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SPRAY APPLICATION QUALITY AS AFFECTED BY SPRAY VOLUME, NOZZLES AND PHENOLOGICAL GROWTH STAGE OF APPLES

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ABSTRACT

The objective of studies was to determine the influence of spray volume and the nozzle type on product deposition and distribution in apple tree canopies, as well as spray coverage on leaves obtained in different phenological growth stages. The spray volumes 250, 500 and 750 $l \cdot ha^{-1}$ were applied with fine spray and coarse spray nozzles generating droplets of VMD around 150 µm and 400 µm respectively. Munckhof cross-flow sprayer was used at the driving velocity of 5.0 $km \cdot h^{-1}$ to apply fluorescent dye as spray liquid. During flowering the greatest deposition was obtained at the spray volume of 250 $l \cdot ha^{-1}$ applied with the coarse spray nozzles. The spray volume 750 $l \cdot ha^{-1}$ resulted in the best coverage in the tree centre. During development of fruit, deposition in the canopy centre was at a constant level irrespective of the spray volume and a droplet size. At the stage of fruit maturity the best coverage was observed for fine spray nozzles and spray volumes of 500 and 750 $l \cdot ha^{-1}$. The use of coarse spray nozzles resulted in the coverage reduction by 50%.

Introduction

The quality of the treatment in the apple tree orchard depends considerably on the even distribution of spray in the sprayed tree canopies. Variability of distribution in tree canopies is usually very high on account of a spacious nature of horticultural crops, dynamic increase of leaves in the vegetation season and the change of the wind direction and speed during the protection treatments. The spray volume and the type of applied nozzles may directly influence even distribution and the level of deposition of spray in particular phenological growth stages.

Labels of the crop protection chemicals include recommendations on the amount of spray volume to be applied for crops, for which these chemicals are registered. In case of the apple tree, these volumes are within 250 to 1000 litres per hectare. In relation to the tree size, doses may be differentiated with the TRV method (Tree Volume Method) (Buyers et al., 1971; Doruchowski et al., 2013). Along with the increase of the spray volume, evenness of the spray distribution in the tree canopies increases. However, due to the limited retention ability of a tree, excessive volumes may increase the spray losses as a result of dripping (Travis et al., 1987a; Doruchowski et al., 1997).

The droplet size depends on the type of applied nozzles. Standard hollow cone nozzles produce fine, fine and average droplets, which means that as much as a several percent of volume of the generated droplets are droplets with a diameter below 100 µm, the most susceptible to drift (Knewitz et al., 2002). Coarse air inclusion nozzles have a great potential of drift reduction (Wenneker et al., 2006). They produce coarse, aerated and less susceptible to drifting droplets and the share of droplets with a diameter lower than 100 µm in the total volume of emitted droplets is usually reduced to a few percent (Knewitz et al., 2002). Coarse spray nozzle treatments result, as a rule, in worse leaves coverage and reduce the spray retention on the sprayed objects (Brunskill, 1965) As a result the finest droplets are obtained in the spraying process and the higher degree of spray coverage of objects (Szewczyk et al., 2013).

A decisive majority of protection treatments in orchard is performed from May to the end of July, that is from the flowering stage to the stage of fruit maturity. In the early phenological growth stages a dynamic growth of leaves and densification of tree canopies takes place. Their retention ability increases considerably. During full leafage, trees retain 40-50% of the applied spray volume and before blossom up to 24% (Siegfried and Holliger, 1996). Therefore, evenness of deposition at full leaf stage is by 50% worse than at the blossom (Godyń et al., 2006), whereas the best uniformity of deposition is obtained in the loose tree canopies (Travis, 1987). Walklate et al. (2000) proved that the level of deposition is inversely proportional to the density of tree canopies.

Objectives

The objectives of the research was to determine the impact of the spray volume and the type of nozzles on the deposition and distribution of spray and leaves coverage in apple trees in various phenological stages.

Materials and Methods

The tests were carried out in 2011-2012 in the experimental orchard of the Research Institute of Horticulture on Jonagold apple trees. The orchard was divided into three blocks, which consisted of three rows. The trees were of 3.0 m height and 1.8 m wide, planted in the 4 m row spacing (volume of tree canopies TRV=13,500 $m^3 \cdot ha^{-1}$). The blocks were separated by the black alder row. Different spray volumes were applied in the form of the solution of fluorescent dye (BSF):

- 250 $l \cdot ha^{-1}$ (volume TRV – 50%), with BSF concentration of 0.05%,
- 500 $l \cdot ha^{-1}$ (volume TRV), with BSF concentration of 0.025%,
- 750 $l \cdot ha^{-1}$ (volume TRV + 50%), with BSF concentration of 0.017%.

