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The Influence of Wetting Agent and Type of Nozzle on Copper Hydroxide Deposit on Sugar Beet Leaves (*Beta vulgaris* L.)

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Abstract: Protective fungicides are sensitive to environmental conditions such as rainfall and solar radiation. Therefore, it is important to prolong the biological activity and fungicide resistance to the above-mentioned factors that can be achieved by adding a wetting agent to the working solution. Additionally, the quality and efficiency of preventive contact fungicides significantly depend on the application technique. Thus, it is important to make the right choice of the nozzles and adjust the working parameters of the treatment. The aim of this work is to determine the influence of a wetting agent and type of nozzle on copper hydroxide (2 L ha^{-2}) deposits on sugar beet leaves. Experiments are set up under laboratory and field conditions. A pinole-based wetting agent is applied at three rates (0.3, 0.6, and 1.0 L ha^{-1}) and two types of nozzles are used (standard with flat jet and modern turbo-drop twin-jet). A brilliant blue tracer is added to a working solution to enable the measurement of copper hydroxide deposits. The deposit amount is recorded before and after the rain simulation (15 L m^{-2}) with a spectrophotometer light beam. In order to ensure the timeliness of the application of fungicides, remote sensing of vegetative indices is used as an indicator of disease occurrence. The results indicated an increase in copper hydroxide deposits with the increase in wetting agent rates for both types of nozzles and in both laboratory and field experiments. Moreover, when applying the copper hydroxide mixtures with modern turbo drop nozzles, the increase in copper hydroxide deposit is significant, compared to the standard nozzles.

Keywords: copper-based solution; fungicide persistence; nozzles; pinole-based adjuvant; protective fungicide; remote sensing

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1. Introduction

One of the most devastating diseases of the sugar beet (*Beta vulgaris* L.) in the continental region is Cercospora leaf spot (CLS), caused by the fungus *Cercospora beticola Sacc* [1,2]. It causes severe leaf necrosis, resulting in decreased root weight, yield, and reduced sugar production and quality [1,3,4], hence significant economic losses [2,5]. Despite crop protection measures, sugar beet yield losses due to pests (such as wireworms, fam. Elateridae), and diseases (such as downy mildew (*Peronospora farinosa*), powdery mildew (*Erysiphe betae*), or Ramularia leaf spot (*Ramularia beticola*), are between 30.2% and 13.1% on sandy, and on average between 37.1% and 16.7% on clay soils, respectively [6]. The most common and effective control measure against this pathogen is the use of fungicides. Several studies report the use of synthetic fungicides in comparison to contact once. According to [7], synthetic compounds such as strobilurin and benomyl, as well as pyraclostrobin + boscalid, were the most effective active compounds for Cercospora sp. Control, followed by folpet, captan and maneb, and copper. The results shown by [8], indicate the high efficacy of strobilurin fungicides, while contact fungicides provided only poor disease control efficacy and also that the combination of systemic and contact fungicides provided significantly better control compared with that obtained by single applications of each mixture component. However, the use of systemic fungicides has several drawbacks, with pathogen resistance being the most significant. This is why the advantage is given to contact fungicides.

According to [3], during the past 15 years in Minnesota and North Dakota, crop rotation and combinations of different fungicides have decreased CLS infection. Many sugar beet cooperatives support the use of forecasting models and decision-support tools to ensure that fungicides are only applied when they are needed. According to [9], the use of a model to determine the time of fungicide application can eliminate up to 50% of spraying compared to a calendar spray schedule. Recommended spray volume and full product label rates should be followed when applying fungicides to achieve good coverage, resulting in better disease management and reduced selection pressure for resistance traits [10]. It is very important to choose the appropriate fungicides, their application rates, and timing, because the treatment must provide a long-lasting fungicide deposit, which is usually achieved by adding an adjuvant or wetting agent. Additionally, for *C. beticola*, it is important to use fungicides as an efficient manner for disease control.

