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Mist spraying with low spray volumes and reduced dosage of pesticides against American mildew *(Sphaerotheca mors-uvae)* and rust *(Cronartium ribicola)* on black currant *(Ribes nigrum)*

Tågesprøjtning med lave væskemængder og reducerede pesticiddoser mod stikkelsbærdræber (Sphaerotheca mors-uvae) *og filtrust* (Cronartium ribicola) *i solbær* (Ribes nigrum)

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Summary

The influence of some spray application factors, especially the spray volume, on the control of American mildew (*Sphaerotheca mors-uvae*) and rust (*Cronartium ribicola*) on black currants (*Ribes nigrum*) was investigated. The spray equipment used was an axial air mist blower with ordinary swivel spray nozzles with a hollow cone. Besides registering the control of the diseases obtained by the treatments, the deposit of fungicide and the drop frequency on the leaves was measured by means of the fluorescent dye »Helios« and watersensitive paper.

The best control of the 2 diseases was obtained with spray volumes from 400 to 1200 l per ha while a spray volume of 200 l per ha gave a poorer control. The measurements showed that the poor control obtained with the low spray volume could be ascribed to an insufficient drop frequency on the leaves, especially on the ventral side of the leaves. Even when using the smallest nozzle size available and increasing the hydraulic pressure to obtain smaller drops and a higher drop frequency, a further reduction of the spray volume could not be obtained.

No differences were found in the control of the diseases obtained with 400, 800 and 1200 l per ha, but the deposition of fungicide on the foliage was highest with 400 l per ha because drip-off of the spray liquid probably occurred at higher spray volumes. Because of these results, a spray volume of 400 l per ha is recommended against rust and mildew on black currants, with the present spray equipment.

Key words: Black currants, American mildew, rust, mist spraying, spray volume, dosage, drop frequency, deposit.

Resumé

Nogle sprøjtetekniske faktorers indflydelse på bekæmpelsen af stikkelsbærdræber (*Sphaerotecha mors-uvae*) og filtrust (*Cronartium ribicola*) i solbær (*Ribes nigrum*) blev undersøgt. De sprøjtetekniske faktorer var væskemængde, dosering og dråbeantal. Der blev benyttet en tågesprøjte med aksial blæser og hvirvelkammerdyser med hul kegle. Foruden måling af behandlingernes biologiske effektivitet blev der målt afsætning af sprøjtevæske og dråbeantal på bladene vha. det fluorescerende farvestof »Helios« og vandfølsomt papir.

Den bedste bekæmpelse af sygdommene blev opnået med væskemængder fra 400 til 1200 l pr. ha, mens 200 l pr. ha gav en dårligere bekæmpelse. De sprøjtetekniske undersøgelser viste, at den utilstrækkelige bekæmpelse, der blev opnået med 200 l pr. ha, skyldtes et utilstrækkeligt antal dråber på bladene især på undersiderne. Selv om den i praksis mindst mulige dysestørrelse blev benyttet, og selv om væsketrykket blev øget for at opnå mindre dråber og et højere antal, var disse tiltag ikke tilstrækkelige til, at væskemængden yderligere kunne nedsættes.

Der blev ikke målt nogen forskel i den bekæmpelse af sygdommene, som blev opnået med 400, 800 og 1200 l pr. ha, men afsætningen af fungicid på bladene var størst efter sprøjtning med 400 l pr. ha, antagelig fordi der skete afdryp af sprøjtevæske efter sprøjtning med de højere væskemængder. Derfor anbefales det at sprøjte med 400 l pr. ha mod filtrust og stikkelsbærdræber i solbær, når man benytter et tilsvarende sprøjteudstyr som i denne undersøgelse.

Nøgleord: Solbær, stikkelsbærdræber, filtrust, tågesprøjtning, væskemængde, dosering, dråbeantal, afsætning.

