important part of these phenolic compounds are tocopherols. Flavonoids and tocopherol are the main components responsible for the antioxidant capacity of the seed. The antioxidant capacity of Chia seeds is 84/g and this value is very close to the antioxidant capacity of blueberries (96/g) (Pellegrini et al., 2003). The high antioxidant capacity allows the seed to be stored for a long time (Yurt & Gezer, 2018). The tocopherol content (238–427 mg/kg) of Chia seeds is similar to the tocopherol content of peanuts (398.6 mg/kg). In addition, the tocopherol content of chia seed is low when compared to the tocopherol amounts of flax seed (588.5 mg/kg), sunflower seed (634.4 mg/kg) and soybean (1797.6 mg/kg) (Muñoz et al., 2013).

The majority of phenolic compounds in Chia seed are chlorogenic acid (7.1 × 10-4 mol / kg), caffeic acid (6.6 × 10-3 mol / kg), quercetin (2 × 10-3 mol / kg) and kaemferol (1.1 × 10-3 mol / kg). It has been reported that the antioxidant properties of these components are much stronger than the antioxidant properties of vitamin C, ferulic acid and vitamin E (Muñoz et al., 2013).

4. THE EFFECT OF CHIA SEED ON HUMAN HEALTH

In recent years, chia seeds have become increasingly important in human health and nutrition due to their high α-linolenic fatty acid content and beneficial health effects when consumed (Coates, 2011). Clinical studies have shown that consumption of chia seeds can provide metabolic control of type 2 diabetes and cardiovascular diseases as well as weight loss in obesity due to nutrient content of the seed (Yurt & Gezer, 2018). Another important factor in increasing consumer interest in chia seeds is due to its role in regulating blood pressure control and blood sugar levels and in the treatment of disorders such as reflux and heartburn (Timilsena et al., 2016). Research studies have reported that the seeds and biochemical components of Salvia hispanica L. help maintain serum lipid levels, increase saturation index, and protect against inflammation, nervous system disorders and diabetes (Jin et al., 2012). A larger α-linolenic fatty acid source improves antioxidant status, fat oxidation capacity, n-3 long-chain polyunsaturated fatty acids content and reduces the activity of fat synthesis biological tissue (Rincón-Cervera et al., 2016). With soluble pulp content, it keeps the water in its structure and increases the feeling of saturation, slows down digestion, and slows insulin release by providing a slow rise in blood glucose after meals (Vuksan et al., 2007). In addition, it changes the intestinal functions in a positive way, decreases the serum cholesterol by inhibiting the absorption of bile acids and reduces the risk of cancer with its antioxidant properties (Borderías et al., 2005). Chia seeds can be seen as a healthy food product that is added to foods in different proportions or can be found in foods as a component. What attracts consumers' attention is their beneficial properties to health. The recommended usage amount on the market is around 15-25g/day. Benefits of daily consumption; It can be listed as lowering cholesterol and blood pressure, helping to lose weight, reducing joint pain, increasing endurance and antioxidant effects (Koç, 2018). Toscano et al. (2014) and Vuksan et al. (2007) reported that chia consumption of 35 to 37 g per day has beneficial effects on health. Orona-Tamayo et al. (2017) reported that ω-3 and ω-6 fatty acids contained in chia oil act as epidermal barrier and prevent melanin hyperpigmentation. Therefore, it is one of the important benefits of the application on the skin. It has been suggested that it can benefit the cosmetic and pharmaceutical industries.

5. USAGE OF CHIA SEED IN FOOD SECTOR

In addition to its rich content and beneficial effects on health, Chia seed is a food with many properties that can be used as thickener, emulsifier and stabilizer in the food industry. Thanks to its high content of chia gamma and mucilage-forming properties, it has a high potential to replace commercial thickeners (Karaki et al., 2016). Unlike other thickeners, chia seeds are expected to replace commercial thickeners as they have other functional components in terms of nutrition (Özbek and Yeşilçubuk, 2018). Chia seed is not allergic, does not show any toxic effects and edible by participating in food has been proved by scientific studies (Borneo et al., 2010). Chia is often consumed as chia seed salad. Chia seeds can also be consumed as drinks, cereals, salad dressings or raw (Mohd Ali et al., 2012). The approval of chia seeds by the European Parliament as New Food has led to the high use of chia seeds in a wide variety of foods. It is already known that Chia has no anti-allergic, anti-nutritional and toxic effects on human health. Biscuits, pasta, cereal bars, snacks, yogurt and cakes are usually supported by chia seeds (Borneo et al., 2010). In 2000, the US Dietary Guidelines recommended the use of up to 48 g of chia seeds per day. The European Commission determined that the use of chia seeds in bread products should not exceed 5% (Mohd Ali et al., 2012). Looking at the updated 2013 proposal, baked goods, breakfast cereals, fruit, nuts and seed mixtures should not contain more than 10% chia seeds. In addition, the consumer should be informed that the packaging does not contain more than 15 g/day chia seeds on the product label (Guevara-Cruz et al., 2011). In the studies using bread with Chia seed flour, it was determined that the use of Chia seed flour did not complicate the bread making process. Adding Chia seed mucilage to bread dough increased dough stability (Zettel et al., 2015). Chia seed flour is an alternative food product with high nutritional value and suitable for consumption of celiac patients because it does not contain gluten (Özbek and Yeşilçubuk, 2018). By using chia seed flour instead of wheat flour in the bread, it was observed that the nutritional value of the end product increased and the staling rate decreased, and an increase was observed in slice volume and hardness (Coelho and de las Mercedes Salas-Mellado, 2015; Pizarro et al., 2015). Costantini et al. (2014), it was observed that total phenolic content increased with the addition of 10% chia seed flour to bread, 75% increase in total antioxidant capacity and suitable for gluten-free bread production.

It has been determined that breads prepared using Chia seeds (11.0g /100g) and flour (0.9g /100g) have an approximately 3-fold increase in the amount of polyunsaturated fatty acids and may be preferred by the consumer (Coelho and de las Mercedes Salas-Mellado, 2015). Zettel et al. (2015), in their study using 5 g and 10 g /g water formed chia seed gels were added to whole grain flour in 1-3%. When the appearance, stability and softness of the bread were evaluated, they observed that an optimal dose of chia gel prepared with 5 g /g water and added with 2% dough or 1% added chia gel with 10 g /g water was formed. Breads prepared with chia gel can be consumed as a functional food (Yurt & Gezer, 2018). Apart from bread, chia seeds have been widely used in the food industry of various countries such as USA, Canada, Chile Australia, New Zealand and Mexico for different applications such as oily breakfast cereals or oily cereals, bars, juices, cakes and yogurt (Borneo et al. 2010). In addition to bread, the use of Chia seed flour has been a suitable raw material in bakery products such as cookies. It was observed that nutritional quality and physical parameters improved in oatmeal cookies, which were made by replacing oatmeal with Chia seed flour, but height increased as the diameter of cookies decreased (Inglett et al., 2014). Chia seed or flour has been the subject of various studies in the evaluation of the appearance and flavor of the final product due to the addition of nutrients. Coorey et al. (2012) using chia flour as an alternative to unhealthy chips in his study; obtained high omega-3 and gluten-free chips with high dietary fiber. Chia flour was used in different amounts (5%, 10%, 12%, 15%) in cips and they observed differences between color, odor and appearance. Consumers' preference was chips with 5% chia flour. Menga et al. (2017) aimed to increase the nutritional profile of pasta by using chia seeds and chia musilage as thickening agent in gluten-free pasta production. It was stated that the nutritional value of the pasta added with chia increased and the phenolic content was higher than the pasta prepared with wheat. In this study, instead of starches used for the development of the structure in products prepared as gluten-free in general, a product with high nutritional value and adhesive properties such as chia has been proposed. In a study using Chia musilage gel instead of oil; It was observed that the appearance, texture and flavor of the cake did not change when chia musilage gel was added instead of 25% of the oil used for cake (Felisberto et al., 2015). In the food industry, the musilage-forming effect of chia seed is used in foods such as mayonnaise, sauces and yogurt in order to make the fom structure more stable (de la Paz Salgado-Cruz et al., 2013). It has been observed that chia seed mucilage extracted under optimal conditions is suitable for use as stabilizer and emulsifier in ice cream (Campos et al., 2016). It was also observed that chia oil added to ice cream increased the amount of omega-3 fatty acids and antioxidant properties in ice cream (Ullah et al., 2017).

In another study, sugar-free marmalade was prepared by adding chia seeds and it was aimed to develop a high-nutritional breakfast product for diabetic patients and individuals aiming to lose weight. In the study conducted by Özbek (2016), chia seeds in strawberry marmalade were used instead of pectin with their thickening properties. It was observed that the gelling capacity of chia seeds was higher than that of chia flour and that the gelling properties of chia seeds were very close to the modified pectin species. The value of 5% for the addition of Chia seeds was found to be the most acceptable level. While the pH of the control sample was 3.43, the pH value of the chia added marmalade was determined to be 4.43 and it was emphasized that the pH level could pose a risk for microbial deterioration. It was determined that phenolic compounds increased by 15.45%, dietary fiber by 168% and energy value decreased by 48%. It was also observed that the viscosity of marmalade increased with the addition of chia seeds. Thanks to the positive results obtained, chia seed added, sugar free strawberry marmalade product was evaluated as functional food.

6. CONCLUSION

As can be seen from this summary information, chia seeds have effects on nutrition and health. Chia seed has a high lipid, protein and fiber content compared to other seeds. Fiber, one of the Chia seed components, is important for the production of other products as emulsifiers due to its high water holding capacity (Coelho and Salas-Mellado, 2014). In addition to being functional raw materials in the food industry, chia seeds and products obtained from chia seeds increase the nutritional value of the nutrients they adapt to their formulations (Özbek and Yeşilçubuk, 2018). To date, some studies have reported beneficial and protective effects of chia seed consumption on cardiovascular diseases and diabetes, hypertension, and other diseases (Vuksan et al., 2007; Toscano et al., 2014; Valenzuela et al., 2015). The content of omega-3 fatty acids of Chia seed appears to have a positive effect on the mechanisms of these chronic diseases (Jin et al., 2012). It has been reported that chia seeds containing high phenolic compounds with antioxidant capacity can provide health benefits when used in food products (Coelho and Salas-Mellado, 2014). In our country, it has gained importance in diets targeting body weight control because it contains a high proportion of dietary pulp and thus reduces the feeling of hunger (Özbek and Yeşilçubuk, 2018).

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VERY SHALLOW GEOTHERMAL SYSTEM FOR ENERGY EFFICIENCY IN DAIRY BARNS

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Abstract: *In dairy farms, energy is used in several activities, one of the most energy consuming phase is the milk cooling. This operation, necessary to guarantee the safety of the product, takes place in cooling tanks powered by electric energy.*

On the other hand, farms must provide large amount of water for cow daily drinking needs. The water is usually supplied by natural wells or aqueduct, in some cases water temperature can be so low that cows are discouraged from drinking, with consequent risks for animal health and production losses. For this reason, a few heat exchangers have been designed to pre-cool milk, taking advantage from cow drinking water and allowing considerable milk temperature reduction and slight water temperature increase. Even though this operation cannot replace cooling tanks, it reduces the energy needs. Recent studies have shown the potentialities of the application of shallow geothermal systems to food processing buildings aimed at energy efficiency. Shallow geo-exchangers configurations can be used to dissipate excessive heat in the ground. Unfortunately, the dissipation potential of the ground is limited, so a large number of geo-exchangers is usually necessary, with related high cost and need of space. A newly developed configuration of spiral geo-exchangers with double circuit could tackle this issue, by dissipating the heat partially to the ground and partially to a secondary fluid. For the specific case of barns, a double advantage should be expected since the waste fluid (water), heated up, can be used as cow drinking water.

The aim of this work is to assess the potentialities of the application of the system in a dairy farm. The study uses experimental data from a thermal response test campaign carried on a shallow geothermal system and data for water consumptions of a farm located in Bologna countryside (Italy).

Key words: *dairy barn, geothermal energy, renewable energy, energy efficiency, shallow geoexchangers*

1. INTRODUCTION

Energy consumptions will significantly increase in all energy-consuming sectors in the future decades [1]. Agri-food is a very complex energy-consuming sector since it is based on several feedstock and manifold production steps. Therefore, understanding the total energy content of final agriculture products and possible applications of renewable energy solutions is currently challenging. Besides, agriculture and livestock are the major energy consuming sectors and they are responsible together for 34% energy embedded in food-production in Europe [2], [3]. According to OECD [4], in the OECD area, 68% of the direct energy consumed in agricultural sector origins from fossil fuels whereas only 4% comes from renewable energy sources entailing an immediate change oriented to energy efficiency and sustainability.

Within this context, the dairy cattle farming sector is characterized by relevant energy demand. Energy requirements for the permanent equipment are mainly due to milk refrigeration, milking operations, artificial lighting, forced ventilation, manure removal. The animal welfare turns out to be an important aspect for both production quantity and milk quality, but at the same time requests specific indoor parameter ranges [5]. A proper environment requires from 50% to 80% of relative humidity [6] and needs of adequate air exchange (Flaba et al. 2014). These parameters are usually summarized by the Temperature-Humidity Index (THI) [7]:

$$THI=0.36\cdot T_{db}+41.2 \qquad (1)$$

where T_{db} represents the dry bulb temperature [°C] and T_{dp} the dew point temperature [°C].

In the warmer season, in order to mitigate the heat stress, which represents a serious threat to cow’s welfare and milk production, energy for microclimate control is needed. Moreover, a slight warming of the drinking water is advisable, especially in the cold days, in order to stimulate water intake so to improve milk production. The scientific literature [8] indicates, as optimal, a warmed water with temperature around 18°C.

Energy saving in dairy cattle barns represents, currently, an unavoidable design target. In particular, the dairy facilities can reuse energy of highly consuming milk cooling process to warm up the drinking water for cows.

Besides energy issues, a few concerns about the environmental impacts of livestock production have grown especially in the last two decades. Livestock productions have been acknowledged as intensive consumers of freshwater resources: beyond the usage for growing feed crops or forages, also drinking, cleaning and processing animal products call for significant water volumes.

Thus, just for example, a cow weighting 750 kg, producing 35 kg of milk/day, with an average temperature of 35°C and 50 g/day of sodium intake, will require about 136 kg/days of water according to Mekonnen and Hoekstra [9].

Energy efficiency strategies, including smart systems for optimal energy use and innovative renewable energy systems, also at the farm scale, are crucial for the progress of the livestock farming sector. Among the most innovative energy solutions, implementation of geothermal systems and utilization of heat waste including use of heat pumps was considered, in recent years, in several national and international projects in the agricultural sector, all of them emphasizing the importance of respecting the specific needs [10], [11].

The use of ground as heat-bank, so to overcome the mismatch between availability and needs, is called Underground Thermal Energy Storage (UTES) and can be used for both long and short-term purposes [12]. Most common types of UTES are confined aquifers [13], Borehole Heat Exchangers (BHEs) [14] and caverns [15]. Recently, Underground Water Tanks (UWT) have been hypothesized for purposes of UTES, too [16]. By using UWT, the heat capacity of the water medium gives the possibility to consider planned and controlled charge/discharge cycles. Moreover, several studies debate the potential of submersing the BHEs in groundwater and surface water, primarily because of the benefits of induced convection phenomena and additional capacity for heat exchange [17]. Recently, Focaccia and Tinti [18] developed a laboratory prototype of an innovative configuration of BHE inserted in a protective casing filled with water. The research has shown, both by analysing thermocouple and visual records, that natural convection movements are triggered in the water inside the UWT, due to the thermal activation of the BHE.

Following the encouraging results of the application of shallow geothermal system in the agri-food facilities [19], [20], this paper presents a pre-feasibility study for an efficient application of UWT as UTES in the livestock sector, with focus on the cow barns needs. Specifically, the aim of this work is to study the feasibility of in integrated system able to both pre-cool the produced milk and warm up the water used for cows' needs (drinking and soaking) by means an innovative shallow geothermal system. The system can also be used as storage of water at optimal temperature. Two scenarios will be tested:

- final milk temperature as variable;
- initial water temperature as variable.

2. Materials and methods

The farm "Montagnini" was selected as case study in the present work. The farm has two main facilities hosting the cows: a new modern barn for the lactating cows and the older stable hosting the dried cows and heifers and housing the milking parlour of the farm. The new barn building is in the Emilia-Romagna Region (in the North of Italy), in a plain countryside about 25 km North of Bologna. 270 lactating cows were reared in the barn. The plant of the barn can be seen in Figure 1.

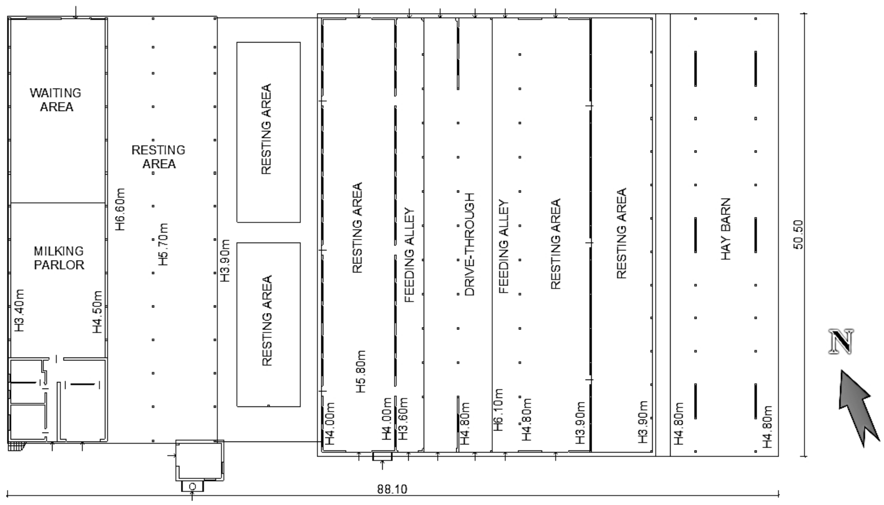

Fig. 1 Transverse cross section of the case study barn.

Indoor thermo-hygrometric conditions are controlled also through forced ventilation, by means of high-volume low speed (HVLS) fans with horizontal blades. Further cooling benefit is achieved through low-pressure, large-droplet water soaker lines installed above the feeding lanes. This sprinkler system completely wets the cows by soaking the hair coat.

In addition to the study case farm, the research group has studied several dairy cattle barns in the Bologna countryside allowing to collect a wide data set on sprinkler systems in order to gather information and assess the water consumptions for each cow (see Figure 2).

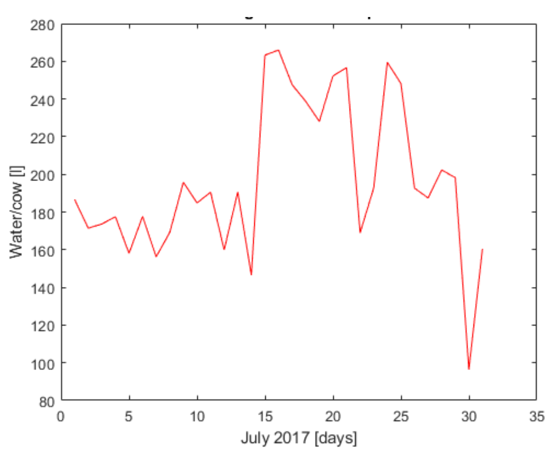

Fig. 2 Soaker water consumption in a typical summer month (1st July – 30th July).

As reference values, from the analysis of the recorded data, we obtain an average water consumption of about 200 liters per cow per day in the typical summer month.

The milking system is represented by a recent 2×15 herringbone milking parlour hosted in the older barn. Regarding the collected data on-site visit to Montagnini barn, daily average milk production per cow is around 35 kg. Since a precise survey for the drinking purpose is missing, an average water consumption of 200l per cow per day was considered according to a sample of farmers interviewed. This value is consistent with scientific literature.

Figure 3 shows the functional scheme of the integrated system. The water is supplied by the well, fills the baskets in the geothermal field, receives the heat from the milk (through an exchange fluid) and goes in the barn for soaking and drinking. The milk (through an exchange fluid) releases heat to the water.

For a precise simulation, a specific test was carried out. The experimental test conducted to verify the efficiency of GeoUWT scheme involved two HHEs: the first one was buried in the ground, 2.0 m deep, and the second one was installed inside a UWT, positioned at 4.0 m of distance, both together forming the GeoUWT [21]. The reason for selecting a helical configuration lies in the fact that it provides higher heat transfer per meter of unit comparing to conventional BHEs [22]. Detailed description of the test site and installation procedures can be found in Tinti et al. [21]. Figure 4 shows the GeoUWT functional scheme and the test setting.

