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APPLICATION OF THE COEFFICIENT OF USING THE ACTIVE SUBSTANCE FOR THE EVALUATION OF THE EFFECT OF CHANGES OF NOZZLE OPERATING PARAMETERS ON THE SPRAYING PROCESS

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Abstract

The aim of the research was to determine the coefficient of using the active substance ($K_{s.a.}$), which was used to assess the quality of the spray. The quality of spraying was determined by the amount of copper deposited used for spraying from two different preparations. Two standard nozzles, flat fan XR 110-02 and double flat fan DF 120-02, were used for testing, which operated at a constant speed of 0.86 m·s^{-1} and two pressures of 0.2 and 0.28 MPa. The foliar fertilizer containing copper and a preparation containing the nano copper particles were used for spraying. The deposition tests were performed in the "Aporo1" spraying chamber. Mineralization was carried out in order to determine the deposition of copper on winter rape plants, and then the concentration of the copper element in the tested plants was measured using a spectrometer. After obtaining the deposition results the coefficient of using the active substance ($K_{s.a.}$) was calculated. It was observed that the $K_{s.a.}$ coefficient increases with the growth of the plant regardless of the spraying process parameters used.

***Key words**: nano copper, copper, foliar fertilizer, nozzle, spraying.*

INTRODUCTION

The quality of the plant spraying treatment depends on many technical and technological factors, as well as the weather conditions under which the spraying is carried out. According to many authors, the quality of spraying depends largely on the selection of the right nozzle. Therefore, the right type of a nozzle, its size and operating parameters (pressure, working height, spacing, setting) should be selected for the treatment. Choosing the right nozzle limits the entry of excess plant protection products into the environment and is a prerequisite for the proper course of spraying, and consequently results in a higher degree of coverage and spray deposition on the sprayed surfaces (Szewczyk et al., 2012; De Souza Christovam et al., 2010a; Hołownicki et al., 2002; Lipiński et al., 2007; Godyń et al., 2008; Kierzek, 2007). The selection of a nozzle is important during the performance of every protection treatment of the field, orchard and covered crops (Hoffmann, Hewitt, 2005; Özkan et al., 2012). The quality of spray deposition on the sprayed plants depends, among others, on the spray characteristics of the liquid stream (drop spectrum, mean droplet diameter and maximum droplet diameter). The efficiency of use of the active substance, and hence the biological effectiveness and the amount of spray liquid depends on the quality of spraying the liquid stream (Douzals, 2012). In the presented work, the authors sought to describe the spraying process of plants, determining its effectiveness with the help of the author's coefficient of using the active substance ($K_{s.a.}$).

The aim of the study was to determine the coefficient of using the active substance ($K_{s.a.}$). This parameter was used to evaluate the process of spraying winter rape in three development phases depending on the selected parameters of the spraying process.

MATERIALS AND METHODS

The experiment of the copper deposition on the sprayed plants was carried out under greenhouse conditions at the Institute of Soil Science and Plant Cultivation - National Research Institute - in the Department of Herbology and Crop Cultivation Techniques in Wroclaw (Poland). The winter rapeseed of the DK EXTROVERT F1 variety was used for testing, which was sown in pots with a 15 cm diameter in the amount of 5 pcs./pot. Ultimately, one plant was left for spraying in the pot. A modified phytotest of the first generation was used to establish the experiment (Sekutowski, 2011). The sowing surface was a peat-mineral mix with a pH = 6.5 and sand with a diameter of 0.6-0.8 mm - mixed in a ratio of 2:1. Winter oilseed rape plants were sprayed in three different development stages: 12, 14 and 16, according to the BBCH scale. Each development phase of the plant was sprayed in triplicate. The absolute control without spraying was also included in triplicates for each development phase of the plant.

The foliar fertilizer Mikrovit Copper 80 was used for the deposition of the Intermag company along with the preparation containing nanoparticles of copper oxide (II) of the < 50 nm size of the Sigma Aldrich Company. Both preparations were used at a dose of 160 g $Cu \cdot ha^{-1}$, whose were dissolved in 250 l of water per hectare at a pressure of 0.20 MPa and 300 l of water per hectare at a pressure of 0.28 MPa. The plants were sprayed in the "Aporo1" spraying chamber, at a constant operating speed of 0.86 $m \cdot s^{-1}$. The spraying treatment was conducted using two standard nozzles: XR 110-02 (flat fan nozzle) and DF 120-02 (double flat fan nozzle), and two operating pressures: 0.20 and 0.28 MPa. The height of the spray tips from the sprayed plants was equal to 0.5 m. The laboratory air temperature during spraying was 20°C, and the humidity was 60%. The plants were cut 24 h after the spraying operation, then dried and subjected to the mineralization process.

