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DEPOSITION OF COPPER DEPENDING ON THE SPRAYING CHARACTERISTICS OF WINTER OILSEED RAPE

Summary

The aim of the study was to determine the dependence of deposition of various forms of copper on winter oilseed rape on its spraying characteristics. The deposition of the utility liquid was determined in the first stage of the studies. The plants were sprayed in the spraying chamber "Aporo", with the copper foliar fertilizer and nano-copper. The tests were performed with a working speed of 0.86 m·s^{-1}, with two operating pressures 0.2 and 0.28 MPa. The spraying was done using standard nozzles: flat fan XR 110-02 and dual flat fan DF 120-02. In order to determine the deposition, the previously dried winter oilseed rape plants were mineralized, and then the concentration of the Cu element was measured using the spectrometer. The second stage of the study included the determination of the plant spraying coefficient K_{po}. For this purpose, the photos of horizontal and vertical surfaces projections were taken of the winter oilseed rape crops in three phases of development. The surface area of the analysed plants was determined using the Scan2Cad and AutoCad 2014 graphical program. It was observed that the plant spraying coefficient K_{po} increases along with the plants' growth. For the applied spraying parameters, higher deposition values of copper were obtained by using Mikrovit Copper 80 foliar fertilizer for spraying.
***Key words**: nano copper, foliar fertilizer, spraying coefficient of the plant, nozzle, spraying*

NANIESIENIE MIEDZI W ZALEŻNOŚCI OD CHARAKTERYSTYKI OPRYSKOWEJ RZEPAKU OZIMEGO

Streszczenie

Celem badań było wyznaczenie zależności naniesienia różnych form miedzi na rośliny rzepaku ozimego od ich charakterystyki opryskowej. W pierwszym etapie badań wyznaczono naniesienie cieczy użytkowej. Rośliny opryskiwano w komorze opryskowej "Aporo", nawozem dolistnym miedzi oraz nanomiedzią. Badania wykonano z prędkością roboczą równą 0.86 m·s^{-1}, przy dwóch ciśnieniach roboczych 0.2 i 0.28 MPa. Oprysk wykonano przy użyciu rozpylaczy standardowych: XR 110-02 i DF 120-02. W celu określenia naniesienia uprzednio wysuszone rośliny rzepaku ozimego zmineralizowano, a następnie przy użyciu spektrometru zmierzono stężenie pierwiastka Cu. W drugim etapie badań wyznaczono współczynnik opryskowy roślin (K_{po}). W tym celu wykonano zdjęcia rzutów powierzchni poziomych i pionowych roślin rzepaku ozimego w trzech fazach rozwojowych. Wielkość powierzchni badanych roślin określono przy użyciu programu graficznego Scan2Cad oraz AutoCad 2014. Zaobserwowano, że współczynnik K_{po} rośnie wraz ze wzrostem roślin. Dla zastosowanych parametrów zabiegu opryskiwania wyższe wartości naniesienia miedzi uzyskano przy użyciu do oprysku nawozu dolistnego Mikrovit Miedź 80.
***Słowa kluczowe**: nanomiedź, nawóz dolistny, współczynnik opryskowy rośliny, rozpylacz, opryskiwanie*

1. Introduction

The indicator of applying the utility liquid, as a quantitative parameter, determines not only the quality and effectiveness of the spraying treatment, but it is also used to evaluate the selection of technical parameters during the treatment (it facilitates, e.g., the selection of the appropriate nozzle for spraying). The sprayed plants differ in morphological characteristics, but above all in the exposure to the sprayed stream of the utility liquid. The horizontal surfaces of the plants are most often several times more exposed to the deposition of the active substance found in the plant protection products or in foliar fertilizers compared to the deposition of the active substance on the vertical surfaces [11]. The characteristics of the sprayed object, determining the surface of the sprayed plants is a factor that is not taken into account when determining the quality of the plant spraying procedure. And it should be kept in mind that the location of the sprayed surface of the plants has a significant impact on the behaviour of droplets and on the retention of the active substance.