Extensive field thermal response test (TRT) and related monitoring campaign were performed for several months in both summer and winter seasons, to conduct power and efficiency analysis and comparison between the two HHEs subjected to heat injection in the ground (thus cooling a hypothetical end user).

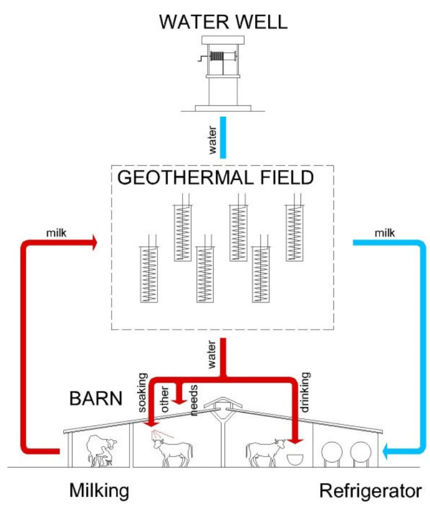

Fig. 3 Simplified operating scheme showing the three parts of the system: the cow barn, the milk refrigerator and the GeoUWT

Moreover, thanks to the monitoring system of ground temperature during the test period, it was possible to verify that GeoUWT did not cause a faster thermal depletion of the surrounding ground than conventional HHE. On the contrary, theoretical efficiency of injected heat dissipation was higher in GeoUWT than in conventional HHE: 1.5 - 2.5 % in summer season and 5 - 10% in winter season [21].

Despite the claimed advantages for cooling, some possibilities should be further explored for a continuous work during the whole year, overall to avoid freezing problem in winter season. These reside in the potential for injecting and storing heat in winter and for the potential of re-using and changing the water in the annulus, thus partially restoring the natural state condition.

Additionally, thanks to the monitoring system of ground temperature during the test period, it was possible to verify that GeoUWT did not cause a faster thermal depletion of the surrounding ground than conventional HHE. On the contrary, theoretical efficiency of injected heat dissipation was higher in GeoUWT than in conventional HHE: 1.5 - 2.5 % in summer season and 5 - 10% in winter season [21]. Possible explanations for this reside in the larger heat exchange area and the induced natural convection effects inside of the casing.

The GeoUWT can provide extra potential for heat exchange and storage and keep the surrounding soil indefinitely below the complete thermal saturation state. A secondary functional usage of the extracted fluid would give an additional value to this concept.

For the specific case study, the following assumptions were made:

- Milk temperature after milking: 40°C;
- Milk temperature for storage: 4°C;
- Water temperature: 14°C (constant, taken from a well at 50 m depth in confined aquifer);
- Optimum temperature of drinking water for cows: 18°C.

A dedicated TRT was conducted on GeoUWT on 21st of January 2019, to recreate a similar situation to that of the cattle barn case study (see above). Period of heat injection (with subsequent cooling of the M-TRT machine's tank water) and heat exchange between the HHE and the water inside the GeoUWT, lasted 1.9 h, with total power of heat exchange 1861.8 W. Therefore, 977 Wh of cooling capacity could be assigned to HHE in the test conditions and they can be used for the energy improvement of the cow barn case study. At the end of the test, temperature of the outlet fluid from the HHE was 19.54°C while the average temperature of the water inside the GeoUWT was 17.8°C.

A research survey allows to analyse different milk pre-cooling solutions in case-study region. Currently, milk direct pre-cooling systems circulate wastewater used for cleaning and provide ΔT of 10-12 °C, with milk temperature decrease from 40 to 30 °C, approximately. On the other hand, ΔT of approximately 20 °C from dedicated TRT indicates the opportunity for significant milk-precooling potential of GeoUWT concept. Final temperature of the water inside the GeoUWT is in the range with optimal temperatures of the drinking waters for the cows. With the available information related to the water and ground annual temperature profiles, it is possible to consider the storage function of the GeoUWT for the water at requested temperature range.

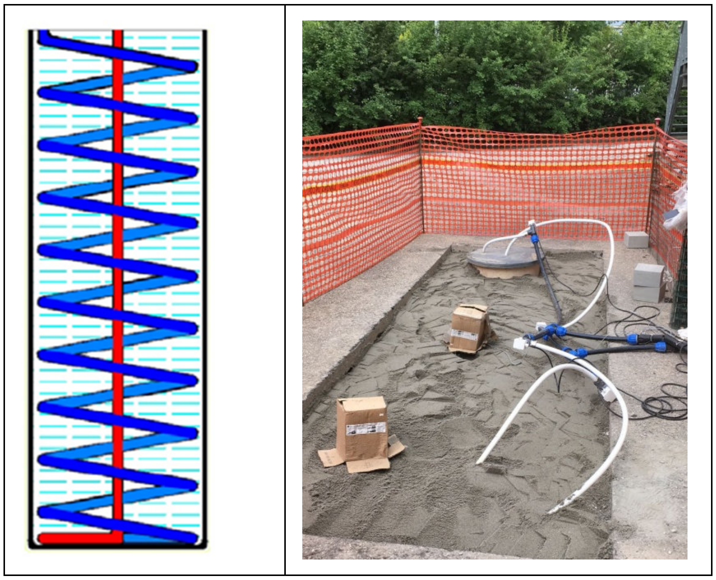

Fig. 4 On the left: simplified GeoUWT scheme showing the the case and the internal helicoidal pipe. On the right the test site.

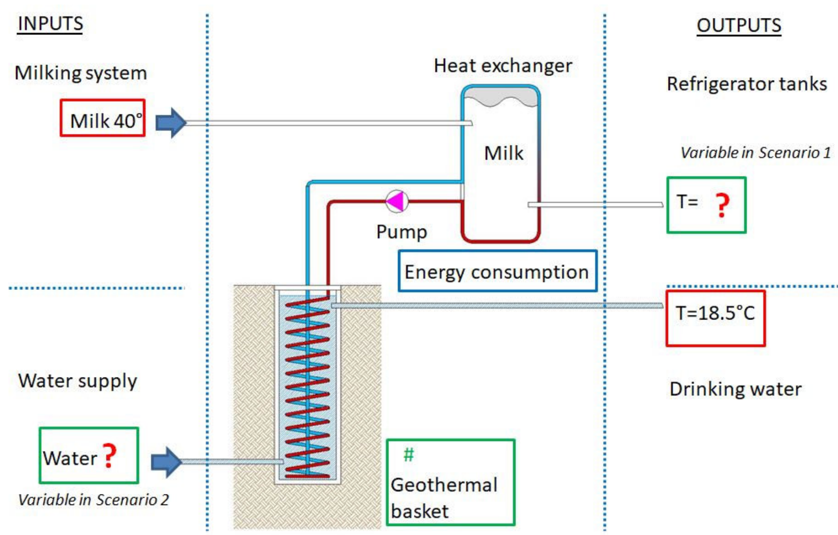

Fig. 5 Simplified operating scheme showing the three parts of the system: the cow barn, the milk refrigerator and the GeoUWT

3 RESULTS AND DISCUSSION

For the case study, two different scenarios have been considered. In the first different target temperatures of the milk were taken into consideration, with fixed number of the cows in the case study. This allowed to compare the results of necessary number of GeoUWTs to suit the energy demand of single milk session with different target ΔT of produced and precooled milk. Table 1 reports the results of this simulation.

Table 1 Results of Scenario 1

Target Tmilk (°C)	En / session (kWh)	n_{GeoUWT} (milk precooling)	El_{pump} / year (kWh)	Yearly pump energy cost (€)	Initial investment (€)
29.0	60.04	62	4 526.00	1 357.80	52 377.60
28.0	65.50	68	4 964.00	1 486.20	57 446.40
27.0	70.96	73	5 329.00	1 598.70	61 670.40
26.0	76.42	79	5 767.00	1 730.10	66 739.20
25.0	81.88	84	6 132.00	1 839.60	70 963.20
24.0	87.33	90	6 570.00	1 971.00	76 032.00
23.0	92.79	95	6 935.00	2 080.50	80 256.00
22.0	98.25	101	7 373.00	2 211.90	85 324.80
21.0	103.71	107	7 811.00	2 343.30	90 393.60
20.0	109.17	112	8 176.00	2 452.80	94 617.60

According to the set milk final temperature, results show the energy produced by the baskets (therefore saved by the milk refrigerator), the needed number of GeoUWT, the electricity need by the pump and costs.

Then, for Scenario 2, the final milk temperature was set a 23.0°C, the well water temperature was considered as variable, and variations in terms of GeoUWT energy, pump energy consumption and heating water time have been calculated and shown in Table 2. Comparison are referred to 15.4°C, the initial temperature of Scenario 1.

Table 2 Result of Scenario 2

	15.4°C	10°C	12°C	14°C	16°C	18°C	20°C
Th. Energy/GeoUWT/(kWh)	**0.977**	1.296	1.1180	1.064	0.947	0.830	0.713
Percentage difference (%)	**0.0%**	32.7%	20.8%	8.9%	-3.1%	-15.1%	-27.0%
Pump energy consumption/session (kWh)	**0.100**	0.119	0.114	0.106	0.098	0.089	0.089
Heating water time	**0.0%**	18.9%	13.8%	6.4%	-2.3%	-11.2%	N/A

This Table exhibits the performance variations related to the water temperature change, this in fact can show a high variability if supplied by the aqueduct. Both the table can be very helpful for the system sizing helping the farm to find its best configuration.

4 CONCLUSIONS

The present study shows the theoretical feasibility of an integrated system water/milk heat exchange, taking advantages of the initial temperatures of both fluids. The system is simple since just a circulation pump is needed, the labor for construction is limited and the materials are easy to find in the market, therefore it proved to be affordable and farmers can consider a homemade installation.

An added value of the system, is given by GeoUWT that, besides the enhanced power, can work as water thermal storage, guaranteeing the proper temperature for drinking and soaking all day long. The system sizing requires the definition of several parameters, such as water and milk initial temperatures, number of baskets, water need, final water temperature and final milk temperature. This allows a high flexibility of the system according to farmers possibilities and needs. Another parameter could be the water amount, but for sustainability reasons, the Authors believe no additional water should be added to the water that the barn usually needs in order to increase the system efficiency. This work was based on this principles and results shows its validity.

Future works will focus on system optimization based on costs and farmers' specific needs.

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ENERGETIC FEATURES AND BUILDING USE FOR NEW EFFICIENT RURAL BUILDINGS

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Abstract. *The introduction of renewable energy sources and the design of energetically high-performance structures are two of the most important features requested to new building generation. Nowadays, these aspects play an important role also in the design of new rural buildings or in the energetic retrofits of the existing constructions. In fact, the total energy consumption of food processing buildings is relevant, and often related to food safety and quality. Then, the research of the most promising strategies in order to design an efficient building is strictly correlated with the choice of wall and roof constructions, shading, glazing, orientation and cooling/heating needs. It is important to recall that the energy behavior of buildings is strongly influenced also by external factor like weather conditions and the effect of climate change increases the complexity to model the building behavior. In this context, the present paper provides some useful insights into the most important variables to control in order to limit or contain energy consumptions by means of computer energy simulations. The evaluation is performed by considering a case study building with different intended use, desired indoor temperature ranges, and different architectural and material choices. The main objective of the paper is to identify possible correlations between the energy consumptions and the variables considered in the paper in order to define which are the parameters most influencing the final building energy consumptions.*

Key words: *Energy efficiency, energy saving, rural building, cooling system, building retrofit, envelope.*

1. INTRODUCTION

The data about the impact of building sector in the overall energy consumption [1] pushed the European Commission and Member States to promulgate stricter and stricter laws to improve the thermal performances of new buildings also encouraging use of renewable energy [2, 3, 4, 5, 6, 7]. The wide range of building solutions and the increasing diffusion of thermal simulations in the design drove also to the development of new methods for the energy need calculation and reliable software. Hence, the building sector can take advantage of the synergy between the innovation coming from new technologies and the solutions provided by the development of energy software, also due to more and more precise process of calibration and validation of energy models [8, 9, 10, 11].

The described innovations involving the building sector have been so far especially finalized to upgrade the residential but limited number of studies analyzed the efficiency of the most widespread energy-saving solution on buildings operating in other sectors [12, 13, 14, 15, 16, 17, 18, 19, 20] like the agricultural sector that shows a remarkable energy use [21, 22, 23]. Even if not comparable with residential, the agrifood processing buildings exhibit relevant energy need mainly due to lighting, hot water, food transformation phases and indoor thermal conditioning. Due to the rise of energy costs and thanks to the increasing attention of both producers and consumers for sustainability, farms are showing interest in buildings with low energy demand. Obviously, the market offers a wide range of solutions, as explained before but, since they were optimized for residential purposes, their efficacy has not been tested yet on food-processing building needs and, in few cases, they proved to be more efficient than in residential sector [6]. For example, in the agrifood sector, the thermal needs differ from residential ones for desired temperature ranges, periods, air changes and power. A typical example can be a winemaking and storage building, where the peak for energy cooling is requested from September to November (in the Northern hemisphere), 24 hours a day, and the storage area can request temperatures ranging from 8°C to 20°C according to the stored wine type. Another typical example can be the cheese factories, in which low temperature ranges, from 0°C to 8°C, should be provided all year long, or again the storehouse groceries where the packaged food is usually stored at room temperature (around 20°C-22°C) since designed for the human presence. Furthermore, the lack of specific sector legislative constraints does not provide any reference for the building design, allowing the personnel involved in the project to avoid thermal systems as results of the adoption of passive solutions. Moreover, in the last decades, several buildings changed the intended use, sometimes entailing different indoor thermal requirement. This study aims at testing the effectiveness of envelope characteristics (walls, roof, glazing, orientation and sun shading) referring to six different temperature ranges (TRs) selected to cover a wide temperature band from 0°C to 24°C and different years. It aims at investigating if a single building configuration shows good performances in all the thermal ranges or, on the contrary, the most energy efficient solutions are different for each thermal range. To achieve this result, the present work, for each temperature range, studies and evaluates the influence of each architectural characteristic on the thermal behavior. The methodology is applied to a case-study building located in Italy. The results on the building thermal behavior are evaluated assessing the influence of temperature ranges and the influence of architectural characteristics and typologies.

2. Materials and methods

2.1. Architectural characteristics and typologies

We consider the following building architectural features: external wall typology (w), roof typology (r), openings glazing typology (g), presence or not of shading system (s) and geographical building orientation (o). In order to investigate and quantify the effect of each architectonical feature on the building thermal behavior, different possible typologies for the same features have been selected. Hence, in the rest of the paper the label architectural feature identifies a building envelope component or system, whereas the typology collects the set of parameters characterizing the thermal performance of that feature. In the following sub-sections both architectural features and typologies are deeper detailed. For details on features and typologies see Torreggiani et al. 2018 [24].

2.2. Definition of the ideal Temperature Ranges (TRs)

In the present paper, six target temperature ranges were selected according to different needs. Their ranges are typical of food preservation and ageing. The last one is also similar to human thermal comfort. For the first range the ideal temperature goes from 0°C to 4°C and is considered the optimal temperature slot for keeping fresh cheese and in general all the foods to be conserved in the refrigerator cell. The second range 4°C-8°C is the optimal temperature for the processing techniques of fresh fruit and vegetables. The third temperature slot 8°C-12°C is the most suitable for second fermentation of classical method wines, while 12°C-16°C and 16°C-20°C are the ideal temperature ranges for conservation of respectively white wines and red wines. Finally, the last temperature range 20°C-24°C investigated here, can be referred to storehouse groceries usually storing food at room temperature close to human comfort range.

2.3. Description of the case study building and energy modelling

Previous studies [24] allowed to use the energy model of an Italian winery as base model for the present work. The model was calibrated and validated on experimental data on an existing winery. The building belongs to *Branchini farm* (Figure 1) and is used as wine-making and storage room. It is an rectangular construction, with the main axis 32° NE oriented, it is 27.75 m long and 18.50 m wide. The height is variable, between 5.30 m and 7.00 m. Six equidistant pillars are located along the main axis and virtually divide the internal space in two zones: the north-east zone hosts the area of wine-making phase, the south-west zone is used as storage for bottled wine. The building envelope is made with traditional materials with low thermal performance. The exteriors walls are made with 32 cm thick plastered concrete brick panels; the floor is a 30 cm thick concrete slab while the roof is made with a non-insulated slab poured directly on the ground. Five single glazed windows are located on the north-east wall, two metallic doors are located on both the two short sides and a canopy on north-west side protects the grape deliver space.

The indoor space is naturally ventilated and has no air-conditioning or ventilation system. The wine kept in the storage area is preserved in bottles (unconditioned containers), differently, the wine in the winemaking area is stored in fermenters (conditioned containers), entailing the wine in the storage area is more sensitive to the room temperature variations. For this reason, the result analysis is applied solely to the storage area. The farm has 20 hectares of vineyards.

The present research aims to provide an assessment of the all-possible combinations of 6 wall constructions, 6 roof constructions, 4 building orientations, 2 windows solutions and 2 sun-shading situations from a thermal point of view. Totally 576 different building combinations are obtained, each building combination has run twice since two different years (i.e. 2007 and 2013) are used as reference for outdoor environmental conditions. Thus, 1152 simulations are run and their results analysed. The building is subdivided in 4 thermal zones: the wine making area, the wine-storage area and other two zones between the previous zones and the roof, as shown in Figure 2.

Fig. 1 The case study building.

The shading surfaces have been modelled as EnergyPlus Shading Surface Objects with solar transmittance equal to 1. Then a specific Schedule Object has been created to control the transmittance according to the seasonal foliar coverage over the year. Specifically, the transmittance coefficient varies from 0.15 in summer to 0.90 in winter, taking into account both the foliar coverage and the steel structure.

Scripts elaborated through Matlab software eased the creation of the architectural element variations combining them in the 1152 models. The model nomenclature is thought to ease the comprehension of the analyzed combination. The energy performance analysis for conditioned buildings is based on energy need (EN). This indicator drive directly to economical assessments such as operating cost, due to energy demand, and payback analysis, obtained by the comparisons between operating and construction costs.

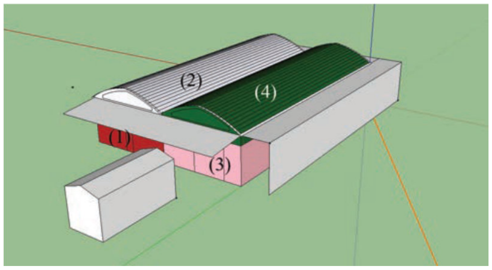
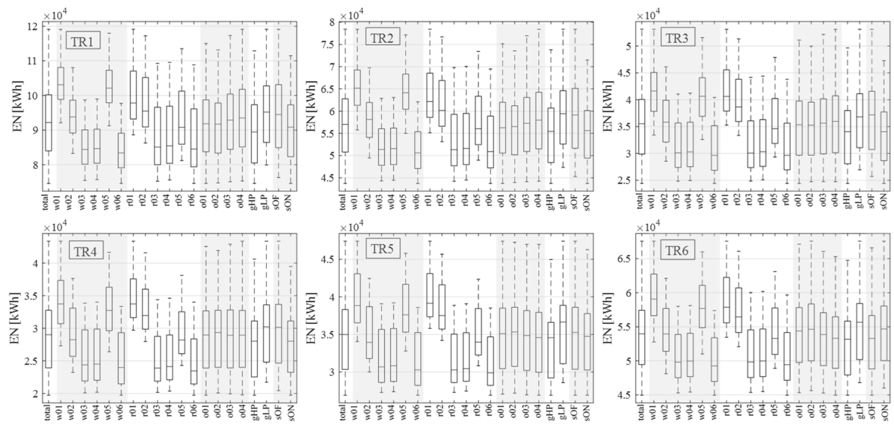


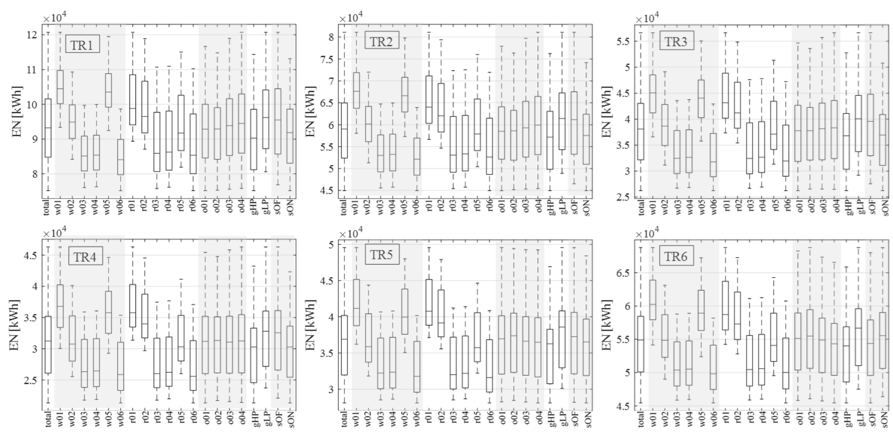
Fig. 2 Thermal zones subdivision in the energy model: 1) wine-making area; 2) wine-making roof area; 3) storage area; 4) storage roof area.