For the control of CLS, the first efficient fungicide was copper-based Bordeaux, which has been the dominant fungicide for several decades. However, limited (low) efficacy in the first place [10] led to the development of other copper-based products, such as cooper oxychloride and copper hydroxide. The copper-based fungicides are usually combined with other active ingredients to obtain multi-site activity (for example, benalaxyl + copper oxichloride). Such mixtures are considered protective or preventive, and they should be applied preventively since they do not affect fungi once they have infected the plant [11]. Contact fungicides, including the copper-based one, have several disadvantages. They do not penetrate into the plant tissue and remain active only as long as the fungicide remains on the plant surface in a sufficient concentration to inhibit fungal growth, usually 7–14 days [12]. Additionally, protective fungicides are sensitive to environmental conditions such as rainfall and solar radiation, in contrast to systemic fungicides, which are absorbed into the leaf after application and are not affected by rain wash-off and solar radiation [12]. This is the main reason why it is important to prolong the biological efficacy of protective fungicide solutions and their resistance to rainfall. According to (13), cooper-hydroxide expressed significant contact activity by inhibiting the development of pathogens on the leaf surface [13]. Such an effect was achieved when fungicide was applied before the infection and when the total coverage (creating a good fungicide deposit) of the entire foliar surfaces was accomplished, including the undersides of leaves where the pathogen typically sporulates. Moreover, it is very important to decrease the influence of environmental conditions such as rainfall by, for example, adding a wetting agent to a working solution. According to [14], controlling the CLS population is the most important thing with different types of fungicides. However, farmers should be aware that, in some cases, fungicide efficacy will be absent, as reported by [15–17].

The quality and efficiency of preventive contact preparations significantly depend on the application technique, nozzle type, and the properly adjusted working parameters of a treatment [18]. These include the size of the droplets in the jet and the uniformity of transversal distribution of the spray swath, which is determined by the coefficient of variation (CV) and its distribution [19]. The use of wetting agents contributes to the quality of application by increasing the deposit of a contact fungicide (copper hydroxide in particular) and provides better coverage and the efficiency of applied fungicides. The type of nozzle may also lead to reduced usage of pesticides in crops. The standard flat fan nozzles produce fine (F) and medium (M) droplets, which are more drift-able, while the air induction nozzles generate coarse (C) and very coarse (VC) droplets, which are less prone to drift. Timetable for application should also be considered among the nozzle types because [20] points out that the optimized management for CLS control must be prepared according to the prediction model of pest infestation as well as a forecast of weather conditions. In this paper, satellite images of plant condition were used, i.e., vegetation indexes were monitored with the aim of accurate detection of disease infestation. The weather conditions not only affect the efficacy of pesticide application but also have an impact on the spread of the pests [21].

The aim of this work is to determine the influence of a wetting agent, applied at different rates, on the deposit quantity of a copper hydroxide-based fungicide solution and also to assess the influence of a nozzle type on the deposit amount. The obtained results will enable environmentally friendly pesticide treatments or integrated plant protection practices for sugar beets.

2. Materials and Methods

The experiment was conducted in two steps, namely, under laboratory and field conditions using the same working parameters for the spray application. In both cases the plants of sugar beet were treated with different combinations of copper hydroxide and a pinole-based wetting agent, which were applied with different types of nozzles. In the laboratory conditions plants were exposed to the "artificial rain" to test the persistence of the deposit depending on the combination of fungicide and wetting agent as well as the type of nozzles.

2.1. Laboratory Experiment

In the laboratory experiment, sugar beet plants were brought from the field, planted in a substrate, and treated with different combinations of copper hydroxide and pinole-based wetting agent. None of the elements which could influence turgor, shape, size, position, or the color of leaves were added to the substrate. The experiment was carried out at a temperature of 21 °C with an average relative humidity of 61%. Plants were grown under the lamp SunMaster 600 W Dual Spectrum Grow + Photonic to provide optimal conditions for plant growth. This lamp emits light from both the red and blue ends of the color spectrum and so is suitable for use as the only light source necessary for both the vegetative and flowering stages. It has 90,000 initial lumens (lumens @ 100 h), K-2000 (correlated color temperature), and 25 CRI (color rendering index).

