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SPRAY DEPOSIT, SPRAY LOSS AND BIOLOGICAL EFFICACY OF CHEMICALS APPLIED WITH DIFFERENT SPRAYING TECHNIQUES IN BLACK CURRANTS

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ABSTRACT

A directed air-jet sprayer (SEPIA) was compared with a conventional radial flow sprayer (TERMIT) to determine possible control of spider mites (*Tetranychus urticae* Koch) and currant rust (*Cronartium ribicola* J. C. Fisher) on black currants when using spray volumes 260, 400 and 600 dm^3 ha^{-1} and different dose rates of chemicals. The Cumulative Infestation Index (CII) for spider mite and percentage of infected leaves for currant rust were evaluated to determin the biological efficacy of applications. The spray deposition across the bushes and spray loss to the soil and to the air were assessed in order to compare the quality of treatments. The efficacy of pest and disease control was reduced for the lower chemical dose rates. Both the sprayers produced similar deposits within currant bushes, however, the directed air-jet sprayer caused considerably lower spray loss than did the conventional sprayer.

Key words: currants, spider mites, currant rust, spray deposit, spray loss

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INTRODUCTION

In Poland black currants are grown at very large scale. To obtain a satisfactory yield and quality of the fruit the currant plantations need intensive plant protection. During the season 8 to 12 chemical treatments are usually made which results in very high total chemical inputs to currant production.

In currant plantations the chemicals are usually applied with conventional orchard sprayers with a radial air flow system. The sprayers designed for trees are not suitable to currant bushes and hence during the treatments high spray volumes are needed to guarantee satisfactory pest and disease control. Besides these sprayers cause relatively high spray loss considerably contributing to the environmental pollution.

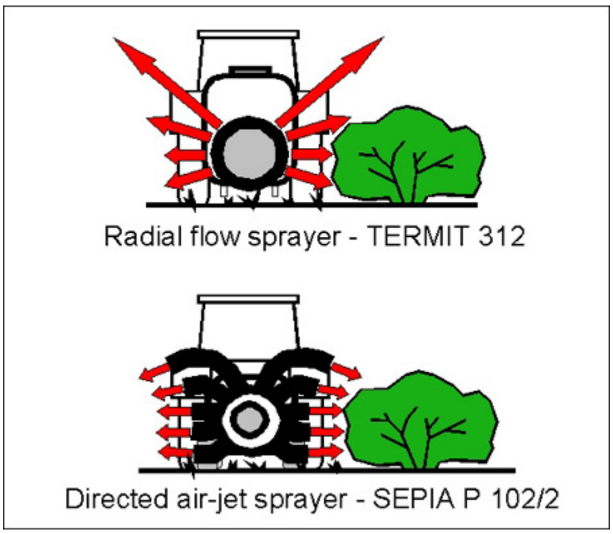
With a radial air flow sprayer Labanowska and Czuba [5] obtained similar or better control of two-spotted spider mite (*Tetranychus urticae* Koch) and black currant stem midge (*Reseliella ribis* Marik.) when using spray volumes 600 and 900 dm^3 ha^{-1} compared to 1800 dm^3 ha^{-1}. This is consistent with the results of Nielsen and Kirknel [6] who observed no difference in control of diseases, American goose-berry mildew (*Sphaerotheca mors-uvae* Berk. et Curtis) and currant rust (*Cronartium ribicola* J. C. Fisher) for spray volumes 400, 800 and 1200 dm^3 ha^{-1}. The researchers also evaluated spray deposit in the crop canopy and they found that higher deposits of fluorescen tracer were recorded when spray was applied at lower volumes. Thus, the high spray volumes necessary for good penetration of dense currant bushes may not guarantee the sufficient deposit of chemical on the plants. This, however, can be achieved when lower spray volumes at higher concentration of chemical are applied with more precise application techniques. Lovelidge [4] reported that for a directed air-jet sprayer equipped with several adjustable air spouts the spray deposit on the leaves of currant bushes was higher by 20% and coverage of the target surface was higher by 50% than those obtained with conventional radial air flow sprayer. Author observed also better penetration and more uniform spray distribution within the crop canopy caused by directed air-jet sprayer which resulted in better control of American goose-berry mildew and black currant leaf midge (*Dasyneura tetensi* Rubs.). In Poland this precise application technique gave satisfactory control of currant rust [1] and two-spotted spider mite [2] after applications at very low spray volumes: 260-400 and 350 dm^3 ha^{-1} respectively.

