A comparison of biological effect and spray liquid distribution and deposition for different spray application techniques in different crops

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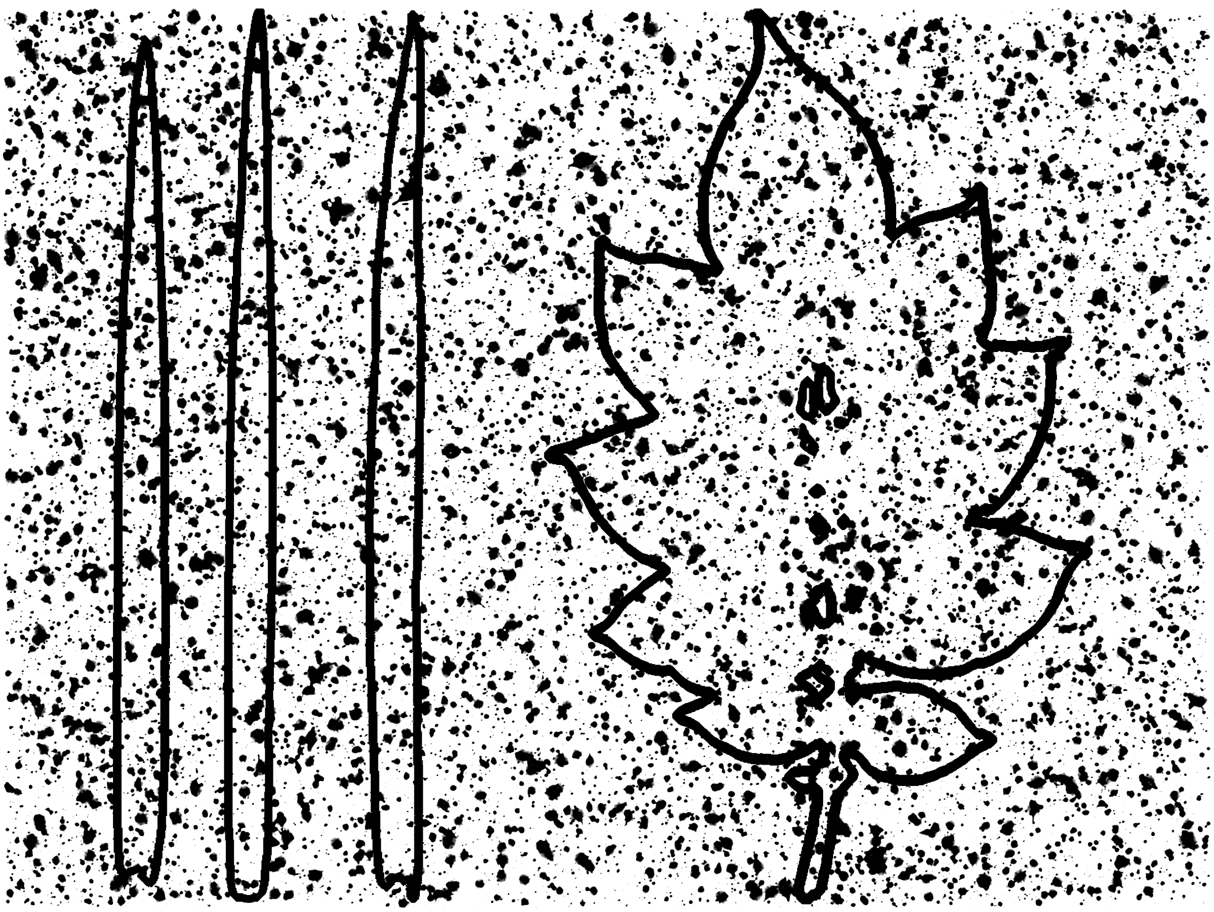

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ABSTRACT

The objective of this study was to compare a selection of spray application techniques with different application volumes, with respect to the spray liquid distribution on flat surfaces, the deposition in fully developed crops and the biological effect. The spray application techniques in this study were conventional spray technique with three different nozzles: TeeJet XR, Lechler ID and Lurmark DriftBeta, and also AirTec, Danfoil, Hardi Twin, Kyndestoft and Släpduk. The dynamic spray liquid distribution was measured on a flat surface, spraying a water and black dye solution on pre-glued wallpaper lengths. Spraying the same dye-water solution in established crops, the spray deposition on plant and on the ground was studied by measuring the absorbance of sampled leafs' and collectors' rinsing water. Spray deposition studies were made in winter wheat and potato. The biological effect was studied in field experiments with plots with linearly increased dose. The field trials in this study were weed control in spring barley, fungi control in winter wheat and potato late blight control. The weed weight was sampled and visual assessments were made of the infection of fungi. Grain yield and 1000-kernel-weight were sampled in the wheat trial. The dynamic spray liquid distribution resulted in coefficients of variation, for all spray techniques, between 5% and 16%, which were considered to be at acceptable levels. Relatively large significant differences were found in the spray deposition measurements in potato canopies. For conventional spray technique, 90% spray deposition was recovered in the top of the canopy. Higher deposition was recovered in the lower part of the canopy and on the ground for Danfoil, Hardi Twin and Släpduk than the other techniques. In the wheat crop, the differences in spray deposition between spray techniques were smaller. Släpduk had the greatest increase in liquid deposition on the head and the flag leaf. The techniques with external air assistance, Hardi Twin and Kyndestoft, had the lowest deposition on the ground. Analysing the effect of weed control in spring barley, fungi control in wheat and potato late blight control, no significant differences were found. This might be seemed remarkable when large differences in spray liquid deposition were found in the potato canopy. One conclusion could be that the penetration ability in dense potato canopies is not of equal importance as to protect the upper parts of the canopy. It is indicated that it could be important to consider other factors, not included in this study, such as the ability to reduce drift and increase capacity, when selecting spray application technique