The experiment was conducted using a laboratory sprayer that has the same elements as the field crop sprayer (Figure 1), with boom width of 3 m. Working parameters of the treatment were chosen based on the operating parameters that are used by the farmer and therefore the application rate of treatment was 208 L ha^{-2}, the speed of demo sprayer was 8 km h^{-1}, and working pressure was 400 kPa. The treatment was conducted with the standard flat fan nozzles ASJ SF11003 (SF) producing fine droplets, and the turbo drop twin-jet nozzles Agrotop TD ADF 11003 (TD ADF), which generate coarse and very coarse droplets [22,23]. The boom sprayer was attached to the carrying frame, which could move on the rails. The movement speed of 8 km h^{-1} was achieved using an electromotor with thyristor regulator. Boom height was 0.5 m above the plants. Nozzle spacing was 0.5 m between them.

Figure 1. Treated sugar beet plants in laboratory conditions.

In detail, the SF nozzle generates flat fan jet with an angle of 110° and a flow rate of 1.2 L min^{-1} at 300 kPa pressure. At working pressure of 300–400 kPa the volume median diameter (VMD) of generated droplets is within the range from 150 µm to 250 µm (fine spray quality) according to the classification ISO 25358:2018 [24]. The nozzle TD ADF is a flat fan air induction twin-jet nozzle. In the nozzle body there is a long injector tube that provides the significant speed of liquid flow (turbo). It produces very coarse droplets of VMD from 400 µm to 450 µm. This nozzle generates two jets, one directed 10° forward, and the other one 50° backwards.

2.1.1. The Experimental Protocol

The experiment protocol means spraying sugar beet in field and laboratory conditions with two nozzle types, fungicide mixtures, and wetting agent. Four spray liquid mixtures composed of copper hydroxide and the wetting agent, based on pinole, were applied at the following different rates:

Copper hydroxide 2 kg ha^{-1} (Treatment I)
Copper hydroxide 2 kg ha^{-1} + pinole 0.3 L ha^{-1} (Treatment II)
Copper hydroxide 2 kg ha^{-1} + pinole 0.6 L ha^{-1} (Treatment III)
Copper hydroxide 2 kg ha^{-1} + pinole 1 L ha^{-1} (Treatment IV)

During the experiment, a tracer of Brilliant Blue was added to the mixture to measure spray deposit with a spectrophotometer.

2.1.2. Measurement of the Deposit Quantity after the Treatment

After the application of all treatments, the plants were left to dry for 1 h under laboratory conditions. Then five samples of the leaves were taken (upper and lower leaf sides) from 5 plants in order to determine the amount of the deposit. It was taken at random 25 samples for each treatment for 3 treatment replications. Samples were taken in dishes. Petri dishes contained the demineralized and deionized water with which the leaves were washed. Area of the leaves was measured to express deposit as mass of tracers per unit area. Leaf samples were taken after the application of fungicide solutions and after the rain simulation.

The concentration of Brilliantine blue tracer was measured based on the absorbance reading on the spectrophotometer Hanna Iris HI801 at a frequency of 630 µm. There was no photo degradation as the experiment was conducted in the dark. Figure 2 illustrates the upper surface of the sugar beet leaves after the treatment.

(**a**) (**b**) (**c**)

Figure 2. The upper surface of the sugar beet leaves after the treatment with fungicide in laboratory conditions with laboratory sprayer and TDADF nozzles (**a**,**b**) and after raining (**c**).

2.1.3. Measurement of the Deposit Quantity after the Rain Simulation

An hour after the treatment, the rainfall was simulated using a deflector nozzle at the low pressure of 150 kPa, falling directly on the sugar beet plants under exact same conditions (speed and size of the drops) as heavy rain in the field (15 L m^{-2}). Disintegrated drops with a diameter of 1000 µm with smaller deviations imitated rain conditions. After 7 min of the simulation of the rain, when leaves dried, the samples of the leaves were taken again (front and back side) five replications to determine the quantity of the deposit.

2.2. Field Experiment

Under field conditions the experiment was conducted on the property of the company Žunji-Silak in Temerin (GPS: 45,4596040, 19,9405830) in the beginning of July 2020, at temperature of 23 °C, with an average relative humidity of 45%, and occasional wind blows of 1–2 m s^{-1} (Figure 3).

Figure 3. Field treatment (tractor field crop sprayer and sugar beet crop in moment of fungicide application).

