

Mist spraying with low spray volumes and reduced amounts of pesticides against apple scab (*Venturia inaequalis*)

Tågesprøjtning med lave væskemængder og reducerede pesticiddoser mod æbleskurv (*Venturia inaequalis*)

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Summary

The possibility of reducing the dose of fungicide by reducing the spray volume by mist spraying in apples was investigated over a 2 year period. The spray volumes used ranged from 400 to 50 l/ha sprayed with the same air volume, nozzle size and average drop size, and doses of pesticides ranged from 100 to 25% of the recommended dose. The fungicides used were captan 83 and captan + penconazol against apple scab (*Venturia inaequalis*). Deposit, number of drops per sq. cm on the leaves and VMD (Volume Median Diameter) of the drops on the leaves were measured by means of fluorescence.

The results show that a reduction of the spray volume from 400 to 50 l/ha by mist spraying with a VMD of 190–235 μm does not increase the effect against apple scab. Thus a reduction of the dose of fungicide against apple scab cannot be determined. Even though an increase in deposit was measured when the spray volume was decreased, in one of the investigation years, no improved effect against apple scab was registered.

The investigation further shows that the spray volume can be reduced from 400 to 50 l/ha (with the same amount of a.i./ha) without reducing the effect against apple scab.

Key words: Apple scab, *Venturia inaequalis*, mist spraying, spray volume, reduced doses of fungicide, deposit, number of drops, VMD.

Resumé

Muligheden for at reducere fungicidforbruget ved at nedsætte væskemængden ved tågesprøjtning i æble blev undersøgt over 2 år. Der blev sprøjtet med væskemængder fra 400 til 50 l/ha, med ens luftvolumen, dysestørrelse og gennemsnitlig dråbestørrelse og med fungiciddoseringer fra den anbefalede dosering og ned til 25% af denne. Der blev sprøjtet med captanmidler mod æbleskurv (*Venturia inaequalis*). Fungicidafsætning, antal dråber pr. cm^2 bladoverflade og VMD (Volume Median Diameter) af dråberne afsat på bladene blev målt ved brug af fluorescens.

Resultaterne viser, at en nedsættelse af væskemængden fra 400 til 50 l/ha ved tågesprøjtning med en VMD på 190–235 μm ikke medfører en forøget virkning mod æbleskurv, der kan begrunde en reduktion.

tion af fungiciddoseringen. Selv om der det ene forsøgsår blev målt en stigende afsætning af fungicid, når væskemængden blev nedsat, gav det sig ikke til udtryk i en bedre virkning mod æbleskurven.

Endvidere viser undersøgelsen, at væskemængden kan nedsættes fra 400 til 50 l/ha (med samme mængde aktivt stof/ha), uden at virkningen mod æbleskurven forringes.

Nøgleord: Æbleskurv, *Venturia inaequalis*, tågesprøjtning, væskemængder, reduceret fungiciddosering, fungicidafsætning, dråbeantal, VMD.

Introduction

The spraying technique in fruit growing is not sufficiently effective. When spraying with air mist sprayers, only 25–50% of the spray liquid is retained by the trees, the rest is lost to the surroundings (6, 7, 8). Improvements of the spray technique can contribute to a reduction of the great amounts of pesticides used. *Vang-Petersen* (9) found that the amount of pesticide could be reduced by 22–36% by reducing the amount of spray liquid from 500 l to 80 l/ha. This result was the basis of the present investigation to find out if a reduction of the spray may result in a reduction of the dose of fungicide against apple scab. This is due to a reduction of the amount of dripping off of spray liquid and a decrease in the number of drops that cover or overlap each other.

Materials and methods

The experiments were carried out in 1983 and 1984 in 3 rows of Spartan, 20 years old, planting space 3,0 × 4,5 m. The sprayings were against apple scab (*Venturia inaequalis*). The treatments differed a little in the 2 years of investigation.