Introduction

Traditional high spray volumes of 1000 l per ha or more have been used when spraying against pests and diseases in bush fruit. The official tests for approval of fungicides and insecticides for bush fruit still use 1200 l spray liquid per ha. On the other hand, the growers have gradually reduced the spray volume to 100–200 l per ha. Thus there seemed to be some uncertainty about the correct spray volume for black currants. Furthermore, it seemed to be of value to establish whether a reduction of the spray volume could improve the efficiency of the application and the disease control, as indicated by *Vang-Petersen* (12).

In order to elucidate these questions, black currants were sprayed with spray volumes from 200 to 1200 l per ha against 2 common diseases: American mildew and rust. Mildew was chosen because it is a common experience that a high spray volume is necessary to obtain good control of mildew, particularly apple mildew (9). In the mildew experiment, the drop size and the droplets per sq.cm of leaf area was changed to observe the effect of these parameters on the control of mildew. Besides the full dose of fungicide, some treatments were sprayed with a reduced dose of fungicide to observe if changes in the spray factors mentioned above might compensate for a reduction of the dosage.

Materials and methods

American mildew

The experimental treatments against American mildew (*Sphaerotheca mors-uvae*) were carried out in 1985 in 3-year-old black currants (*Ribes nigrum*) 'Greens Blacks' spaced at 1.25 × 4.0 m. The experimental design was a factorial experiment with the spray volume, the hydraulic pressure and the dosage as variable factors. The spray volumes were 200, 400, 800 and 1200 l per ha, and as the spray volume was reduced, the dose of fungicide was proportionally increased. The

hydraulic pressures used were 8 and 24 bars. The doses of fungicide were a full dose and a dose reduced by 25%. Each experiment was designed with 3 blocks, and the treatments were applied at random in each block. The number of black currants per plot was 5.

The sprayings took place in the daytime with a tractor-mounted axial air mist blower »Holder« and 3 »Holder D-10« swivel spray nozzles with hollow cones ∅ 1.0 mm at each side. The sprays were applied with a fixed hydraulic pressure and a fixed number of nozzles, so that the only variable left to regulate the application of the different spray volumes was the driving speed. This meant that when the spray volume was reduced, the driving speed was proportionally increased. One should be aware of this when evaluating the experimental results as a fast driving speed influences the penetration of the spray liquid into the canopy.

The fungicide used was triadimefon (»Bayleton 5 WP«). The full dose was fixed at 60 g triadimefon per ha (1.2 kg »Bayleton 5 WP«), which is twice the dose approved by the Danish Research Service for Plant and Soil Science. The sprays were applied 3 times before the assessment of the mildew infestation according to the official guidelines (3). The first spraying took place on 3 June at the growth stage »all fruit set«. The second and third treatments were applied 2 1/2 and 5 weeks later. The infestation with mildew was very severe.

Spray measurements

Spray measurements were made in the mildew experiments. Water-sensitive paper (»Ciba-Geigy«) was used to measure the frequency of drops on the leaves. Water-sensitive papers 25 × 20 mm were fastened to the top and ventral side of 8 leaves in the central bush of each plot. The 8 pieces of paper were fixed to the bush with 4 pieces exposed to the driving track uniformly distributed from top to basis. The remaining 4 pieces of paper were places in the middle of the bush with the same vertical distribution. After the spraying, the pieces of paper were removed from the leaves and the droplets were counted through a 15 × measuring microscope. The volume median diameters were calculated after (12).

Fluorescent dye was used to register the deposit on the leaves. 2 l »Helios 010 EC« with 20 g a.i. per ha was used as by *Fischer* (6) with the modification of the »Helios« being washed off the leaves with a solution of 5% acetone in hexane instead of carbontetrachloride. The analyses of the fluorescent deposit were made with a »Farrand Ratio Fluorometer-2«. The leaf samples were picked from the bushes at the places where the watersensitive pieces of paper were placed. The results are the combined average of the deposit of fluorescence on the top and ventral side of the leaves.

Both the deposit and the drops per sq.cm are given as median values.