SAMMANFATTNING

Syftet med denna studie var att jämföra ett urval av appliceringstekniker, med olika vätskemängder, med avseende på vätskefördelning på en plan yta, avsättning i etablerade bestånd och biologisk effekt. Appliceringsteknikerna i denna studie var konventionell appliceringsteknik med tre spridartyper, TeeJet XR, Lechler ID och Lurmark DriftBeta, samt AirTec, Danfoil, Hardi Twin, Kyndestoft och Släpduk. Fördelning av sprutvätska på en plan yta, den dynamiska vätskefördelningen, har studerats genom att färgad sprutvätska applicerats på förklistrade tapetvåder utlagda på marken. Färgad sprutvätska har även applicerats i växande gröda och avsättningen på planta och på mark har studerats genom att mäta absorbansen för plantdelars och fångstobjekts sköljvatten. Avsättningsstudier har utförts i höstvete- och potatisbestånd. Den biologiska effekten av bekämpning med de olika teknikerna har studerats i fältförsök med linjär förändring av dosen. Försök har utförts med ogräsbekämpning i vårkorn, svampbekämpning i höstvete och bladmögelbekämpning i potatis. Ogräsvikt och svampinfektionsgrad mättes. Kärnskörd och tusenkornvikten registrerades för höstveteförsöket. Variationskoefficienterna, för mätningar av den dynamiska vätskefördelningen, varierade mellan 5 % och 16 %, vilket ansågs vara acceptabla nivåer. Fördelningen av sprutvätska i potatisbeståndet uppvisade relativt stora skillnader. För konventionell teknik återfanns ungefär 90 % av återfunnen sprutvätska på de översta bladen i beståndet. Danfoil, Hardi Twin och Släpduk placerade större andel av sprutvätskan längre ner i beståndet och på marken än övriga tekniker. I vetebeståndet var skillnaderna mellan teknikerna mindre. Släpduk gav störst ökning av andel avsatt sprutvätska på ax och flaggblad. Teknikerna med yttre luftassistans, Hardi Twin och Kyndestoft gav minst avsättning på marken. Studierna av den biologiska effekten vid bekämpning gav inga signifikanta skillnader vid vare sig ogräsbekämpning, svampbekämpning eller bladmögelbekämpning. Detta ansågs som anmärkningsvärt när det var stora skillnader i avsättning i potatisbestånd. En slutsats skulle kunna vara att nedträngningsförmågan i täta potatisbestånd inte är lika viktigt som att skydda de övre delarna av beståndet. Denna studie indikerar att det är viktigt att ta hänsyn till andra faktorer, än de som inkluderats i denna studie, som t.ex. teknikens förmåga att minska vindavdriften och öka kapaciteten, vid val av appliceringsteknik.

PREFACE

This report is based on the experiments and analysis made within a four-year project financed by the Swedish Board of Agriculture and executed under the responsibility of the Department of Agricultural Engineering, at the Swedish University of Agricultural Sciences. The project has contributed to a higher standard of attainment, both for farmers and for advisers, in the area of spray application technique and its implication on an effective, environmental friendly and operator safely plant protection. The demands, when selecting the appropriate spray application technique, are expected to be better known. During the project the spray application techniques have been exposed in papers, conferences, seminars and lectures. Such an exposure can hopefully contribute to the developing of new farm sprayers, which better lives up to present demands, which benefits us all.

A report in Swedish, on the described project, has previously been written by Per Wretblad and sent to Swedish Board of Agriculture, but otherwise not published. This English report, at hand, is mainly based on the report by P. Wretblad.

During the project, a dialog with the producers has been maintained. The producers have also been invited to contribute with their knowledge and expertise in the experimental parts of the project in order to ensure correct usage of the spray equipment. Producers have in this way also participated at several occasions.

Former project leader Per Bengtsson and Patrik Enfält are recognized for taking on the responsibility for invaluable efforts in the planning, execution and analysis of the project this report is based on. Thank you.

Sincere gratitude is expressed to the Swedish Board of Agriculture for financing the project. Equally sincere gratitude is also expressed to the producers for supplying sprayers and nozzles and, in that way, made the realization of this project possible.

We would like to thank Lars-Erik Fransén for his invaluable help and hospitality when conducting field trails on his properties. We would also like to thank to the Rural Economy and Agricultural Society in Kalmar for the assistance in planning the potato field trials and to the SLU's farm property at Ultuna that kindly placed their fields at our disposal to use for field trials.

Finally we would like to thank Assistant Professor Jan-Eric Englund at the Department of Biometry and Informatics, SLU, for his help with the statistic treatment of the data.

CONTENTS

INTRODUCTION

There are increasing demands on food producers, from consumers, the society as well as from the industry itself, for improved food quality, environmental consideration and profitability. In different ways, this leads to increased demands on reducing the pesticide use in the agricultural food production, and this has lead to the development of several new spray application techniques. This technical development ranges from low-cost solution, such as new nozzle designs, to more expensive, state-of-the-art, equipment like air-assistance sprayers. The general characteristics of these technical solutions are increased wind drift reduction potential, and, in several cases, increased possibilities to use low application volumes. Lower application volumes results in an increased efficiency when spraying, i.e. more time is spent in the field, spraying, in relation to the time spent filling the sprayers tank.

The objective of this study was to compare a selection of spray application techniques, available on the market, with different application volumes, with respect to the spray liquid distribution on flat surfaces, the deposition in fully developed crops and the biological effect.

MATERIALS AND METHODS

Dynamic spray distribution

The evenness of the spray liquid distribution affects the biological effect of the spray application treatment and, also, the dose required to achieve a specific effect (Enfält et al. 1995). The dynamic spray distribution, measured for a moving sprayer, differs from the static, stationary spray boom, distribution. Measuring the static distribution is the most common method to evaluate the spray distribution for sprayers and spray booms. The dynamic distribution includes the variations, detected in static distribution measurements, but will also be influenced by wind, air turbulence, and the movements of the boom.

The influence of dynamic factors, e.g. the sprayers travelling speed, was considered important, why dynamic distribution measurements were preferred in this study. In addition, the static spray distribution, using a conventional patternator, could not be measured for some of the air assisted techniques.

The coefficient of variation, calculated from spray distribution measurements, is a measure of the quality of the spray application technique, which, in turn, can be linked to the biological effect (Enfält et al., 1996). Consequently, this can be used to evaluate the spray application quality. The wallpapers from the dynamic spray distribution measurements, as described below, have also a pedagogical value since unevennesses in the spray distribution is clearly seen.

The method used to measure the dynamic distribution is to spray a Nigrosin WLF, a water-soluble black pigment, and water solution on pre-glued wallpaper lengths. The spray distribution on these wallpaper lengths can then be measured using an image analysis system (Enfält et al., 1997). This method is further described by Öhlund (1996).

In these experiments, the measurements have been made on a flat asphalt surface. Two wallpaper lengths were sprayed, by the boom on one side of the sprayer, for each run (see Figure 1). The spray application techniques and application volumes, in the dynamic spray distribution experiment, are shown in Table 1.