In scientific literature, the parameters that determine the surface of the examined plants include the leaf area index LAI and the mean tip angle MTA. The LAI leaf area index was defined as the relation of the surface of the leaf assimilating organs to the soil surface occupied by the plants [13]. This parameter is determined by optical methods or by direct sampling [6, 17]. The value of this indicator depends on many factors, among others, the genetic traits of the plants, their habitat or agro-technical factors [6, 13]. The LAI indicator, as the basic indicator of the leaf structure, is used to evaluate the rate of growth and accumulation of biomass, the average lead setting angle (MTA) is the second indicator [5]. According to some researchers, the level of agro-technology affects the shaping of the LAI and MTS indicators, mainly fertilization and plant protection against pests [1, 12]. Andruszczak et al. [2] found that the MTA index of oat leaves increases with the application of herbicides in spraying. Other researchers have reported the effect of increased nitrogen fertilization [3, 4] and NPK fertilizer [5] on the increase of the LAI index value.

The analysis of the studied literature indicates that there is no clear way to combine morphological features of crop plants and basic indicators determining the quality of spraying. It is predicted that combining the deposition of the utility liquid with morphological features of the sprayed crop plants will cause the reduction in the agro-chemicals used in crop plant protection and the acquisition of a more effective and efficient plant protection treatment. This will contribute to the protection of the environment, including surface waters and groundwater. Therefore, the purpose of the research was to determine the dependence of depositing various forms of copper on winter oilseed rape plants (for three analysed phases of development: 12, 14, 16 BBHC) on the spraying coefficient of the K_{po} plant.

2. Materials and methods

The experiment was conducted in 2016 under greenhouse conditions, at the Institute of Soil Science and Plant Cultivation, National Research Institute, Department of Weed Science and Tillage Systems in Wroclaw (Poland). The modified I generation fitotest was used [15]. The experiment was carried out in 3 series, each of which indicated another developmental phase of the plant, determined according to the BBCH scale. Each series consisted of 3 repetitions. Absolute control (no spray in triplicates for each series) was also included. Winter oilseed rape, DK EXTROVERT F1, was observed in the following development phases: 12 BBCH (2 leaves), 14 BBCH (4 leaves), 16 BBCH (6 leaves). Winter oilseed rape was planted in pots with a diameter of 15 cm in the amount of 5 units / pot. The seedbed was a mixture of peat-mineral (pH = 6.5) and sand (0.6-0.8 mm diameter) mixed in a 2: 1 ratio. When the plants reached the assumed development stage, in each pot 1 plant was left - the remaining ones were removed.

The first stage of the research consisted in determining the deposition of the test liquid onto the plants. The foliar fertilizer Mikrovit Copper 80 from Intermag (first experiment) and copper oxide (II) oxide nanoparticles (Sigma Aldrich) <50 nm (second experiment) were used for plant spraying. The following parameters of the spraying process were adopted: dose of 160 $gCu \cdot ha^{-1}$, speed 0.86 $m \cdot s^{-1}$, pressure 0.20 and 0.28 MPa, nozzle height 0.5 m. Winter oilseed rape was sprayed in a spraying chamber of the “Aporo” company using standard flat fan nozzles XR 110-02 and standard double flat fan nozzles DF 120-02. The air temperature in the laboratory during spraying was 20˚C, and humidity 60%.

Before spraying, the plants at different phases of development were photographed at first, according to the methodology for determining spray characteristics. Then, 24 hours after the treatment, they were cut, dried and crushed. Control samples were subject to the same procedure for determining the spray characteristics. The next step consisted in performing the mineralization of the dried plants. Mineralization was carried out by “wet” microwave dissolution technique using nitric acid (V) (Sigma Aldrich, 69.0-70.0%). 0.5g of material was weighed from each sample, and then placed in HP 500 Teflon dishes, to which 5 ml of HNO_3 acid was added, and mineralized in the microwave oven Mars 5 (CEM, USA). Similar tests were performed on control plants. The analysis of the Cu element was performed by atomic absorption method using the spectrometer SpectrAA FS220, of the Varian company. The correctness of the assay was verified with reference material ERM-CD281 Rye Grass at the level of 97%.

The second stage of the research included determination of the spraying characteristics of the analysed plants. For this purpose, the photos of the surfaces of horizontal and vertical projections of the analysed plants were taken. The photos were taken with the Nikon D90 camera. The images of the vertical planes were taken six times, every 60°. Then, the photos were subject to graphical processing, the images were transformed into a vector image in the Scan2Cad program. Vector images were open in the AutoCad 2014 program, scaled to the actual size, and the size of the projections of the analysed plants was read. The results of six vertical projection surfaces were averaged, and then multiplied by four, with respect to the approach and leaving vertical surfaces as well as the right and left side of the plant, which are important during spraying. While the final value of the horizontal projection was multiplied by two, which meant taking into account the lower and upper surface of the plant. After obtaining the results of the graphical analysis, the K_{po} plant spraying coefficient was calculated, which was described by the authors with equation 1.