Rust

The experimental treatments against rust (*Cronartium ribicola*) were carried out in 1985 in 3-year-old black currants var. 'Wellington XXX', spaced at 1.3 × 2.3 m. The experimental design was a factorial experiment with the dosage and the spray volume as variable factors. The dosages were a full dose and a dose reduced by 25%. The spray volumes were 200, 400, 800 and 1200 l per ha, and as the spray volume was reduced, the dose of fungicide was proportionally increased. The treatments were applied at random to each of 3 blocks. The number of black currants per treatment was 6. The black currants were sprayed 6 times with a motorized knapsac air mist sprayer »Hardi« in the daytime. The same nozzle and air volume was used in all the treatments. Only the walking speed was changed. This means that the drop size spectrum was the same in all the treatments. The fungicides used were 60 g triadimefon per ha (1.2 kg »Bayleton 5 WP«) for the first 5 sprayings and 51 g fenarimol per ha (0.420 kg »Rubigan«) for the last spraying.

The control of the rust obtained by the treatments was measured once early in October ac-

cording to the official guidelines (3). The infestation with rust appeared late in the season and was light.

Results

American mildew

Table 1, 2 and 3 show the infestation level of American mildew on the black currants and the deposit of the fluorescent dye »Helios« on the leaves after treatment with different spray volumes, fungicide dosages and hydraulic pressures.

Table 1. The infestation level of American mildew on black currants and the deposit of fluorescence on the leaves after treatment with 4 different spray volumes.
Angrebsgraden af stikkelsbærdræber i solbær og afsætningen af fluorescens på bladene efter sprøjtning med 4 forskellige væskemængder.

Spray volume *Væske-mængde* l/ha	Conc. of liquid *Konc. af væsken* X	Level of infestation *Angrebsgrad*	Deposit of fluorescence *Afsætning af fluorescens* ng/cm²
200	6	64 a*	24 a
400	3	55 b	31 a
800	1.5	47 b	29 a
1200	1	53 b	25 a

Level of infestation in control was 70.
Angrebsgraden i ubehandlet var 70.
* Numbers followed by different letters within columns are significantly different at P = 0.01.
Tal efterfulgt af forskellige bogstaver i hver kolonne er signifikant forskellige for P = 0.01.

The control of the mildew obtained with 200 l per ha was significantly poorer than the ones obtained with the higher spray volumes. The column with the deposit of fluorescence shows that the deposit increased when the spray volume was reduced from 1200 l per ha to 800 l and further down to 400 l per ha, while the deposit was reduced with the further reduction of the spray volume to 200 l per ha. Even though these differences between the deposits of fluorescence are not significant, the effect of the spray volumes on the deposit is substantiated by the fact that it was repeated in all 3 experimental blocks.

Table 2. The level of infestation with American mildew on black currants and the deposit of fluorescence on the leaves after treatment with 2 different fungicide dosages.
Angrebsgraden af stikkelsbærdræber i solbær og afsætningen af fluorescens på bladene efter sprøjtning med 2 forskellige fungiciddoseringer.

Fungicide dose *Fungicid dose*	Level of infestation *Angrebsgrad*	Deposit of fluorescence *Afsætning af fluorescens* ng/cm²
Full dose *Fuld dosering*	52 a*	27 a
75% of full dose *75% af fuld dosering*	58 a	22 b

Level of infestation in control was 70.
Angrebsgraden i ubehandlet var 70.
* Numbers followed by different letters within columns are significantly different at P = 0.01.
Tal efterfulgt af forskellige bogstaver i hver kolonne er signifikant forskellige for P = 0.01.

The infestation level of mildew after the application of the full and the reduced doses was not significantly different at P = 0.05, although the level of infestation was found to be higher after the treatments with the reduced dose in all 3 experimental blocks.

The sprayings with the dose reduced by 25% gave a deposit which was 19% lower than the deposit obtained with the full dose.

No interaction was found between the dosages and the spray volumes.

Table 3. The infestation level of American mildew on black currants and the deposit of fluorescence on the leaves after spraying with 2 different hydraulic pressures.
Angrebsgraden af stikkelsbærdræber i solbær og afsætningen af fluorescens på bladene efter sprøjtning med 2 forskellige væsketryk.