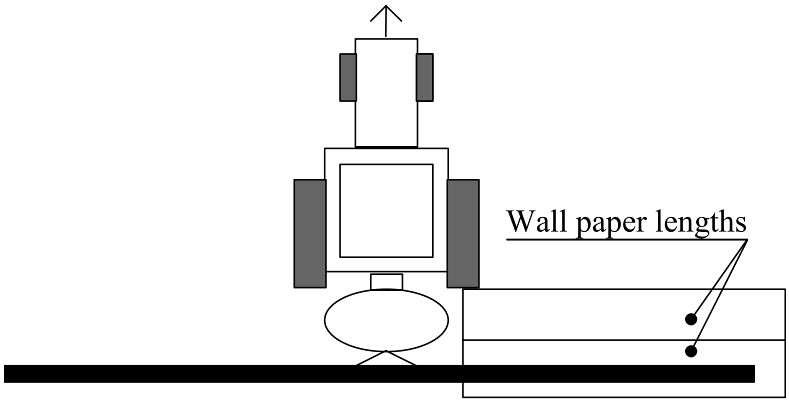


Figure 1. The experimental arrangement of the dynamic spray distribution measurements, spraying a Nigrosin-water solution on wallpaper lengths.

Table 1. The experimental plan for the dynamic spray distribution measurements describing spray application technique, application volume and other settings

Spray technique	Application volume [l/ha]	Speed [km/h]	Nozzle	Pressure [bar]	Spray quality	Other
TeeJet XR	75	6.0	TeeJet XR 110 01	2.8	Fine	
TeeJet XR	150	6.0	TeeJet XR 110 02	2.8	Fine	
Lechler ID	150	6.0	Lechler ID 120 015	5.0	Coarse	
Lechler ID	200	6.0	Lechler ID 120 02	5.0	Coarse	
Lurmark DriftBeta	150	6.0	Lurmark DB 02 F120	2.6	Coarse	
Lurmark DriftBeta	200	6.0	Lurmark DB 02 F120	5.0	Coarse	
AirTec	75	6.0	Restrictor 35	1.6	Fine	Air pressure 1.0 bar
AirTec	105	6.0	Restrictor 35	2.5	Fine	Air pressure 1.4 bar
Danfoil	30	6.0				Air 11 cm WC
Danfoil	50	6.0				Air 11 cm WC
Hardi Twin	75	6.0	TeeJet XR 110 01	2.8	Fine	Air 70%, backwards
Hardi Twin	150	6.0	TeeJet XR 110 02	2.8	Fine	Air 70%, backwards
Kyndestoft	75	6.0	TeeJet XR 110 01	2.8	Fine	Low air flow, backwards
Kyndestoft	150	6.0	TeeJet XR 110 02	2.8	Fine	Low air flow, backwards
Släpduk	75	6.0	TeeJet XR 110 01	1.2	Fine	
Släpduk	150	6.0	TeeJet XR 110 015	2.2	Fine	

Spray deposition analysis

The dynamic spray distribution describes the two dimensional distribution of the spray liquid on the ground surface. In an established crop, the third dimension of spray liquid distribution can be assessed through measuring the deposition of spray liquid in defined levels in the plant stand and on the ground. Provided that the deposition level, in a plant stand, where maximum effect is achieved using a specific pesticide is known, spray techniques can be evaluated for a defined objective of control, e.g. fungi control. The dye Nigrosin WLF was added to the spray liquid and leaves and artificial collectors placed on the ground were collected after spraying. These objects were washed in a defined volume of water and the rinsing water's light absorbance was measured using a spectrophotometer. Using a calibration procedure the amount of deposited spray liquid could be calculated using the rinsing water's and a tank sample's light absorbance value. See Wretblad (1997) for further details.

Spray deposition analyses have been done in plant stands of wheat and potato using the different spray techniques. Detailed plans for the trials are given in the following sections.

Spray deposition in wheat

This trial was carried out in beginning of July 2000 in a spring wheat crop, near Uppsala, in development stage with decimal code 59.

The spray deposition was measured in field trial plots, three repetitions for each spray technique and application volume (see Table 2). Before spraying a plot, two artificial deposition collectors, made of plastic sheet, were placed on the ground at each of three random sampling locations in the plot. After spraying the plot, all ground deposition collectors and all shoots within a sampling area of 0.25 m^2 at each sampling location were collected. A tank spray liquid sample, for determination of the spray deposition as described above, was collected for each spray technique.

Of each of the nine samples, for each spray technique and application volume, 30 random shoots were sampled and each shoot were cut and divided in the fractions: head, flag leaf, leaf 2 (from top of the shoot), leaf 3 and the remainder, including the stem and the remaining leafs. The rest of the sampled shoots fresh weight was recorded. The five fractions were collected separately in plastic bags and the two ground deposition collectors were collected in one plastic bag. The weight for each plant fraction bag was recorded. A defined volume of water was added to each plastic bag and the rinsing water's absorbance was measured using a spectrophotometer.

Assuming that the 30 shoots were representative for the whole sample, the deposited spray liquid in the crop per m^2, for each of the five fractions, can be calculated using the weight of the 30 shoots in relation to the total weight in the 0.25 m^2 area. In the statistical analysis, differences at a 95% confidence level were calculated for the recovered spray liquid for each plant fraction.

Spray deposition in potato

The potato trial was carried out in three days, beginning September 8 1998 in Kalmar. the stand height was 0.75-0.80 m and the variety was "Kardal", used for industrial starch production.

The spray deposition was measured in 15 separate samples for each spray technique and application volume, described in Table 3. Before spraying water with Nigrosin four ground deposition collectors were placed at each sample location, two on the ridge and two in the furrow. After the application of spray liquid, the ground deposition collectors and five leafs each in three fractions, top, middle and bottom level, from one plant stand were collected. A tank sample of the spray liquid was collected for each spray technique.

The absolute spray deposition on the leafs in each fraction was measured using recordings of the absorbance of the rinsing water, as described above. The leaf sample's area were measured through weighing the dry mass, drying the samples in 105°C in 24 h, and determining the relation between leaf area and dry weight in each fraction for a limited number of leaves.

In the statistical analysis, differences at a 95% confidence level were calculated for the recovered spray liquid per leaf area for each leaf fraction.