3. RESULTS AND DISCUSSION

The investigation we considered is relative to the effects of the combination of different architectural features and typologies on the evaluation of the thermal behaviour of the case study building. In this context, it results appealing to properly identify and quantify, for the various cases, the architectural feature most influential on central value and scatter of the outcomes. In order to identity, for each TR, the architectural features that most affect the energy performance of the models, an in-depth statistic data elaboration was adopted. We consider the boxplot representation reported in Figure 3.



(a)



(b)

Fig 3 Boxplot representation of EN indicator for the six temperature ranges (TR) for the year (a) 2007 and (b) 2013.

Figures 3a exhibit, for 2007, the annual EN distribution of the data set relative to each of the 20 typologies belonging to the 5 different architectural features. In each subfigure, the first left boxplot is relative to the total data set.

The typologies of the same architectural features are highlighted by means of the vertical green coloured strips. On each box, the central red mark indicates the median, the bottom and top edges of the box indicate the 25th (quartile 1: Q1) and 75th (quartile 3: Q3) percentiles, respectively. The whiskers extend to the most extreme data points outliers excluded. Then, the outliers were identified as the values falling outside the range from Q1-1.5IQ and Q3+1.5IQ where IQ is the interquartile distance. The outliers are plotted individually using the red '+' symbol. These choice for the graphs can help to visually identify the typologies most affecting the performances by analysing the interquartile distance IQ. As a representative example we consider w01 of TR1 in Figure 3a (this boxplot shows the performances of all models containing w01). It is visible that the best performance would be higher than 92000 kWh regardless the other typologies and 50% of all models containing r01 (interquartile Q1-Q3) returns performance in a very limited range (99000kWh-108000kWh). Under this light, the interquartile distance can be taken as reference for the single typology influence on building thermal behaviour: the smaller the interquartile distance, the higher the influence of the typology on the building thermal behaviour. As far as the main outcomes are concerned, the typologies showing the major influence are w01, w02, w05, r01, r01, w01 respectively from TR1 to TR6. Similar results can be found by considering the year 2013 by confirming the validity of the outcomes (see Figure 3b). In conditioned buildings walls and roof always prove to be the most relevant feature. This outcome highlights how the influence of each feature is affected in a significant way also by the chosen temperature range and by the scenario, confirming that those input data should be carefully taken into account during the design phase for new and existent building overall when changes of intended use are considered.

4. CONCLUSIONS

The research aimed to assess the influence of architectural characteristics and typologies on the building thermal behavior, and thus to help the professionals involved in the design of new buildings or retrofit interventions to analyze the suitability of the building with temperature/humidity control systems, to host food or, as alternative, to host human activities. These evaluation are made assessing the thermal performance achieved varying the architectural elements.

All the investigated building combinations show a strong temperature swing reduction with respect to the outdoor environment. More specifically, among the analyzed architectural set variations, walls and roof proved to have the highest influences on the thermal behavior, but their thermal properties (time shift and transmittance) can provide positive or negative effects on the comfort level according to the temperature range TR. For example, the most insulated materials have positive effects for temperature ranges close to the yearly average, TR2 and TR3, and negative for TR1, TR6. High values of time shift (therefore low level of decrement factors) seem to play a positive role. The orientation does not play a crucial role in the thermal behavior; nevertheless, we consider this result strongly connected to the building shape (symmetrical, wide surface, small height). Likewise, wall and roof variation, the contribution of sun-shading and high-performance windows can be positive or negative referred to the TR.

Summing up the high-performance solutions designed to reduce energy consumption, do not necessarily give a positive contribution in conditioned building. We observed that TRs with the lowest energy demand are those closer than yearly outdoor average temperature at the site. It was visible how some characteristics affect the building thermal behavior being more effective than others are. Further, for TR6, we found that some typologies, such as walls, if worsen in terms of thermal capacities can improve performances in a conditioned scenario. In the context of an energy retrofitting interventions design, this last outcome entails that the strategy to improve the performance of a building must be carefully selected as a function of the optimal indoor temperature requested by the processes in the building reducing in a drastic way the number of effective solutions to adopt in a design.

Finally, simple statistical analyses defined the most influential typologies and architectural characteristics on the thermal performances of the building. Remarkably, the introduction of a specific typology could produce very different effects. This outcome highlights how the influence of each characteristic/typology is affected in a significant way by the chosen temperature range and by the scenario, confirming that those input data should be carefully taken into account during the design phase for new and existent building overall when changes of intended use are considered.

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EXPERIMENT OF THE SNCR DENITRIFICATION OF FLUE GASES PRODUCED BY BIOMASS COMBUSTION

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Abstract: *Biomass, as well as any other fuel, emit certain pollutants during combustion, which should not be neglected. The emission of nitrogen oxides (NOx) generated during biomass combustion, especially agrarian one, is one of the key challenges for the use of this fuel. In order to investigate the potential of emitted NOx reduction, the experimental denitrification chamber was designed. The secondary denitrification technique of selective non-catalytic reduction (SNCR) on a synthetic mixture of gasses simulating real flue gasses during biomass combustion was tested. This paper provides a description of the experimental denitrification chamber as well as the experimental results obtained as the function of flue gas temperature, NO concentration, and NH3/NO molar ratios.*

The optimization of the denitrification process under controlled conditions provided by the experimental denitrification chamber is the starting point for the optimization of the SNCR process on real-scale plants combusting biomass or any other fuels with increased NOx emission.

Keywords: *biomass combustion, NOx emission, denitrification, SNCR*

1.INTRODUCTION

The harmonization between the growing energy needs of modern society and environmental protection promotes the use of biomass as a substitute for fossil fuels and a viable option to reduce greenhouse gas emissions. However, there are some disadvantages related to the combustion of biomass as a fuel, such as relatively high NOx emissions. This is of great importance for the utilization of agricultural biomass, as a renewable energy source containing a high percentage of nitrogen due to the protein nutrient properties and use of nitrogen fertilizers [1, 2]. Therefore, the investigation of possibilities of flue gas denitrification during the combustion of agricultural biomass and their continuous control represents a great technical challenge especially because of more strict environmental regulations.

NOx reduction measures are generally related to the following measures:

- pretreatment - the usage of low N-content fuel, modifying fuel composition by additives, different N-content biomass mixing or biomass and coal co-combustion;
- primary (combustion control) - acting on the combustion process itself, inhibiting some of the influencing factors (combustion temperature, the residence time of combustion products, O_2 concentration) to nitrogen oxide emissions, and
- secondary (flue gas treatment, FGT) - removing already formed NOx from flue gases.

Improving environmental parameters with less investment is the driver of the use of biomass as fuel, so this concept has to be considered when choosing deNOx technology. Economically observed primary *i.e.* combustion control measures are the most cost-effective because they implied modifying the combustion process without the use of additional pollution abatement equipment behind the main combustion zone. As combustion of biomass usually occurs at relatively low temperatures in order to inhibit or alleviate alkaline-related problems, these measures are limited to reducing oxygen concentrations in the combustion zone and improving mixing conditions. In the combustion of biomass, the influence of N content in fuel has a dominant effect on NOx emissions [1], so combustion control techniques themselves are often not sufficient to meet strict emission limits. The necessary reduction of nitrogen oxides is achieved by applying more efficient FGT measures, especially in N-rich biomass, but with higher investments. The most widespread dry secondary deNOx techniques are a selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR). The last listed deNOx technique is the theme of this paper.

SNCR is the reduction of NOx to N_2 in the presence of O_2 in reactions with reagents on the amino base, either ammonia (NH_3) or urea (CO $(NH_2)_2$) at a temperature of ≈ 800 - 1100 °C (Fig. 1) with a higher temperature needed for the urea. Although the reagent can react with numerous smoke components, it prefers to react with NOx rather than the far more plentiful oxygen, O2, for a certain temperature range; therefore, it is a selective chemical process [2, 3].

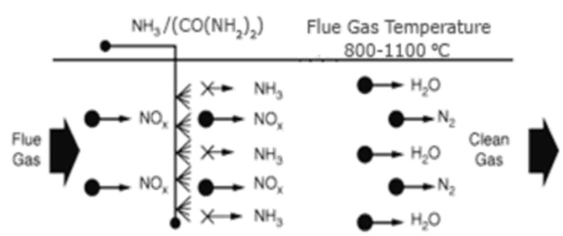


Fig.1. Scheme of selective non-catalytic reduction

The key to the SNCR process is an optimization of reagent injection with the flue gas within a specific temperature window. For urea, this window is approximately 950°C-1150°C. For ammonia, the window is slightly lower at 820°C-980°C. The reagent is directly injected into the combustion chamber. Urea-based SNCR has a certain advantage over systems based on ammonia due to urea non-toxicity, greater stability, and easier storage and manipulation. The fact that the urea drops injected into the boiler penetrate further, mixing better with flue gases, favors its application in large plants. In addition to being more expensive, urea-based SNCR systems require higher temperatures, which is not appropriate for the temperature range in which biomass is combusted 770-870°C [2].

2. DESCRIPTION OF THE EXPERIMENTAL DENITRIFICATION CHAMBER

For the purpose of better acquainting the mechanism of selective non-catalytic reduction, the most commonly used measures of secondary denitrification, an adiabatic chamber for denitrification of a mixture of gases, which simulates the composition of flue gas from biomass combustion, was designed, with the accompanying measuring and acquisition equipment, given in Figure 2.

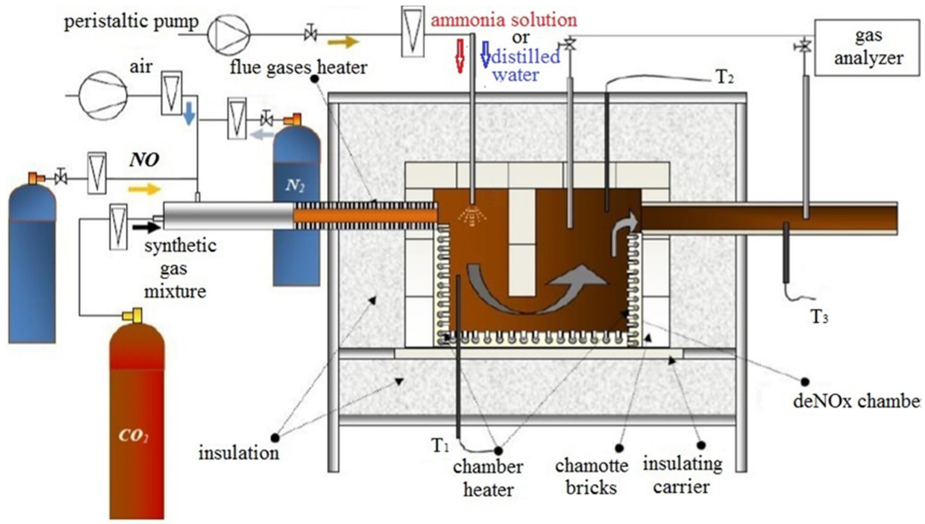


Fig. 2. Scheme of experiment setup with denitrification chamber

The isolated denitrification chamber dimension of (120 × 400 × 500) mm with one bulkhead (allowing better mixing of flue gases), is coated with a chamotte brick and coated with multilayer insulation with a total thickness of 180 mm (Fig.2). In the deNOx chamber, an electric heater in the ceramic is placed, which maintains the desired temperature for the SNCR process. The insulated chamber is located in a tin casing. Flue gases (an appropriate mixture of carbon dioxide, CO_2, nitrogen, N_2, air and nitrogen monoxide, NO) are introduced through the heating pipe into the denitrification chamber. The air duct consists of an air blower, a voltage variator, which adjusts the desired flow and rotameter flowmeter. All gases and air make an appropriate representative mixture of flue gases in front of a heating pipe introducing them into a tempered adiabatic chamber. The flue gas composition corresponds to the composition of the actual flue gas produced by the biomass combustion, and the predicted temperatures in the chamber should be such that thermal NOx does not occur so that the inserted NO simulates the amount of nitrogen monoxide released during the combustion of biomass: 230-600 ppm [1].

2.1. Acquisition

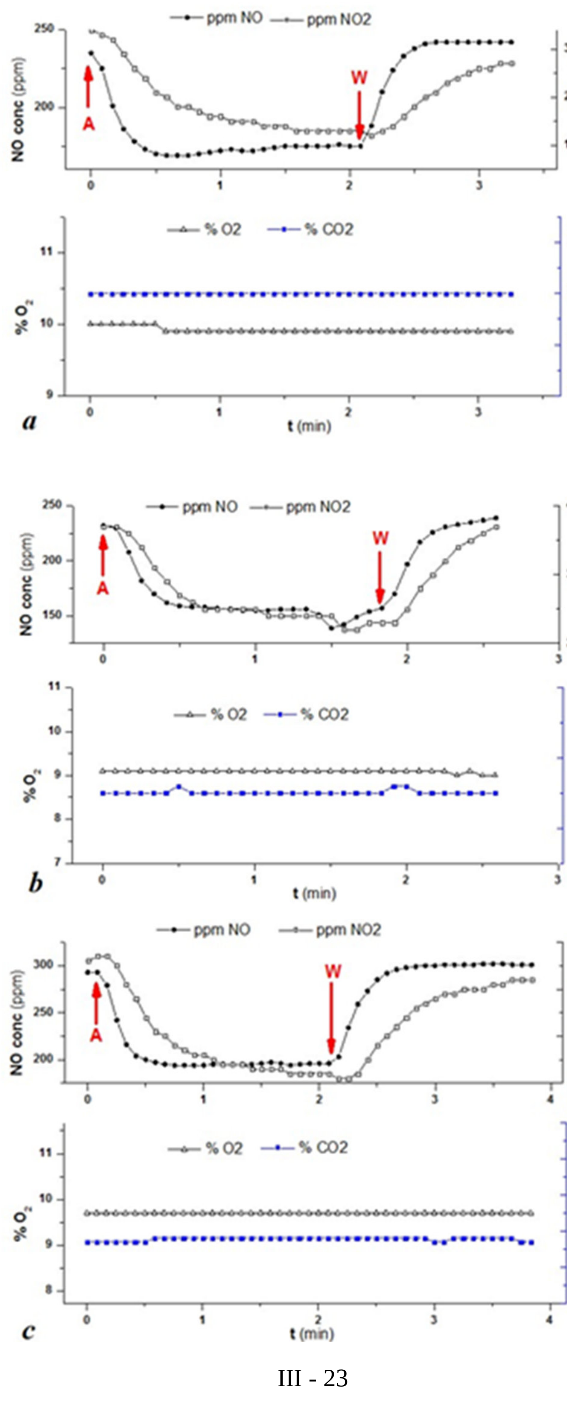
Temperature acquisition during denitrification testing is performed by the KEITHLEY acquisition system with continuous data recording at a selected sampling time of 2 seconds. The MRU Air fare Varioplus Industrial gas analyzer, with the continuous data recording, performs analysis of the flue gas composition at the outlet of the chamber, before and after the reagent dosing. The flow of gases was measured and regulated by valves and corresponding rotameters. A low-flow peristaltic pump dosed ammonia solution or distilled water continuously through a small-bore probe in the first displacement of the chamber. The flue gas rate and the flow measurements have been calibrated by an anemometer and rotameter, respectively.

2.2. Chemicals

A synthetic gas mixture that simulates real flue gases was obtained by mixing commercially available gases nitrogen, carbon dioxide and 2% NO in nitrogen, all purchased from Messer, Serbia, with air. Ammonia (25%) was used as a reagent for denitrification. Distilled water was used in the chamber directly as well as for the preparation of ammonia solutions of concentrations in the range of 0.5 - 4 %. In a synthetic gas mixture, NO concentrations were in the range 230 - 566 ppm, corresponding to values at agricultural biomass combustion. Denitrification was tested in the range of NH_3/NO from 0.47 to 3.5. Oxygen concentration was adjusted to correspond to concentrations in flue gases obtained from biomass combustion (8.8 -11.1%).

3. Results and discussion

In order to get to know the mechanism of denitrification, a series of experiments, presented in fig.3, was performed. Based on the reactions kinetic curves presented in Figure 3, it can be observed that the decrease in NO concentration induced by NH_3 addition (A), as well as the re-growth of NO-induced by water addition to the gas mixture (W), can be described by the kinetics of pseudo-first-order (exponential dependence).



ppm NO
ppm NO2
NO conc (ppm)
NO2 conc (ppm)
A
W
% O2
% CO2
t (min)
a
b
c

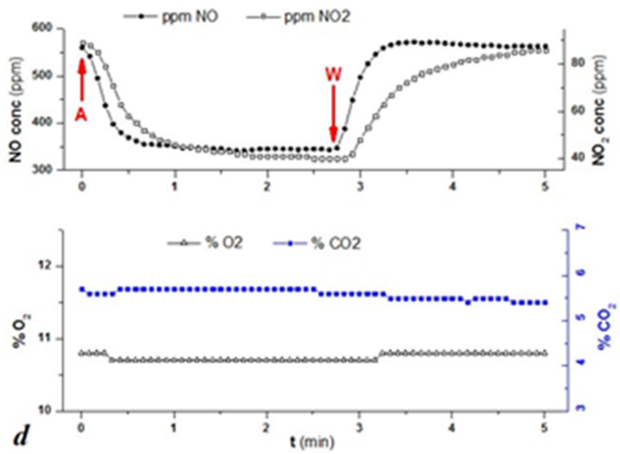


Fig. 3. Representative time dependences of NO, NO_2, O_2 and CO_2 concentrations after addition of ammonia solution A and distilled water W (moments of addition are indicated by arrows)

a) 1.0% ammonia solution; initial NO concentration 235 ppm; temperature 1094 K (821°C)

b) 0.5% ammonia solution; initial NO concentration 232 ppm; temperature 1139 K (866°C)

c) 1.5% ammonia solution; initial NO concentration 293 ppm; temperature 1095 K (822°C)

d) 4.1% ammonia solution; initial NO concentration 560 ppm; temperature 1100 K (827°C)

Table 1. Denitrification process parameters

Exper.	NH_3/NO ratio	NO decrease %	overall rate constant 1 min^{-1}	overall rate constant 2 min^{-1}	O_2 %	CO_2 %
a	1.49	28.09	6.67 ± 0.44	5.88 ± 0.35	9.92	7.60
b	1.04	32.76	8.33 ± 0.28	6.67 ± 0.58	9.09	6.51
c	1.94	33.79	7.69 ± 0.59	4.35 ± 0.19	9.70	7.78
d	2.42	36.96	4.35 ± 0.76	4.55 ± 0.21	10.74	5.60

Based on the experimental results presented, it is evident that the addition of reactants significantly reduces NO from the gas mixture, and that by injecting water vapor and discontinuing NH_3, NO returns to its original concentration while NO_2 decreases slightly.

It is also evident from Table 1 and Figure 3 that the NO reduction process is more intense with a higher molar NH_3 / NO ratio as well as at higher temperatures.

4. CONCLUSION

The optimization of the denitrification process under controlled conditions, enabled by the experimental denitrification chamber, is the starting point for the optimization of the SNCR process and the capacity assessment of the real scale denitrification system for the combustion of biomass and other fuels in which the nitrogen oxide emissions during combustion are expressed.

The functionality of the designed denitrification chamber was confirmed by a series of experiments, of which the most representative ones are presented in this paper. Experiments have shown that the degree of denitrification, in addition to temperature in the molar ratio of reactants, is also affected by the chemistry of the process, i. e. chemical reaction overall rate constant.

The experimental deNOx chamber can also provide data on the influence of various parameters:

- flue gas flow,
- quantity and selection of the reagent,
- the influence of the enhancers (H_2) on the reduction of the temperature denitrification window,
- the influence of the furnace temperature,
- the time of flue retention in the furnace, as well as
- the impact of the CO on decreases in the concentration of nitrogen oxides.

Also, the same data can also be used in the formation of mathematical models of denitrification processes in the combustion of biomass, as well as other solid fuels.

The advantage of the experimental deNOx chamber shown, in relation to those available in the scientific literature, is that it stimulates the real conditions in the furnace:

- the walls of the chamber are from the chamotte (not smooth)
- and there is turbulence in the flow of flue gases, due to the presence of an obstacle (not just a simple laminar flow).