Experimental design

The fungicide used was captan 83% in 1983 and captan 47.5% + penconazol 2.5% (Topas C 50 WP) in 1984.

The spray volumes used were 400, 200, 150 and 75 l/ha in 1983 and 400, 200, 100 and 50 l/ha in 1984.

With every spray volume the dose of fungicide recommended by the Research Centre for Plant Protection was applied.

This means that when the spray volume was reduced the concentration of the fungicide in the

spray liquid was increased. In 1983 3.0 kg captan 83% was applied per ha (2.49 kg a.i./ha) and 80 and 60% of the full dose. In 1984 2.0 kg Topas C 50 WP was applied per ha (0.95 kg captan + 0.05 kg penconazol/ha) in addition to 75, 50 and 25% of the full dose.

The experiments were designed as blocks of 3 trees and replicated 3 times. In 1983 the blocks were distributed systematically, and at random in 1984.

Sprayings

The apple scab infection was very severe both years. The sprayings were made in the daytime on dry leaves. In 1983, the spring was very warm and humid, which caused an early and very heavy infection of apple scab while frequent rainfall at the same time delayed the first spraying. 6 sprayings were made with a knapsack AS 1. The same air volume and air velocity was used every time. In 1984 the first scab infections were observed as late as end of June. 9 sprayings were made with a tractor mounted air mist blower from Holder with swivel spray nozzles with hollow cone Ø 1.0 mm. To ensure a uniform drop size and distribution in all the treatments, the same nozzle diameter, air volume and velocity and as far as possible the same liquid pressure and driving velocity were used. To be able to spray with the different spray volumes the number of nozzles were varied. This must have influenced the covering of the trees and the drop sizes, because when 4 nozzles are used instead of one, more drops will hit each other and form larger drops before they reach the target. Table 1 shows the liquid pressure and the number of nozzles used to reach the different spray volumes.

Table 1. Technical data from the sprayings with the tractor mounted air mist blower in 1984.

Tekniske data fra sprøjtingerne med den traktormonterede tågesprøjte i 1984.

Spray volumes in l/ha <i>Væskemængde i l/ha</i>	Liquid pressure in bar <i>væsketryk i bar</i>	Number of nozzles <i>antal dyser</i>
400	17	4
200	8	4
100	8	2
50	8	1

The apple trees were protected against insects and mites with pesticides which show no effect against apple scab.

Measurements of the biological effects

During both years of investigation the leaf infections were assessed 3 times during the season, and the fruit infections once at harvest according to (1).

Spray technical measurements

Fluorescent dyes were used to measure the deposit on leaves and the number of drops per leaf area. The volume median diameter was calculated according to *Vang-Petersen* (9). These measurements were made once every year in late summer in all the blocks. The fluorescent dye was mixed with the fungicide used. The analyses of the fluorescent deposit were made with a Farrand Ratio Fluorometer-2 at the Laboratory for Pesticide Analysis, The Research Centre for Plant Protection, under the guidance of Dr. *Erik Kirknel*.

In 1983 Na-fluoresceine with 3 kg/ha and the method of *Vang-Petersen* (9) were used. The leaf area was measured with an area integrator A-LI-COR 3000. No discrimination was made between the top and underside of the leaves. The measurements were made on 9 leaves evenly distributed in the middle tree of every block.

In 1984 the fluorescent dye Uvitex OB 010 EC with 1 l/ha and the method of *Fischer* (5) was used. The fluorescence was caught on filter paper

(5 × 2 cm) and the number of drops was assessed with water sensitive paper (7.6 × 2.6 cm) from »Ciba-Geigy«. Both kinds of paper were fastened to the top or underside of 8 leaves evenly distributed in the middle tree of every block.

The results of the investigations of both years are the combined average of the top and underside of the leaves. The results are given as median values.

