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APPLICATION OF CONTEMPORARY TECHNICAL SYSTEMS IN CHEMICAL PROTECTION OF FIELD CROPS: CASE STUDY OF WHEAT PRODUCTION IN SERBIA

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INVITED PLENARY LECTURE

Abstract: *The application of precision agriculture in chemical plant protection enables the realization of high yields while preserving natural resources. The quality of chemical applications depends on the type of technical system that performs for this job. The task of the technical system is to protect the cultivated crop precisely, economically and while preserving the environment, and all that depends on the precission and the quality of application of the protective liquid. The use of UAV´s in chemical plant protection enables precise application of protective liquid, so their application is increasing in the protection of numerous crops. The same trend has been observed in field production, where the use of UAV´s is on the rise. The paper compares the exploatational and technological characteristics of the field sprayer (FS) and unmanned aerial vehicle (UAV) in the chemical protection of wheat. The amount of deposited protective liquid on plants and losses of deposited on the surface of the earth were monitored. Using UAV (T4: V = 3 m·s^{-1}, H = 1 m), the amount of protective liquid on the plant was determined to be 0.185 mg·l^{-1} compared to 0.037 mg·l^{-1} at FS, while the losses were 0.01 mg·l^{-1} at FS and 0.085 mg·l^{-1} at UAV. The presence of Fusarium (Fusarium spp.) after chemical protection was analyzed according to the compared technical systems and set treatments. It was recorded for 20% higher efficiency in protection against Fusarium (Fusarium spp.) using UAV (T5: V = 3 m·s^{-1}, H = 2 m) compared to FS. The values of wheat yield were measured according to the compared technical systems and set treatments, where the highest wheat yield was achieved using UAV (T5) with 10,667.7 kg·ha^{-1}, while using FS, 14.84% lower yield was achieved. The application of UAV´s in the segment of chemical plant protection enables us to effectively protect crops, economical and optimized production, while preserving the environment in a way that has been completely new and unknown until now.*

Keywords: *unmanned aerial vehicle - UAV, field sprayer, protective liquid, quality of application, yield.*

1. INTRODUCTION

The growing need for food in the 21st century has led to the intensive development of agricultural production. The growth of agricultural production relied primarily on the application of modern agricultural machinery and adequate use of pesticides. To achieve the highest possible yields and profits, inappropriate treatment norms are often applied and the basic principles of chemical plant protection are not respected. Inadequate application of chemical agents in plant production causes a decrease in the quality of soil, water and air. The impact of such bad practices is particularly reflected in the quality and safety of food for human and animal health 5, 9, 10..

Chemical plant protection is one of the important agro-technical measures that affects the quality and quantity of field crops. Properly performed chemical protection can significantly reduce the occurrence and intensity of pests on cultivated crops, and thus the scope of chemical protection. The better and more timely the chemical protection, the less need for additional chemical measures is, and the more successful the protection itself. The crucial factor on the effect of chemical protection of field crops is the selection of the appropriate pesticide and its proper application to the cultivated crop 8.. Rational use of pesticides implies application in a given norm by means of a technically correct and adjusted technical system.

Precision agriculture offers several different techniques and technologies whose applications can successfully overcome the problems in the field of chemical plant protection. With the help of various sensors, the parameters of production processes can be determined and recorded in real time, on the basis of which the reasons for efficient/inefficient operation can be precisely determined 9, 10.. The use of precision agriculture technologies in chemical plant protection has enabled an increase in the results of agricultural production, but also a reduction in the negative impact on the environment from the excessive use of chemical agents 10.. The full effect of the application of precision agriculture is visible through the economy of production, optimization of the costs of inputs in production, reduced engagement of agricultural machinery and human labor, as well as a positive impact on environmental protection 7..

The last decade has been marked by the study of the effects of the application of precision agriculture on various operations in agriculture. The various technologies of precision agriculture that are used in the chemical protection of crops are interesting from a professional but also scientific point of view, where the goal is to verify the set assumptions. Some of the current technologies are: VRA of pesticide, Spot Spray Systems, Unmanned Aerial Vehicle sprayers - UAV sprayers 2, 3.. The application of UAV sprayers in chemical protection was originally intended to protect crops on smaller plots and plots with inaccessible terrain 4, 11.. In recent years, the application of UAV sprayers in the chemical protection of field crops has become more intensive, so the question arises: what is the quality of chemical protection of field crops using UAV sprayers?

In this paper, a comparative analysis of the operation of the field sprayer and UAV sprayer in the chemical protection of wheat is performed, with reference to the production results during wheat cultivation, as well as the operational characteristics of the applied technical systems.