Table 2. The experimental plan for the spray deposition measurements in wheat describing spray application techniques, application volume and other settings

Spray technique	Application volume [l/ha]	Speed [km/h]	Nozzle	Pressure [bar]	Spray quality	Other
TeeJet XR	75	6.0	TeeJet XR 110 01	2.8	Fine	
TeeJet XR	150	6.0	TeeJet XR 110 02	2.8	Fine	
Lechler ID	150	6.0	Lechler ID 120 015	5.0	Coarse	
Lechler ID	230	6.0	Lechler ID 120 02	6.5	Coarse	
AirTec	75	6.0	Restrictor 35	1.6	Fine	Air pressure 1.0 bar
AirTec	105	6.0	Restrictor 35	2.5	Fine	Air pressure 1.4 bar
Danfoil	30	6.0				Air 19 cm WC
Danfoil	50	6.0				Air 19 cm WC
Hardi Twin	75	6.0	TeeJet XR 110 01	2.8	Fine	Air 85%, slightly forward
Hardi Twin	150	6.0	TeeJet XR 110 02	2.8	Fine	Air 85%, slightly forward
Kyndestoft	75	6.0	TeeJet XR 110 01	2.8	Fine	High airflow, slightly backward
Kyndestoft	150	6.0	TeeJet XR 110 02	2.8	Fine	High airflow, slightly backward
Släpduk	75	6.0	TeeJet XR 110 01	1.2	Fine	Nozzle height 0.0 m
Släpduk	150	6.0	TeeJet XR 110 015	2.2	Fine	Nozzle height 0.0 m

Table 3. The experimental plan for the spray deposition measurements in potato describing spray application techniques, application volume and other settings

Spray technique	Applicatio n volume [l/ha]	Speed [km/h]	Nozzle	Pressure [bar]	Spray quality	Other
TeeJet XR	150	6.0	TeeJet XR 110 02	2.8	Fine	
TeeJet XR	300	6.0	TeeJet XR 110 04	2.8	Medium	
Lechler ID	150	6.0	Lechler ID 120 015	5.0	Coarse	
Lechler ID	300	6.0	Lechler ID 120 02	5.0	Coarse	
Lurmark DriftBeta	150	6.0	Lurmark DB 02 F120	2.6	Coarse	
Lurmark DriftBeta	300	6.0	Lurmark DB 02 F120	5.0	Coarse	
AirTec	105	6.0	Restrictor 35	2.5	Fine	Air pressure 1.4 bar
AirTec	150	6.0	Restrictor 35	3.9	Medium	Air pressure 1.7 bar
Danfoil	30	6.0				Air 25 cm WC
Danfoil	50	6.0				Air 25 cm WC
Hardi Twin	150	6.0	TeeJet XR 110 02	2.8	Fine	Max. air, slightly backward
Hardi Twin	300	6.0	TeeJet XR 110 04	2.8	Medium	Max. air, slightly backward
Kyndestoft	150	6.0	TeeJet XR 110 02	2.8	Fine	Max. air, slightly backward
Kyndestoft	300	6.0	TeeJet XR 110 04	2.8	Medium	Max. air, slightly backward
Släpduk	150	6.0	TeeJet XR 110 015	2.2	Fine	Nozzle height 0.0 m
Släpduk	300	6.0	TeeJet XR 110 03	2.2	Medium	Nozzle height 0.0 m

Dose response studies with linear change of dose

An evaluation of the different spray application techniques were made by studying the dose response function of biological effect with respect to dose, using different pesticides in different crops. The shape of the dose response function depends on different parameters, such as the chemical, meteorological factors, yearly variations in weather conditions, spray application technique etc. In this study, the dose response experiments were weed control in spring barley, fungi control in winter wheat and in late blight control in potato. In the field trial plots, linearly increased dose was used. This technique makes it possible to study the dose response, from zero to recommended dose, in a single plot. Also, the influence of field variations is reduced. This, together, increases the possibilities to study parameters, such as the influence of spray application technique. A detailed description of the methodology can be found in Alness et al. (1996).

The trial plots, treated with linearly changed dose, were four meters wide and 30 meters long. Figure 2 shows a plot and the principle of linearly increased dose. Every spray technique and application volume was randomly repeated in three trial plots.

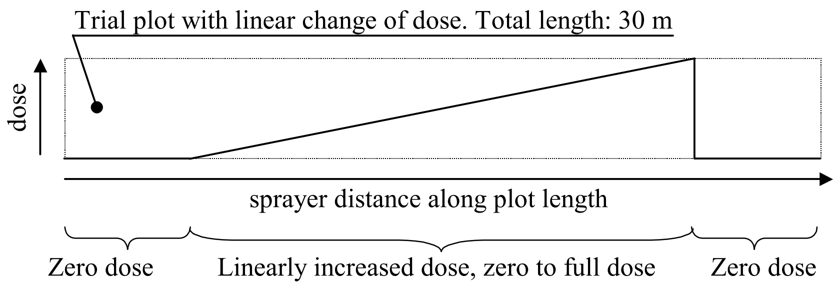


Figure 2. A description of the field trial plots with linear change of dose. Plot width was 4 m.

In the analysis, a dose response function was fitted to experimental data. The dose response function can be described by two parameters: ED_w and the slope of the curve. ED_w is the dose needed to reach *w* % effect. In this analysis, ED_{70} and ED_{90} were used. Statistical analysis of ED_w has been made to find significant differences between the spray techniques and application volumes. A typical dose response function and the theory of ED_w are exemplified in Figure 3. The theory of dose response functions is further described by Halldin (1998).

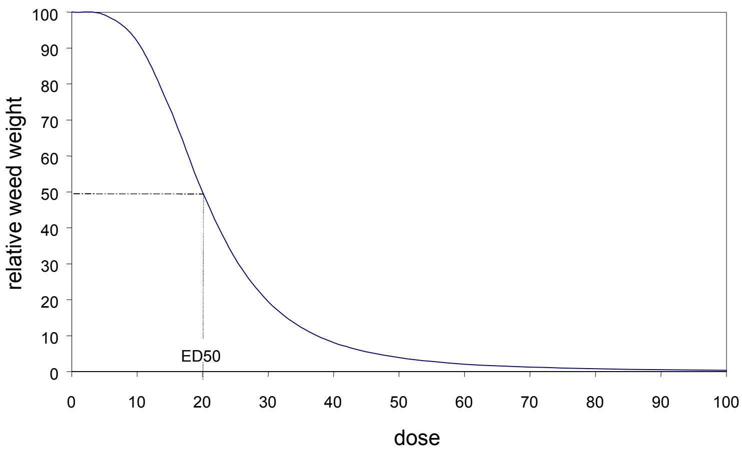


Figure 3. An example of a dose response function and the resulting ED50, i.e. the effective dose required to reach 50% of full effect.