$$K_{po} = \frac{A_{shp}}{A_{svp}}, \qquad (1)$$

where:
K_{po} – plant spraying coefficient,
A_{shp} – surface areas of horizontal projection,
A_{svp} – surface areas of vertical projection,

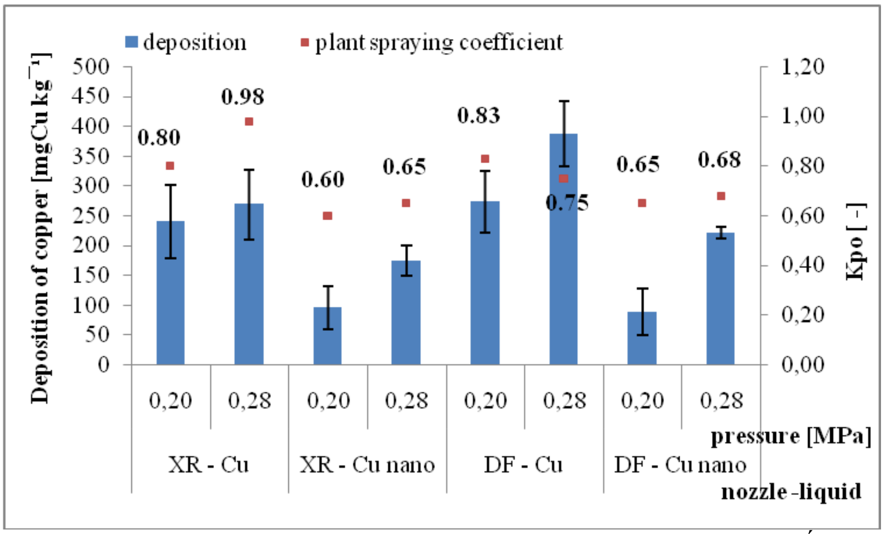
3. Results

The research results of the spraying characteristics of the analysed plants are presented in Table 1. From the data presented in Table 1, it was observed that winter oilseed rape plants at all studied phases of development are characterised by a greater number of horizontal surfaces. The number of horizontal surfaces in the 16 BBCH development phase is up to 44 times greater, while in the 14 BBCH phase, 16 times bigger than in the 12 BBCH phase of development. In turn, the number of vertical surfaces in the 16 BBCH phase is more than 30 times bigger, while in the 14 BBCH phase – 11 times bigger compared to the size of surfaces obtained for the 12 BBCH phase of development.

The results of the study on the deposition of copper (N) on winter oilseed rape plants, depending on the calculated K_{po} spraying coefficient of the plant for the analysed phases of development, are presented in figures 1to 3. The graphs show the mean values from the repetitions along with the calculated standard deviations. In the control plants no element content of copper.

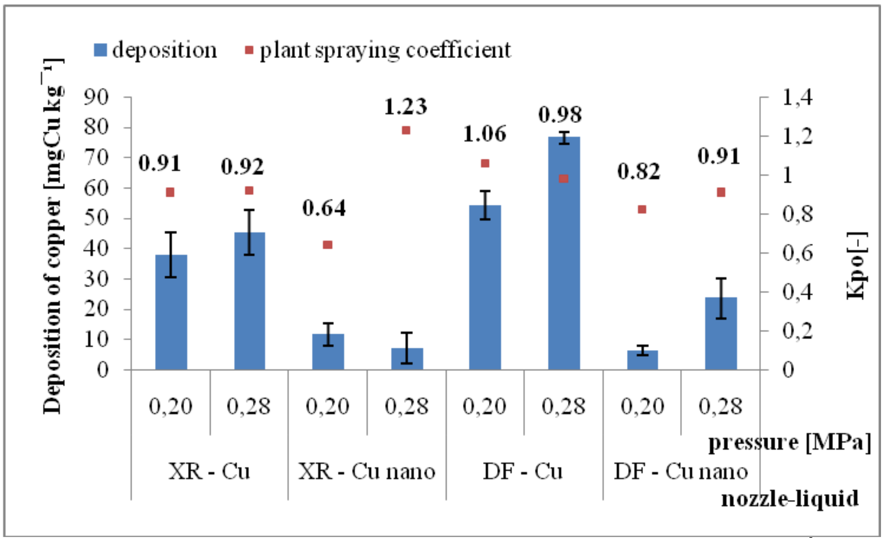
Based on the analysis of figures 1 to 3, it was observed that the K_{po} plant spraying coefficient increases with the growth of plants. This means that the smaller the plant, the bigger the number of vertical surfaces, while the number of horizontal surfaces increases with its growth. Based on figures 2 and 3 we can observe that the K_{po} coefficient is close to unity, indicating that winter oilseed rape plants in the 14 and 16 BBCH phases of development are characterised by a similar value of the horizontal and vertical surfaces.