In addition, by a simple modification of the chamber, which implies the installation of a catalyst in a chamber with a temperature range of 250-400 ° C, the same principle can be tested and optimized the selective catalytic reduction process - SCR.

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GUIDELINES FOR ORGANIZED AND ENERGY EFFICIENT USE OF BIOMASS AND THE KEEPWARM INTERNATIONAL PROJECT PROMOTION

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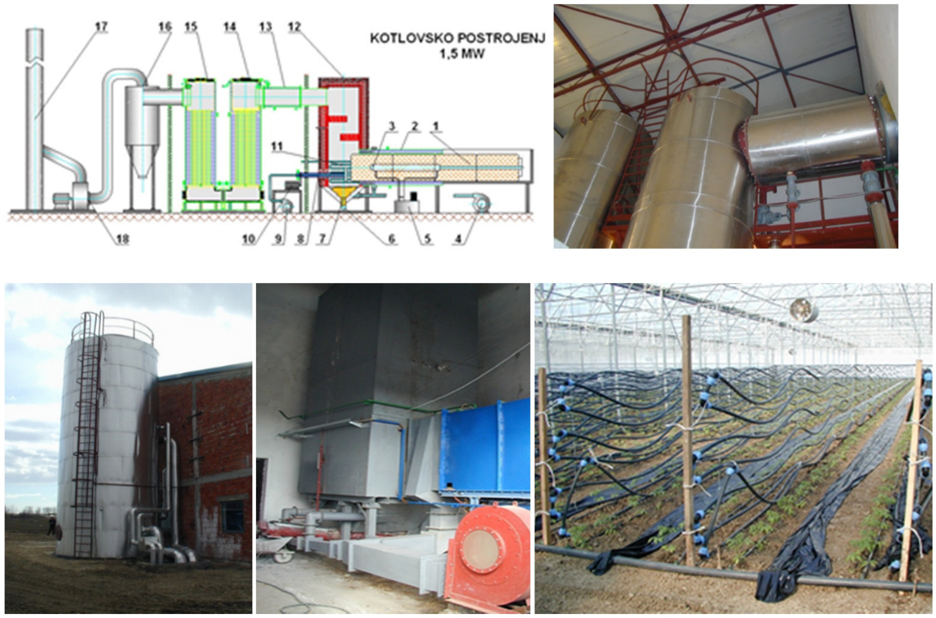
Abstract *This article represents an attempt to improve the use of available biomass for energy purposes. It represents a compilation of the laboratory's long-term experience on projects considering the development of technologies for the application of biomass and other renewable energy sources. The basic guidelines for the adoption of the solution for popularization and the specific application of biomass for energy purposes have been presented through four basic considered issues:available resources and possible combustion technologies,the concept of construction of the plant, a multidisciplinary approach to the problem and the tendency for more intensive use of biomass in district heating systems through the KeepWarm project.*

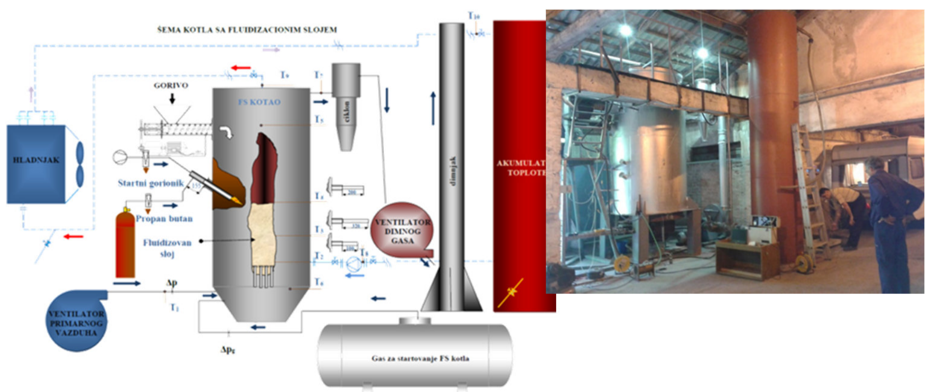
Keywords: *biomass combustion, DHS, KeepWarm*

1. INTRODUCTION

For the last decades, the research team at the Laboratory for Thermal Engineering and Energy INN Vinča, LTE, has been intensively addressing the problem of biomass combusting. As a result of these activities, technology for the combustion of baled agricultural biomass with combustion in a fluidized bed of ash has been developed. LTE also has a demonstration - industrial boiler, max power of 500kW, with fluidized bed combustion technology (FB), located within the existing boiler room of the Institute, where experimental tests of combustion of different types of biomass fuels (paper sludge, corn kernels, hazelnut husks, etc) have performed. Schemes and photographs of both facilities are given in Figure 1. In addition to these industrial-type facilities, LTE also has a number of experimental apparatus that can be used to study virtually all aspects of combustion of this type of fuel in an efficient and controlled manner, by varying different parameters. Expertise and competence in the field of biomass energy use, proven both in practice and in numerous scientific publications and technical solutions, gives us the right to give recommendations for more efficient use of this renewable fuel.



a)



b)

Fig. 1 a) Industrial 1.5 MW boiler of baled biomass, in PKB, exchangers, buffer, hydraulic bale feeder and 1 hectare of a greenhouse; b) Semi-industrial 500kW FB boiler

2. AVAILABLE RESOURCES AND POSSIBLE COMBUSTION TECHNOLOGIES

According to the official data of the Ministry of Mines and Energy of the Republic of Serbia, the biomass has the largest potential of renewable energy in the country, which is about 61% of the total RES [1]. Of that amount, about 60% are agricultural production residues and the rest is wood/forest biomass. Differences in the characteristics of agricultural and forest biomass as fuels are significant and are based on mechanical properties, chemical composition, thermal power, average moisture content, bulk density, ash quantity and composition, ash melting characteristics, method of collection, transport, storage and preparation for combustion, etc. All differences directly affect the combustion characteristics and consequently, the choice of combustion technologies. Wood chips and chopped straw, for example, cannot burn in the same way due to different ash sintering temperatures (about 1000°C and 800°C, respectively). The different bulk density (wood chips ≈500 kg/m3, weighed straw ≈100-150 kg/m3), makes it impossible to apply the same fuel feeding and transport systems [2-5]. Using of different types of biomass in a single boiler considerably complicates its operation. These problems are more pronounced for boilers with smaller capacities.

Environmental issues, gaseous and solid combustion products, must also be taken into account in selecting the appropriate combustion technology. The forest biomass contains significantly less ash than agricultural; therefore, the particulate matter control system in flue gases is smaller for wood biomass. It would be preferable if the biomass ash were returned into the soil of biomass origin, reducing the use of artificial fertilizers, and using it as a manure stabilizer. When returning the ash in the field, attention should be paid to the content of heavy metals in it (concentrated in the fine fractions caught in the flue gas) [6]. As for the emissions of pollutants, it is necessary to bear in mind that the burning of agricultural biomass can increased nitrogen oxide emission [7,8], which is not common for forest biomass. In that case, the systems for the neutralization of harmful gases must be foreseen.

Table 1. Overview of biomass combustion technologies [9]

Combustion technology	Form of biomass					
	Firewood	Wood chips	Powder biomass	Pellets	Briquettes	Straw*
Open fire	0	-	-	-	0	-
Household ovens	+	-	-	-	+	-
Automatic burners	--	+	-	++	--	+
Combustion in batches	0	--	--	--	-	+
Inclinated grate	--	+	-	+	-	-
Travelling grate	--	++	-	++	-	+
Vibrationg grate	--	+	-	+	-	+
Furnace	--	+	-	+	--	-
Powder burners	--	--	+	--	--	-
Cigarette combustion	--	--	--	--	--	++
Fluidized bed**	--	++	++	++	--	0

* Baled straw, ** Added by authors of the article

Legend: (--) unapplicable, (-) not suitable, (0) possible, (+) suitable, (++) very suitable

In choosing combustion technology, a report of the EU Institute of Energy, Peten, Holland [9] should have a significant impact. The table 1 shows that no combustion technology is suitable for all the forms of biomass. Based on the explanations given so far, as well as the information in the table above, it is recommended to select biomass combustion technologies according to the "++" mark. Generally, for all types of biomass plants, frequent outages are not advisable; the organization of the operation should be continuous, with as short and slower power oscillations as possible.

3. CONCEPT OF BIOMASS PLANT CONSTRUCTION

This issue depends on several variables: available biomass resources in the immediate location of a future plant, established energy and power needs, phase-building, the cost-effectiveness of investment, property relations (public-private partnerships, etc.).

Taking into account the overall energy efficiency biomass with the largest available potential in the immediate vicinity in a form that requires the least preparation for combustion should be used. For example, it is incorrect to separate the energy efficiency of plant fueled with pellets, from the amount of energy consumed to make pellets from raw wood. This amount of energy is at the level of 30% of the total energy potential of raw wood [10, 11]. Bearing this in mind, the pellet is reasonable to be used in a smaller capacity, up to 100 kW and that reasonable unit capacity to which the use of pellets is recommended authorities should determine. In addition, as already stated, more than one type and form of biomass should be avoided in a single boiler.

The concept of storage for forest and agricultural biomass is very different. Agricultural biomass is collected in a significantly shorter period, during harvesting, and if is collected in the form of bales, the moisture and the possibility of self-ignition must be taken into account. Therefore, smaller biomass storage near the plant facilities, and more warehouses near the collection site, are recommended. This reduces the possibilities of self-ignition and the engagement of mechanization at harvest time when it is most needed. Wood biomass can be collected almost whole year and the possibility of self-ignition of this biomass is less, so warehouses for it can be smaller.

The concept of energy demand refers to heat (HS) and cogeneration (CHP) plants. Heating plants transport produced heat by hot flue gases, hot air, warm or hot water, steam (saturated, superheated) or hot oil, using it for residential heating or industrial processes. It should be kept in mind that in our climates the heating system in the heating season usually used on average 45% of the maximum required power, 18 hours per day. Therefore, consideration should be given to the optimization and to power control capabilities of planned HS. The use of heat storage greatly helps in choosing optimal solutions. It is also recommended, to harmonize the operation of heating plants with the industry needs, extending the plant's exploitation time to a whole year, positively affecting the investment repayment period. Heating plants, designed for industrial purposes, are usually specialized and work throughout the year without a need for heat storage or with a need for those with significantly smaller capacity.

Cogeneration plants (CHP) are attractive to investors because of the preferential price of electricity produced from RES (feed-in tariff). However, the monetary income (investor earnings) should not be a decisive factor for CHP. The construction of facilities that do not have the ensured consumption of "waste" heat during the entire operation time should be prevented. Otherwise, a plant that produces only electricity would have irreversibly dumped up to 75-85% of the biomass energy input. Thus, it is even better to leave biomass in the fields to rotate there.

Generally, two CHP types are used: steam with conventional steam turbines and so-called ORC (Organic Rankine Cycle) systems with hot oil boilers and steam turbines working with the silicone oil steam. In general, the steam turbine is better for larger system (>10MW_e) while for smaller ORC system is preferable.

The concept appropriate to energy needs is always related to the energy medium. In heating systems, the energy medium is usually warm (≤110°C) or hot water (>110°C). If thermal energy is consumed both for heating and for industrial needs, the plant is usually adapted to the industry demands. Technological processes require hot gases (e.g. brick industry), hot air (e.g. dryers of agricultural products), or warm and hot water and steam (e.g. slaughter industry), etc. Sometimes the needs for different heat carriers (hot and warm water, steam, hot air) are simultaneous. For that matter, boilers with thermal oil are the most suitable solution since the subsequent heat exchange between the thermal oil and the required energy carrier takes place in very simple heat exchangers, and boilers work in a manner of hot water boiler but with higher temperatures of the working fluid - thermal oil. Similar conclusions apply also to cogeneration plants.

Construction of biomass energy plants can be

- phased (modular), with phased installation of several smaller units in order to reach the planned overall capacity of the plant, or
- construction of the complete energy plant with full installed capacity in a single stage.

Energy needs will be better matched by phased construction of several smaller units compared toone large power plant because:

- biomass infrastructure (logistics centres and supply chains) in Serbia is limited,
- biomass market in Serbia is still not organized, especially agricultural one,
- a couple of smaller units provide better energy supply security than a single large boiler plant, because it is less likely that two or more plants/units will deteriorate at the same time,
- power regulation is easier and can be done in a wider power range if multiple modular units exist, and
- phased construction implies phased investment cost which may be more convenient for the investor than investing in complete plant at once, despite higher overall cost.

A modular approach is also possible with CHP. By using the ORC system, the possibility of phase construction of CHP is increasing, since a thermal installation (boiler) can be started first. A thermal oil boiler can be easily installed in heating systems, industry or combined, with minimal energy losses. Hot oil boiler works at low pressures as well as hot water ones, only their outlet oil temperature is higher than the output water in the water-heat boilers. After gaining experience in the operation of hot oil boilers in the thermal regime, parts for the electricity production could easily be connected. Because of the lower pressures in the hot oil boilers the risk of explosion is reduced so the necessary safety measures are lower than those for steam boilers. Therefore, the required level of training of the staff managing these boilers is lower than that of the steam boiler, which is not negligible, especially if plants are built in rural areas. The presence of high-performance personnel in steam boiler operation is mandatory. Phased construction of a steam cogeneration plant is not rational.

4. MULTIDISCIPLINARY APPROACH

To make the use of biomass widespread, a strategic approach which involves synchronous and mutually coordinated government action is needed:

- **Ministry of Mining and Energy**,

supporting high energy efficiency projects that are in accordance with the recommendations of the combustion technology selection (Tab. 1) and to set criteria for that;

- **Ministry of Agriculture, Forestry and Water Management**,

taking care that companies participating in the biomass supply chain must also have an obligation to prevent the devastation of forest and agricultural land, by afforestation and / or leaving part of the crop plants to plow;

- **Ministry of Economy**,

favouring biomass plants, whether HS or CHP, which have year-round production and heat consume supply;

- **Ministries of Education, Science, and Technological Development**,

financing R&D projects of RES energy production and consumption;

- **Ministries for Labour, Employment, Military and Social Affairs**,

influencing the revitalization of rural areas by employing their population in the biomass supply and subsiding small biomass plants that also produce heat for technological purposes, such as drying agricultural products;

- **Ministry of Environmental Protection**,

taking care that the construction of biomass-fuelled plants does not have a negative impact on the environment (cutting of forests that leads to soil erosion, landslides and like, as well as unauthorized emission of harmful substances either of solid or gaseous);

- **Chamber of Commerce of the Republic of Serbia,**

mediating between producers of energy equipment, potential investors, local authorities and interested consumers of biomass energy, and

- **Local governments/authorities**, where the biomass plant would be built,

providing favorable conditions for the biomass use for energy purposes in their territories and thus attract potential investors.

5. KEEP WARM APPROACH IN DHS MODERNIZATION AND USE OF BIOMASS FOR HEATING

Combustion of all kinds of fuels is linked to emission of certain pollutants. This needs to be kept in mind constantly; therefore it is necessary to use biomass in the energy systematically and in a controlled manner. The beneficial effect of district heating (DHS) on the local air quality should be pointed out. Larger and professionally-maintained boilers with flue gas cleaning and with high stacks replace many individual heating installations of low efficiency, with low stacks and poorly controlled pollutant emission, especially in urban areas. If a heating plant also plans to use renewable energy sources in an energy-efficient manner, its chances of attracting investments for modernization are greater.

As a competent partner, LTE was recognized by the German Corporation for International Cooperation GmbH (GIZ), engaging LTE on the project KeepWarm. This project has several major goals that are pictured in fig. 2. The first successfully completed task in the modernization of DHS was the training of thermal power plant personnel and other external stakeholders (Work package N°2, fig.2).

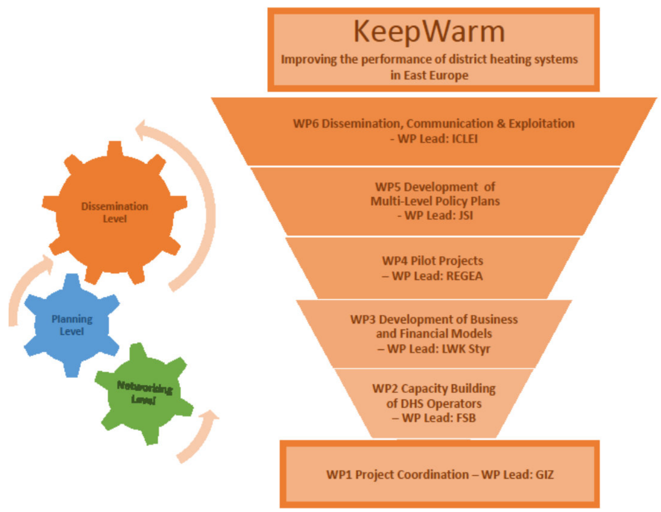


Fig. 2 KeepWarm chart

The trainings were organized from January 30th to May 22nd, 2019. LTE acknowledged the participants' feedback during training needs assessment and organized training as two-day workshops. The workshops were organized as a series of lectures with room for discussion. Besides lectures, field trips to neighbouring plants were organized to present good practice examples and enrich the lectures with a practical demonstration. The lecturers were employees of Vinča Institute, academic professionals and employees of companies involved in DH with relevant knowledge and experience. The participants were mostly employees of DH companies, but other external stakeholders such as representatives of development and energy agencies, members of academia and local government also participated in training sessions.

Training materials were mostly printed scripts and presentations and are also available online http://www.keepwarmeurope.eu/countries-in-focus/serbia.

To successfully address all aspects of DHS, training topics were divided into main topic groups as follows:

- Capacity development on technical concerns
- Capacity development on the utilization of RES, waste and excess heat
- Organizational capacity development
- Capacity development on financing topics
- Managerial capacity development.

Capacity building in **Technical topics**, dominantly for engineers, was organized in Zlatar as a two-day block consisted of 8 lectures and 2 field trips - to 0.9 MW biomass (pellet) plants - Priboj, as well as a tour of the wood chips and pellet production company Jela Star, Prijepolje. Training in technical aspects gathered 19 participants, 11 are employees of 7 DHSs, and 8 participants are external stakeholders. In total, training lasted for 20 hours. Many technical topics were addressed, with emphasis on energy loss reduction, heat storage, system optimization and practical application.

Priboj is a leading example in the transition from fossil fuels to biomass in Serbia. In 2016 light fuel oil-powered boiler was replaced with a pellet-powered boiler, which resulted in significant environmental benefits, especially for citizens living in the narrower center where soot and pollution were common. The plant supplies: a school, preschool, cultural center and municipal building. During training, a study visit to Priboj city was organized, and the operation of a biomass boiler (0,9 MW) was demonstrated.

Fig. 3 Photos from training at Zlatar

The participants were introduced to the benefits of using RES - biomass and were introduced to the boiler operation, starting with the delivery and storage of wood pellets and ending with an automatic boiler and heat storage system. Participants assessed the training with average training grade equalled 4.72, ranging from 4.41 for the effectiveness of group work to 5.0 for presenters' expertise and knowledge.

Capacity building in RES and EE topics was organized in Vinča Institute for Nuclear Science as a two-day workshop consisting of 9 lectures and 2 study visits.

Fig. 4 Photo from training at Vinča Institute

The topics ranged from renewable energy in general to specific biomass preparation and combustion technologies. The lecturers presented renewable energy in Serbia with an emphasize on biomass supply, possible models for biomass collecting and practical aspects of experimental biomass testing were elaborated in presentations and during laboratory visit. 13 individuals were included in 20 hours of training in RES and EE topics. Eight are employees of 5 DHS operators, and 5 are other stakeholders. They expressed positive feedback evaluating the training with 4.85 points on average. Training aspects such as quality of materials and lecturers' competencies were awarded excellent 5.0 points and, on average, 4.73 points were given for usefulness of the presented information. Participants especially appreciated the opportunity to get acquainted with accredited laboratories and methods for biomass quality assessment.

Training in **organizational topics** was held in Šabac and consisted of 8 lectures and 3 study visits.

Figure 5. Photos from training at Šabac

The main objective was to strengthen the capacity of selected Serbian pilot DHS operators' specialists and other DHS employees, academic sector representatives, energy experts and other interested stakeholders. The training was meant to extend their knowledge about new tendencies, technologies and other innovative experiences, to share experiences among themselves and to see in practice applied solutions in Šabac as a city that smartly plans its energy development.