Hydraulic pressure *Væske-tryk* bar	Level of infestation *Angrebsgrad*	Deposit of fluorescence *Afsætning af fluorescens* ng/cm²
8	52 a*	27 a
24	54 a	33 a

Level of infestation in control was 70.
Angrebsgraden i ubehandlet var 70.
* Numbers followed by different letters within columns are significantly different at P = 0.05.
Tal efterfulgt af forskellige bogstaver i hver kolonne er signifikant forskellige for P = 0.05.

Increase of the hydraulic pressure from 8 to 24 bars caused an increase in the deposit of fluorescence, but the increase was not significant. No difference was found in the biological effect of the 2 treatments.

No interaction of the hydraulic pressures and spray volumes was found.

In the experiments where the bushes were treated with 2 different pressures, the frequency of drops on the leaves was registered and the results are shown in Fig. 1.

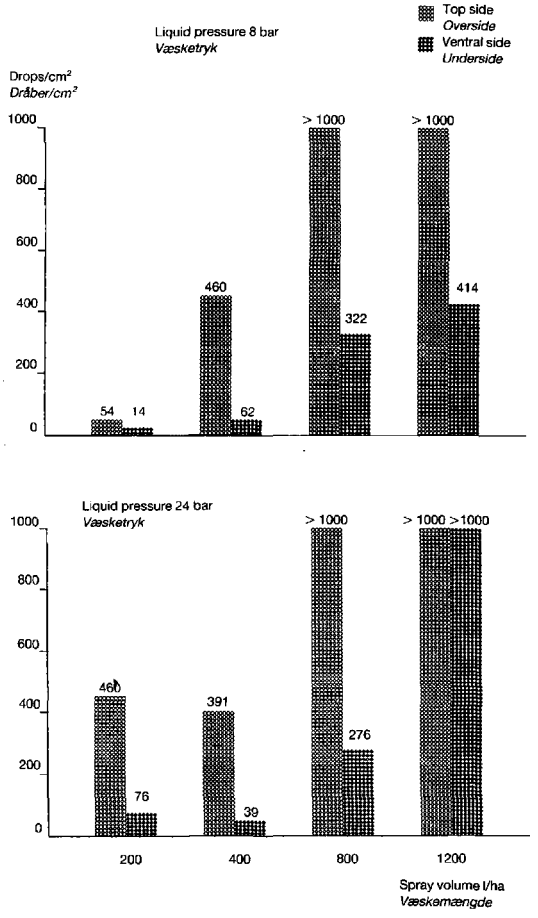

Fig. 1. Drops per sq.cm top and ventral side of leaves of black currants sprayed with 4 different spray volumes and 2 hydraulic pressures.
Antal dråber pr. cm² bladoverside og -underside ved sprøjtning af solbær med 4 forskellige væskemængder og 2 væsketryk.

The drop frequency of course reflected the spray volumes used, i.e. the smaller the spray volume, the smaller the drop frequency. Furthermore, the results show a big difference in the drop frequency on the top and ventral side of the leaves. The frequency on the ventral side was more than 4 times smaller than on the top side.

The effect obtained by increasing the hydraulic pressure from 8 to 24 bars was seen as a higher average frequency of drops on the leaves.

Calculation of the VMD's was only possible with the low spray volumes, because, with the high spray volumes, an exact count of the drops was impossible, as the number of droplets exceeded 1000 per sq.cm. The dimensions are illustrated by the VMD obtained with 200 l per ha and 8 and 24 bars which was 177 μm and 125 μm respectively.

Rust

The results of the treatments against rust on black currants are shown in Table 4.

Table 4. The infestation level of rust on black currants treated with 4 spray volumes and 2 doses of fungicide, i.e. full dose and 75% of full dose.
Angrebsgraden af filtrust i solbær efter sprøjtning med 4 væskemængder og 2 fungiciddoseringer, som var fuld dosering og 75% af fuld dosering.

Spray volume *Væske-mængde* l/ha	Conc. of liquid *Konc. af væsken* x	Level of infestation *Angrebsgrad* — *Dose* full dose	reduc. dose	Average *Gns.*
200	6	7	7	7
400	3	4	1	3
800	1.5	4	2	3
1200	1	1	1	1
Average/*Gns.*		4	3	

Level of infestation in control was 34.
Angrebsgraden i ubehandlet var 34.