Each block consisted of two fields for each type of nozzles:

- fine spray nozzles (VMD=approx.150 µm),
- coarse spray nozzles (VMD=approx. 400 µm).

Experimental fields consisted of three rows of tress 10 m long. In the central part of each, 2 trees were selected for collecting samples of deposition and coverage.

Spraying with a fluorescent dye was carried out in the atmospheric conditions suitable for treatments, namely, at the wind speed up to 3.0 $m \cdot s^{-1}$. In the experiment a cross-flow sprayer Munckhof was used at the driving speed of 5.0 km·h^{-1} (table 1) maintaining the same settings of a fan for all combinations in three phenological growth stages: flowering, development of fruit and maturity of fruit.

Tabele 1
Spray application parameters

Spray wolume (l·ha^{-1})	Working speed (km·h^{-1})	Number of nozzles	Nozlles type Lechler	Workin pressure (MPa)	Nozzle flow rate (l·min^{-1})	VMD (µm)
250	5.0	16	TR 80-01 ID 90-01	0.6	0.52	150 400
500	5.0	16	TR 80-015 ID 90-015	0.95	1.04	150 378
750	5.0	16	TR 80-02 ID 90-02	1.15	1.56	157 371

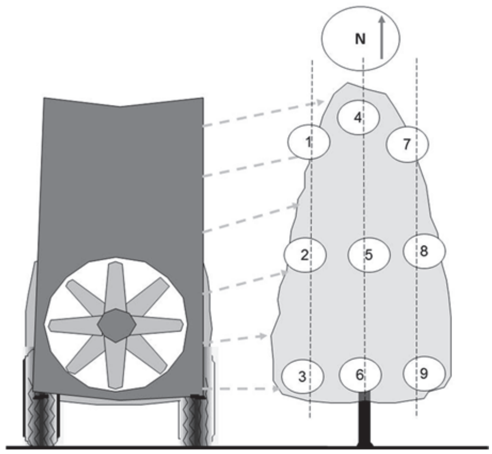

Figure 1. Sampling layout for deposition and coverage evaluation within tree canopy

Deposition of the fluorescent dye in tree canopies was measured on leaves, whereas the coverage was measured with the use of water-sensitive paper samples (WSP) mounted on leaves. From each of nine points, selected from two tree canopies, five leaves were collected for the deposition evaluation, which constituted the repeat of combinations of volumes and the nozzle type (fig.1)

The deposit of the dye was expressed as the mass of the substance per cm^2 of leaves. It was determined with the luminescent spectometer Perkin Elmer LS 55 and the digital planimeter with the image analysis system WinDias 3 (for area determination). The leave coverage degree was measured optically with the use of the multi-task microscope Nikon AZ100 with the image computer analysis system. All measurements and analyses were carried out in the according to the standard methodology used for this type of experiments in Department of Horticultural Engineering of the Research Institute of Horticulture.

Research results

The mean values of deposition and coverage in tree canopies obtained from two vegetation seasons are presented in figures 2-7. In order to determine the evenness of deposition and coverage, results were grouped in three vertical planes according to the plan of collecting samples presented in figure 1:

- external eastern plane,
- plane of tree row axis,
- external western plane.

In the flowering stage, the highest deposition in all tree planes was obtained for the spray volume of 250 l·ha^{-1} and the coarse spray treatment (figure 2). The average deposit for the coarse spray treatment in the tree axis was 25% higher than the deposit for fine spray treatment. In the early period of shaping leaves high spray volumes did not cause higher deposition in the canopies of the sprayed trees. In case of spray volumes of 500 and 750 l·ha^{-1} and both categories of droplet size and for the volume of 250 l·ha^{-1} and the fine spray treatment, mean values of deposition for particular vertical places did not differ significantly. It proves a high uniformity of deposition in tree canopies. According to the expectations, the highest coverage resulted from high spray volumes (figure 3).

For the spray volume of 750 l·ha^{-1} and both categories of droplet size, no significant differences were reported in coverage between extreme vertical planes and tree axis. The applied spray volume of 500 l·ha^{-1} in the form of fine droplets resulted in the coverage at the equally high level. The lowest coverage was obtained for 250 l·ha^{-1} and coarse droplets.