Weed control in spring barley

In the trial, situated near Uppsala, weed control was carried out in a spring wheat crop spraying a mixture of Express (tribenuronmetyl 50 % by weight) and Starane (fluroxypyr 180 g/l) in the morning of June 3, 1999. Maximum dose was 7.5 g/ha Express and 0.5 l/ha

Starane. Spray techniques, application volumes and other settings are described in Table 4. Weed samples, i.e. weights and counts, were collected in 0.25 m long and 1.00 m wide sample areas. In each plot, with linearly increased dose, two weed samples were collected in the untreated part in the beginning of the plot and at 8 different doses along the treated part approximately 30 days after spraying.

Table 4. The experimental plan for the field trial on weed control in barley describing spray application techniques, application volume and other settings

Spray technique	Application volume [l/ha]	Speed [km/h]	Nozzle	Pressure [bar]	Spray quality	Other
TeeJet XR	75	6.0	TeeJet XR 110 01	2.8	Fine	
TeeJet XR	150	6.0	TeeJet XR 110 02	2.8	Fine	
Lechler ID	150	6.0	Lechler ID 120 015	5.0	Coarse	
Lechler ID	200	6.0	Lechler ID 120 02	5.0	Coarse	
Lurmark DriftBeta	150	6.0	Lurmark DB 02 F120	2.6	Coarse	
Lurmark DriftBeta	200	6.0	Lurmark DB 02 F120	5.0	Coarse	
AirTec	75	6.0	Restrictor 35	1.6	Fine	Air pressure 1.0 bar
AirTec	105	6.0	Restrictor 35	2.5	Fine	Air pressure 1.4 bar
Danfoil	30	6.0				Air 11 cm WC
Danfoil	50	6.0				Air 11 cm WC
Hardi Twin	75	6.0	TeeJet XR 110 01	2.8	Fine	Air 70%, backward
Hardi Twin	150	6.0	TeeJet XR 110 02	2.8	Fine	Air 70%, backward
Kyndestoft	75	6.0	TeeJet XR 110 01	2.8	Fine	Low airflow, backward
Kyndestoft	150	6.0	TeeJet XR 110 02	2.8	Fine	Low airflow, backward
Släpduk	75	6.0	TeeJet XR 110 01	1.2	Fine	
Släpduk	150	6.0	TeeJet XR 110 015	2.2	Fine	

Fungi control in winter wheat

Fungi control trials in winter wheat were carried out near Uppsala at two occasions, daytime June 27 1997 and in the evening June 20 2000.The herbicide Tilt Top 500 EC (propiconazol 125 g/l, fenpropimorf 375 g/l) was used and maximum dose was 1.0 l/ha. The development stage of the crop, on both occasions, was decimal code 55-59. Visual assessment of Tan Spot (*Drechslera tritici-repentis*) on wheat were made three and a half weeks after spraying 1997 and three weeks after spraying 2000. Spray techniques, application volumes and other settings are described in Table 5 and 6.

The assessment of fungi infestation was made using samples of 20 random shoots each. Samples were made at seven doses along the plot, with linearly increased dose, zero dose included. Visual assessments on percentage necrosis of the leaf area were made for the fractions of flag leaf and second leaf from the top. The grain yield and the 1000kernel-weight, in samples of approximately 3000 kernels, were recorded, for both trials, at 11 different dose levels, zero dose included.

The fungi infestation data was analysed fitting a dose response function to the visual assessments of the percentage necrosis of leaf area for each field trial plot. The 1000kernel-weight analysis was made through fitting a straight line to the data with respect to dose. The

1000kernel-weight data were better described and the fitting procedure was more robust using a linear function of the first order than using a dose response function.

Table 5. The experimental plan for the 1997 field trial on fungi control in winter wheat describing spray application techniques, application volume and other settings

Spray technique	Application volume [l/ha]	Speed [km/h]	Nozzle	Pressure [bar]	Spray quality	Other
TeeJet XR	150	4.0	TeeJet XR 110 015	2.2	Fine	
TeeJet XR	300	4.0	TeeJet XR 110 03	2.2	Medium	
Danfoil	30	4.0				Air 16 cm WC
Danfoil	50	4.0				Air 16 cm WC
Hardi Twin	75	4.5	TeeJet XR 110 01	1.5	Fine	Air 85%, straight down
Hardi Twin	150	4.0	TeeJet XR 110 015	2.2	Fine	Air 85%, straight down
Kyndestoft	75	4.5	TeeJet XR 110 01	1.5	Fine	High airflow, slightly backward
Kyndestoft	150	4.0	TeeJet XR 110 015	2.2	Fine	High airflow, slightly backward
Släpduk	75	6.8	TeeJet XR 110 01	1.5	Fine	Nozzle height: 0.0 m
Släpduk	150	6.1	TeeJet XR 110 015	2.2	Fine	Nozzle height: 0.0 m

Table 6. The experimental plan for the 2000 field trial on fungi control in winter wheat describing spray application techniques, application volume and other settings

Spray technique	Application volume [l/ha]	Speed [km/h]	Nozzle	Pressure [bar]	Spray quality	Other
TeeJet XR	75	6.0	TeeJet XR 110 01	2.8	Fine	
TeeJet XR	150	6.0	TeeJet XR 110 02	2.8	Fine	
Lechler ID	150	6.0	Lechler ID 120 015	5.0	Coarse	
Lechler ID	230	6.0	Lechler ID 120 02	6.5	Coarse	
AirTec	75	6.0	Restrictor 35	1.6	Fine	Air pressure 1.0 bar
AirTec	105	6.0	Restrictor 35	2.5	Fine	Air pressure 1.4 bar
Danfoil	30	6.0				Air 19 cm WC
Danfoil	50	6.0				Air 19 cm WC
Hardi Twin	75	6.0	TeeJet XR 110 01	2.8	Fine	Air 85%, slightly forward
Kyndestoft	75	6.0	TeeJet XR 110 01	2.8	Fine	High airflow, slightly backward

Late blight control in potato

The potato late blight trial was carried out near Kalmar and treated with Shirlan (fluazinam 500 g/l) at six different occasions from June 7 to August 17 1999. Maximum dose was 0.4 l/ha. Spray techniques, application volumes and other settings are described in Table 7.

The trial was inoculated with a spore suspension on three occasions in July to accelerate the development of the late blight infestation. Visual assessments of percentage necrosis on leaves in the canopy were made four times in August. The analysis is based on data from the last assessment, August 25.