The lecturers presented current state and challenges in DH in Serbia, legislative framework, energy efficiency in buildings, addressed the issues such as increasing the efficiency in production and distribution of energy and increasing the quality of heating services through compliance with standards and written procedures on real-life example – Šabac DHS. Additionally, site visits to Šabac DHS, Šabac swimming pool, and wastewater treatment plants were organized to present the use of biomass, solar heat and heating pumps. Furthermore, during the capacity building representative from the company for plumbing, gas and heating installations presented thermal energy projects from design to construction and installation of pre-insulated pipes. In total, 23 individuals participated in capacity building in organizational topics, 17 employees of 6 DH companies and six external stakeholders. In general, they expressed positive feedback and rated overall training experience with 4.89 points.

Capacity building **in financing topics** was organized in Vinča Institute. Many financing topics were addressed with a focus on business plan development covering key business plant elements such as business plan preparation process, necessary information, market analysis, capital requirements, financial analysis, financial resources, etc. In relation to the lectures, a workshop was also organized, where techno-economic analysis of replacement of heavy fuel oil boilers with biomass boiler was presented in detail and a study visit to the Laboratory for Thermal Engineering of Vinča Institute was organized.

Figure 6. Photo from training in financing topics

On average, training was awarded 4.73 points with grades ranging from 3.92 for the ability to apply the gained knowledge to 5.0 for the lecturers' competence and knowledge.

Capacity building in management topics was organized in Herz company in Nova Pazova. Training for managerial and business support staff consisted of 9 lectures and one study visit where 45 kW biomass boiler was demonstrated. Lecturers were Herz Armature company employee and professors from Vinča Institute who presented modern heating systems, information on the legal framework for the application of RES and held several lectures regarding biomass as a renewable fuel. Training participants are the managerial staff of heating plants or DHSs, and one person is a financial officer in DHS.

Figure 7. Photos from training in management topics

The presenters mostly concentrated their lectures on different aspects regarding biomass powered DHSs such as the use of biomass in cities and densely populated villages, ecological and economic aspects of biomass use, the security of supply, techno-economic analysis of replacement of fossil fuel-powered boiler with a biomass boiler, planning and reconstruction of biomass heating plant etc. During the study visit the operation of wood chips/wood pellet boiler was presented as well as the operation of boiler house and regulation and automation of boiler and heat storage. Training in management topics gathered 10 employees from 7 DHS companies and two other stakeholders, equalling 12 participants in total. Trainees provided positive feedback and awarded the training with 4.57 points on average. The grades ranged from 3.82 for the ability to apply topics in their respective plants to 5.0 for lecturers' knowledge and quick response to questions.

6. CONCLUSION

The objective of the project "Improving the performance of district heating systems in Central and Eastern Europe" – or KeepWarm, launched in April 2018, is to accelerate cost-effective investments in the modernization of DHS around the whole region and to reduce greenhouse gas emissions by improving system operations and promoting a switch to less-polluting sources, like renewables. The eleven project partners strive to ensure that best practices for environmental-friendlier heating and cooling will be taken up across Europe, replicating KeepWarm's approach in other countries and regions, even beyond the end of the project in September 2020.

The intention of the LTE team, to transfer its acquired knowledge in the field of biomass combustion from the usual scientific environment into the domain of real apply, has been implemented in the KeepWarm project. Over the years, the lessons learned and the commitment to the rational and sustainable use of biomass in energy and thus the district heating systems have been successfully transferred during the capacity building of DHS operators and other stakeholders. The training provided enabled the future development of feasibility studies and business plans for Serbian DHS participating in the project, which will attract investors.

In total, 100 hours of capacity building was held within five training blocks according to topics defined in the KeepWarm project. The number of individuals participating in capacity building in Serbia equaled 55, of which 28 are employees of DHS operators and 27 are external stakeholders from development/energy agencies, local and regional public authorities and ESCO companies. Finally, training organizers in Serbia exceeded the goal regarding the number of participants and included an additional 27 external stakeholders in capacity development.

The authors hope that this work can help in popularizing and organizing biomass applications for energy purposes. In addition, the authors argue that theories from practice can also help in affirming public-private partnerships as well as addressing possible donations and incentives in the direction that this work suggests.

Note: The authors reserve the right to present the views expressed in this paper on other occasions whenever possible.

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ENVIRONMENTAL RISK OF UTILIZATION OF BOTTOM AND FLY ASHES FROM CIGAR BURNER BIOMASS COMBUSTION SYSTEM AS A SOIL FERTILIZER

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Abstract: *During the combustion of different types of fuels numerous compounds have been emitted directly into the atmosphere or have been concentrated on the ash particles. In Serbia agricultural biomass has a great potential of use as a renewable energy resource. Biofuels are being increasingly used worldwide in order to replace fossil fuels. Among pollutants which can be emitted, there are many volatile and semi-volatile organic compounds. These compounds are formed due to incomplete combustion or reformed in the flue gas. Their concentrations depend on the fuel composition, combustion conditions and treatment of flue gases before emission. Since some of these compounds, such as polycyclic aromatic hydrocarbons (PAHs) are potentially carcinogenic and toxic, it is necessary to monitor their concentrations in order to optimize the combustion efficiency and to reduce potential environmental risk. Besides, it is imperative to determine major (Ca, K, C, O, H, N), minor (Mg, Na, S, P, Cl) and trace elements (Mn, Zn, Cu, Fe, Mo, B) in ash samples for their suitability for soil amendment and as a soil fertilizer.*

Key words: *agricultural biomass ash; major, minor and trace elements; PAHs; soil fertilizer; environmental risk*

1. INTRODUCTION

Biomass is important as an energy carrier in the last decades due to its high diversity and availability [1]. Its combustion technologies have already achieved a high level of development. According to the National Renewable Energy action plans published in 2014, its consumption in 2020 was projected to be 22% higher than it was in 2012 [2].

Among the most significant advantages of biomass fuels are: very low CO_2 emission during combustion, lower CO- and TOC emission levels comparing to fossil fuels.

The amount of ash produced in biomass combustion varies significantly on the type of feedstock material, used technology and operating conditions [3]. Three different ash fractions remain after biomass combustion: bottom ash, cyclone fly ash and filter fly ash. Bottom ash is incombustible byproduct in the primary combustion chamber, which accounts for 60-90% wt (d.b.) and can contain mineral impurities. Cyclone and filter fly ashes include finer particles and account for 10-35% wt (d.b.) and 2-10% wt (d.b.), respectively. Cyclone fly ash is composed of mainly inorganic material and is collected in the multi cyclones placed directly behind the boiler, while filter fly ash contains particles collected by emission control equipment such as electrostatic precipitators or bag house filters [4].

The elemental composition, mineralogy and crystallinity of biomass ashes usually differ due to the extremely high variations of moisture, ash yield and types of inorganic matter in the biomass. As biomass energy becomes more widely used, the utilization of ash will become more important to reduce landfilling space.

The combustion of various agricultural biomasses (wheat straw, soybean straw) produce ashes with plant nutrients like K, P, Mg and Ca in relatively soluble forms which makes application of ash on soils very promising. Fertilization by biomass ashes brings to reduction of artificial fertilizers use which makes natural mineral cycles closed (soil/nutrients - root/plant - combustion - ash - soil) [5, 6]. Besides, biomass ash has a high neutralizing potential which enables its use as a substitute for lime fertilizer in reclamation work [7]. The use of biomass ash is a significant environmental challenge owing to its chemical composition (especially toxic metal compounds and organic pollutants such as polycyclic aromatic hydrocarbons (PAHs)) and properties (such as great sorption capacity for various pollutants due to large surface area of ash particles) that pose the risk to the environment [8, 9].

Before a sustainable ash utilization (recycling to agricultural fields) it is necessary to examine its composition, especially the content of environmentally hazardous substances such as heavy metals or persistent organic pollutants [10]. PAHs are created by secondary aromatization reactions in char, in the pyrolysis phase of incomplete biomass combustion at temperatures higher than 400°C [11]. For almost all types of combustion technologies PAHs are emitted as byproducts in the environment. They pose carcinogenic potential [12] and may act as major contributors to the mutagenic activity of ambient aerosols [13, 14]. High content of heavy metals in ash and their mobile forms under environmental conditions represents a limiting factor for the direct environmental application of ash [15].

All over the world regulations concerning the use of different ashes are not clearly defined and harmonized. For example, in Sweden the only recommendation regarding to PAHs from wood ash intended for recycling states is that the overall concentration of 16 US-EPA PAHs should not exceed 2 mg/kg [16]. To our knowledge, in Serbia there are no strict regulations regarding to PAHs maximal allowed concentrations, so their monitoring is optional. Further, there is a lack of studies which deals with environmental assessment of biomass ash.

The aim of this paper was to characterize bottom and fly ashes which originate from cigar burner biomass combustion system located in Agricultural Corporation PKB and to estimate environmental risk of potential use of ash as a soil fertilizer.

2. MATERIALS AND METHODS

2.1. Chemicals

LGC standard PAH-Mix 14 (PAHs concentration 2000 µg/mL) in acetone/benzene as solvent (Dr. Ehrenstorfer GmbH, Augsburg, Germany) which contains 16 priority PAHs and additionally 1-Methyl-Naphthalene and 2-Methyl-Naphthalene.

2.2. Sample collection and storage

The soybean straw is applied as fuel for greenhouse heating in Agricultural Corporation PKB more than a decade. Around 2 kg of both bottom (BA) and fly ash (FA) were taken. BA was collected from combustion chamber and FA from cyclone of plant. Ash samples were homogenized and stored at a dark place under the temperature below 15°C.

2.3. Loss on ignition (LOI) and ultimate analysis of soybean straw and ashes

The combustible components were determined according to standard methods EN 14775:2009 and EN 14774-1:2009 adjusted to thermogravimetric analyzer LECO TGA 701. Ultimate analysis (content of C, H and N) was determined on LECO CHN 628 series, while total S was determined by separate S module of this analyzer according to the standard methods BS EN ISO 16948:2015 and ASTM D5016:2008, respectively. The oxygen content was calculated as the difference of combustible components content and sum of C, H and N.

2.4. pH measurement

5 g of each sample was mixed with 50 mL of deionized water on an IKA KS130 orbital shaker (560 rpm) during 90 min. Measurement of pH was performed using a calibrated pH meter (WTW Gmbg INO Lab, Germany) equipped with a glass WTW SenTix 61 pH electrode. Measurements were performed in triplicate and obtained pH values represent an arithmetic mean of those 3 measurements. Except water extracts, pH measurements of acidified extracts were done, too.

2.5. Determination of inorganic ash content

Sample preparation was done on a MILESTONE Ethos Easy Advanced Microwave Digestion System. 0.2 g of ash samples or soybean powder (up to 200 µm) was mixed with 8 mL of conc. HNO_3 (Fisher Chemical) and 2 mL of H_2O_2 (Alkaloid, Skopje) in TFM vessels. Digestion lasted 30 min (vessels heating from room temperature to 200°C lasted 15 min and then hold at 200°C for 15 min). After digestion, samples were diluted by deionized water up to ratio 1:10 (v/v) and filtered by 0.22 µm nylon syringe filter

ESF-NY-13-022 of 13 mm (Kinesis) prior to further analysis. Below in the text these filters are noted just as syringe filters.

Acidified extracts of metals were obtained after mixing 5 g of ash/soybean powder with 50 mL of deionized water acidified with HNO_3 up to pH 4.1. Extractions were done by an IKA KS130 orbital shaker (560 rpm) for 12 hours. After extraction samples were filtered by syringe filter and diluted tenfold by deionized water acidified by 30 µL of concentrated nitric acid.

For element determination ICP/OES spectrometer ICAP 7400 DUO Thermo Fisher Scientific (Ca, Mg, Mn, Zn, Fe, P, B, Cu and Mo) and Flame Photometer Sherwood model 360 (K and Na) were used. For determination by ICP/OES multi-element standard solution IV with 23 elements (Merck, 1000 mg/L) was used.

Chlorine was determined by standard method ISO 587:1997.

2.6. Ion chromatography

5 g of each sample was mixed with 50 mL of deionized water on an IKA KS130 orbital shaker (800 rpm) for 180 min. Anions (sulphates, nitrates, phosphates and chlorides) were determined by ion chromatograph Dionex AQUION, Thermo Fisher Scientific. Column Dionex IonPac AS22, RFIC, 4×250 mm was used as a stationary phase. Column and cell temperatures were 30°C and 35°C, respectively. Isocratic method with mobile phase 4.5 mM Na_2CO_3/1.4 mM $NaHCO_3$ was used. Flow rate was 1.2 mL/min and injected volume of diluted sample extract 75 µL. Run time was 15 min.

2.7. Determination of PAHs by LC/DAD

PAHs were extracted from the soya ash samples by a solid-liquid extraction. For extraction of ash samples n-hexane (p.a. grade, Carlo Erba), acetone (p.a. grade, Zorka Pharma) and 18.2 MΩ deionized water were used. 5 g of ash was mixed with 90 mL of 1:1 (v/v) hexane:acetone mixture, and stirred on an IKA KS130 orbital shaker with maximum speed of 800 rpm for 90 min. After that, the mixture of ash samples with solvents was filtered through Whatman No. 44 filter paper and ash was washed out several times with in total 20 mL of acetone:hexane mixture (1:1). Then, the extract was transferred quantitatively into separating funnel; deionized water was added and after shaking extract was divided into two layers. The upper hexane layer was dried by anhydrous Na_2SO_4 (Sigma Aldrich) and concentrated up to 1 mL by a vacuum rotary evaporator (Heidolph Instuments GmbH, Germany). After that the concentrated extract was evaporated to dry in a nitrogen stream, 0.5 mL of acetonitrile was added and filtered by syringe filter prior to further analysis. In order to check the reproducibility of extraction the procedure was done in triplicate.

A Thermo Fisher Scientific Dionex UltiMate 3000 HPLC system with diode array detector (DAD) was used. Envirosep-PP 125×2 mm column, with particle size 5 µm (Phenomenex) was used. All analyses were performed using a mobile phase consisting of 10% acetonitrile in water and acetonitrile in gradient conditions [17] at a constant flow rate of 0.35 mL/min. For chromatographic separations HPLC grade acetonitrile from J.T.

Baker and deionized water were used.The software Chromeleon 7 was used for setting experimental conditions as well as for the analysis of experimental data.

3. RESULTS AND DISCUSSION

3.1. Loss on ignition and ultimate analysis of soybean straw and ashes

As it is shown in Table 1 unburnt carbon and LOI are higher in fly ash than in bottom ash which indicated increased content of biomass char in FA sample. That is indication that soybean straw is quality fuel and that cigar burner biomass combustion system worked at optimal operating conditions. The total carbon content in ash depends on the biomass type. For instance, for ashes from deciduous wood combustion lower unburnt carbon was noted comparing to coniferous trees [18].

Table 1 Combustible components and results of ultimate analysis of soya and ashes

sample	combustible	moisture	N	C	H	O
	% dry basis					
BA	0.92	0.49	0.07	0.66	0.04	0.16
FA	1.72	1.65	0.17	1.38	0.06	0.11
Soya	99.05	5.14	0.83	45.22	6.00	46.99

3.2. Characterization of ash samples

3.2.1. Acidity of ash samples

Acidity higher than pH 13 observed both for BA and FA in aqueous and acidified extracts indicate that they are highly basic in their raw form, possibly due to the presence of the soluble alkaline and alkaline earth oxides such as K_2O, Na_2O, CaO and MgO.

Table 2 pH values of ash extracts

sample	water extract	acidified water extract
	pH	
BA	13.6	13.2
FA	13.8	13.5

Biomass ash is highly alkaline (Table 2) which leads to higher concentrations of metals (particularly heavy metals) and thus increase their mobility and toxicity potential. This results with the need to monitor metal concentrations. As the comparison pH values of aqueous and acidified extracts of soybean powder are 6.2 and 5.7, respectively.

3.2.2. Inorganic ash content

Both aqueous and acidified water extracts contain metals in forms which after leaching can easily penetrate into groundwater. Other metals which remain in the ash can get into the environment under more specific conditions such as the action of either more aggressive extractants or microorganisms [19]. In Fig. 1 concentrations of metals which are important as plant nutrients, determined in water and acid extracts are shown. It is seen that the potassium and sodium exist as water soluble salts while calcium and magnesium may exist in a more complex form.

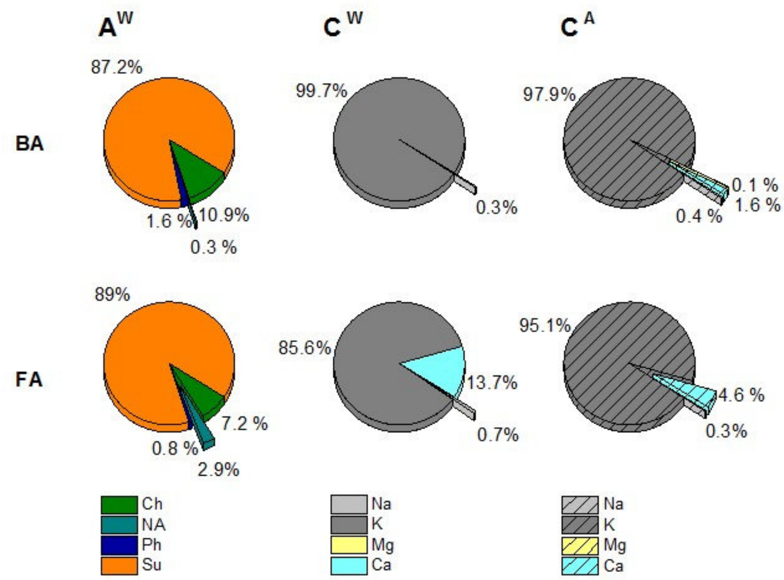

Fig. 1 Determined concentrations of cations (C) and anions (A) extracted by addition of distilled water (^{W}) and acidified water, pH 4 (^{A}) in BA and FA

According to literature data in biomass ash there are many mineral species in which these metals are included. Among them are: Ca, K and Mn as silicates, then K, Na and Ca as chlorides, then Ca and Mn as oxides, as well as K, Ca, Mg and Na as carbonates, sulphates, and phosphates (doesn't occur in coal ash) [18].

The content of analyzed elements in the BA, FA and soybean straw is shown in Fig. 2. Among major elements (>1% of dry weight of ash) are: C, O, H, N and Ca, while minor elements (1-0.1%) are: Mg, Na, S, P and Cl. Trace components (less than 0.1% of dry weight) include mainly: Mn, Zn, Fe, B, Cu and Mo. The content of metals in biomass ash depends on many factors, such as: the type and origin of biomass, fertilizer, applied pesticide doses, harvesting time, collection technique, transport, storage, pollution and combustion technology. The bottom and fly ashes are characterized by high content of alkaline substances - in particular calcium and potassium oxide [20]. During biomass combustion at high temperature the compounds are mineralized and the basic cations are transformed into oxides, which are slowly hydrated and subsequently carbonated under atmospheric conditions [3]. Several trace metals (Mn, Fe, Zn and Cu) seemed occasionally to be enriched in FA samples compared with BA samples.

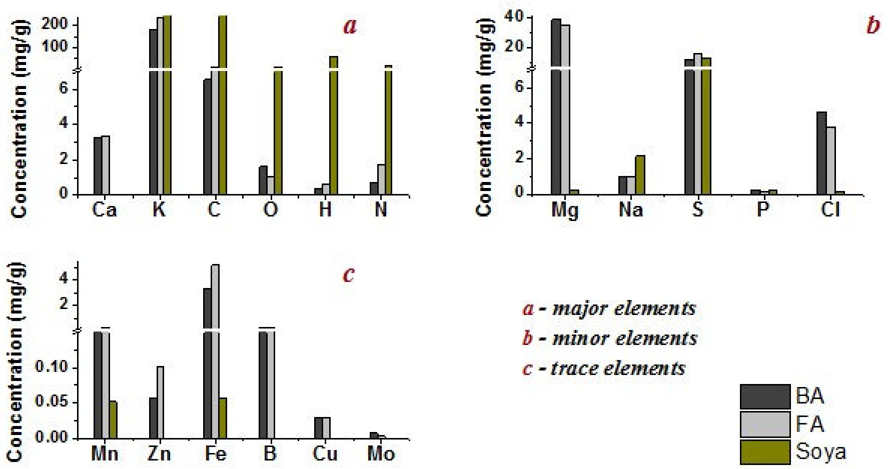

Fig. 2 Parallel representation of concentrations of major, minor and trace elements in BA, FA and soybean straw

More than 80% of the total sulphur, phosphorus and chlorine also exist in the form of sulphates, phosphates and chlorides.

3.2.3. Determination of PAHs

Table 3 shows a list of investigated PAHs in BA and FA samples, their abbreviations and concentrations. As it can be seen all eighteen PAHs are found in the FA sample, while DahA and IP are not detected in BA. PAHs concentrations for FA are found to be higher than for BA. The high level of PAHs in ash sample is associated with high carbon content [21].