2. MATERIAL AND METHODS

The research was conducted during 2020/21 wheat production year, on a field near Belgrade (44°50'44.5"N 20°11'08.7"E) on a plot of 60 ha. Data on qualitative and quantitative indicators of performed chemical protection in wheat production were collected in the experimental field. The wheat cultivar Apilco Ig was grown in a conventional production system. During the year, the crop required only one chemical protection treatment, which was performed in parallel using two technical systems: a field sprayer and a UAV sprayer. The same mix of pesticides was used in both technical systems used: Prosaro 250 EC (a.s. Tebuconazole 125 $g \cdot l^{-1}$; a.s. Prothioconazole 125 $g \cdot l^{-1}$) with an amount of 1 $l \cdot ha^{-1}$; Vantex 60 CS (a.s. Gamma-cyhalothrin 60 $g \cdot l^{-1}$) with an amount of 50 $ml \cdot ha^{-1}$.

The field sprayer (Kubota - iXtrack T3) used in the experiment has a working width of 21 m and a tank volume of 2,600 l. Lechler IDKT 12005 sprayers were used on the field sprayer. The working parameters of the sprayer were: speed of movement 5 $m \cdot s^{-1}$; system operating pressure 0,8 MPa; treatment rate 200 $l \cdot ha^{-1}$. The UAV sprayer (M4E TTA) used in the experiment has a working width of 4 m and a tank volume of 4 l. Lechler 110-015 sprayers were used on the UAV sprayer. The operating parameters of the UAV sprayer were: flight speed (V1 = 3 $m \cdot s^{-1}$; V2 = 5 $m \cdot s^{-1}$); flight altitude (H1 = 1 m; H2 = 2 m); system operating pressure 0,5 MPa; treatment rate 40 $l \cdot ha^{-1}$.

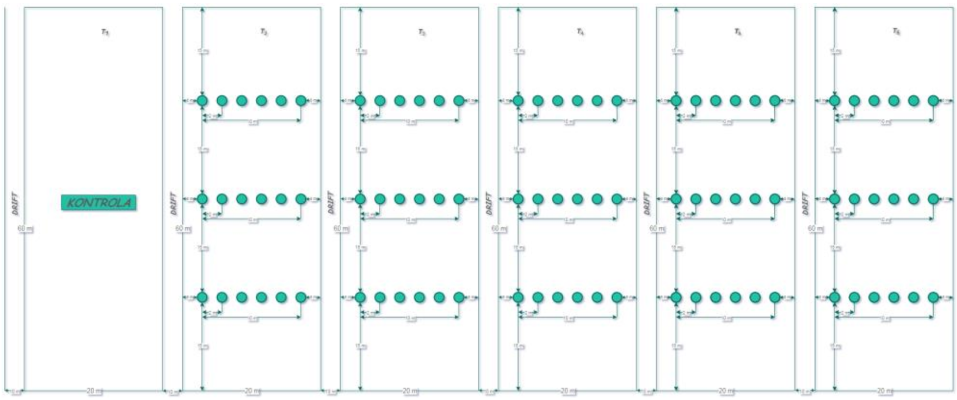

Figure 1. Scheme of the experiment

The labels used in Figure 1 have the following meanings:

B - Working width of the technical system

V - Speed of movement of the technical system during chemical protection

H - Height of application of protective liquid when treating wheat

T1 - Treatment where no chemical protection of crops was performed (control plot)

T2 - Treatment with a field sprayer (B = 21 m; V = 5 $m \cdot s^{-1}$; H = 0.5 m)

T3 - Treatment with UAV sprayer (B = 4 m; V = 3 $m \cdot s^{-1}$; H = 1 m)

T4 - Treatment with UAV sprayer (B = 4 m; V = 5 m·s^{-1}; H = 1 m)

T5 - Treatment with UAV sprayer (B = 4 m; V = 3 m·s^{-1}; H = 2 m)

T6 - Treatment with UAV sprayer (B = 4 m; V = 5 m·s^{-1}; H = 2 m)

Drift - The part of the experiment from which no samples were taken, due to the possible drift of the protective liquid

Figure 1 shows the scheme of the set experiment, where the measuring points (from which the samples were taken) are marked with green circles. Samples were taken after chemical protection from two heights, in three surface zones for each of the experimental treatments, with 6 repetitions. The distance between the sampling points is 2 m, and the distance between the sampling zones is 15 m. The exact locations of the sampling sites were verified using a Garmin eTrex GPS locator. At each sampling point, metal support was placed on which water-sensitive paper WSP2 (dimensions 26 mm x 76 mm) and filter paper (diameter 90 mm) were placed. Water-sensitive paper is used to assess the characteristics of the protective liquid (coverage area, droplet size), while filter paper is used to determine the deposition-retention of protective liquid on plants. The applied pesticide mix was colored red (Allura red) at a dose of 450 g·ha^{-1} to facilitate the determination of the deposition of protective liquid on plants.