Graphs 1 to 3 have also shown that the standard double flat fan nozzle DF 120-02 is generally characterised by higher values of deposition of copper found in the folicle fertilizer Mikrovit Copper 80 and the formulation containing nano copper. The exception was found in the deposition of the nano copper formulation on the sprayed plants at the pressure of 0.2 MPa, where the use of a standard flat fan nozzle XR 110-02 resulted in a higher deposition in the 12 BBCH phase of development by 8% and 14 BBCH by 87%, compared to the deposition values obtained for the standard double flat fan nozzle DF 120-02.



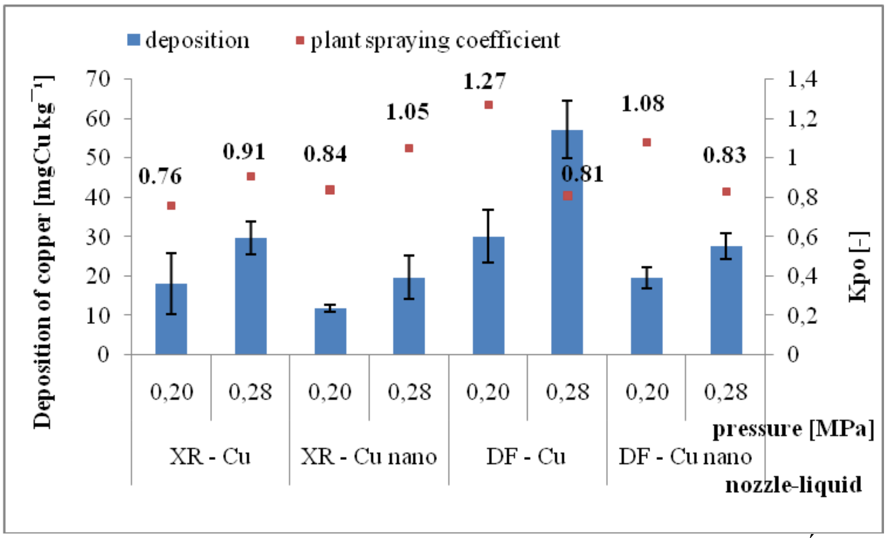
Source: own study / Źródło: opracowanie własne

Fig. 1. Deposition (N) of copper onto winter oilseed rape plants in phase 12 BBCH for the test nozzles, pressure, and K_{po}
Rys. 1. Naniesienie (N) miedzi na rośliny rzepaku w fazie 12 BBCH dla badanych rozpylaczy, ciśnienia oraz K_{po}



Source: own study / Źródło: opracowanie własne

Fig. 2. Deposition (N) of copper onto winter oilseed rape plants in phase 14 BBCH for the test nozzles, pressure, and K_{po}
Rys. 2. Naniesienie (N) miedzi na rośliny rzepaku w fazie 14 BBCH dla badanych rozpylaczy, ciśnienia oraz K_{po}



Source: own study / Źródło: opracowanie własne

Fig. 3. Deposition (N) of copper onto winter oilseed rape plants in phase 16 BBCH for the test nozzles, pressure, and K_{po}
Rys. 3. Naniesienie (N) miedzi na rośliny rzepaku w fazie 16 BBCH dla badanych rozpylaczy, ciśnienia oraz K_{po}

Table 1. The size of surface projections of the analysed plants, and the corresponding K_{po} spraying coefficient, along with the values of standard deviations

Tabela 1. Wielkość rzutów powierzchni badanych roślin, oraz odpowiadający im współczynnik opryskowy K_{po}, wraz z wartościami odchyleń standardowych