The objective of the experiment was to evaluate the spray deposit and spray loss as well as the efficacy of pest and disease control for applications made with a directed air-jet sprayer and conventional axial fan sprayer at low spray volumes and reduced doses of chemicals in black currant plantation.

MATERIALS AND METHODS

The three-year experiment was carried out in a black currant plantation, Ojebyn cv., planted 4,0×0,3 m and located in central Poland, near Skierniewice. Two spray application methods (fig. 1) were compared: a) conventional technique represented by a standard axial fan sprayer (TERMIT 312) with radial air flow; b) precise, target-matched technique represented by a directed air-jet sprayer (SEPIA P 102/2) with ten adjustable air spouts. The scope of air stream in the axial fan sprayer was not limited. The nozzles, however, were set so they produced a spray plume limited to the size of currant bushes. In the directed air-jet sprayer the air spouts were adjusted according to the size and shape of bushes in order to ensure precise spray application.

Fig. 1. Sprayers used in the experiment



Both the sprayers were used at spray volumes 260, 400 and 600 $dm^3 ha^{-1}$. For the volumes 260 and 400 $dm^3 ha^{-1}$ both full and reduced doses of chemicals were used. The complete information concerning working parameters of the sprayers and chemical doses for all the treatments are given in table 1. Each treatment was made at the plot consisting of three 50 m long rows of bushes. The rows in the plot of unsprayed check were 25 m long.

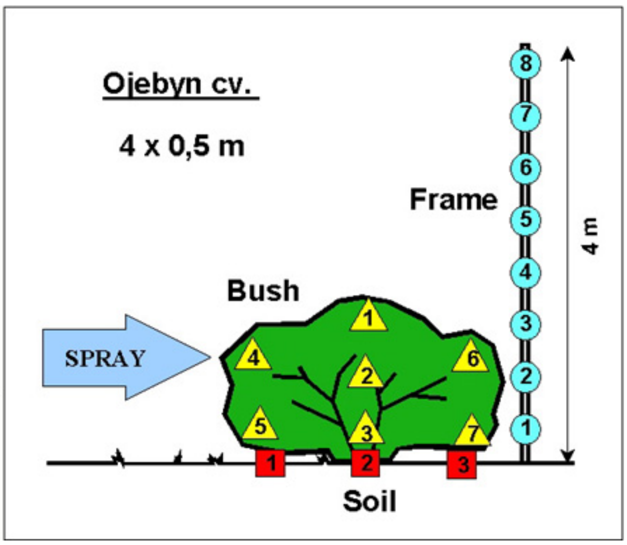
Table 1. Working parameters of radial flow sprayer (Termit) and directed air-jet sprayer (Sepia) during spray applications in black currants, Ojebyn cv.

Sprayer	Air volume $m^3 h^{-1}$	Air velocity $m s^{-1}$	Travel velocity $km h^{-1}$	Number of nozzles	Spray volume $dm^3 ha^{-1}$	Size of nozzles (Albuz)	Pressure MPa	Size of droplets VMD* µm	Chemical rate
Termit 312	20 000	35	5	2×5	260	12	0.6	86	1/1
									2/5
					400	12	1.6	70	1/1
									2/3
					600	16	1.1	98	1/1
Sepia P 102/2	11 000	40	5	2×5	260	12	0.6	86	1/1
									2/5
					400	12	1.6	70	1/1
									2/3
					600	16	1.1	98	1/1

*** VMD – Volume Median Diameter of droplets – according to the manufacturer of nozzles, based on measurements with laser analyzer Malvern Instrument**

For the evaluation of spray deposit and spray loss the fluorescent tracer (Sodium Salt of Fluorescein) was used. In order to minimize the rate of degradation of the tracer under UV radiation the experiment was carried out on a cloudy day with temperature around 20°C. The tracer was diluted in water at concentration 0.02%. Prior to each treatment the filter paper collectors were attached on the upper and lower surfaces of 7 leaves located in the bush canopy, on 3 locations on the soil under the bushes and at 8 heights on the vertical frame behind the bushes (the layout of the samples is shown on fig. 2). Such a set of samples was placed in four bushes as replicates. The bushes were sprayed from one side. After spray application the samples were collected within 5-10 minutes to minimize the time of collectors' exposure to UV radiation. In the laboratory the fluorescent tracer was extracted from each sample with 20 ml of water solution of NaOH (0.005 mol) and surfactant Sandovit (0.01%). The concentration of the tracer in rinsing solution was analyzed with filter fluorometer Sequoia-Turner Model 450. Data was calculated to express the results of spray deposit in ng cm^{-2}. ANOVA followed with Duncan's Multiple Range Test at P = 0.05 was used to separate mean values of spray deposit. Prior to the statistical analysis the raw data was transformed according to the formula: $y = x^{0.25}$