The winter oilseed rape mineralization was carried out in a laboratory located at the Institute of Biology (Department of Hydrobiology and Aquaculture) at the Faculty of Biology and Animal Breeding of the Wroclaw University of Environmental and Life Sciences (Poland). The technique of the microwave "wet" dissolution was performed in order to determine the copper deposition on the plants using the nitric acid (V) (69.0-70.0%, Sigma Aldrich). 0.5 g of material was weighed out of each sample, and then 5 ml of the HNO_3 acid was poured and mineralized in a Mars 5 microwave digestion system (CEM Corporation, USA). The content of the studied element (Cu) was measured by atomic absorption using the FS220 spectrometer of the Varian Company. The correctness of the determinations was verified with the reference material ERM-CD281 Rye Grass at the level of 97%.

After obtaining the results of the copper deposition on the studied plants, the coefficient of using the active substance ($K_{s.a.}$) was calculated, which was described by the authors with the formula 1:

$$K_{s.a.} = \frac{V_{s.a.}}{V_w} \times g \text{ [-]} \quad (1)$$

where:

$V_{s.a.}$ - the amount of active substance assimilated by the plants during the treatment (deposition) [$kg_{s.a.} \cdot kg_{s.m.}^{-1}$]; s.m.- dry mass; s.a.- active substance;

V_w - the amount of active substance being splashed onto a given surface (dose) [$kg_{s.a.} ha^{-1}$];

g - density of plants [$kg_{s.m.} \cdot ha^{-1}$].

The plant density was calculated according to formula 2:

$$g = i \times m_{s.m.} \text{ [}kg_{s.m.} \cdot ha^{-1}\text{]} \quad (2)$$

i - the number of plants on a given area, 400000 [$plants \cdot ha^{-1}$] were adopted for calculations;

$m_{s.m.}$- mass of one dry plant [$kg_{s.m.} \cdot plant^{-1}$]; s.m.- dry mass.

The formula 1 is subject of the patent application (no. P. 423023).

The statistical analysis of the test results was performed using the Statistica 12.5 program. On the basis of conducted normality tests (Shapiro-Wilk) and homogeneity of variance (Levene), it was shown that the conditions for the applicability of multivariate analysis of variance are not met. Therefore, the non-parametric Mann-Whitney U test was used to determine the effect of the factors. The tests were carried out at the significance level $\alpha=0.05$. The assessment of the impact of the nozzle, preparation and pressure on the coefficient of use the active substance ($K_{s.a.}$) was analyzed.

RESULTS AND DISCUSSIONS

The results of the study of the coefficient of using the active substance ($K_{s.a.}$), for winter oilseed rape in the development phases of the plant: 12, 14 and 16 BBCH and the examined spraying process parameters are presented in figures 1-3. The highest values of the coefficient of using the active substance ($K_{s.a.}$) were noted for the development stage of winter oilseed rape 16 BBCH for all tested parameters of the spraying process. While the lowest values of the $K_{s.a.}$ coefficient were noted for the development phase 12 BBCH, except for the values obtained using liquids containing nano copper for spraying, where slightly lower values were noted for both types of tested nozzles for the 14 BBCH development phase. Differences of these values for the pressure of 2.0 MPa were equal to: 0.001 (flat fan nozzle XR 110-02) and 0.002 (double flat fan nozzle DF 120-02). The lowest value of the $K_{s.a.}$ coefficient (0.015) was observed for the 14 BBCH development phase when spraying winter oilseed rape with a double flat fan nozzle DF 120-02 and spray liquid containing nano copper. Increasing the working pressure to 0.28 MPa increases the value of the $K_{s.a.}$ coefficient for both types of nozzles and both spray liquids used. The exception was the higher value of the $K_{s.a.}$ coefficient by 0.006 at a lower pressure (0.20 MPa) for winter oilseed rape plants in development phase 14 BBCH at spraying with the XR 110-02 nozzle and liquid containing nano copper.