Four treatments in different plots at one time, were carried out under filed conditions. The same four treatments in different plots at one time were carried out in the laboratory experiment. Moments of treatment in field and laboratory are in correlation with prevention of cercospora infestation. For both treatments, we apply the following spray mixtures:

Copper hydroxide 2 kg ha^{-1} (Treatment I)
Copper hydroxide 2 kg ha^{-1} + pinole 0.3 L ha^{-1} (Treatment II)
Copper hydroxide 2 kg ha^{-1} + pinole 0.6 L ha^{-1} (Treatment III)
Copper hydroxide 2 kg ha^{-1} + pinole 1 L ha^{-1} (Treatment IV)

Treatment was applied using field crop sprayer "Agromehanika AGS 1500 EN" with a spray boom of 18 m. On the boom were mounted the same nozzles as used in the laboratory experiment, namely, SF and TD ADF. One type was placed on the left and one on the right side of the boom. Working parameters were the same as the ones during the laboratory experiment, 0.5 m above the plants and 0.5 m was the distance between nozzles, therefore the application rate of treatment was 208 L ha^{-1}, with its speed of 8 km h^{-1}, and a work pressure of 400 kPa. The spray canopy deposition was measured using fluorescent tracers.

2.3. Remote Sensing of Disease Infestation

Remote sensing was used for detecting appearance and possible infestation of cercospora on sugar beet leaves. Multispectral images should help for faster monitoring of growth, development, and attacks of the cercospora during the season. Cercospora infestation on sugar beet leaves can be detected using vegetation indices. Any damage to the leaves or the appearance, physical presence, is manifested in the way that the sugar beet leaf reflects sunlight differently. Images were taken (multispectral reflectance) from mid-June until the end of July. The plot was recorded with a multispectral camera, the MicaSense RedEdge 5-band sensor. These images were used to calibrate Planet Explorer 3 × 3 m/pixel satellite images with a correction of 0.25 × 0.25 m/pixels from the same source [25]. Any change on the leaf is manifested with a different reflection of light at different wavelengths of the light spectrum. The change in the spectrum is most often visible in the near-infrared, red, and green spectra of light. For that reason, different vegetation indices were selected, calculated, and tested, which should show the difference between a healthy and a damaged leaf. It was used triangular greenness index (TGI, 1). This index approximates the area of a triangle bounding a leaf reflectance spectrum, where the vertices are in the red, green, and blue wavelengths.

$$TGI = \pm 0.5\left[(\lambda_{RED} - \lambda_{BLUE})(\rho_{RED} - \rho_{GREEN}) - (\lambda_{RED} - \lambda_{GREEN})(\rho_{RED} - \rho_{BLUE})\right] \quad (1)$$

The lambda (λ) terms represent the center wavelengths of the respective bands. The Rho (ρ) terms represent the pixel values of those bands. The original TGI equation used 670 nm, 550 nm, and 480 nm for the red, green, and blue wavelength centers, with a 10 nm band width [26]. The TGI is highly correlated with leaf chlorophyll content. TGI values are positive when the green reflectance is greater than a line between the red and blue vertices. This corresponds to green vegetation. TGI is negative when the green reflectance is less than the line between the red and blue vertices. This corresponds to features such as red soils. Because this index measures red, green, and blue wavelengths, it is suitable for use with unmanned aerial vehicle (UAV) sensors with RGB cameras.

2.4. Statistical Data Processing

The obtained data were processed using software StatSoft Statistica 13. Statistical analysis of the data included descriptive statistics, followed by testing hypothesis for two factor experiments using one-way ANOVA significance test. The hypotheses were tested using the Duncan test as part of one-way ANOVA. During the work the coefficient of variation was used in order to show the uniformity of the distribution of the fungicide on the sugar beet plants.

3. Results

3.1. Laboratory Experiment—The Influence of Wetting Agent and Nozzle Type on Copper Hydroxide Deposit

During the application of solution with only copper hydroxide at a rate of 2 kg ha^{-1}, 66.24% of the solution was deposited on the leaves when treated with nozzle type SF and 87.60% using the nozzles TD ADF. The tracer recovery rates are presented in Table 1.

Table 1. Tracer recovery rate on sugar beet leaves before and after the rain using SF and TD ADF nozzles in the laboratory test.