Fig. 2. Layout of samples for spray deposit and spray loss evaluation



In the first and the third year of the experiment the efficacy of two-spotted spider mite was evaluated. The mites counting took place before each acaricide treatment and several times after treatments with 1-2 week interval. For each counting the sample consisting of 25 leaves in 4 replicates was collected at random from the currant bushes within each treatment plot. The population of mites was evaluated according to Henderson and McBurnie [3]. Based on this data a Cumulative Infestation Index (CII) was calculated for each year according to Wratten et al. [7]. ANOVA followed with Duncan's Multiple Range Test at $P = 0.05$ was used to separate mean values of CII for treatments. Prior to the statistical analysis the logarithmic transformation of raw data was performed: $y = \log(x + 1)$.

The efficacy of currant rust was evaluated during all three years of the experiment. During each season 100 leaves in 4 replicates were collected at random from currant bushes within each treatment plot. The percentage of leaves with symptoms of disease was determined for each sample. ANOVA followed with Duncan's Multiple Range Test at $P = 0.05$ was used to separate mean values of percentage of infected leaves for treatments. Prior to the statistical analysis the raw data was transformed according to Bliss: $y = \arcsin[(x/100)^{0.5}]$.

RESULTS AND DISCUSSION

The results of spray deposit within the currant bushes are given in table 2 and data on spray loss in table 3.

Table 2. Spray deposit (ng cm^{-2}) within the current bushes, Ojebyn cv., produced by radial flow sprayer (Termit) and directed air-jet sprayer (Sepia) during spray application. Location of samples according to figure 2

Sprayer	Spray volume dm^3 ha^{-1}	Location of samples							Mean
		1	2	3	4	5	6	7	
Termit 312	260	159	110	11	101	191	8	3	83.1 a
	400	123	35	10	129	114	8	3	60.1 a
	600	129	81	41	221	161	20	24	96.6 a
	Mean	136.9 a	75.2 b	20.7 c	150.1 a	155.2 a	11.9 cd	9.6 cd	79.95 x
Sepia P 102/2	260	8	92	81	357	182	5	28	107.5 a
	400	77	146	20	124	190	5	3	80.5 a
	600	83	83	30	182	95	8	3	69.2 a
	Mean	55.7 b	107.2 a	43.3 b	221.0 a	155.6 a	5.9 d	11.6 c	85.75 x

Means followed by the same letter do not differ significantly (Duncan's Multiple Range Test at $P = 0.05$)

Table 3. Spray loss to the soil and to the air (frame) produced by radial flow sprayer (Termit) and directed air-jet sprayer (Sepia) during spray application in black currants, Ojebyn cv.

Sprayer	Spray volume dm^3 ha^{-1}	Mean spray deposit on:			Loss to the soil %	Loss to the air (frame) %
		Bushes	Soil	Frame		
Termit 312	260	83.1 a	6.9 a	52.8 a	0.36	4.40
	400	60.1 a	5.7 a	46.0 a	0.30	3.83
	600	96.6 a	10.9 a	37.3 a	0.57	3.11
	Mean	79.95 x	7.84 x	45.35 x	0.41	3.78
Sepia P 102/2	260	107.5 a	7.4 a	0.5 c	0.38	0.04
	400	80.5 a	14.2 a	3.5 b	0.74	0.29
	600	69.2 a	11.7 a	3.0 b	0.61	0.25
	Mean	85.75 x	11.07 x	2.30 y	0.58	0.19

Means in columns followed by the same letter do not differ significantly (Duncan's Multiple Range Test at $P = 0.05$)

No differences in average spray deposit were observed between sprayers and spray volumes. However directed air-jet sprayer SEPIA produced higher deposits inside the crop canopies (sample locations 2 and 3) and lower at the tops of bushes (sample location 1) compared to conventional sprayer TERMIT. This superior penetration of bushes caused by SEPIA sprayer, representing more precise application technique, was observed despite 50% lower air volume produced by this sprayer (table 1).