Results

In Figs. 1 and 2 the efficiency on leaves and fruits is shown as well as the deposit of fungicide on leaves by the treatments with the 4 spray volumes in 1983 and 1984. In Figs. 3 and 4 the efficiency on leaves and fruits is shown as well as the deposit of fungicide on leaves in relation to the doses used in 1983 and 1984. The values of the deposit of fungicide on the leaves are calculated from the deposit of fluorescence on the leaves.

The efficiency on leaves and fruits of the treatments with the 4 spray volumes (Fig. 1) did not differ significantly from each other either in 1983 or in 1984 even though the deposition of fungicide in 1984 (Fig. 2) rose significantly ($P < 0.01$) when the spray volume was reduced. Figs 3 and 4 show that the efficiency and the deposit of fungicide decreased with the reduction of the doses in both years.

Table 2. The retention of spray liquid per sq.cm leaf per litre sprayed liquid in μg per sq.cm per litre for the different spray volumes in 1983 and 1984.

Retentionen af sprøjtevæske/cm² blad/l udsprøjtet væske i $\mu\text{g}/\text{cm}^2/\text{l}$ for de anvendte væskevolumener i 1983 og 1984.

1983	1984
400 l/ha: 2.47	400 l/ha: 1.40
200 l/ha: 1.94	200 l/ha: 2.37
150 l/ha: 2.09	100 l/ha: 2.98
75 l/ha: 2.47	50 l/ha: 4.02

Table 2 shows the retention of spray liquid per sq.cm leaf per litre sprayed liquid for the spray volumes used. In 1983 there was no difference but in 1984 the retention rose when the spray volume was reduced.

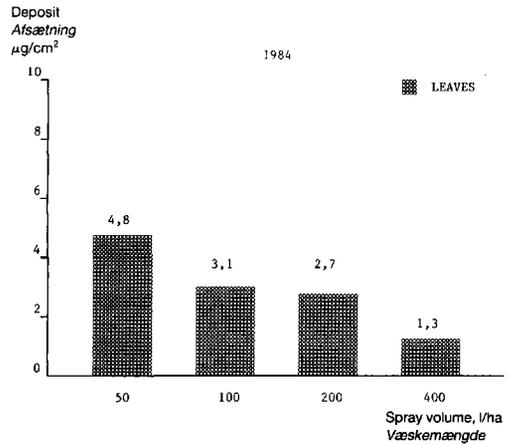
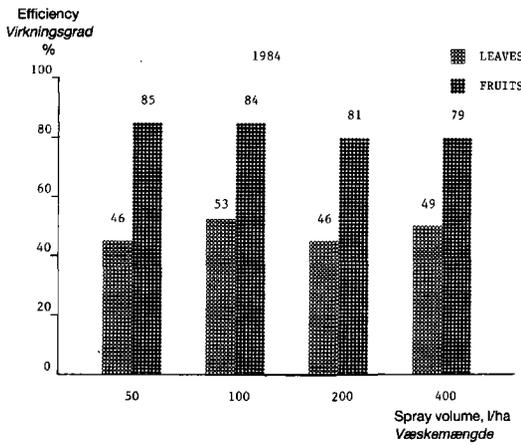
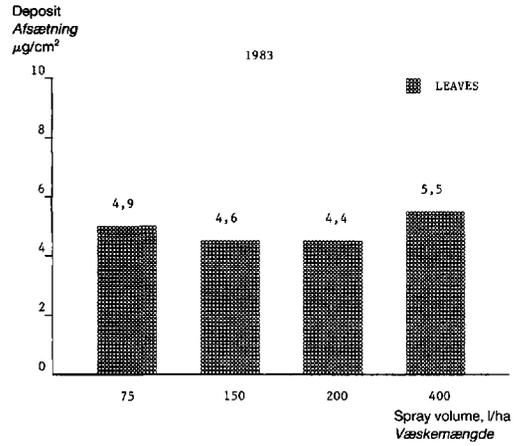
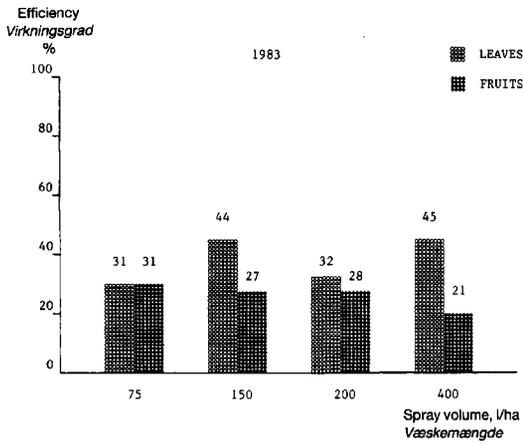