Many of the plots showed no or only weak infestation. This gave a distribution of the infestation which was definitely not normal. Neither did transformation of the measurements by means of the logit-equation as by *Zadoks* and *Schein* (14)

result in a normal distribution. Therefore, an analysis of variance was given up.

It appears from the results that there is a tendency for 200 l per ha to give poorer control of the rust than the higher spray volumes. This was seen with both doses of fungicide. The results further show that the reduced dose, which was reduced by 25% compared to the full dose, gave just as good a control of the rust as the full dose.

Discussion

Spray volume

The control of American mildew on black currants obtained with 200 l per ha was significantly poorer than the control obtained with higher spray volumes, whereas no difference could be seen in the results obtained with the different volumes above 200 l. The same results were obtained in the experiments with rust on black currants, i.e. the control of the rust obtained with 200 l per ha was poorer than the control obtained with 400, 800 and 1200 l per ha, which, on the other hand, was indistinguishable.

The plots with American mildew were sprayed with a tractor-mounted axial air mist blower with ordinary swivel spray nozzles while the plots with rust were sprayed with a motorized knapsac air mist sprayer. In spite of the difference in spray equipment, the results from the experiments are comparable because the only variable factor involved in obtaining the different spray volumes was the driving speed and the walking speed, respectively.

Comparable spray experiments in bush fruit are scarce; so the results have to be compared with results from experiments in apples. As most of the present results deal with American mildew, it seems natural to compare with results from experiments with apple powdery mildew (*Podosphaera leuchotricha*). *Butt et al.* (4) obtained similar results as in the present investigation when spraying against apple powdery mildew with 50, 100, 150 and 600 l per ha. The control of the mildew was best with the high spray volume, and the control decreased with each reduction of the spray volume. The results of *Herrington et al.* (9) is also in agreement with the present results. In the light of a number of spray experiments with apple powdery mildew, *Herrington et al.* concluded that a better control of mildew was obtained with spray volumes of 500–800 l per ha than with lower volumes even though the low volumes deposited as much or more fungicide than the higher volumes on the leaves. These differences were explained by the differences in coverage, i.e. high spray volumes cover larger portions of the foliage than lower volumes. On the other hand, *Bayss* and *Charlton* (5) and *Whan et al.* (13) found no differences in the control of apple powdery mildew obtained with 94, 562 and 2247 l per ha, respectively 56, 560 and 2250 l per ha. The results are clearly conflicting. The conflicting results must be due to use of different experimental methods, tree dimensions, spray equipment and technique.

The spray measurements made in the mildew experiments were meant to extend our knowledge of the results of the disease control. The deposit of fluorescence reflects the deposit of fungicide on the foliage. Table 1 shows that the deposit of fluorescence after spraying with 200 l per ha was the same as after spraying with 1200 l per ha. It means that the reduced control of the mildew obtained with the low spray volume was not caused by lack of fungicide.

Table 1 further shows that the deposit of fluorescence was reduced when the spray volume was reduced from 1200 to 800 and further down to 400 l per ha. This result is similar to the results obtained by *Vang-Petersen* (12) and, to some extent, to those obtained by *Nielsen* (10) with treatments against apple scab (*Venturia inaequalis*), and it must be ascribed to the fact that some of the spray liquid dripped off the leaves after the application with the higher volumes.

Reduction of the spray volume from 400 to 200 l per ha caused a fall in the deposit of fluorescence found on the leaves. This fall was probably caused by the fact that the driving speed had to be very high in order to apply the low spray volume (8).

An increase in the deposit of flourescence was observed when the hydraulic pressure was increased from 8 to 24 bars. This result might be related to the fact that the average drop size was reduced and the drops per sq.cm was increased along with the increase of the pressure. But why this should cause an increase in the deposition of flourescence is not clear. At least, it cannot be a matter of reduced drip-off spray liquid in the case of the low spray volumes.