Type of Nozzle	Treatment I	Treatment II	Treatment III	Treatment IV	F Ratio
		Deposit Before the Rain (%)			
SF	66.24 ^{ab}	68.28 ^{a}	84.77 ^{c}	92.50 ^{d}	5.65
TD ADF	87.60 ^{cd}	87.82 ^{cd}	91.36 ^{cd}	93.83 ^{d}	4.22
CV* SF	5.69	5.73	3.04	1.78	
CV* TD ADF	1.93	3.04	6.17	2.46	
		Deposit After the Rain (%)			
SF	5.43 ^{a}	25.00 ^{b}	45.33 ^{d}	57.00 ^{e}	7.8
TD ADF	7.65 ^{a}	46.43 ^{c}	55.21 ^{ef}	73.33 ^{f}	3.66
CV* SF	19.56	8.18	6.30	9.41	
CV* TD ADF	19.09	5.91	8.80	1.40	

* CV—coefficient of variation (%). [a]—statistical significance (one-way ANOVA significance test, confidence interval $p = 0.05$).

When copper hydroxide was used in a mixture with a wetting agent at a rate of 0.3 L ha^{-1} the measured deposit on the leaves was 68.28% when applied with SF nozzles. When the concentration of the wetting agent was doubled, the deposit of the solution reached 84.77% and was statistically higher compared to the first two treatments with SF nozzles ($p < 0.05$, F = 5.65). Additionally, the increase of the dose of the wetting agent to 1.0 L ha^{-1}, resulted in the increase of the deposit to 92.50% when the SF nozzles was used, and to 93.83% when the TD ADF was used ($p < 0.05$, F = 4.22).

After the rain simulation (15 L m^{-2}), the deposit significantly decreased ($p < 0.05$, F = 7.8) due to flushing. When applied without a wetting agent, 5.43% of the copper hydroxide solution remained on the leaves. When adding the wetting agent (0.3 L ha^{-1}), the deposit increased (25%) when the SF nozzles were used. A higher dose of the wetting agent resulted in a higher deposit on the leaves, so when 0.6 L ha^{-1} of wetting agent was used, 45.33% of solution was detected on the surface of the leaves in treatment with SF nozzles and 55.12% in the case of TD ADF. In the laboratory conditions, the quantity of the deposit significantly differed depending on the type of nozzles. It can be estimated with 95% of certainty that the TD ADF nozzles statistically significantly increased the deposit compared to SF nozzles ($p < 0.05$, F = 3.66). The quantity of the deposit when TD ADF was applied in the laboratory conditions varies from 87.6% to 93.83%. Moreover, under the conditions of artificial rain, the application of copper hydroxide with the addition of a wetting agent at all rates (0.3, 0.6, or 1 L ha^{-1}) increased the deposit in the case of both nozzle types (Table 1). Treatment with TD ADF nozzles with the addition of different wetting agent rates increased the deposit after rain simulation from 46.43% to 73.33%. In the treatment with copper hydroxide without a wetting agent, the deposit of hydroxide solution was significantly lower (7.65%).

The application of the solution based on copper hydroxide without wetting agent, after the rain, shows a very low quantity of the deposit and an unacceptably high CV of 19.56 for SF nozzles and for TD ADF that is 19.09%. However, on the other side, these values of CV are unexpectedly low because they were measured in dynamic conditions during the spraying. This CV shows a very good transverse spray distribution of fungicide during spraying because many horizontal and vertical boom movements have an impact on nozzle transverse distribution.