Control of disease and insects occurance was performed before and after chemical protection 6.. The control of the presence of insects was performed the day before the chemical protection, and the efficiency of the insecticide action was determined after the 3rd and after the 7th day from the performed protection treatment. From each treatment in the experiment, 50 plants were taken by the method of random sampling, where the number of present insects was recorded. The appearance of the disease was followed by sampling the same number of samples after the 15th day of chemical protection of wheat.

The speed of airflow during the performance of chemical protection was recorded with the help of the Testo 410i Smart Probe device, while the temperature and humidity of the air were determined using the Voltcraft DL-140TH device. The analysis of the filter paper was performed in laboratory conditions on a WTW PhotoLab 6000 spectrophotometer. The analysis of water-sensitive papers was performed using the DepositScan software in laboratory conditions (the papers were originally scanned at a resolution of 600 dpi). Analysis of yield parameters (morphological characteristics and yield) were performed in laboratory conditions after taking five samples from each of the treatments (all plants were removed from an area of 1 m^2 - per sample). All collected data were processed by statistical methods using the software package SPSS 17.0.

3. RESULTS AND DISCUSSION

The results the filter paper samples analyzes for the treatments from the experiment are shown in Table 1. The values in Table 1 indicate the percentage of deposition of protective liquid on wheat leaves in the examined leaf zone. The obtained results show that the deposition is higher in the higher zones of the plant. Between the treatments, it was noticed that higher deposition is achieved by applying a UAV sprayer when flying at a flight speed of 3 m·s^{-1} (in treatments T3 and T5), regardless of the set flight altitude.

Table 1. Results of coverage of analyzed filter paper samples (%) by treatments

Sampling site	Treatment	T2	T3	T4	T5	T6
The middle of the height of the plant		10,7	21,4	7,7	23,4	6,5
At the ground		3,9	16,0	4,0	10,9	5,5

Figure 2 shows a graph showing the percentage of plant leaf mass area on which the protective liquid (leaf coverrage during chemical protection) was applied after the chemical protection was performed. Leaf coverage during chemical protection, which we detected via water-sensitive paper, is best in T2 treatment when using a field sprayer. The reason for such a high coverage lies in the sprayer treatment rate of 200 l·ha^{-1} compared to 40 l·ha^{-1} as the UAV sprayer treatment rate.

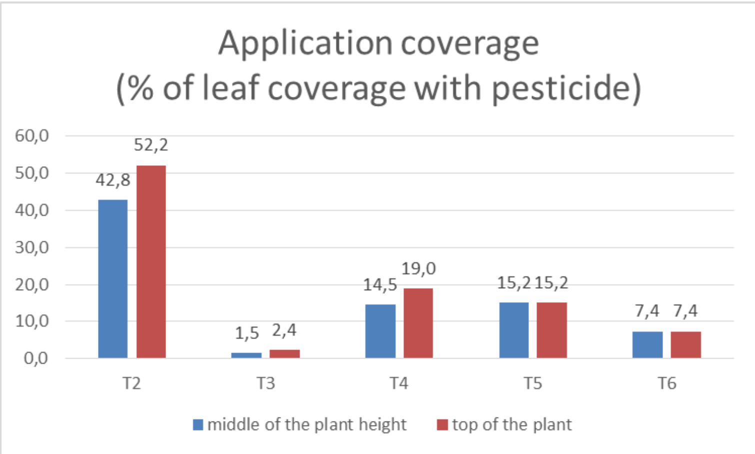

Figure 2. Achieved coverage of wheat leaf mass with protective liquid after treatments

After the 15th day from the day of applied chemical protection, sampling for the presence of the disease was performed and compared with the results from the samples taken immediately before the chemical protection. It was found that the greatest effect of protection against Fusarium (80% protection) was achieved by using a UAV sprayer in the T5 treatment. The T2 treatment performed with the field sprayer had a 60% effect of protection against Fusarium. The results of the samples analyzed for the effectiveness of protection of applied pesticides against Fusaruim are shown in Figure 3.