PAHs fraction in BA and FA are equal to: 27.4 and 29.1% (3 rings) and 56.7 and 62.5% (4 rings), respectively. Three and four ring PAHs are commonly found in combustion byproducts as an indicator of less efficient combustion. The less abundant are PAHs with 6 rings which account 0.3 and 2.4% for bottom ash and fly ash, respectively. According to literature data the most dominant among individual PAHs are: Fla, Pyr, BaA, Chry, BbF i BaP [22]. Sum of their concentrations reach 59.6 and 65.4% of overall PAHs sum. As seen from Table 3, the concentrations of Fla, Phe and Pyr are fairly high. Together they account 60.4 and 76.6 % for BA and FA, respectively. In Table 3 rows with the most toxic PAHs are marked.

It is obvious from Table 3 that BaP concentration is much higher for fly ash comparing to bottom ash. BaP toxic equivalency factors (TEFs) are used to calculate BaP equivalent concentrations (BaP_{eq}). It is equal to sum of products of each individual PAH concentration with correspondent TEF value. BaP_{eq} is used in order to estimate risk of soil contamination with PAHs. As measure of toxic potential, BaP_{eq} values for BA and

FA are equal to 1.80 and 39.01 ng/g, respectively. According to Canadian Council of Ministers of the Environment [23], the safe BaP_{eq} value is lower than 600 ng/g.

Table 3 List of tested PAHs, abbreviations, ring numbers and determined concentrations in BA and FA with corresponding standard errors, and overall PAHs concentrations with measurement uncertainties

PAHs	**Abbrev.**	**Ring numbers**	**Concentration** (ng/g)	
			BA	**FA**
Naphthalene	Nap	2	2.86 ± 0.18[a]	16.17 ± 0.85
Acenaphthylene	Acy	3	1.53 ± 0.12	92.14 ± 4.64
1-Methyl-Naphthalene	1mNap	2	1.32 ± 0.11	19.55 ± 0.92
2-Methyl-Naphthalene	2mNap	2	2.57 ± 0.15	16.71 ± 0.89
Acenaphthene	Ace	3	0.27 ± 0.05	1.94 ± 0.15
Fluorene	Flu	3	11.26 ± 0.52	57.64 ± 2.92
Phenanthrene	Phe	3	11.80 ± 0.57	371.86 ± 18.45
Anthracene	Ant	3	0.52 ± 0.04	24.74 ± 1.15
Fluoranthene	Fla	4	32.55 ± 1.45	773.78 ± 38.46
Pyrene	Pyr	4	11.69 ± 0.65	300.60 ± 15.12
Benzo(a)anthracene	BaA	4	5.17 ± 0.32	40.79 ± 2.13
Chrysene	Chry	4	3.15 ± 0.23	64.48 ± 3.20
Benzo(b)fluoranthene	BbF	5	2.32 ± 0.15	27.46 ± 1.39
Benzo(k)fluoranthene	BkF	5	5.05 ± 0.32	6.46 ± 0.36
Benzo(a)pyrene	BaP	5	0.43 ± 0.07	26.45 ± 1.35
Dibenzo(a,h)anthracene	DahA	5	< 0.05	0.33 ± 0.05
Benzo(g,h,i)perylene	BghiP	6	0.24 ± 0.06	25.92 ± 1.32
Indeno(1,2,3-c,d)pyrene	IP	6	< 0.10	19.61 ± 0.91
Sum of PAHs			92.73 ± 14.84[b]	1886.63 ± 301.86
[a] standard errors; [b] measurement uncertainties				

4. Conclusion

It is well known that application of biomass ash could reduce usage of artificial fertilizers. In this paper we examined bottom and fly ash from cigar burner biomass combustion system. The combustion of soybean straw produces ash rich with plant nutrients such as K, P, Mg and Ca. These nutrients are available in soluble forms which facilitate their uptake by plants. Due to potential risk to the environment, it is of great importance to characterize ash content.

Since PAHs emitted as combustion byproducts are toxic compounds, the estimation of of soil pollution related risks is done by BaP equivalent concentrations. Obtained BaP_{eq} values for BA and FA are lower than maximal allowed which means that the ash is convenient for use as a fertilizer.

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COMPARISON OF SEMI-VOLATILE ORGANIC COMPOUNDS CONTENT IN ASHES FROM COMBUSTION OF AGRICULTURAL BIOMASS AND COAL

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Abstract: *During combustion of coal and biomass different compounds have been generated. There is increasing concern regarding the negative environmental impact of CO_2 formed during coal combustion. Biomass, as a source of renewable energy, could play a significant role in the reduction of greenhouse gases concentration. The ashes generated by burning of biomass or coal may pose threat to the environment due to the presence of toxic pollutants, so it is necessary to determine their content in order to estimate the environmental risk. Biomass and coal ashes are not so often characterized for organic compounds such as polycyclic aromatic hydrocarbons (PAHs). Their distribution in ash particles is important because of their toxic and carcinogenic effects to humans and animals. In accordance to this, the determination of PAHs by HPLC/DAD in extracts of ashes from combustion of soybean straw in PKB and coal in Thermal Power Plant was done. In this paper environmental impact of PAHs in biomass and coal ashes was estimated according to their physical and chemical properties.*

Key words: *semi-volatile compounds, biomass ash, coal ash, comparison, HPLC/DAD*

1. INTRODUCTION

Coal is used worldwide as a main source of power generation. Fossil fuels resources are limited, and therefore using different kinds of biomasses, with different physical and chemical properties, is increasing. Biomass is a largest source of renewable energy and it contribute to lower emission of CO and total organic carbon (TOC), but there are also some problems related to emissions - more volatile and semi-volatile hydrocarbons such as polycyclic aromatic hydrocarbons (PAHs) and unburned char. The main producer of electricity in Serbia is Elektroprivreda Srbije (EPS) with capacity of 7662 MW, while main source of renewable energy is hydro power with capacity of 2835 MW, and only 4% comes from other renewable sources. Ashes generated from combustion of coal or biomass can pose threat to environment [1] due to presence of toxic substances. Because of that, ashes are often characterized for heavy metals, but not so often for toxic organic compounds, such as PAHs.

PAHs represent stable hydrophobic organic compounds which contain between two and seven aromatic rings. They belong to persistent organic pollutants (POPs). PAHs content in ashes depend on: type of a fuel which is used (H/C molar ratio, chlorine and sulphur content, ash and volatile yield), combustor type and combustion conditions (temperature, air inlet etc.) [2]. There are different classifications of PAHs according to their physicochemical properties, toxicity, carcinogenicity or environmental fate. According to ring number PAHs are classified by molecular weight in following three groups: low molecular weight (LMW), medium molecular weight (MMW) and high molecular weight (HMW) (Table 1). Differences in the structure and size of individual PAH result in variability in their physical and chemical properties and, consequently their behavior in the environment. As molecular weight increases, the carcinogenicity of PAHs also increases, and the HMW PAHs are known to be more persistent and toxic in the environment [3].

United States Environmental Protection Agency (US EPA) listed 16 PAHs as priority pollutants due to their toxic, mutagenic and carcinogenic effects [4]. The most toxic among them are: benzo(a)pyrene and dibenzo(a,h)anthracene. Some recent studies investigate PAHs formed by combustion of coal and biomass both in fly and bottom ashes [5-7]. But still the published data on PAHs content in biomass and coal ashes are limited although they are very necessary because of their toxic effects to humans, animals and on the environment.

The aim of present study is to investigate content of 18 PAHs, where 16 among them are listed as primary pollutants, in: fly and bottom ashes, collected from a plant for heating greenhouses using soybean straw as fuel in Agricultural Corporation PKB, in fly ash from thermal power plant Kolubara and to compare environmental risk of potential usage of these ashes.

2. MATERIALS AND METHODS

2.1. Chemicals

For the qualitative and quantitative analysis of biomass and coal ash extracts, a standard solution of PAHmix 14 (Dr. Ehrenstorfer GmbH, Augsburg, Germany), 2000 μg/mL in acetone/benzene was used. The list of PAHs present in PAHmix 14 is shown in Table 1. For the preparation of the mobile phase, acetonitrile (HPLC grade, J.T.Baker) and deionized water (18.2 MΩ) were used.

For extraction of the biomass and coal ash samples following reagents were used: acetone, acetonitrile, hexane (all reagents were HPLC grade and purchased from J.T.Baker) and anhydrous sodium sulfate (Sigma Aldrich).

Table 1 The list of 18 PAHs present in PAHmix 14 with abbreviations and details about PAHs distributions used in this paper

<table>
<tr><th rowspan="2">PAHs</th><th rowspan="2">Abbrev.</th><th colspan="4">PAHs distribution relative to:</th></tr>
<tr><th>ring number</th><th>molecular weight</th><th>octanol/water partition coeff.</th><th>toxicity</th></tr>
<tr><td>Naphthalene</td><td>Nap</td><td>2</td><td rowspan="6">LMW</td><td rowspan="6">Kow3</td><td rowspan="7">O</td></tr>
<tr><td>Acenaphthylene</td><td>Acy</td><td>3</td></tr>
<tr><td>1-Methyl-Naphthalene</td><td>1mNap</td><td rowspan="2">2</td></tr>
<tr><td>2-Methyl-Naphthalene</td><td>2mNap</td></tr>
<tr><td>Acenaphthene</td><td>Ace</td><td rowspan="4">3</td></tr>
<tr><td>Fluorene</td><td>Flu</td></tr>
<tr><td>Phenanthrene</td><td>Phe</td><td rowspan="4">MMW</td><td rowspan="6">Kow2</td></tr>
<tr><td>Anthracene</td><td>Ant</td><td>T3</td></tr>
<tr><td>Fluoranthene</td><td>Fla</td><td rowspan="4">4</td><td rowspan="2">O</td></tr>
<tr><td>Pyrene</td><td>Pyr</td></tr>
<tr><td>Benzo(a)anthracene</td><td>BaA</td><td rowspan="8">HMW</td><td>T2</td></tr>
<tr><td>Chrysene</td><td>Chry</td><td>T3</td></tr>
<tr><td>Benzo(b)fluoranthene</td><td>BbF</td><td rowspan="4">5</td><td rowspan="6">Kow1</td><td rowspan="2">T2</td></tr>
<tr><td>Benzo(k)fluoranthene</td><td>BkF</td></tr>
<tr><td>Benzo(a)pyrene</td><td>BaP</td><td rowspan="2">T1</td></tr>
<tr><td>Dibenzo(a,h)anthracene</td><td>DahA</td></tr>
<tr><td>Benzo(g,h,i)perylene</td><td>BghiP</td><td rowspan="2">6</td><td>T3</td></tr>
<tr><td>Indeno(1,2,3-c,d)pyrene</td><td>IP</td><td>T2</td></tr>
</table>

2.2. Sample collection

2 kg of fly (FA) and bottom ash (BA) were collected from a plant for heating greenhouses using soybean straw as fuel in Agricultural Corporation PKB. The plant uses the technology of cigarette combustion of baled straw. Coal fly ash was collected from Kolubara thermal power plant (PPK). The samples were stored in a dark place in the laboratory at a temperature up to 15°C.

2.3. Proximate and ultimate analysis

The proximate and ultimate analysis of coal and biomass used as a fuel was done by using of the standard test methods (EN 14775:2009, EN 14774-1:2009, ASTM D7582:2012, BS EN ISO 16948: 2015, ASTM D5373-14:2014, ASTM D5016:2008). The combustible components and ash content were determined by thermogravimetric analyzer LECO TGA 701. Elemental analysis using a LECO CHN628 Series and LECO

CHN628 Series Sulfur add-on module were applied to determine elemental content of N, C, H and S, while oxygen content was calculated according to the Equation 1:

$$O\ (\%) = 100\ \% - C\ (\%\ d.b.) - H\ (\%\ d.b.) - N\ (\%\ d.b.) - S\ (\%\ d.b.) - Ash\ (\%\ d.b.) \quad \text{(Eq. 1)}$$

where d.b. stands for dry basis.

2.4. Ash samples extraction

5 g of ash was mixed with 50 mL of acetone:hexane mixture (1:4, v/v). Extraction was carried out by Grant XUB ultrasonic bath, Grant Instruments (Cambridge Ltd, UK) and it lasted 70 min. Afterwards the mixture of ash samples with solvents was filtered through Whatman No. 44 filter paper and ash was washed out several times with in total 20 mL of acetone:hexane mixture (1:4). Then, the extract was transferred quantitatively into separating funnel; deionized water was added and after shaking, extract was divided into two layers. The upper hexane layer was dried by anhydrous Na_2SO_4 and concentrated up to 1 mL by a vacuum rotary evaporator (Heidolph Instuments GmbH, Germany). After that the concentrated extract was evaporated to dry in a nitrogen stream, 0.5 mL of acetonitrile was added and filtered by 0.22 μm nylon syringe filter ESF-NY-13-022 of 13 mm (Kinesis) prior to further analysis. In order to check the reproductivity of extraction the procedure was done in triplicate.

2.5. Chromatographic separations

A Thermo Fisher Scientific Dionex UltiMate 3000 HPLC system with quaternary pump, autosampler, column compartment and diode array detector (DAD) was used. Envirosep-PP 125×2 mm column, with particle size 5 μm (Phenomenex) was used. All analyses were performed using a mobile phase consisting of 10% acetonitrile in water and acetonitrile in gradient conditions [8] at a constant flow rate of 0.35 mL/min. The software Chromeleon 7 was used for setting experimental conditions as well as for the analysis of experimental data.

3. Results and Discussion

3.1. Proximate and ultimate analysis of fuels

PAHs formation process can be associated with carbon content, H/C molar ratio and volatile yield of fuels [9]. Fuels properties were determined by proximate and ultimate analysis and summerized in Table 2. In the case of soybean straw, ash and moisture content are lower, while volatiles, carbon content and H/C molar ratio are higher comparing to lignite (Table 2). Higher H/C molar ratio is indication of lower contribution of aromatic structure in soybean straw [10], higher volatile matter can be beneficial for ignition and combustion processes [11], but it enhance tendency for increasing PAHs content in ash. Higher total carbon content in biomass shows better characteristics as a combustion feedstock, but increase adsorptive area for PAHs [12].

Table 2 Part of the results obtained by proximate and ultimate analysis of the soybean straw sample used as a fuel in plant PKB and coal from thermal power plant Kolubara

		Soybean straw	Lignite used in PPK
		dry basis	
Moisture	%	5.14	14.07
Ash		0.95	38.75
C-fix		21.53	21.59
Volatile		**77.52**	**39.66**
Total carbon		**45.22**	**40.44**
Hydrogen		6.00	3.68
Nitrogen		0.83	0.69
Oxygen		46.99	15.68
H/C molar ratio		**1.59**	**1.09**

3.2. PAHs content

In Fig. 1 concentrations and percentages of each individual PAH in fly and bottom ash from Agricultural Corporation PKB and fly ash from thermal power plant Kolubara are presented.

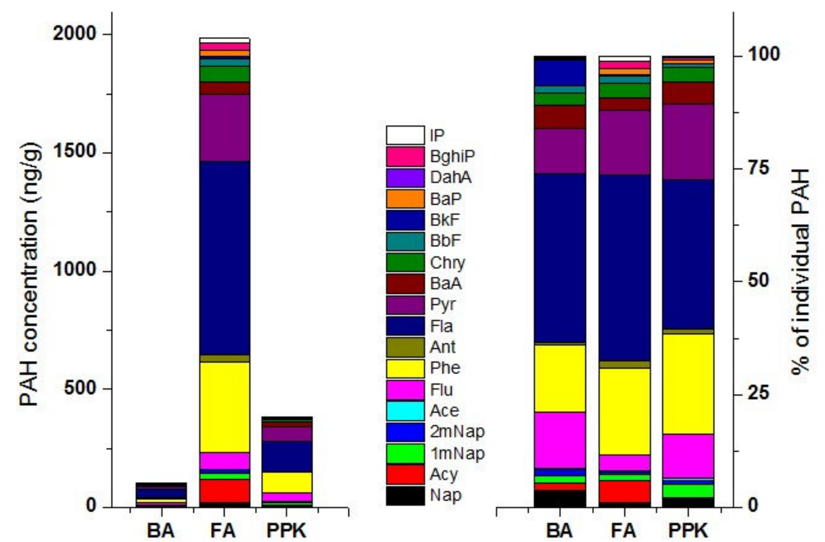

Fig. 1 PAHs concentration in bottom ash (BA), fly ash (FA) and ash from power plant Kolubara (PPK) (left) and their portion in these ashes (right)

The concentrations of overall PAHs in FA, BA and PPK ash are 1.99, 0.10 and 0.38 mg/kg, respectively. In literature PAHs in fly ash from thermal power plants range from 0.20 to 32.4 mg/kg [7, 13], and in wood and straw biomass ash PAHs content varied from

15 to 733 mg/kg [14]. As it can be seen from Fig. 1, the highest PAHs concentration is observed in FA from PKB, and the lowest in BA, which is not expected to have any organic material. The greater abundance of PAHs in FA is probably due to higher specific surface area than bottom ash.

3.3. Enviromental aspects of PAHs distribution

In Fig. 2 a) the dependence of PAHs concentrations according to number of rings is presented. Phenathrene (with 3 rings) and fluoranthene (with 4 rings) are the most abundant among PAHs for all ashes. Their concentrations are the highest probably due to lower quality of combustion processes. Some authors suggested that incomplete combustion could be the reason why fluoranthene has highest yield in ash samples [13]. In Fig. 2 b) LMW, MMW and HMW fractions of PAHs in ash samples are shown.

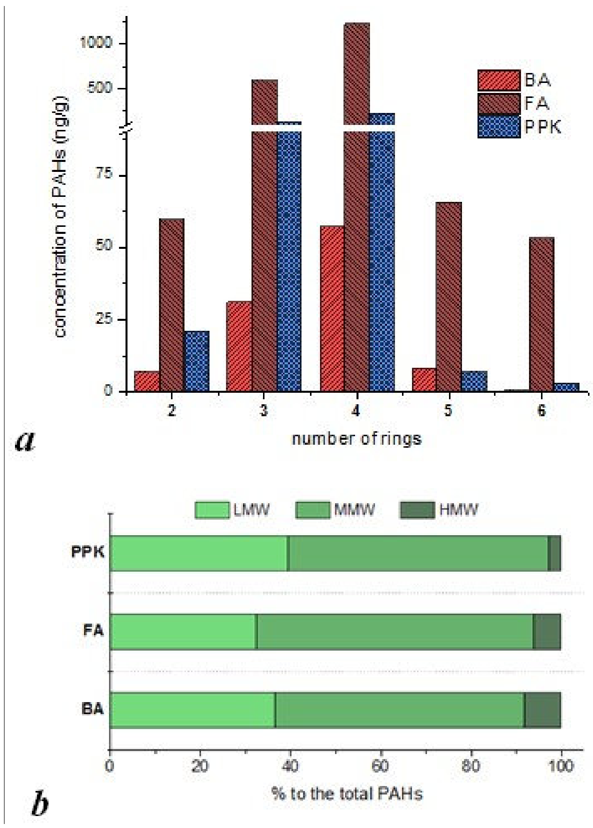

Fig. 2 PAHs concentrations as the function of the number of rings (a); comparison of LMW, MMW and HMW PAHs fractions in BA, FA and PPK ash (b)

The highest contribution of HMW PAHs is in BA and for LMW PAHs is in PPK sample. Higher amount of HMW PAHs is noticed comparing to BA samples, which is in accordance with literature data [5].

The distributions of 18 quantified PAHs according to octanol/water partition coefficient (Kow) and their toxicity (T) are presented in Fig. 3. In accordance to the values of Kow, PAHs are divided into three groups: Kow1, Kow2 and Kow3, while there are four groups according to toxicities: T1, T2, T3 and O (see Table 1).

The octanol–water partition coefficient (Kow) is a physiochemical property useful for evaluation of fate and transport of organic pollutants in the environment. The higher Kow value indicates the greater tendency of some organic pollutant to be sorbed by soil/sediment or to be accumulated in biota. PAHs are divided into three groups according to their rising Kow values. PAHs with logKow values between 3.07 and 4.01 are included into Kow3 group, while those from 4.34 to 5.52 and from 6.11 to 6.70 are included in groups Kow2 and Kow1, respectively. The highest PAHs content is noticed for Kow2 group.