3.2. Remote Sensing in Disease Infestation on Sugar Beet Leaves

TGI ranged from a few thousand to a few tens of thousands. The lowest value indicated dry leaves, while the highest value indicated leaves in excellent condition. By using the TGI index, all changes in the leaf or chlorophyll can be monitored. Since disease damages the leaf, the chlorophyll will be reduced, and the index can be used for detection because it has the ability to differentiate leaves with greater or lesser damage. Changes in the NIR and green reflectance spectrum change the active surface area formed by the NIR (NIR-infrared) red and green parts of the light spectrum. The damage to the sugar beet leaf was registered on 30 June 2020. The proportion of chlorophyll-free leaves increased. Figure 4 shows that damaged leaves and leaves with spots can be seen all over the plot. It is characteristic and easy to notice that a drastic difference is registered between the spot and the leaf (living and non-living part), which can be easily differentiated. The camera detected damaged and dry leaves. There was detected damage to the leaves; moreover, there are dry leaves, as well as the presence of young, smaller leaves. The second part of the observation was in August. In the first period, out of the total number of plants, 11.58% of plants had either leaf damage and/or dry leaves. Based on the imaging on from 22 August 2020, the situation was more severe. The presence of dry leaves and spots on the leaves ranged from 21.11% to 25.07%.

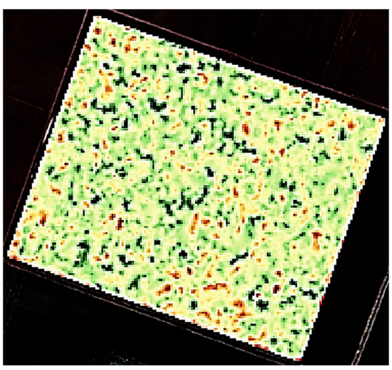

Figure 4. TGI index of 30 June 2020 for sugar beet to observe the presence of disease (black pixels mark potential infested area).

3.3. Field Experiment—The Influence of Wetting Agent and Nozzle Type on Copper Hydroxide Deposit

The influence of the nozzle type and wetting agent on the quantity of copper hydroxide deposit in field conditions is presented in Table 2.

Table 2. Tracer recovery rate solutions on sugar beet leaves using SF and TD ADF nozzles in tests under field conditions.

Type of Nozzle	Treatment I	Treatment II	Treatment III	Treatment IV
SF	31.50 ^{c}	36.50 ^{a}	36.73 ^{a}	43.30 ^{bd}
TD ADF	40.82 ^{b}	41.82 ^{bd}	45.82 ^{e}	50.73 ^{ef}
CV* SF	26.66	17.91	24.51	62.81
CV* TD ADF	28.40	33.93	10.64	43.73

* CV—coefficient of variation. ^{a}—statistical significance (one-way ANOVA significance test, confidence interval $p = 0.05$).

The deposit of copper hydroxide on the sugar beet leaves was statistically significantly lower when using the standard SF nozzles compared to the deposit when using the TD ADF nozzles. During the application of fungicide based on copper hydroxide without the wetting agent, the deposit was 31.5% when applied with SF nozzles. Using TD ADF nozzles with two jets the recorded deposit was 40.82%, indicating that TD ADF nozzles made a 10.1% higher deposit (Table 2).

The copper hydroxide treatment with the addition of a pinole-based wetting agent at a rate of 0.3 L ha^{-1} did not significantly affect the deposit quantity. With further increases of the wetting agent (0.6 and 1 L ha^{-1}) statistically significant increase occurred. The deposits reached 43.3% with SF nozzles and 50.73% with TD ADF nozzles when the wetting agent was added into the solution (Table 2).

4. Discussion

The presented results indicate that the increase in wetting agent rate influences the copper hydroxide deposit on the sugar beet leaves. A similar effect was observed by [12,27] in their field trials on soybeans.

It is interesting to note that in field conditions, the quantity/amount of deposit was 50% lower than in laboratory experiment. This is due to weather conditions which exist in the field during the period of protection of sugar beets, which assume higher temperatures, lower air humidity, and blowing winds typical for the lowlands of the Vojvodina area where the experiment was conducted. This speculation is supported by [21], who reports that the weather conditions affect the efficacy of pesticide application.

During the field experiment, there was no precipitations, but we speculated that the trend of fluctuation of the deposit value after the rain would coincide with the laboratory-simulated trend of a decrease caused by the mentioned weather conditions.