Table 7. The experimental plan for the field trial on late blight control in potato describing spray application techniques, application volume and other settings

Spray technique	Application volume	Speed	Nozzle	Pressure	Spray quality	Other
	[l/ha]	[km/h]		[bar]		
TeeJet XR	150	6.0	TeeJet XR 110 02	2.8	Fine	
TeeJet XR	300	6.0	TeeJet XR 110 04	2.8	Medium	
Lechler ID	150	6.0	Lechler ID 120 015	5.0	Coarse	
Lechler ID	300	6.0	Lechler ID 120 02	5.0	Coarse	
Lurmark DriftBeta	150	6.0	Lurmark DB 02 F120	2.6	Coarse	
Lurmark DriftBeta	300	6.0	Lurmark DB 02 F120	5.0	Coarse	
AirTec	105	6.0	Restrictor 35	2.5	Fine	Air pressure 1.4 bar
AirTec	150	6.0	Restrictor 35	3.9	Medium	Air pressure 1.7 bar
Danfoil	30	6.0				Air 25 cm WC
Danfoil	50	6.0				Air 25 cm WC
Hardi Twin	150	6.0	TeeJet XR 110 02	2.8	Fine	Max. airflow, slightly backward
Hardi Twin	300	6.0	TeeJet XR 110 04	2.8	Medium	Max. airflow, slightly backward
Kyndestoft	150	6.0	TeeJet XR 110 02	2.8	Fine	Max. airflow, slightly backward
Kyndestoft	300	6.0	TeeJet XR 110 04	2.8	Medium	Max. airflow, slightly backward
Släpduk	150	6.0	TeeJet XR 110 015	2.2	Fine	Nozzle height: 0.0 m
Släpduk	300	6.0	TeeJet XR 110 03	2.2	Medium	Nozzle height: 0.0 m

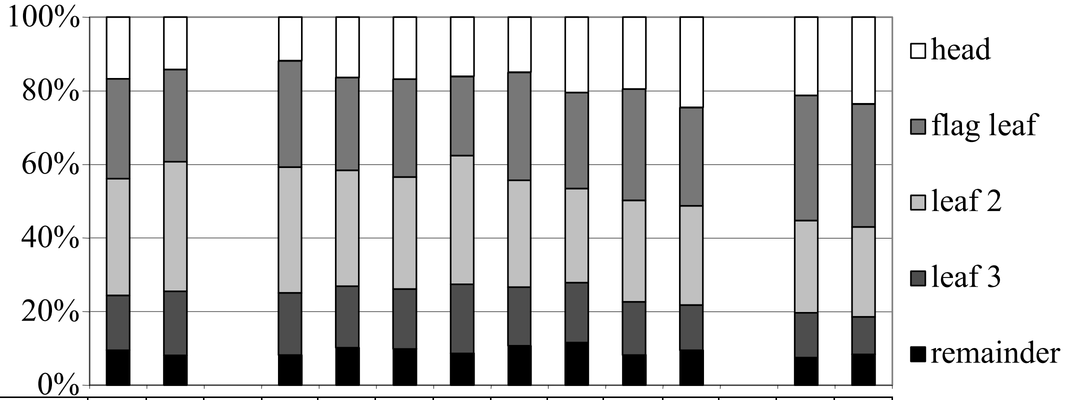
RESULT AND DISCUSSION

Dynamic spray distribution

The coefficients of variation for the dynamic spray distribution measurements were in the range 5% to 16%. Generally, these values can be considered acceptable for the dynamic spray distribution. One exception was the distribution measurements made with the Danfoil technique before the company changed the construction 1998. The nozzle was changed in order to improve the spray distribution and complementary measurements of the dynamic spray distribution showed improvement. Before the reconstruction, streaks were clearly seen on the wallpaper lengths after spraying water and Nigrosin. This effect could not be seen after the reconstruction. Concentration of spray liquid could also be seen on the wallpaper lengths after spraying the Nigrosin solution with Hardi Twin air assistance technique. One possible cause could be the air movements from the opening in the air tube at the joint between boom sections. The purpose of this opening in the tube is to make the folding of the boom possible. Further investigation is needed to confirm this theory.

Spray deposition in wheat

The results of these trials show that the spray deposition in a developed crop can be controlled through the application technique. The trial was sprayed when the wheat's head was just fully emerged. The deposition on the head and the flag leaf was relatively low, most likely because, at this development stage, both the head and the flag leaf was in an upright, erect, position. A higher deposition in these uppermost fractions might otherwise be expected due to the open position in the canopy, with unobstructed exposure to the spray droplets. Because the head and the flag leaf can be of importance to protect when spraying fungicides, it can be of importance to increase the deposition of spray liquid on these plant parts. Figure 4 shows the spray deposition on the different plant part fractions using the different spray techniques and application volumes. Two of the experimental treatments could not be executed due to the prevailing weather conditions.



Spray technique	TeeJet XR		Lechler ID		AirTec		Danfoil		Hardi Twin		Kyndes-toft		Släpduk	
Application volume [l/ha]	75	150		150	75	105	30	50	75	150	75		75	150

Figure 4. Recovered spray liquid in different fractions in the crop in the spray deposition experiments in wheat.

The statistical analysis of the deposition on the head and flag leaf showed, at 95% confidence level, that Släpduk, 75 and 150 l/ha, had higher deposition compared to AirTec, 75 and 105 l/ha, Danfoil 30 l/ha, Hardi Twin 150 l/ha and TeeJet XR. In addition Släpduk gave higher deposition on the flag leaf than Kyndestoft 75 l/ha and higher deposition on the head than Danfoil 50 l/ha and Lechler ID 150 l/ha. Also, Hardi Twin 75 l/ha gave higher deposition on the head than Lechler ID 150 l/ha.

The deposition on the second leaf from the top was lower for Hardi Twin 150 l/ha than for AirTec 105 l/ha, Danfoil 30 l/ha, Lechler ID 150 l/ha, TeeJet XR 75 and 150 l/ha and Släpduk 150 l/ha. Also, on the second leaf, Lechler ID had higher deposition compared to Hardi Twin and Kyndestoft 75 l/ha, and Danfoil 30 l/ha had higher deposition than Kyndestoft 75 l/ha.

On the third leaf, Kyndestoft 75 l/ha resulted in lower deposition than AirTec 105, Hardi Twin 75, Lechler ID 150 and TeeJet XR 150 l/ha. Hardi Twin 150 l/ha had lower deposition than AirTec 105 and TeeJet XR 150 l/ha.