Fig. 1. The efficiency of the treatments on leaves and fruits by spraying with different spray volumes in 1983 and 1984.

Virkningsgraden på blade og frugter ved sprøjtning med forskellige væskemængder i 1983 og 1984.

Fig. 2. The deposit of fungicide on leaves in µg per sq. cm by spraying with different spray volumes in 1983 and 1984.

Afsætning af fungicid på blade i µg pr. cm² ved sprøjtning med forskellige væskemængder i 1983 og 1984.

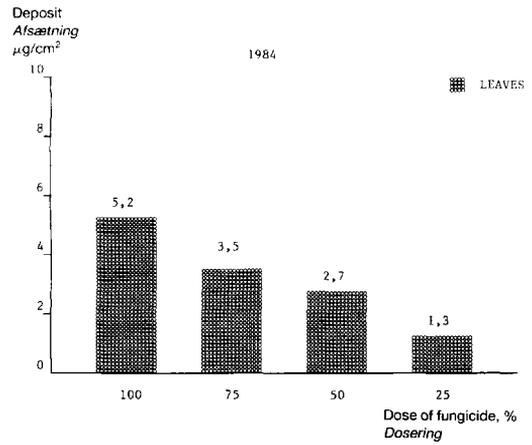
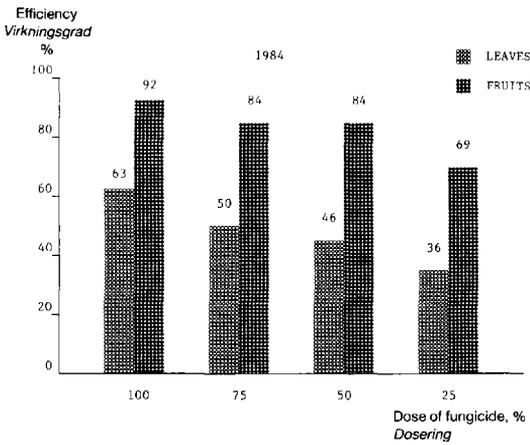
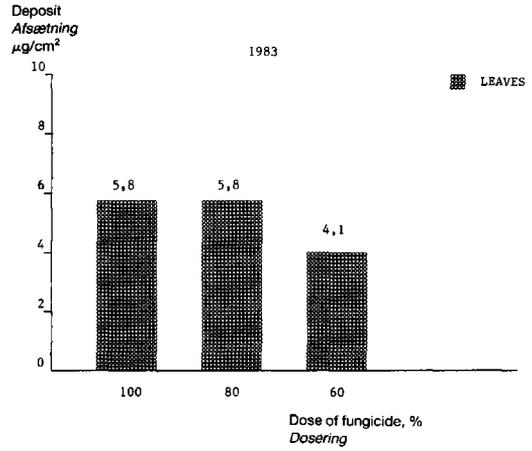
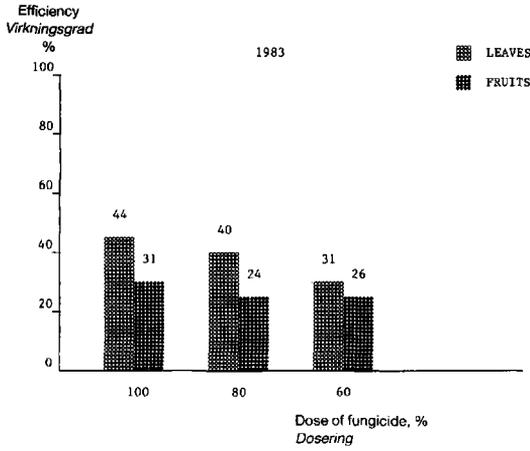