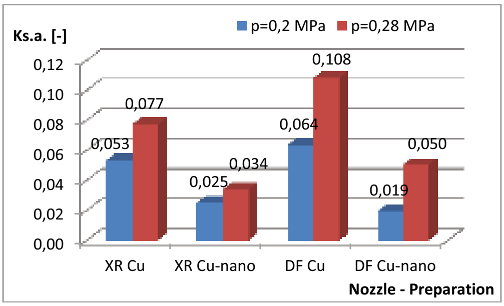

Figure. 1. Coefficient of using active substance ($K_{s.a.}$) for winter oilseed rape in development stage 12 BBCH and the selected parameters of the spraying process (XR - flat fan nozzle XR 110-02, DF - double flat fan nozzle DF 120-02, Cu - fertilizer Mikrovit Copper 80, Cu-nano - preparation containing nano copper)

Based on the data presented in figure 1, it was observed that the pressure of 0.2 MPa and the spray performed with the foliar fertilizer Mikrovit Copper 80, the value of the coefficient $K_{s.a.}$ is by 0.011 higher for the double flat fan nozzle DF 120-02 compared to the flat fan nozzle XR 110-02. However, when the pressure increased to 0.28 MPa, the increase in the value of $K_{s.a.}$ was noted for the double flat fan nozzle DF 120-02 o 0.031. We can conclude that, with lower pressure, both flat fan and double flat fan nozzles can be used for spraying, while at increased pressure it is more beneficial to perform spraying with a double flat fan nozzle. A similar situation was observed for the spray liquid containing nano copper.

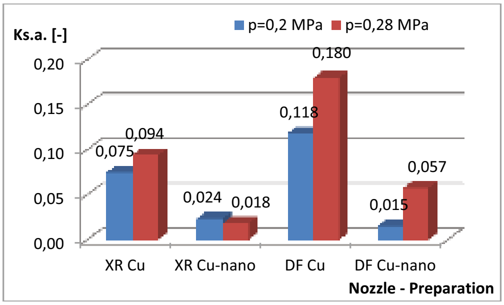

Figure 2. Coefficient of using the active substance ($K_{s.a.}$) for winter oilseed rape in the development stage 14 BBCH and the selected parameters of the spraying process (XR - flat fan nozzle XR 110-02, DF - double flat fan nozzle DF 120-02, Cu - fertilizer Mikrovit Copper 80, Cu-nano - preparation containing nano copper)

Based on the analysis of the data included in Figure 2, it was observed that the values of the $K_{s.a.}$ coefficient obtained for winter oilseed rape during the 14 BBCH development phase are definitely higher in the case when the spraying treatment was performed using the foliar fertilizer Mikrovit Copper 80.

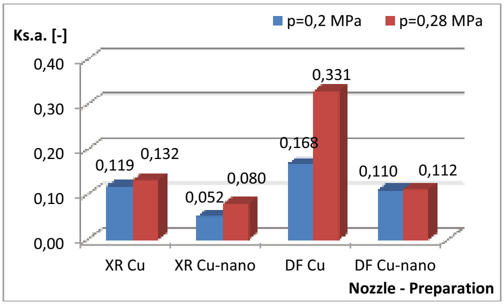

Figure 3. Coefficient of using the active substance ($K_{s.a.}$) for winter oilseed rape in the development stage 16 BBCH and the selected parameters of the spraying process (XR - flat fan nozzle XR 110-02, DF - double flat fan nozzle DF 120-02, Cu - fertilizer Mikrovit Copper 80, Cu-nano - preparation containing nano copper)

For a double flat fan nozzle DF 120-02 and liquid pressure of 0.2 MPa a 0.103 higher $K_{s.a,}$

coefficient value was obtained, when spraying with the foliar fertilizer Mikrovit Copper 80, than when spraying plants with a preparation containing nano copper (at a pressure increased to 0.28 MPa this value was higher by 0.123).

In the case of spraying the winter oilseed rape in the development phase 16 BBCH (Figure 3), similar values of the $K_{s.a.}$ coefficient were obtained, for the XR 110-02 nozzle and the foliar fertilizer Mikrovit Copper 80 for both tested pressures. Similarly, for the DF 120-02 nozzle and the preparation containing nano copper a similar value of the $K_{s.a.}$ coefficient was noted for both tested pressures. There was also a significant increase in the value of the $K_{s.a.}$ coefficient (by 0.163) for the double flat fan nozzle DF 120-02 and the fertilizer Mikrovit Copper 80 with the pressure increased up to 0.28 MPa.

The results of the statistical analysis (assessment of the impact of the nozzle, preparation and pressure on the coefficient of use the active substance $K_{s.a.}$) are presented in Table 1.

Therefore, in 2010, in Romania there were just 45% of dairy cows compared to the year 1990. Taking into account the dynamics of cattle and dairy cows stock, the share of dairy cows in the cattle stock has recorded a similar decreasing trend. In the year 1990, dairy cows represented 59.46% of the cattle livestock and in the year 2010, they registered just 53.73% (Table 1).