The coefficient of variation (CV) of a transverse distribution depends on the application of the wetting agent. For laboratory conditions, the CV of the transverse spray distribution measured on the paternator should be lower than 10% and ideally lower than 7%. Only such a distribution guarantees the good quality and efficiency of protection on the whole working surface of the sprayer booms [28]. It is interesting to analyze the behavior of the coefficient of variation (CV) of the transverse distribution of nozzles with the increase in the rate of pinole-based wetting agent. At a rate of 1 L ha^{-1} CV increases from 43.73% to 62.81%. With rates of 0.3 and 0.6 L ha^{-1}, the CV value is not high but is unacceptable because it ranges from 10.64% to 33.93% for TD ADF nozzles and 17.91 to 24.51% for SF nozzles. It is a totally different situation than in laboratory experiment where CV decreases with the addition of a wetting agent.

Using a wetting agent, the hydraulic characteristics of the working liquid change and, therefore, the behavior of the drops during disintegration in nozzles changes too [29,30]. This, in combination with field conditions and working parameters, is the probable reason for the high coefficient of variation in the field treatment when applying pinole-based wetting agent at a rate of 1 L ha^{-1}. The solution for the optimal coefficient of variation needs to be searched for in a good combination of the nozzle type, working parameters of a treatment, and wetting agent rate. In this work, the mentioned solution was achieved when wetting agent was applied at a rate of 0.6 L ha^{-1} using TD ADF nozzles.

Even though the results suggested that increasing the rates of wetting agent increases cooper hydroxide deposits on sugar beet leaves, there is a question of an allowed increase in the wetting agent concentration. According to available information, the maximum allowed dosage of a pinole-based wetting agent, depending on the region, is 1.5 L ha^{-1} (source: Miller solutions), while in the Republic of Serbia it is registered at a dosage of 0.3 L ha^{-1}. The obtained results open new research possibilities for the determination of antifungal effects on the CSL causal agent under these conditions. Moreover, there is a possibility to reassess and reestablish the lowest amount of a wetting agent sufficient for providing satisfactory efficacy of copper hydroxide for protection of sugar beet against CLS causal agent.

Satellite images can be used for early detection of CLS in sugar beet [28]. Based on the obtained values and the analysis of the TGI vegetation index, the beginning of the infection with CLS on the sugar beet leaves was determined. Therefore, it is evident that this tool is very useful in plant protection. It can provide an initial signal to the plant protection specialists or farmers to start with the control measures, aiming to prevent significant spread of the disease. By remote sensing, a specialist or a farmer is given the opportunity to timely identify problematic areas in the field, inspect them and determine the actual condition of the crop, detect the beginning of the disease infestation, and decide when it is the proper time to apply fungicides. Since copper is a preventive fungicide, it is crucial to apply it timely. In this regard, the vegetation index serves as an additional tool for the specialists to be able to analyze larger areas. Satellite imaging has the potential to become an integrated part of pest management practice since it enables both the prevention and timely suppression of diseases. There are many attempts to reduce the usage of pesticide through modelling as a prediction of a pest's attack [31]. These models consider many factors for achieving optimum timing and rates of pesticide applications within integrated pest management principles [32,33].

5. Conclusions

The comparison of the copper hydroxide deposit quantity under field and laboratory conditions depending on the amount of the pinole-based wetting agent resulted in an evident increase in the deposit with the increase in wetting agent rates for both types of nozzles.

Furthermore, a huge difference in the deposit with the same type of nozzles but among different treatments in laboratory and field conditions is obvious. The deposit of SF flat fan nozzle in the laboratory without wetting agent was lower in comparison to TD ADF. Under field conditions, the value of the deposit was 50% lower than under laboratory conditions, with the same conclusion drawn. Namely, the deposit from the SF nozzles was lower than from the TD ADF turbo-drop twin-jet nozzle.

Based on the results of this work, it is concluded that the application of wetting agents increases the deposit of the copper hydroxide-based solutions during the treatment of sugar beets, which can provide better protection against the Cercospora leaf spot pathogen. The timely application, which facilitates remote sensing, raises the efficiency of protection to an even higher level. The increase in the dosage of wetting agent statistically increases the deposit with both types of nozzles in the case of rain after the treatment. Applying modern turbo drop nozzles increases the deposit of solution based on copper hydroxide compared to standard nozzles.

Using a wetting agent and modern nozzles is a good solution for quality treatment with contact fungicide, such as copper hydroxide, in terms of providing a sufficient deposit even in the case of bad weather conditions after the treatment for suppressing the Cercospora leaf spot pathogen.

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