Fig. 3. The efficiency of the treatments on leaves and fruits by spraying with different doses in 1983 and 1984. *Virkningsgraden på blade og frugter ved sprøjtning med forskellige doseringer i 1983 og 1984.*

Fig. 4. The deposit of fungicide on leaves in µg per sq. cm by spraying with different doses in 1983 and 1984. *Afsætning af fungicid på blade i µg pr. cm² ved sprøjtning med forskellige doseringer i 1983 og 1984.*

Table 3. Number of drops per sq. cm leaf for the different spray volumes in 1983 and 1984.

Antal dråber/cm² blad for de anvendte væskemængder i 1983 og 1984.

1983	1984
400 l/ha: 106	400 l/ha: 242
200 l/ha: 79	200 l/ha: 107
150 l/ha: 55	100 l/ha: 85
75 l/ha: 24	50 l/ha: 32

Table 3 shows that the number of drops per sq. cm leaf decreased when the spray volume was reduced. As expected the VMD was independent of both the spray volume and the dose, because the same liquid pressure and nozzle size were used in all the treatments. VMD was 235 μ m in 1983 and 193 μ m in 1984.

Discussion

Efficiency/dosage

With the reduction of the dosage, the efficiency decreased on the leaves and to a lesser degree on the fruits both years (Fig. 2). The percentage fall in the efficiency on leaves is considerably smaller than the percentage reduction of the dosage as can be seen from Table 4.

Table 4. Concentration and efficiency on leaves in 1983 and 1984 given as comparative values.

Dosering og virkningsgrad på blade for 1983 og 1984 angivet som relative værdier.

	1983			1984			
Concentration	100	80	60	100	75	50	25
<i>Dosering</i>							
Efficiency, leaves	100	91	71	100	79	73	57
<i>Virkningsgrad, blade</i>							

This situation is probably due to the fact that the values are on the upper part of a sigmoid dosage-effect curve.

Efficiency/spray volume

The effect of the treatments against apple scab

was the same both years irrespective of which spray volume was used. This is immediately surprising because the degree to which the leaves were covered, measured as the number of drops per leaf area, was 4 to 8 times less with 75 and 50 l/ha as with 400 l/ha (Table 3). Moreover, no difference was found in VMD of the drops deposited on the leaves by the different spray volumes.

A possible explanation could be that dew dissolved and redistributed the fungicide on the leaves. This may have equalized the expected effects of the different degrees of leaf coverings found by the different spray volumes. If this explanation is correct, a reduction of VMD to obtain a better degree of leaf covering with the same spray volume will not result in a better effect against apple scab. These conditions will be further elucidated in a future investigation.

Whan *et al.* (10) found no difference in the effect against apple scab when mist spraying with 2250, 560 or 56 l/ha. Baraldi *et al.* (2) obtained the same effect against apple scab with 1600 l/ha (mist spraying) and 100 l/ha (spinning disc), while 50 l/ha (spinning disc) only reduced the apple scab infection half as much as the other 2 treatments. Cooke *et al.* (4) obtained a smaller effect against apple scab with 22.5 l/ha than with 225 l/ha.

These results together with the results of the present investigation show that when spraying against apple scab it is possible to reduce the spray volume to 50–100 l/ha without reducing the efficiency.