Table 1. Mann-Whitney U test results for $K_{s.a.}$ coefficient and individual development phases of winter oilseed rape

Factors	Value p		
	Development phase of winter oilseed rape		
	12 BBCH	14 BBCH	16 BBCH
Nozzle	0.370845	0.174854	0.022577
Preparation	0.002437	0.000077	0.007260
Pressure	0.008616	0.340779	0.260237

The data presented in Table 1 shows that the type of preparation used for spraying plants had a significantly statistical effect (at the significance level of $\alpha = 0.05$) on the value of $K_{s.a.}$ for all studied development stages of winter oilseed rape. The data presented in Table 1 shows that the type of preparation used for spraying plants had a significantly statistical effect (at the significance level $\alpha = 0.05$) on the value of $K_{s.a.}$ coefficient for all development phases of winter oilseed rape examined. There were no statistically significant impacts of the nozzle type (plant development phase 12 and 14 BBCH) and pressure (plant development phase 14 and 16 BBCH) on the value of the $K_{s.a}$ coefficient.

For the research of the usable spray deposition, samplers in the form of filter papers are used most commonly, while the researchers use the following, among others, as markers: fluorescein, nigrosine, BSF, copper oxychloride or tartrazine (Sánchez-Hermosilla et al., 2012; Godyń et al., 2011; Hołownicki et al., 2012, De Souza Christovam 2010a and b; Celen 2009; Larsolle, 2002). The authors used the foliar fertilizer Mikrovit Copper 80 and the preparation containing nano copper in own studies, while the deposition tests were carried out performing the mineralization of whole plants and checking the amount of copper element absorbed by them.

According to some scientists, the factor influencing the spray deposition indicator on the sprayed trees is their phenological phase. Świechowski et al. (2012) examined the effect of the liquid dose and the type of the nozzle on the spray deposit in the crown of apple trees in various phenological phases. Two types of nozzles were analysed: hollow cone nozzles TR 80-01 and air-injector nozzles ID 90-01. Larger deposition of the liquid was obtained by the authors in the phase of establishing and full fruit development for the hollow cone nozzles TR 80-01. De Souza Christovam et al. (2010a) performer studies aimed at determining the impact of various spraying techniques on the deposition of copper on the soybean plants. Standard flat fan nozzles TeeJet XR8002 were analysed, which operated at a pressure of 0.287 MPa, speed of 2 $m \cdot s^{-1}$and a liquid dose of 130 $l \cdot ha^{-1}$ and rotary nozzles LVO (low volume oily), which operated at the pressure of 0.621 MPa, operating speed of 1.5 $m \cdot s^{-1}$and a liquid dose of 40 $l \cdot ha^{-1}$. Both nozzles operated at different air velocities (0, 2.5 and 8 $m \cdot s^{-1}$) produced by the fan of the nozzle with the auxiliary air stream. These authors have stated that the air velocity has no effect on the amount of copper deposition on the leaf surfaces in the upper part of the soybean plants. However, in the presented own research, the authors used two nozzles producing fine droplets (XR 110-

02 and DF 120-02). Own research shows that higher values of the $K_{s.a.}$ coefficient were obtained for the double flat fan nozzle DF 120-02, regardless of the pressure and liquid used to spray the winter oilseed rape.

Many authors analysed the effect of various parameters of the spraying process on the value of spray deposit on the sprayed plants. In the presented own research, the author's coefficient of using the active substance $K_{s.a}$ was proposed, checking the influence of the parameters of the spraying process on its value. Similarly to other researchers, it was observed that the type of the nozzle used and the pressure value influence the deposition of the spray liquid and the value of the $K_{s.a.}$ coefficient.

It was observed that the value of the $K_{s.a.}$ coefficient also depends on the development phase of the plant, the bigger the plant the bigger the value of the $K_{s.a.}$ coefficient. The coefficient of using the active substance $K_{s.a.}$ presented by the authors is used as the description of the plant spraying process in terms of its effectiveness.

CONCLUSIONS

1. The highest values of the coefficient of using the active substance ($K_{s.a.}$) were recorded for winter oilseed rape plants in the development stage 16 BBCH, with all the spraying parameters used.
2. The value of the $K_{s.a.}$ coefficient increases with the growth of the plant, which is a consequence of the greater mass (surface) of the plant, allowing greater absorption of the preparation.
3. Taking into account the $K_{s.a.}$ coefficient when comparing the nozzles used in the research, it can be concluded that the best results were obtained for the double flat fan nozzle DF 120-02, at a pressure of 0.28 MPa and using the foliar fertilizer Mikrovit Copper 80 for the spraying treatment, for all analysed development phases of the winter oilseed rape.

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