The spray loss to the soil was similar for all the treatments showing no difference between spray volumes and in average between sprayers. The loss to the air (recorded on the frame placed behind the bushes) produced by the

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conventional sprayer TERMIT was several times higher than that obtained when directed air-jet sprayer SEPIA was used. This loss indicates the magnitude of possible airborne drift which can be carried away with the wind at far distance from the application site. The airborne drift is a major source of contamination of the sprayed area surroundings and therefore it is of great societies' concern. Thus, avoiding this kind of spray loss is highly desired and in the areas of dense population it is a must. From this point of view SEPIA sprayer showed considerable environmental advantage in relation to conventional sprayer TERMIT.

The results of biological efficacy of control of two-spotted spider mite and currant rust are given in table 4. Similar effect of mite control was obtained for all tested spray volumes and full dose of acaricide, both in the first and the third year of experiment. The reduction of chemical doses resulted in higher mite population in all cases. This increase of pest population was lower for TERMIT sprayer in the first year and for SEPIA sprayer in the third year.

Table 4. Cumulative Infestation Index (CII) for two-spotted spider mite (*Tetranychus urticae* Koch) and percentage of leaves with symptoms of currant rust (*Cronartium ribicola* J.C. Fisher) controlled with different spray volumes and chemical doses applied with radial flow sprayer (Termit) and directed air-jet sprayer (Sepia) in black currants Ojebyn cv.

Sprayer	Spray volume $dm^3\ ha^{-1}$	Chemical rate	CII for two-spotted spider mite		Percentage of leaves with symptoms of currant rust			
			Year I	Year III	Year I	Year II	Year III	Average of three years
Termit 312	260	1/1	8.1 ab	5.9 abc	11.7 ab	0.0 a	11.4 ab	11.5 ab
		2/5	14.9 b	16.3 de	41.4 d	0.3 a	23.9 cd	32.3 d
	400	1/1	15.1 b	10.6 bcde	9.9 ab	0.0 a	5.3 ab	7.4 a
		2/3	33.8 cd	11.8 cde	33.4 cd	0.0 a	29.7 d	31.6 d
	600	1/1	5.1 a	4.5 ab	11.4 ab	0.0 a	10.1 ab	10.7 ab
Sepia P 102/2	260	1/1	9.1 ab	3.2 a	20.5 bc	0.0 a	5.3 ab	11.8 ab
		2/5	37.0 d	9.6 bcd	19.9 bc	0.1 a	27.9 d	23.8 cd
	400	1/1	5.9 a	3.2 a	30.4 cd	0.0 a	8.0 ab	17.8 bc
		2/3	51.6 e	10.7 bcde	24.2 c	0.0 a	13.2 bc	18.4 bc
	600	1/1	15.1 b	5.0 abc	7.3 a	0.0 a	3.3 a	5.1 a
Unsprayed check			100.0 f	100.0 f	93.9 e	16.8 b	86.2 e	90.4 e

Means in columns followed by the same letter do not differ significantly (Duncan's Multiple Range Test at P = 0.05)

The currant rust was best controlled when full dose of fungicide was applied within any treatment. A significant reduction of disease control was observed for lower chemical doses applied with TERMIT sprayer at 260 and 400 $dm^3\ ha^{-1}$ and with SEPIA sprayer at 260 $dm^3\ ha^{-1}$.

Thus, both two-potted spider mite and currant rust can be successfully controlled in black currants with the volumes of spray as low as 260 or 400 $dm^3\ ha^{-1}$, provided a full recommended dose of chemical is applied. This result is consistent with what was reported by many researchers that the same dose of chemical applied at a lower spray volume may be equally or more efficient in fighting the pests and diseases. It certainly has a lot to do with considerably smaller droplets used when lower spray volumes are applied (see VMD of droplets in table 1) and hence better spray coverage of the protected area and lower spray run-off (see "Loss to the soil" in table 3).

CONCLUSIONS

1. The directed air-jet sprayer SEPIA with adjustable air spouts produced similar spray deposit in the black currant bushes and much lower spray loss to the air and by that it caused lower environmental contamination than did the conventional axial fan sprayer TERMIT with a radial air flow.
2. The efficacy of two-spotted spider mite and currant rust control was reduced when lower then recommended doses of chemicals were applied in black currants.
3. The reduction of spray volumes from 600 to 260 $dm^3\ ha^{-1}$ and yet maintaining high biological efficacy of threatments was possible only with SEPIA sprayer in case of two-spotted spider mite and with both the sprayers in case of currant rust.
4. SEPIA sprayer proved to be more effective and environmentally friendly for spray applications in black currant plantations.

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