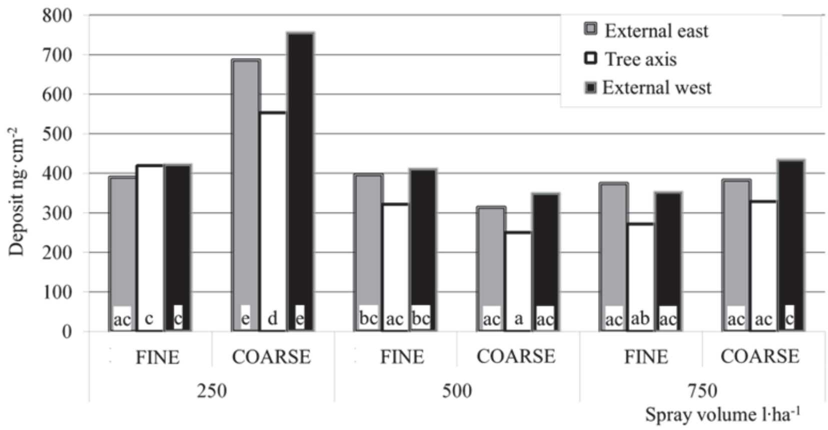

Figure 2. Mean values of deposition in vertical planes of tree canopies during flowering stage (means followed by the same letters do not differ significantly according to Duncan's Test, p=0.05)*

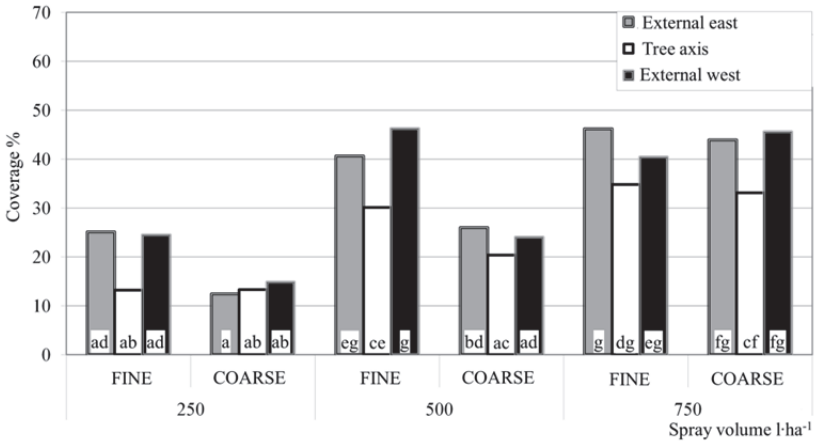

*Figure 3. Mean values of coverage in vertical planes of tree canopies during flowering stage (*means followed by the same letters do not differ significantly according to Duncan's Test, p=0.05)*

During development of fruit, a dynamic increase of leaf area took place. Tree canopies became dense, which resulted in increase of retention of spray. Despite expectations, higher spray volumes did not cause higher deposition. A considerable level of deposition was reported in comparison to the earlier phenological growth stage. Provided that in the flowering stage the level of deposition in particular vertical planes of tree canopies for all combinations of volumes and the sizes of the applied droplets was within 250-750 ng·cm^{-2}, during development of fruit stage it was only 150-350 ng·cm^{-2} (fig. 4).

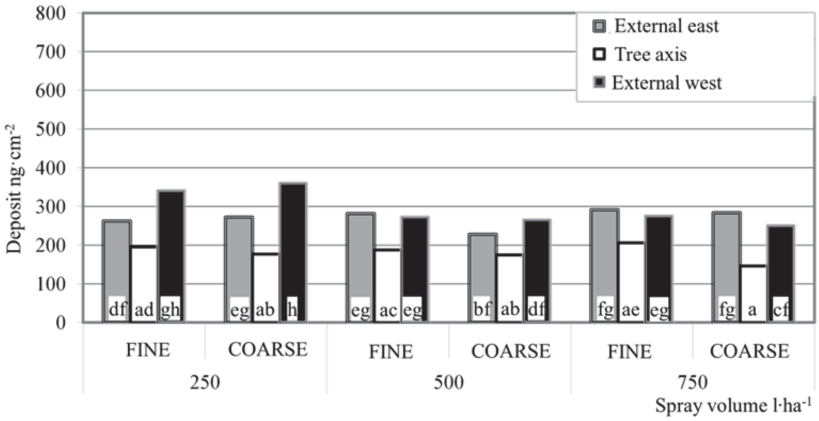

*Figure 4. Mean values of deposition in vertical planes of tree canopies during development of fruit (*means followed by the same letters do not differ significantly according to Duncan's Test, p=0.05)*