Fig. 1 shows that the poor control of mildew obtained with the low spray volume of 200 l per ha must be ascribed to an insufficient drop frequency on the leaves, especially on the ventral side. *Frick* (7) reached a similar conclusion in an investigation of the influence of spray factors on the control of apple powdery mildew on small apple trees. *Frick* concluded that the drop frequency was all-important for the control: the higher the drops per sq.cm leaf area, the better the control of mildew, even at very low doses.

Fig. 1 further shows that increasing the hydraulic pressure from 8 to 24 bars caused a higher drop frequency because the VMD was reduced and the drops per sq.cm were increased. This improvement in the drop frequency was connected with a highter deposition of fungicide as mentioned above, but surprisingly, this was not reflected in a better control of the mildew.

The number of drops per sq.cm leaf area obtained with 400 l per ha and a pressure of 24 bars shown in Fig. 1 is unrealistically low and must be due to an experimental mistake.

The drops per sq.cm obtained with 800 and 1200 l per ha were more than thousand. The presence of this enormous number of droplets supports the assumption mentioned above that some drip-off spray liquid from the leaves did occur after spraying with the high spray volumes.

The very uneven distribution of the spray liquid between the top and ventral side of the leaves clearly demonstrates that the spray equipment and application technique which were used were insufficient.

Dosage

The efficiency of triadimefon (»Bayleton 5 WP«) against American mildew on black currants was very unsatisfactory although the full dose used was 60 g a.i. per ha, which is twice the dose approved by the Danish Research Service for Plant and Soil Science. Reducing the dose by 25% caused a fall in the efficiency against the mildew. Using 30 g triadimefon per ha, which was half the dose used in the present investigation, *Rasmussen & Schadegg* (11) obtained an efficiency against American mildew in black currants that was about half the one obtained in the present investigation, while other fungicides showed a satisfactory efficiency in the same experiment. These results indicate that the recommended and the approved dose of triadimefon against American mildew is too low.

Experimental results from 1978 and 1980 with 30 g triadimefon per ha against American mildew (1,2), on the other hand, show a very good effect of triadimefon against the mildew. The results indicate that, for some reason, the effect of triadimefon against American mildew has been considerably reduced.

A quite different trend was seen in connection with triadimefon against rust on black currants. Here no difference was found in the effect of 60 g and 45 g triadimefon per ha against rust. However it must be taken into account that the infestation of rust was not very severe. The rust experiments constitute an example which shows that it is possible to reduce the use of pesticide by adapting the dosage to the level of infestation.

Conclusion

This investigation showed that when spraying with an axial air mist sprayer and ordinary swivel spray nozzles with hollow cone against fungus diseases on black currants, a spray volume of at least 400 l per ha must be used. Even when using the smallest nozzle size available (∅ 1.0 mm) and a high hydraulic pressure to obtain a small drop size and a high droplet frequency, the spray volume could not be further reduced.

The present spray equipment has the disadvantage that when a reduction of the spray volume is desired and the smallest nozzle size available is already in use, the only possibilities left are to reduce the hydraulic pressure, increase the driving speed or reduce the number of nozzles. All these solutions are unsuitable. Reducing the hydraulic pressure will create bigger drops, which is the opposite of what is desired, because when the spray volume is reduced, smaller droplets and a higher frequency of drops are needed to compensate for the reduced spray volume. Increasing the driving speed too much reduces the efficiency of the application. Reducing the number of nozzles results in a more uneven distribution of the spray liquid on the foliage. It may be concluded that this type of spray equipment is not suitable for low spray volumes.

To be able to reduce the spray volume further, the use of other kinds of spray equipment must be considered. Pneumatic nozzles should make it possible to reduce the spray volume by increasing the air volume in the nozzle and at the same time obtaining smaller drops. Another possibility is the use of spinning disc equipment.

No differences were found in the control of the diseases obtained with 400, 800 and 1200 l per ha, but the deposition of fungicide on the foliage was highest with 400 l per ha because drip-off of the spray liquid probably occurred with the higher spray volumes. In view of these results a spray volume of 400 l per ha is recommended against rust and mildew on black currants with the present spray equipment.

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