Nozzle/ Pressure [MPa]/ Liquid	12 BBCH				14 BBCH				16 BBCH			
	K_{po} [-]	SD	A_{shp} [cm²]	A_{svp} [cm²]	K_{po} [-]	SD	A_{shp} [cm²]	A_{svp} [cm²]	K_{po} [-]	SD	A_{shp} [cm²]	A_{svp} [cm²]
XR/ 0.20/ Cu	0.80	0.01	30.12	37.52	0.91	0.05	317.80	351.60	0.76	0.40	836.88	1153.32
DF/ 0.20/ Cu	0.83	0.16	36.30	44.24	1.06	0.38	387.78	362.36	1.27	0.63	1311.36	1316.08
XR/ 0.28/ Cu	0.98	0.25	48.10	48.08	0.92	0.28	291.44	323.24	0.91	0.57	615.76	742.72
DF/ 0.28/ Cu	0.75	0.13	31.88	42.64	0.98	0.27	375.42	388.40	0.81	0.36	863.62	1236.12
XR/ 0.20/ Cu nano	0.60	0.28	27.92	49.68	0.64	0.37	281.66	545.76	0.84	0.23	527.20	635.00
DF/ 0.20/ Cu nano	0.65	0.16	27.76	43.88	0.82	0.13	363.66	441.04	1.08	0.31	919.50	837.92
XR/ 0.28/ Cu nano	0.65	0.10	30.32	46.56	1.23	0.22	505.18	414.92	1.05	0.30	560.34	557.76
DF/ 0.28/ Cu nano	0.68	0.19	26.10	38.84	0.91	0.10	296.94	322.80	0.83	0.21	1150.28	652.76

Source: own study / Źródło: opracowanie własne

4. Discussion

The LAI and MTA indicators are used primarily to assess the size of the analysed plants. The MTA indicator can determine the competitive capacity of crop plants. The more horizontal the setting of leaves, the better the shade of the soil, and hence the growth of weeds is more difficult [8]. Andruszczak et al. [1] in their studies prove that the lower the MTA index, the leaf areas is situated more horizontally to the soil surface. The LAI indicator is used to assess the dynamics of plant development, the tolerance of the analysed plants on the effect of the applied plant protection products or monitoring the crop status [2-4, 7].

Modern measurement techniques allow for the rapid and non-invasive determination of LAI and MTA indicators; for this purpose, the scientists use various instruments, e.g.: meters: LAI-2000 of the LI-COR (USA) company, SunScan Canopy Analysis System (ΔT Devices Ltd., UK); a portable computer with a scanner along with a leaf-analysing program or the automatic planimetre LI-COR model 3100 Area Meter [2, 12, 14, 18]. Other researchers, in order to determine the surface and angle of leaf inclination, constructed a measuring system consisting of the following elements: a CDD-555 video camera, a computer with the AWER 2000 card, a table equipped with a crystalline glass and a light source, and a glass pressing the analysed leaf with the force of 5N [10]. However, these methods are not applicable to the assessment of plant protection products, because they do not clearly identify the horizontal and vertical surface projections of the analysed plants. And during the plant protection treatment, the nozzle creating the sprayed stream sprays only on the vertical and horizontal surfaces, distinguishing only the position/location of the leaves in the space in terms of their exposure to the falling droplets.

Evaluation of the plant spraying procedure can be done, among others, by determining the indicator of coverage degree and deposition of the utility liquid on the sprayed plants. According to Łuczycka et al. [11], additional information in the evaluation of the spraying process is provided by the plant spraying characteristics, which determine the size of the sprayed surfaces at individual stages of development by determining the coefficient of the plant's spraying surface location W_{po}. The W_{po} coefficient was calculated as a relation of the vertical and horizontal surface projections [11]. The authors in their own studies have determined the characteristics of the sprayed plants as the inverse of the spray surface coefficient (W_{po}), that is the ratio of the horizontal and vertical surface projections, defining it as K_{po}, and thus fundamentally changing its designation. In calculations, taking into account two surfaces of the plant's horizontal projection (upper and lower) and four surfaces of the vertical projection (left, right, approach and leaving – according to the driving direction of the nozzle and nature of the nozzle's operation). The reversal of the W_{po} coefficient, and the inclusion of two horizontal and four vertical surfaces, according to the authors, allows a more precise description of the phase of development of the analysed plants.

5. Conclusions

1. It was found that higher values of copper deposition for the applied spraying procedure parameters were obtained using the follicle fertilizer Mikrovit Copper 80 for spraying.

2. The plants' spraying coefficient K_{po} increases with the growth of plants, which means that the winter oilseed rape plants in phases 14 and 16 BBCH are characterised by the bigger amount of horizontal surfaces, compared to the surfaces of vertical projections.

3. In general, the higher values of copper deposition were recorded using the double flat fan nozzle DF 120-02 for spraying.

6. References

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