Moreover, significant differences in deposition between extreme vertical planes and the plane in the tree axis for all applied volumes and the droplet size, were reported. However, for fine spray treatments, an increase trend of deposition in the tree axis was reported. The highest mean values of coverage were obtained for fine spray treatments for volumes of 500 and 700 $l\cdot ha^{-1}$ (fig. 5).In both cases for coarse droplet treatments almost two times worse coverage in the tree axis plane was reported. In case of the volume of 250 $l\cdot ha^{-1}$ fine spray treatments resulted in identical coverage in all vertical planes as for the volume of 500 $l\cdot ha^{-1}$ and coarse droplets.

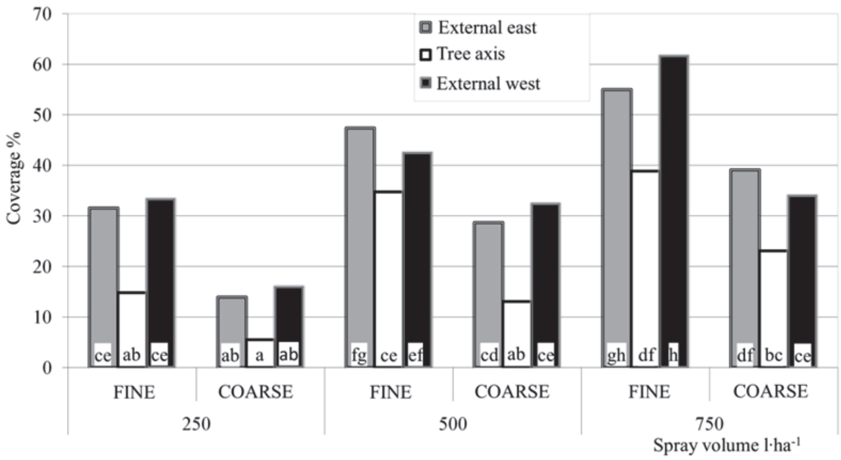

*Figure 5. Mean values of coverage in vertical planes of tree canopies during development of fruit stage (*means followed by the same letters do not differ significantly according to Duncan's Test, p=0.05)*

In the stage of the fruit maturity, the level of deposition in vertical planes of tree canopies for all combination of volumes and the sizes of the applied droplets was within 168-295 $ng\cdot cm^{-2}$. The highest uniformity of deposition was reported for the volume of 750 $l\cdot ha^{-1}$ and the fine spray treatment (fig. 6). For the remaining combinations of volumes and droplet sizes differences of deposition between the extreme vertical planes and in the tree canopies axis were reported. Except for the volume of 750 $l\cdot ha^{-1}$ and the fine spray treatment, similarly as in the previous phenological stage, deposition in the vertical plane of tree canopies axis was at the same level not related to the applied spray volume and the droplet size. A trend for higher deposition in the tree axis for a fine spray treatment and the volumes of 500 and 750 $l\cdot ha^{-1}$ in comparison to the coarse spray treatment was also reported. Moreover, mean coverage reported for the volume of 500 $l\cdot ha^{-1}$ and the fine droplets was at a similar level as for the volume of 750 $l\cdot ha^{-1}$ and the coarse droplets.

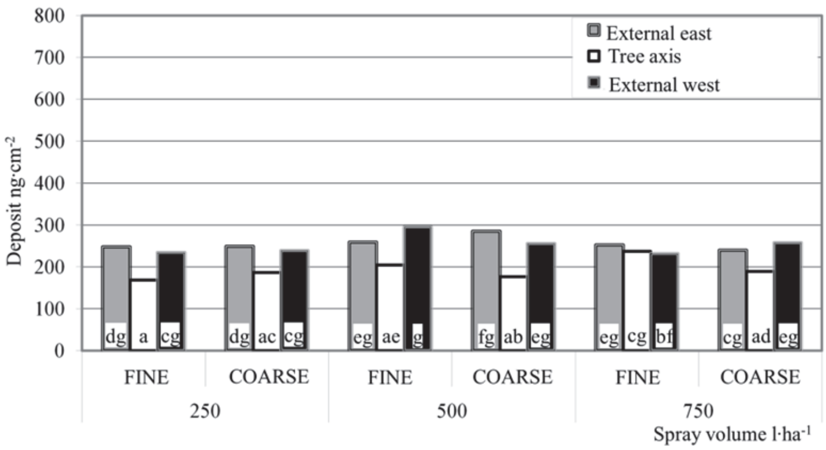

*Figure 6. Mean values of deposition in vertical planes of tree canopies during maturity fruit stage (*means followed by the same letters do not differ significantly according to Duncan's Test, p=0.05)*