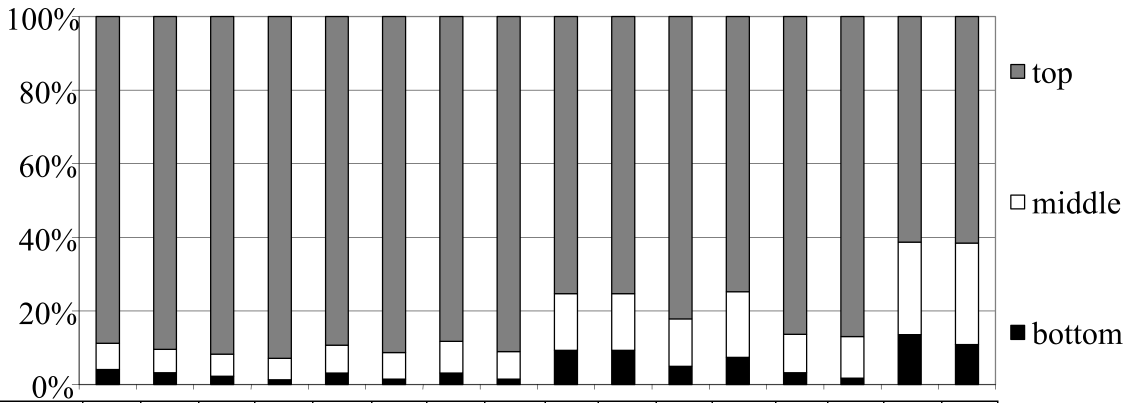
On the last fraction, "remainder", including the stem and the remaining leafs, the only significant difference was that Hardi Twin 150 l/ha had lower deposition than AirTec 105 l/ha.

The depositions on the ground were in the range from 9% to 28% of the applied volume. Hardi Twin had significantly lower deposition on the ground than several of the other spray techniques and application volumes. Also Kyndestoft had lower deposition on the ground compared to Danfoil 30 l/ha and Lechler ID. Lechler ID, on the other hand, had significantly higher deposition compared to Hardi Twin, Kyndestoft, Släpduk and TeeJet XR 75 l/ha.

For both spray techniques with external air assistance, it was recommended that the air boom, in the case of Kyndestoft, and the air-spray boom, in the case of Hardi Twin, were tilted. For Hardi Twin, slightly forward and for Kyndestoft's, slightly backward. I was clearly obvious that this resulted in lower deposition of spray liquid on the ground. Släpduk had the highest increase of deposition on the head and the flag leaf.

Spray deposition in potato

The results from the deposition measurements in potato clearly shows that different spray techniques have different spray depositions in the canopy levels, shown in Figure 5. The potato canopy was dense and fully closed and the major part of the recovered spray deposition was found in the top of the canopy, in contrast to the deposition trials in wheat.



Application volume [l/ha]	150	300	150	300	150	300	105	150	30	50	150	300	150	300	150	300
Spray technique	TeeJet XR		Lechler ID		Lurmark Drift Beta		AirTec		Danfoil		Hardi Twin		Kyndes-toft		Släpduk	

Figure 5. Recovered spray liquid in different fractions in the canopy in the spray deposition experiments in potato.

The statistical analysis showed a significantly higher deposition in the top of the canopy for TeeJet XR, 150 and 300 l/ha, and for Kyndestoft 300 l/ha compared to several of the other spray techniques. Danfoil 30 l/ha and Släpduk had significantly lower than all other spray techniques in the top of the canopy. While spraying the trial plots, it was noted that Släpduk, a type of crop opening technique, turned some of the uppermost leaves over and spray liquid was applied on the underside of these leaves.

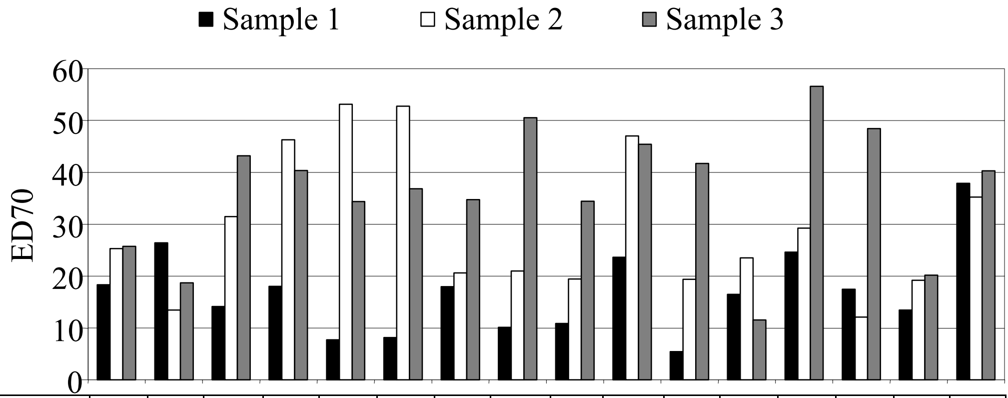
Lechler ID 300 l/ha gave significantly lower deposition in the bottom of the canopy in relation to most of the other spray techniques and application volumes. Hardi Twin, Släpduk and Danfoil resulted in an increased deposition in the canopy bottom compared to, above all, Lechler ID 300 l/ha, but also compared to Lechler ID 150 l/ha, Kyndestoft 300 l/ha, Lurmark DriftBeta and AirTec. The depositions on the ground were between 0.3% and 2% of applied volume of spray liquid. Danfoil 50 l/ha, Släpduk 300 l/ha and Hardi Twin 300 l/ha had the highest depositions on the ground. However, it is clear that the dense canopy resulted in an overall low deposition on the ground, especially in relation to the results from the deposition measurements in wheat.

Some sources of uncertainty, measuring the deposition in potato canopy, are worth mentioning. Firstly, soil occurred on potato leaves at the very bottom of the canopy. This could have affected the absorbance when measuring the concentration of Nigrosin in the rinsing water with the spectrophotometer. Secondly, the spray deposition on the underside of a potato leaf was harder to wash of with water than the deposition on the leaf's upper side.

Weed control in spring barley

One weed control trial in spring barley using linearly increased dose was carried out 1999. A dose response function was fitted to the total weed weight with respect to the herbicide dose. ED70 for each trial plot is shown in Figure 6.

No significant differences could be found, neither for the shape of the dose response curve nor for ED70, i.e. the required dose to achieve 70% weed effect. The variations were high and the fitting of the dose response function was not exemplary. This was primarily explained by high local variations of weed density and composition of weed species. However, satisfying treatment effect was achieved by all spray techniques and ED70 was in some cases reached at doses as low as 10% to 20% of recommended dose.



Application volume [l/ha]	75	150	150	200	150	200	75	105	30	50	75	150	75	150	75	150
Spray technique	TeeJet XR		Lechler ID		Lurmark Drift Beta		AirTec		Danfoil		Hardi Twin		Kyndes-toft		Släpduk	

Figure 6. ED70, i.e. the dose required the achieve 70 % of full effect, for each spray technique, application volume and repetitive sample in the barley weed control experiment.