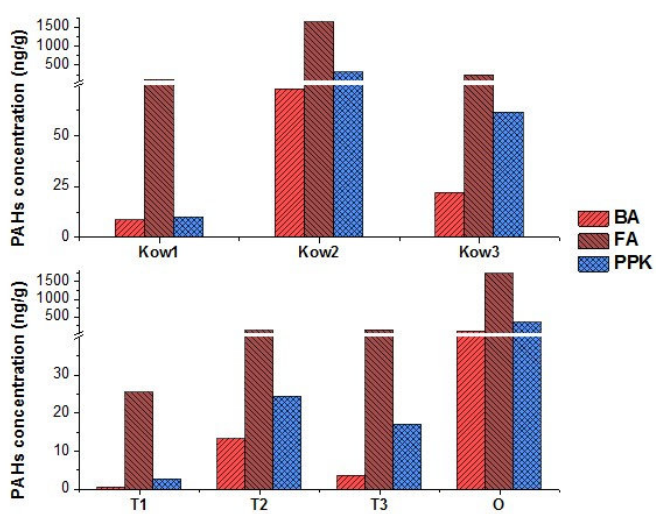

Fig. 3 PAHs concentrations as the function of octanol/water partition coefficient (Kow) and toxicity (T)

The toxicity of PAHs is one of key concerns. Generally, the higher ring number and molecular weight the higher toxicity of the PAHs. As the most toxic one benzo(a)pyrene is taken as a toxic benchmark, with toxicity equivalency factor (TEF) equal to 1. In order to evaluate the toxicity of a particular sample, very often, total PAHs concentration is expressed as BaP equivalents (BaP_{eq}). BaP_{eq} value represents a sum of products of individual PAH concentrations with correspondent TEF value. In the case of T2, T3 and O group of PAHs, TEF values are 0.1, 0.01 and 0.001, respectively. Among ashes which are investigated in this paper, FA has the highest BaP_{eq} which is equal to 39.82 ng/g. This value is under the limit which is recommended by Canadian Council of Ministers of the Environment [15].

4. CONCLUSION

In this paper concentrations of 18 PAHs in biomass fly and bottom ash, and coal fly ash have been quantified and compared. The PAHs content in ashes varied widely among the samples. The highest content of total PAHs (1986.49 ng/g) is found in biomass fly ash. In general, fly ashes (FA and PPK) contain much higher levels of PAHs than bottom ash (BA), while HMW PAHs concentration is higher in BA samples. Due to incomplete combustion, Phe and Fla are the most abundant among investigated PAHs. FA contains the highest amount of most toxic PAHs (BaP and DahA). The highest PAHs content for all ash samples has been noticed in Kow2 fraction, which has moderate logKow values. It is of great importance to estimate BaP equivalent concentrations on ash particles. As a measure of ash toxic potential BaP_{eq} value is the highest in FA sample (39.82 ng/g), but it is still safe because it is lower than 600 ng/g.

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ENERGY AND EXERGY ANALYSIS OF FUEL CONSUMPTION IN AGRICULTURAL SECTOR – SERBIAN CASE

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Abstract. *Agricultural sector is of great importance to every society. It is also a great energy consumer. Based on the relevant statistical data on the use of various energy sources, it can be concluded that diesel is the most used fuel in Serbia today. It is used to run the agricultural machineries. Therefore, a thermodynamic analysis of energy use in the agricultural sector of Serbia was conducted considering the fuel consumption for the ten-year period from 2008 to 2017. The paper presents an energy and exergy analysis of the use of energy products for the needs of agricultural mechanization in Serbia. A comparison was made with the available data from other countries.*

Key words: *energy efficiency, exergy efficiency, agricultural machinery, transport diesel, diesel gas oil*

1. INTRODUCTION

Agriculture has a great importance for every society. It ensures not only the food security of the country but also the production of raw materials for its own purposes and for the demands of other branches of the economy. Furthemore, taking into account the world trade of agricultural products, agriculture has a huge impact on the social and demographic aspects of every country. Considering the significant available natural and human resources and the achieved level of production and processing, agricultural activity in the Republic of Serbia is one of the key economic activities.

Serbia's agricultural sector is also a major energy user, using 2% of total final energy. Based on the data of the Total Energy Balance in 2017 [1], an overview of the use of total final energy by different sectors is shown in Figure 1**.**

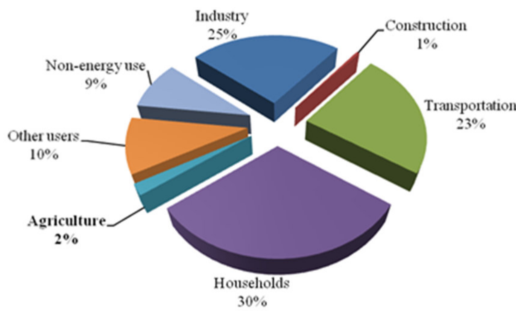


Fig. 1 Utilization of total final energy by different sectors in 2017 [1]

Agriculture consumes large quantities of scarce oil derivatives. Based on the relevant statistics on the use of different energy products in this sector, it can be concluded that diesel fuel is the most used energy source in Serbia today. A comparative overview of diesel fuel use in agriculture and other economic activities [2] is given in Figure 2.

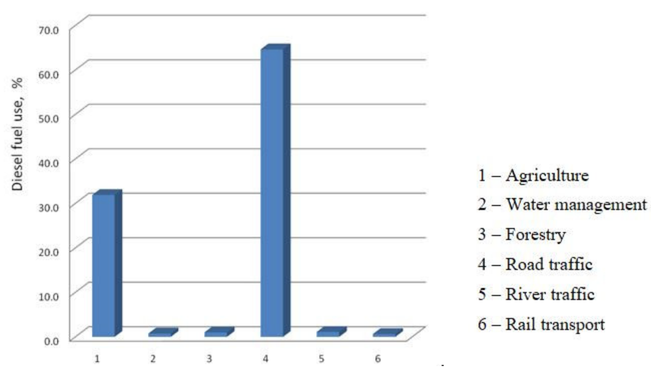


Fig. 2 Use of diesel fuel by different economic activities in 2003

A comprehensive approach considering energy use in the agricultural sector involves not only the amount of energy used, but also its quality, which can be achieved through exergy analysis. This paper analyzes the energy and exergy needs for agricultural machinery in Serbia and compares it with available data from other countries.

2. THEORETICAL BASIS OF ENERGY AND EXERGY ANALYSIS

The first law of thermodynamics is the law of energy conservation. However, it does not provide information on how, when and where amount of performance is degraded. Exergy or work potential is the quantity that provides this information. In thermodynamics theory exergy is usually defined as maximal useful work, which could be obtained by existence of thermodynamic non-equilibrium between the observed system and environment [3]. Unlike energy, in energy processes exergy is lost, destroyed, which means that energy loses quality (energy degradation takes place). Exergy analysis

allows us to locate processes and devices where energy quality is lost and to devise strategies and measures for thermodynamical improvements.
Energy and exergy balances of an open thermodynamic system, at steady state process, can be written in the form:

$$Q + W_t + \sum_{ul,i} m_{ul,i} (h_{ul} + e_{k,ul} + e_{p,ul})_i = \sum_{izl,j} m_{izl,j} (h_{izl} + e_{k,izl} + e_{p,izl})_j \quad (1)$$

and

$$Ex_Q + Ex_W + \sum_{ul,i} m_{ul,i}\, e_{x,ul,i} = \sum_{izl,j} m_{izl,j}\, e_{x,izl,j} + Ex_{gub} \quad (2)$$

Where m_{ul} and m_{izl} represent, respectively, the mass of the substance entering the system and the mass of the substance exiting the system; Q is the heat transfer between the system and the environment; Ex_Q is the exergy by heat transfer Q; W_t represents the work performed by the system; Ex_W is the exergy transfer by work; W_t; Ex_{gub} represents exergy losses. The working substance under consideration is at temperature T, pressure p and has specific values of enthalpy h, kinetic energy e_k, potential energy e_p and flow exergy e_x.
Exergy losses due to thermodynamic irreversibility during the process are determined on the basis of the expression:

$$Ex_{gub} = T_0\, \Delta S_{is} \quad (3)$$

Where $Ex_{gub} > 0$ for an irreversible process and $Ex_{gub} = 0$ for a reversible process.
The exergy by heat transfer is determined by applying equation:

$$Ex_Q = Q\left(1 - \frac{T_0}{T}\right). \quad (4)$$

The exergy transfer by work equals the work performed:

$$Ex_W = W_t \quad (5)$$

When it comes to flow exergy of a working substance it consists of the exergy of macroscopic kinetic energy e_k, the exergy of potential energy e_p, and the physical e_f and chemical part of exergy e_{ch}, arising from the thermodynamic imbalance of the fluid flow with respect to the environment. The environment is in equilibrium at constant values of temperature T_0 and pressure p_0, while the concentration of individual components in the environment is different from their concentrations in the working substance itself. In the general case the flow exergy can be written in the form:

$$e_x = e_k + e_p + e_f + e_{ch} \quad (6)$$

In the case of hydrocarbon fuels, including diesel fuel, (assuming $e_k = 0$ and $e_p = 0$) the physical part of exergy at conditions close to the environment is approximately equal to zero $e_f = 0$. What follows is that the flow exergy of a fuel is equal to its specific chemical exergy, which can be written in the form [3-5]:

$$e_x = e_{ch} = \gamma_f H_f \quad (7)$$

where γ_f is quality factor of the fuel, H_f is the higher heating value of the fuel. The value γ_f, which depends on the fuel composition, is determined according to the models available in the literature. Table 1. gives H_f, e_{ch} and γ_f for the most commonly used fuels. The values shown are determined for a constant reference state of the environment - air at temperature $t_0 = 25^o C$ and pressure $p_0 = 1$ atm .

Table 1 Properties of appropriate fuels [4]

Fuel	H_f [kJ/kg]	e_{ch} [kJ/kg]	γ_f [−]
Gasoline	47.849	47.394	0.99
Natural Gas	55.448	51.702	0.93
Fuel Oil	47.405	47.101	0.99
Diesel	39.500	42.265	1.07

The performance of the device can be described by energy (η) and exergy (η_{ex}) efficiencies, which are defined in the usual way - as the ratio of useful and input value. The useful effect of agricultural machinery is in the form of mechanical work, which is obtained at the expense of motor fuel combustion. What follows is that the energy and exergy efficiency of machines using a certain type of fuel can be expressed in the form of:

$$\eta_m = \frac{W_t}{m_f \, H_f} \tag{8}$$

and

$$\eta_{ex,m} = \frac{Ex_W}{m_f e_f} = \frac{W_t}{m_f \, \gamma_f \, H_f} = \frac{\eta_m}{\gamma_f} \tag{9}$$

3. DATA ANALYSIS, RESULTS AND DISCUSSION

The analysis of the amount of energy products used in the agricultural sector was conducted on the basis of database Balance of Oil and Oil Derivates within the annual energy statistics of the Statistical Office of the Republic of Serbia. The analysis covers the share of *transport diesel* (diesel label) and *diesel gas oil* (gas oil label), which are assumed to be used in their entirety as an energy source for the operation of agricultural machinery. The participation of the remaining energy sources is very small, which is why it is neglected in this paper.

The overall energy efficiency of oil and oil derivates use in the agricultural sector of Serbia is determined by the expression:

$$\eta = \eta_{diesel} + \eta_{gas\ oil} = \eta_{m,diesel} \cdot f_{diesel} + \eta_{m,gas\ oil} \cdot f_{gas\ oil} \tag{10}$$

while the following is used to determine the overall exergy efficiency of oil and oil derivates use:

$$\eta_{ex} = \eta_{ex,diesel} + \eta_{ex,gas\ oil} = \eta_{ex,m,diesel} \cdot f_{diesel} + \eta_{ex,m,gas\ oil} \cdot f_{gas\ oil} \tag{11}$$

which on the basis of expressions (9) and (10) can be represented in the form:

$$\eta_{ex} = \frac{\eta_{m,diesel}}{\gamma_{diesel}} \cdot f_{diesel} + \frac{\eta_{m,gas\ oil}}{\gamma_{gas\ oil}} \cdot f_{gas\ oil} = \frac{\eta_{diesel}}{\gamma_{diesel}} + \frac{\eta_{gas\ oil}}{\gamma_{gas\ oil}} \tag{12}$$

Energy fraction of fuel f represents the energy share of a given type of fuel in the considered sector. When it comes to the energy efficiency of agricultural machinery, its value is about 35% [6] in the case of modern machinery. Considering the characteristics of agricultural machine park in Serbia, energy efficiency ranges from 30-35%. In practice agricultural machines do not operate continuously at nominal regime, their energy efficiency is slightly lower. It is estimated that in real conditions the energy efficiency of agricultural machinery in Serbia is around 27%. An overview of the used data [7], as well as energy fraction of fuels, for the ten-year period from 2008 to 2017, is given in Table 2.

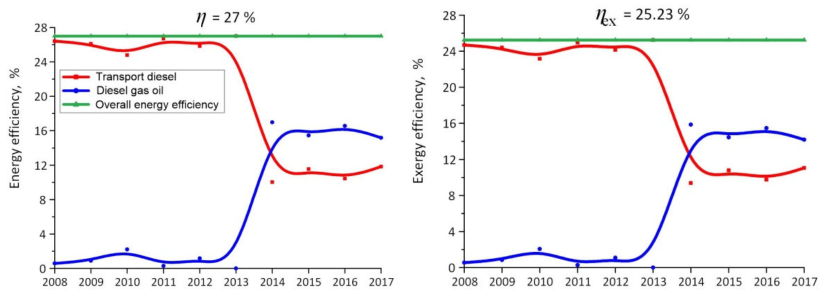
Table 2 Data on energy use in the agricultural sector of Serbia

Year	Energy input [TJ]		Energy fraction of fuel [%]		Estimated energy efficiency [%]
	Transport diesel	Diesel gas oil	f_{diesel}	$f_{gas\ oil}$	η_m
2017	2400	3079	43,80	56,20	27
2016	2138	3391	38,67	61,33	27
2015	1777	2380	42,75	57,25	27
2014	1766	2990	37,13	62,87	27
2013	5099	-	100	-	27
2012	4827	218	95,68	4,32	27
2011	2270	25	98,91	1,09	27
2010	1923	172	91,79	8,21	27
2009	2899	100	96,67	3,33	27
2008	1924	43	97,81	2,19	27

Based on the expressions (10) and (12) and the presented statistics, energy and exergy efficiency of agricultural machinery in Serbia in the period from 2008 to 2017 were determined (Figure 3).

The diagram clearly shows a decline in the use of transport diesel, with a simultaneous increase in the use of diesel gas oil starting in 2014. This is due to the ban on the production and marketing of D2 diesel in the domestic market, which was introduced to follow European Union standards. As a substitute for this fuel, which was used as an energy source for agricultural machinery, new, higher quality fuel was introduced - diesel gas oil 0.1.

The comparison of the diagrams shows that the energy and exergy efficiency of agricultural machines in Serbia are very close to each other. This is also true when comparing the efficiencies of machines that use transport diesel, and those that use diesel gas oil, and it also applies when comparing the overall energy and exergy efficiency of oil and oil derivates use.



a) Energy efficiency of agricultural machinery
b) Exergy efficiency of agricultural machinery

Fig. 3 Efficiency of machines in the agricultural sector of Serbia from 2008 to 2017

This is due to the use of high quality fossil fuels to drive mechanization in the Serbian agricultural sector, which have quality factors of the fuel around 1.

Average values of energy and exergy efficiency of agricultural machinery for the analyzed types of fuel, which are equal to the product of machine efficiency and energy fraction of a given type of fuel, as well as the overall average energy and exergy efficiency of oil and oil derivates use in the agricultural sector of Serbia, are shown in Table 3.

Table 3 Average energy and exergy efficiency of agricultural machines for the period from 2008 to 2017

Types of fuel	Average energy efficiency [%]	Average exergy efficiency [%]
Transport diesel	20.07	18.75
Diesel gas oil	6.93	6.48
Overall average	27	25.23

Based on the presented values, it is concluded that the overall average energy and overall average exergy efficiency of oil and oil derivates use in the agricultural sector of Serbia for the period 2008 to 2017 are respectively 27% and 25.23%.

A comparison of these values was made with the overall average energy and exergy efficiency of oil and oil derivates use in the agricultural sector of Malaysia [4] and the transportation sector of Saudi Arabia [8]. Comparative results are shown in Figure 4.

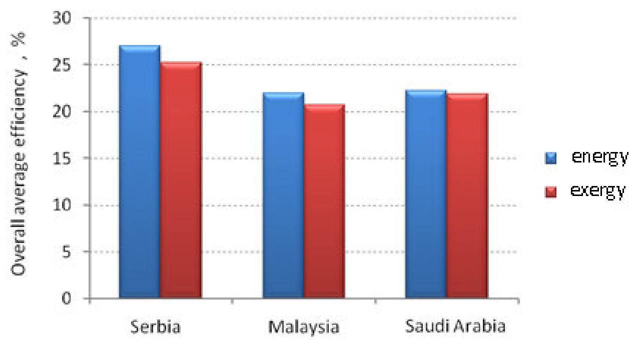


Fig. 4 Comparison of the overall average energy and exergy efficiency of the Serbian agricultural sector with other countries

The values of efficiency in these countries are approximate, but in the case of Serbia the values are slightly higher. The overall average exergy efficiency of all three analyzed sectors is lower than energy efficiency. This is due to the fact that diesel in all three countries, along with gasoline in Saudi Arabia, is a prime energy source whose quality factor is slightly greater than 1.

4. Conclusions

Based on the available data, an analysis concerning the energy and, for the first time, the exergy efficiency of energy use in the agricultural sector of Serbia was conducted. From the obtained results the following can be concluded:

- The overall average values of energy and exergy efficiency of oil and oil derivates use for the purposes of agricultural machinery in Serbia in the period 2008 to 2017 are 27% and 25.23% respectively.
- The exergy efficiency of the Serbian agricultural sector has a similar, slightly lower value than the energy efficiency, due to the use of high quality diesel fuel as a prime energy source.
- The overall average energy and exergy efficiency of the agricultural sector of Serbia, the agricultural sector of Malaysia and the transport sector of Saudi Arabia have approximate values, although in the case of Serbia they are slightly higher.
- The presented analysis was conducted from the final energy use point of view in the agricultural sector of Serbia. In order to obtain a more complete qualitative picture on the basis of which an improvement strategy in this sector would be devised, it is necessary to observe the entire flow of energy transformations from primary to final energy.
- Renewable energy sources have lower factors of converting final energy into primary energy [9]. In this regard it could be shown that the use of e.g. biodiesel would be more favorable choice than conventional fossil fuels.

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EVALUATION OF INVESTMENTS IN GPS GUIDANCE SYSTEMS AT SERBIAN CROP FAMILY FARMS

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Abstract. *Agricultural production in Serbia is characterized by dominance of small family farms. Majority of them cultivate less than 3 hectares and therefore have very small economic size (less than 3,999 EUR). One of the ways to improve their economic performance and competitiveness is to use precision agriculture technologies. Considering the fact that such technologies are commonly used on big farms the question arises if such technologies are adequate for small farms cultivating less than 100 hectares. Therefore, the goal of this analysis is to evaluate economic efficiency of investments in global positioning systems on specialized crop farms using up to 100 hectares of arable land. Data for the research are gathered by survey of 30 family farms (operating in the region of Vojvodina) which specialized in crop production. Methodology is based on discounting approach for investment evaluation and use of annualized cost savings. To perform the analysis farms are divided in two groups – first group cultivates up to 50 hectares and uses state subsidies for investments in such technology, while second group of farms cultivates between 50 and 100 hectares and is not suitable for using subsidies. In total, four scenarios concerning investments in global positioning guidance system are analyzed in the paper. As a result, for all of them break-even number of hectares for various levels of costs savings have been determined. State subsidies proved to be significant incentive for introduction of precision agriculture technology.*

Key words: *precision agriculture, GPS guidance systems, investments, family farms, costs savings, subsidies*

1. INTRODUCTION

According to the results of Agricultural census, which was conducted in Serbia in 2012, structure of farms was very unfavorable because it is dominated by very small farms. The census revealed that 60% of farms use less than 3 hectares, while only 0.29%

of farms use more than 100 hectares[1]. Besides, 68% of farms in Serbia have economic size[2] less than 3,999 EUR of standard output and such farms cultivate less than 3 hectares. Therefore, the question of how to improve economic results of small farms arises. Use of advanced technical solutions (such as precision agriculture technology) could improve profitability, sustainability and competitiveness of farms of all sizes. Such technologies offer solutions which enable increase of production and/or cost reduction with rather small investments. At the same time precision agriculture technology improves food safety and food security which is very important for emerging European Union (EU) market.