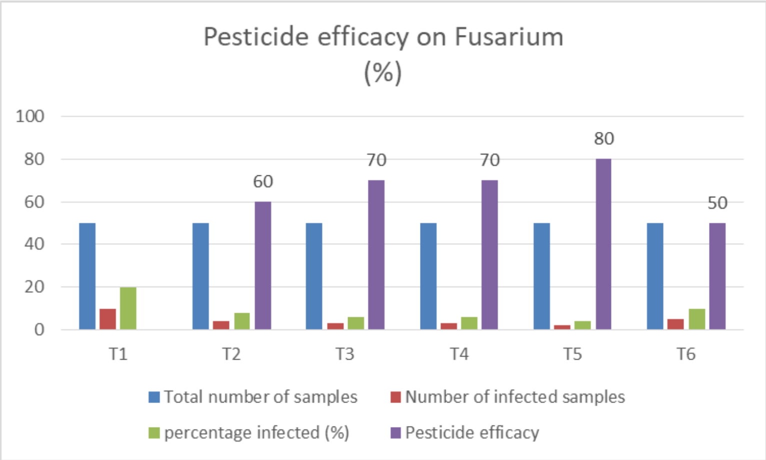

Figure 3. Achieved level of protection from Fusarum on wheat by different treatments

Of all yield parameters, grain yield was singled out as the most important in wheat production. The yield was determined by two methodological principles: analysis in a macro experiment; and sampling in a micro experiment. Sampling in the micro-experiment was performed by standard methodological principles (yield data collected from measuring points from an area of 1 m^2) 1., while in the macro-experiment it was performed by measuring the total wheat yield sample from the entire observed treatment (analysis of data from harvesting by combine). Data from micro and macro experiments are uniform and show that the highest wheat yield was achieved in the T5 treatment where chemical protection was applied by UAV sprayer. Figure 4 shows the realized yields by treatments depending on the applied technical system of chemical protection and operating parameters. It is evident that UAV sprayer flight speeds over 3 $m{\cdot}s^{-1}$ negatively affect the achieved yields (visible in treatments T4 and T6).

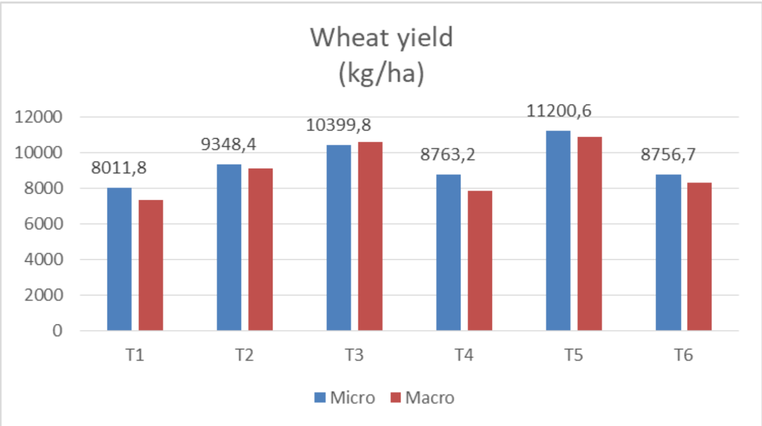

Figure 4. Realized wheat grain yields by treatments

Wheat yields recorded through the macro experiment give a more comprehensive and accurate presentation of the realized yields in the field compared to the results from the micro experiment. The reasons for such a setting are based on the larger sampling area and the cancellation of specific deviations caused by random sampling of yields in micro-experiments.

4. CONCLUSION

A comparative analysis of the achieved results in the quality of the performed chemical protection between the field sprayer and the UAV sprayer showed that the field sprayer with a higher treatment rate achieves better coverage of the wheat leaf surface. However, the higher coverage achieved with field sprayers does not imply greater penetration of the protective liquid into the deeper layers of wheat. The lower permeability of the protective liquid during the application of the field sprayer is reflected in the lower efficiency in the protection against Fusarium, and consequently in the lower yields.

During the application of UAV sprayer, it was noticed that the higher flight altitude enables better coverage of the leaf mass, but weaker penetration of the protective liquid into the lower layers of plants. The T5 treatment achieved a 16.5% higher yield compared to the yield achieved by the application of the field sprayer. This data indicates a serious potential application of UAV sprayer in chemical protection of field crops. If we observe only treatments where the chemical protection of wheat was performed only by UAV sprayer, higher yields were achieved in treatments where the flight altitude was 1 m, regardless of the flight speeds used during application. The highest yield of 11,200.6 $kg \cdot ha^{-1}$ was achieved in the T5 treatment when the flight speed was $V = 3\ m \cdot s^{-1}$, and the flight altitude $H = 2$ m. The application of UAV sprayers in chemical protection will consequently have an increasing popularity and thus a higher number of UAVs used in field production.

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