Number of drops per sq. cm leaf

The number of drops per sq. cm leaf was most numerous when spraying with 400 l/ha and was reduced when the spray volume was reduced, but the percentage reduction in the number of drops per sq. cm leaf did not follow the percentage reduction of the spray volume. Vang-Petersen (9) found the same results when reducing spray volumes from 635 to 80 l/ha. The results are due to the fact that the number of drops per sq. cm is underestimated when spraying with 400 l/ha and in 1984 also with 200 l/ha because the registration method used will registrate overlapping drops as

one drop. In 1983 where the knapsack was used, 49% of the drops were overlapping when spraying with 400 l/ha, while the overlap was low with the smaller spray volumes. In 1984 where the air mist sprayer was used, 59% of the drops were overlapping with 200 l/ha, while the overlap was low with 100 and 50 l/ha. The overlap of drops with 400 l/ha in 1984 cannot be calculated, because a higher water pressure was used when spraying with this volume than with the lower spray volumes.

The results clearly show that by mist spraying the higher degree of leaf covering obtained through increased spray volume will be »paid for« by an increased overlapping of drops, which must be regarded as a waste.

Deposit of fungicide

The deposit of fungicide by spraying with 200 l/ha and a dose of 3.0 kg/ha of the 2 fungicides was 6.8 μg per sq.cm in 1983 and 6.0 μg per sq.cm in 1984. By way of comparison it may be mentioned that with the same dose and spray volume *Vang-Petersen* (9) found a deposit of captan on 2.3 μg per sq.cm. The air mist sprayer used was a special type supplied with pneumatic nozzles.

By mist spraying with 560 l/ha and the same dose of a.i./ha *Morgan* (7) found a deposit of captan on 2.5–9.0 μg per sq.cm and with the same spray volume and dose *Church et al.* (3) found a deposit of captan on 2.44 μg per sq. cm using a knapsack.

The results indicate that the fungicide deposit in the present investigation was high both years. The reasons for differences in the effectiveness of the sprayings may be many. Factors to be mentioned may be water pressure nozzle size and type, air volume and velocity, driving speed, tree size, planting system and air temperature and humidity at the time of spraying.

The retention of spray liquid per sq.cm leaf per 1 sprayed liquid (Table 2) did not differ significantly between the 4 spray volumes in 1983. This indicates that there was no dripping off at the highest spray volumes. In 1984 the retention of spray liquid per sq.cm leaf per 1 sprayed liquid

rose significantly ($p < 0.01$) when the spray volumes were reduced, even though it was not reflected in a higher efficiency against apple scab at the low spray volumes. A possible explanation is that dripping off took place at the high spray volumes.

Vang-Petersen (9) also found that the retention of spray liquid per sq.cm leaf per l sprayed liquid rose by 22–36% when the spray volume was reduced from 511 to 80 l/ha. On the other hand, *Herrington et al.* (6) measured a halving of the percentage retention of spray liquid in the trees when the spray volume was reduced from 1125 to 560 l/ha. The results are far from unambiguous.

When all the results from 1983 and 1984 are compared, it can be seen, that they only differ substantially in regard to the deposit of fungicide when spraying with different spray volumes. The only obvious difference between the experiments in 1983 and 1984, which may have influenced the deposit of fungicide, is the use of 2 different sprayers in the 2 years. This suggests that the cause of the divergence between the deposits in the 2 years and maybe also between the investigations quoted above, is to be found in differences between the sprayers used, but it is not possible to give a more specific explanation.

Conclusion

Through this investigation it has not been possible to confirm that a reduction of the spray volume from 400 to 50 l/ha by mist spraying with a VMD on 193–235 μm can result in a reduction of the dose of fungicide against apple scab. Even though in one of the years of investigation an increased fungicide deposition was found when the spray volume was reduced, it did not bring about any better efficiency against apple scab.

The investigation has further shown, that the spray volume may be reduced from 400 l/ha and even down to 50 l/ha (with the same amount of a.i./ha) without reducing the efficiency against apple scab.

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