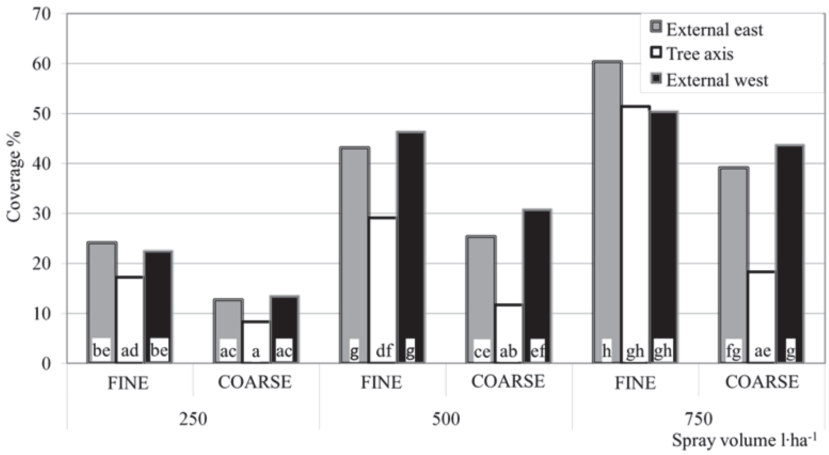

*Figure 7. Mean values of coverage in vertical planes of tree canopies during maturity fruit stage (*means followed by the same letters do not differ significantly according to Duncan's Test, p=0.05)*

Conclusions

1. In the flowering stage deposition in the zone, which was difficult to access namely in the tree axis for the coarse spray treatment and the spray volume 250 l·ha^{-1} was higher by 25% than the deposition caused by the fine spray treatment.
2. In all phenological stages, higher spray volumes did not cause the increase of deposition.
3. In the stages of fruit development and fruit maturity a clear decrease of the level of deposition of the fluorescent dye on leaves in comparison to the flowering stage was reported.
4. In both later phenological stages, the coverage in the tree axis as a result of fine spray and volumes of 500 and 750 l·ha^{-1} was two times higher than the coverage caused by the coarse droplets.

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WPŁYW DAWKI CIECZY, RODZAJU ROZPYLACZY ORAZ FAZY FENOLOGICZNEJ NA JAKOŚĆ ZABIEGU OCHRONY W SADZIE

Streszczenie. Celem badań było określenie wpływu dawki cieczy i rodzaju rozpylaczy na naniesienie i rozkład cieczy w koronie drzewa jabłoni oraz na pokrycie liści w różnych fazach fenologicznych. W badaniach stosowano zabiegi drobnokropliste (VMD=ok. 150 μm) i grubokropliste (VMD=ok. 400 μm) oraz dawki: 250, 500 i 750 $l \cdot ha^{-1}$. Opryskiwanie znacznikiem fluorescencyjnym wykonano opryskiwaczem z poprzecznym systemem emisji Munckhof przy prędkości roboczej 5,0 $km \cdot h^{-1}$. W okresie kwitnienia największe naniesienie uzyskano dla dawki 250 $l \cdot ha^{-1}$ i zabiegu grubokroplistego, natomiast dawka 750 $l \cdot ha^{-1}$ powodowała największe pokrycie w osi drzew. W okresie zawiązywania owoców naniesienie w osi drzewa utrzymywało się na tym samym poziomie niezależnie od dawki cieczy i wielkości kropel. W okresach zawiązywania i pełnego wykształcenia owoców największe pokrycie odnotowano dla zabiegów drobnokroplistych i dawek 500 i 750 $l \cdot ha^{-1}$. Zabiegi grubokropliste powodowały dwukrotnie mniejsze pokrycie w osi drzew.

Słowa kluczowe: naniesienie,pokrycie, jakość rozpylania,parametry zabiegu, opryskiwanie sadu