Nevertheless, there are restricted possibilities for self-financing in Serbian agriculture "primarily due to lower labor productivity leading to lower rate of surplus value" (Božić et al., 2009) so that farmers have to use other forms of financing. This is why size of farms plays significant role in adoption of precision agriculture technologies. Therefore, at the beginning, investments in such technology were economically efficient and financially feasible only for the biggest farms. It could be explained by the level of investment capacity which is closely related to the size of farms (Vasiljević and Sredojević, 2005). Nowadays technologies related to precision agriculture are primarily spreading among farms that cultivate more than 100 hectares. On the other hand, small family farms cultivating less than 100 hectares still do not have satisfying access to technologies related to precision agriculture. Such phenomenon is not present only in Serbia, but also in the EU countries where less than 25% of farmers have an access to such technologies (Dryancour, 2017).

Therefore, state subsidies for agriculture are an important incentive for distribution of precision agriculture technologies among small farms. In Serbia, subsidies for investments in global positioning (GPS) guidance systems are at the moment available only to farmers cultivating less than 50 hectares. These subsidies could speed up an introduction of precision agriculture technology resulting in increase of economic performance of small farms. Without state support small farms would have difficulties in future to compete with farms from the EU, as well as with big farms operating in Serbia (which have recently increased their investments in precision agriculture). Without production systems related to precision agriculture small crop farms would be not only less profitable and competitive but also unable to fulfill ecological standards in the future.

Having that in mind, the goal of this research is to determine economic efficiency of investments in GPS guidance system on family farms directed to crop production which use less than 100 hectares of arable land.

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[1] According to "Census of Agricultural 2012 in the Republic of Serbia", Statistical Office of the Republic of Serbia.

[2] According to the EU methodology defined by the Commission Regulation (EC) No. 1242/2008 of 8 December 2008) and appropriate approach developed by the Statistical Office of the Republic of Serbia.

2. MATERIAL AND METHOD

To analyze possible purchase of high precision guidance system authors used model of specialized crop family farm. Data for this research are gathered by survey of 30 holders of family farms (operating in the region of Vojvodina) specialized in crop production which cultivate between 10 and 100 hectares. The farms are divided in two groups where the first group is made of farms cultivating up to 50 hectares. Such farms could use state subsidies for investments in GPS guidance systems if they produce cereals, industrial crops and forage plants. The second group consists of farms cultivating 50 – 100 hectares (farms of that size are not suitable for receiving above mentioned subsidies).

The farms are divided in these two groups having in mind their ability to use subsidies, while both groups of farms have to be registered with appropriate state Register[3]. According to the preliminary results of the most recent Farm Structure Survey conducted in 2018[4] family farms with 10 – 100 hectares cultivate 48.7% of utilized agricultural area (UAA) in the region of Vojvodina. More detailed analysis show that 35.5% of UAA in Vojvodina is used by farms cultivating 10 to 50 hectares while 13.2% of UAA in the same region is used by bigger farms (cultivating 50 to 100 hectares). All the data gathered by the survey (questionnaire) are referring to production years 2017/2018 and 2018/2019. The questionnaire is used to collect data on sowing structure, technology of crop production, as well as production costs for all the crops grown at a farm.

The basic assumption in this research is that family farms have different sizes and sowing structure, and that they do not use the same production technology. This is why production costs differ among analyzed family farms. Taking into account production costs for each crop, as well as participation of individual crops in the sowing structure of the observed farms authors generated a weighted average costs per hectare.

Four scenarios concerning investments in GPS guidance system are analyzed in the paper. For all of them break-even number of hectares for various levels of costs savings (which are achieved using precision agriculture technologies) have been determined.

Economic evaluation of investments in high precision guidance system is based on calculation of annual equivalent cost of using the system. According to Bierman and Smidt (2007) the annual equivalent cost is sum of annual equivalent of an initial outlay (investment) and operating costs per year. The annual equivalent of an initial investment is calculated by multiplying amount of the investment by the corresponding capital recovery factor. This approach is similar to an annuity method described by Gogić (2014). The capital recovery factor is calculated as follows:

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[3] According to regulations published in „Official Gazette of the Republic of Serbia", No. 48/18 of June, 23rd 2018 and „Official Gazette of the Republic of Serbia", No. 29/19 of April 19th 2019.

[4] Preliminary results of Farm Structure Survey conducted in 2018 by the Statistical Office of the Republic of Serbia on the sample of 120,000 farms.

$$\text{Capital recover factor} = \frac{r}{1-(1+r)^{-n}} \quad (1)$$

where:

r - represents interest rate per period and
n - life of an asset in years.

Application of this approach assumes that the high precision guidance system will be replaced at the end of its useful life with equivalent new equipment (technology) having the same annual equivalent costs.

Prices of high precision guidance systems used in this research are the average market prices for such systems in Serbia. Useful life of 5 years for the systems is assumed, with a cautionary note that fast development of technology could make guidance system obsolete in two to three years. Therefore, estimating a salvage value for these assets is difficult. Having all that in mind, it is assumed that the guidance system will become obsolete at the end of its useful life and will have no salvage value.

Financing of the investment in high precision guidance systems is supposed to be from equity funds (50%) and from loan (another 50%). After the purchase of the system, farms cultivating less than 50 hectares would receive state subsidy for the investment, while bigger farms are not eligible for such type of state support. On the basis of opportunity costs for equity funds (interest rate 0.5%) and interest rate for borrowed capital (which is estimated to be 6.5%) authors determined weighted average cost of capital (WACC) which is 3.5%. Generally WACC is considered to be appropriate estimation of discount rate for investment evaluation process (Needles and Crosson, 2005; Weygandt et al., 2002; Brigham and Gapenski, 1997; Ivanović and Marković, 2018; Ivanović, 2018).

Costs related to repair, maintenance and upgrade of the system are estimated to be 10 percent of the original purchase price of the asset per year. It is also necessary to take into account costs of annual subscription fees for real-time kinematic (RTK) correction signal.

3. RESULTS AND DISCUSSION

The farm size and sowing structure play an important role in evaluation of economic efficiency of investments in high precision guiding systems in agriculture (Table 1).

Table 1 Sowing structure for farms of various sizes

Crop	Farms cultivating 10 to 50 hectares	Farms cultivating 50 to 100 hectares
Maize	47.78%	49.07%
Wheat	27.93%	20.18%
Sunflower	18.63%	11.31%
Soybean	5.66%	8.20%
Sugar beet	0.00%	11.24%
Total	100.00%	100.00%

Source: Authors' calculation

Concerning family farms in question, their sowing structure is dominated by cereals, while industrial crops are less important. It is noticeable that an increase in farm size leads to a smaller participation of wheat in sowing structure, due to sugar beet production. This phenomenon could be explained by capability of bigger farms to use sophisticated and expensive agricultural mechanization which is needed for sugar beet production.

Sowing structure has significant influence on the cost savings achieved by the use of precision agriculture technologies. Farms producing crops that require high input (such as sugar beet) are also having higher costs (such as fuel, fertilizers, pesticides) which leads to bigger cost savings due to the use of high precision guidance systems. Therefore, higher participation of sugar beet in sowing structure increases economic efficiency of investments in GPS systems.

Besides, it should be noticed that economic efficiency of such systems also depends on the size of individual plots as well as on the size of equipment used in production process. Costs related to material, labor and other production resources for various farm sizes (having different sowing structure and production technology) are presented in table 2.

Table 2 Production costs for various farm sizes (EUR per ha)

Crop	Seed	Fertiliz.	Pesticid.	Fuel, M&R	Labor costs	Total
Farms cultivating 10 to 50 hectares						
Corn	82.01	278.88	65	173.41	17.05	616.35
Wheat	81	266.38	21.87	112.65	13.59	495.48
Sunflower	61.69	252.61	67,8	147.86	16.58	546.54
Soybeans	61.46	218.24	43.63	147.69	19.44	490.47
Farms cultivating 50 to 100 hectares						
Corn	78.91	268.34	62.54	243.41	17.39	670.59
Wheat	77.94	256.31	21.04	174.44	14.1	543.82
Sunflower	59.36	243.06	65.24	200.22	15.31	583.2
Soybeans	59.14	210	41.99	190.4	16.87	518.39
Sugar beet	66.2	384.3	264.04	357.76	27.07	1,099.37

Source: Authors' calculation

Taking into account participation of certain crops in sowing structure (Table 1) and amount of costs per hectare (Table 2), weighted average costs per hectare are determined for various farm sizes (Table 3).

Table 3 Weighted average costs per hectare for analyzed farms sizes (EUR per ha)

Crop	Farms cultivating 10 to 50 hectares	Farms cultivating 50 to 100 hectares
Corn	294.47	329.09
Wheat	138.41	109.73
Sunflower	101.83	65.96
Soybeans	27.75	42.51
Sugar beet	0.00	123.55
Total	562.46	670.84

Source: Authors' calculation

Several authors such as Debain et al. (2000), Cordesses et al. (2000), Stoll and Kutzbach (2000), Han et al. (2004) and Dunn et al. (2006) summarize the following general benefits from the use of guidance systems: reduction in driver fatigue, reduction in costs, increase in productivity, improved work quality, improved safety, less impact on the environment, possibility for work at night and when visibility is poor. Kvíz et al. (2014) found that the regular overlap of passes was in the range between 1% and 6% of machine's working width with drivers who were aware of the test setup. Bombien (2005) and Reckleben (2008; 2011) assume that overlap of passes for operations performed without some kind of visual support for driver is 8%. Some authors assumed (Nieminen and Sampo, 1993; Griffin et al., 2005) that farmers have a tendency to overlap their work about 10% of the implements width. Also, as producers move towards larger farming operations (Key and Roberts, 2007) they are purchasing wider equipment to speed up field operations (Luck et al., 2010). As implement width increases, the potential for swath overlap also increases, especially in end and point rows (Luck et al., 2010). Nevertheless, when the same operations are performed with automatic guidance using GPS overlap decreases to 0.96%. These electronic steering automation methods have widely been developed (Mousazadeh, 2013). Average potential savings caused by use of GPS in PKB corporation (Republic of Serbia) applying automatic guidance for tractors and other machinery (considering sowing structure in production year 2009/10) were 15.92 EUR per hectare. This amount represents only savings in inputs and fuel, while some other benefits also have to be considered. Some of them are savings in number of working hours and possibility to perform operations when visibility is poor or during night (Marković et al., 2012; Marković et al., 2011). Related to that, average potential savings caused by the use of RTK navigation system in the Republic of Slovenia, on two parcels (whose size is 172 x 58 meters), and the two working machines (that are 3 and 6 meters wide) were 15.7% of the time and 8.66% of the fuel (on a working machine that is 3 meters wide) and 12.6% of the time and 8.28% of the fuel (on a working machine that is 6 meters wide) (Kelc et al., 2019; Vajda et al., 2018). At the same time, authors emphasized that the main savings originate from reduction of fertilizers costs and pesticides costs.

Production costs differ among family farms of various sizes due to differences in sowing structure and production technology. Therefore, costs savings achieved by use of high precision guidance systems are different for farms of various sizes. The range of savings generally varies from 2 percent to 8 percent with an average savings of 5 percent. Keeping this in mind three estimates of savings are reported in Table 4 (2 percent, 5 percent, and 8 percent).

Table 4 Costs savings for analyzed farms sizes (EUR per ha)

% of cost savings	Farms cultivating 10 to 50 hectares	Farms cultivating 50 to 100 hectares	Difference (EUR per ha)
2% costs savings	11.25	13.42	2.17
5% costs savings	28.12	33.54	5.42
8% costs savings	45.00	53.67	8.67

Source: Authors' calculation

Economic efficiency of investments in high precision guidance systems is based on determination of annual equivalent costs and their comparison with appropriate savings per hectare presented in Table 4. Therefore, annual equivalent costs for various scenarios are calculated in Table 5.

Table 5 Economic efficiency of investments in high precision GPS guidance systems on family farms directed to crop production

Elements of calculation	**Farms cultivating 10 to 50 hectares**		**Farms cultivating 50 to 100 hectares**	
	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
Investment amount – initial outlay (EUR)	12,000.00	12,000.00	12,000.00	14,400.00
Investment subsidy (%)	0%	50%	0%	0%
Investment subsidy value (EUR)	0.00	5,000.00	0.00	0.00
Salvage value (EUR)	0.00	0.00	0.00	0.00
Amount to be recovered (EUR)	12,000.00	7,000.00	12,000.00	14,400.00
Discount rate (%)	3.50%	3.50%	3.50%	3.50%
Life of the asset (years)	5	5	5	5
Capital recovery factor	0.22148	0.22148	0.22148	0.22148
Annual equivalent of an initial outlay (EUR)	**2,657.78**	**1,550.37**	**2,657.78**	**3,189.33**
Annual repair costs (10% of new over life) (EUR)	240.00	240.00	240.00	288.00
Annual subscription fee (EUR)	300.00	300.00	300.00	300.00
Operating costs per year (EUR)	**540.00**	**540.00**	**540.00**	**588.00**
Annual equivalent costs (EUR)	**3,197.78**	**2,090.37**	**3,197.78**	**3,777.33**

Source: Authors` calculation

Scenario 1 describes farms cultivating less than 50 hectares which do not use state subsidies, while scenario 2 represents the same farms which use state subsidies for investments in GPS guidance system. On the other hand, scenarios 3 and 4 represent bigger family farms cultivating 50 do 100 hectares which do not have possibility to use state subsidies for such an investment. In scenario 3 farms invest in GPS system equal to the system used by smaller farms (described by scenarios 1 and 2). On the other hand scenario 4 represents farms investing in more sophisticated and more expensive GPS guidance system.

Annual equivalent costs are the lowest for scenario 2 (which assumes use of state subsidies for investment in GPS guidance system) while they are the highest for scenario 4 (assuming investment in the most advanced GPS guidance system while there is no possibility to receive appropriate state subsidies). Considering annual equivalent costs, as well as appropriate cost savings per hectare, authors determined break-even number of hectares for each scenario and each level of costs savings (Figure 1 and Figure 2). At the break-even number of hectares the investors (holders of family farms specialized in crop production) are indifferent between possibility to continue current practice and an option to invest in high precision guidance systems.

The results indicated that for small farms which do not use state subsidies for investments (scenario 1) it is not economically efficient to invest in high precision guidance system. In other words, such farms have to cultivate 71 hectares to reach break-even point, which exceeds limits assumed for this model. On the other hand, for small farms (cultivating up to 50 hectares) using subsidies for investments (scenario 2) it is economically efficient to invest in GPS guidance system only if their costs saving level is the highest possible (8%). In this case their break-even number of hectares is 46, which indicates that the break-even point is very close to the upper limit (50 hectares).

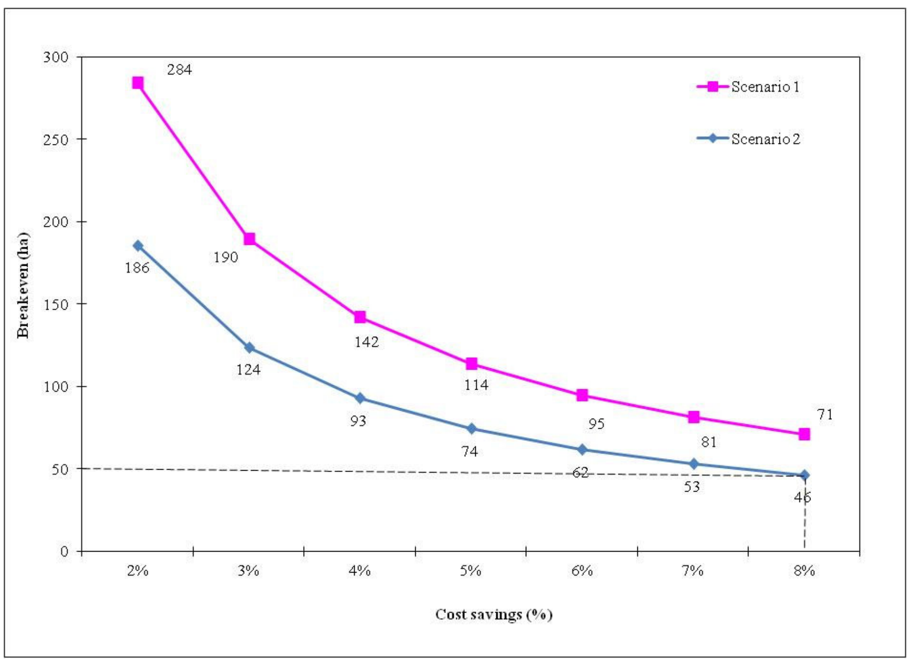

Fig. 1 Break-even number of hectares over the range of 2 percent to 8 percent savings for scenario 1 and 2 (Source: Authors' calculation)

Considering bigger family farms which cultivate between 50 and 100 hectares and which are not able to use investment subsidies (scenario 3 and scenario 4), level of investment efficiency in GPS guidance system is much higher. Nevertheless, to keep break-even number of hectares below 100 it is necessary to have appropriate level of cost savings – which is at least 5% for scenario 3 (break-even number of hectares is 95) and 6% for scenario 4 (break-even number of hectares is 94).

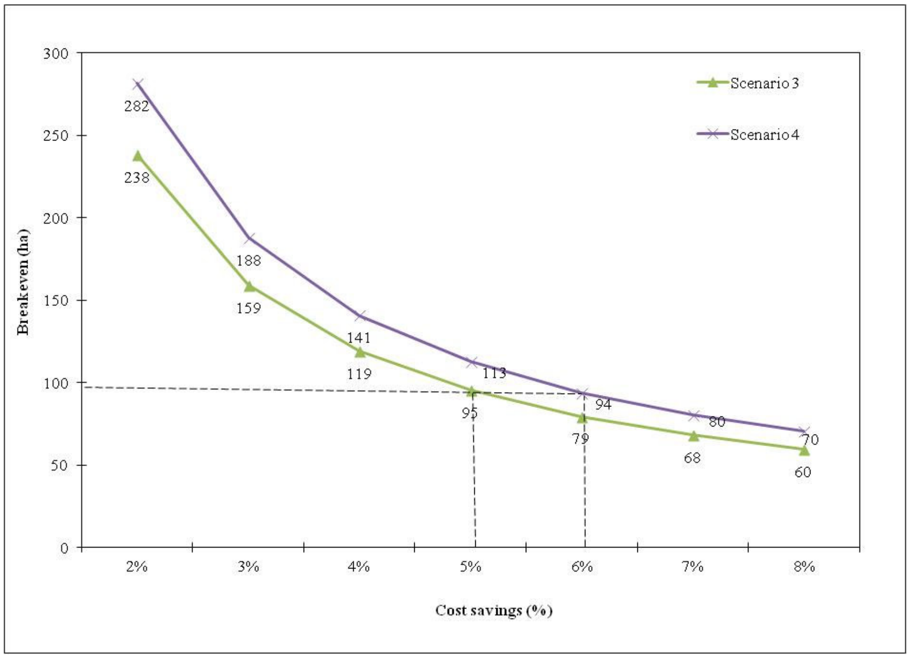

Fig. 2 Break-even number of hectares over the range of 2 percent to 8 percent savings for scenario 3 and 4 (Source: Authors' calculation)

It is necessary to emphasize that savings related to labor also have consequence on some managerial issues of family farms. Labor savings might be important on farms where labor is limited resource, while dynamics of labor use during the year indicate that labor force could be in deficit at the peak of the season. On family farms specialized for crop production the most critical months are April and October. According to Munćan et al. (2008) this problem is especially related to farms cultivating more than 45 hectares (for October) and farms cultivating over 70 hectares (for April). Use of high precision guidance systems decreases labor consumption and facilitates labor management in critical months, so that farmers should also estimate additional benefits related to the investments in GPS guidance system.

4. CONCLUSION

Investments in high precision guiding systems are useful tool for improvement of farms economic performance, primarily due to cost reduction, but many other benefits should not be neglected. Economic efficiency of investments in such systems primarily depends on a level of cost savings, as well as amount of cash outlay for purchase of GPS guidance system and level of operating costs related to its use. Results of this analysis indicated that, in Serbian conditions, purchase of high precision guiding systems is economically efficient for small farms (cultivating less than 50 hectares) only if they use state subsidies for investments. On the other hand, investments in such system on bigger crop family farms (cultivating between 50 and 100 hectares) are economically efficient even without subsidies, provided that they achieve certain level of cost savings.

The results indicate that state subsidies for agriculture are an important incentive for distribution of precision agriculture technologies among small farms. Without state support small farms would have difficulties in future to compete with farms from the EU, as well as with big farms operating in the Republic of Serbia (which have recently increased their investments in precision agriculture). Without systems related to precision agriculture small farms would be not only less profitable and competitive but also unable to fulfill ecological standards in the future.

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