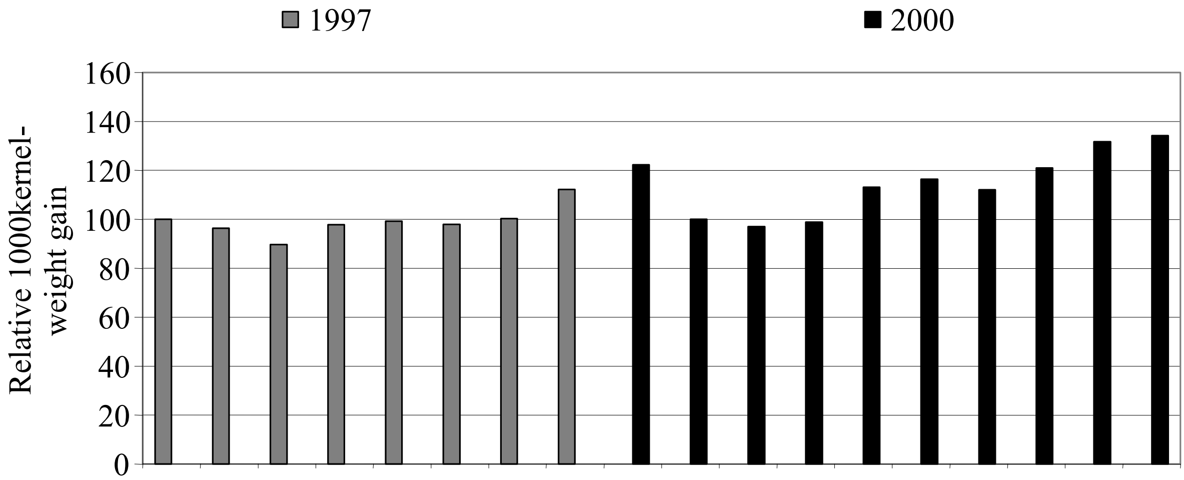
Fungi control in winter wheat

Fungi control trials in winter wheat were carried out in 1997 and in 2000. The analysis were based on the visual assessment of percentage necrosis of the leaf area of the two uppermost leaves and on the 1000kernel-weight.

A straight line was fitted to the 1000kernel-weight with respect to herbicide dose, within each treatment. In this analysis, totally four observations in different treatments were identified as outliers and were excluded from the analysis. The slope of the lines can be seen as a measure of the effectiveness of the spray techniques. Figure 7 shows the slope of the lines for the spray techniques and application volumes in relation to conventional spray technique, i.e. TeeJet XR with application volume 150 l/ha.

No significant differences could be found in the statistical analysis for leaf fungi infestation assessments or for 1000kernel-weight. Nor could any similar tendencies be found for the two years. In year 2000, low application volumes seemed to increase the 1000kernel-weight, but this was not the case in 1997.

Leaf fungi infestation was higher in 1997 than in 2000. The mean 1000kernel-weight for untreated observations, i.e. zero dose, was 30.9 g and for recommended dose 34.7 g. Year 2000 the corresponding 1000kernel-weight values were 36.0 g and 38.3 g respectively. The relative increase of 1000kernel-weight for treatment with recommended dose was, as expected, higher when the general fungi infestation level was higher.



Application volume [l/ha]	150	300	75	150	75	150	75	150	75	150	150	230	75	105	30	50	75	75
Spray technique	TeeJet XR		Hardi Twin		Kyndes-toft		Släpduk		TeeJet XR		Lechler ID		AirTec		Danfoil		Hardi T.	Kyndest.

Figure 7. The 1000kernel- weight gain, i.e. the slope of a straight line fitted to experimental data with respect to dose, in relation to the TeeJet XR 150 l/ha treatment each year.

Late blight control in potato

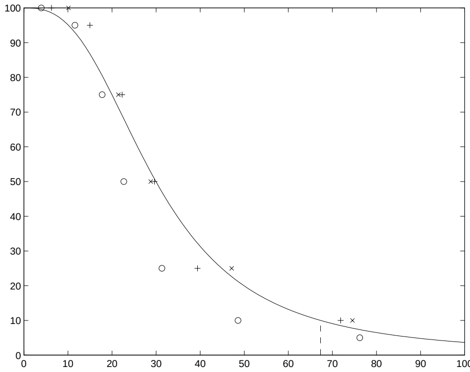
The trial was visually assessed with respect to percentage necrosis on leaves in the canopy. Leaf fungi infestation assessments were fitted to a dose response function (see Figure 8). Statistical analysis were made on the shape of the dose response function and for ED90, i.e. the dose required to achieve 90% of the full effect of treatment. One of the three AirTec 105 l/ha trial plots were excluded from the analysis because of a below standard quality of application cased by external circumstances.

No significant differences between the treatments could be found, despite clear differences between spray techniques in the spray deposition studies, as described above.

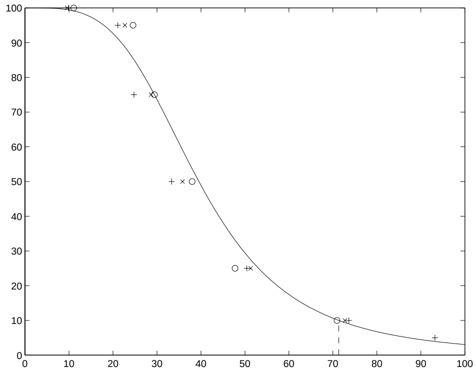
An important observation was that, in the plot treated with Släpduk, some necrosis could be found on the uppermost leaves in the canopy, in spite of the fact that the steep part of the dose response function did not occur at higher doses than the other spray techniques. On one hand, this could be caused by the significantly lower deposition of spray liquid in the top of the canopy, compared to conventional spray technique. This is not likely, though, because the main part of the spray liquid volume still can be found in the top of the canopy. On the other hand, in the spray deposition study, it was observed that Släpduk turns the uppermost leaves over and applies some spray liquid on the leave's underside. Shirlan is a contact active fungicide and, in this case, a sufficient protection on the upper side of those leaves, where the airborne spores lands, might not have been achieved.

From the fact that equally good treatment effect have been achieved, both with spray techniques with low penetration ability as with techniques with high penetration ability, one conclusion is that the penetration ability in dense potato canopies is not of equal importance as to protect the upper parts of the canopy, where canopy grows and where the spores lands, against fungi infestation.

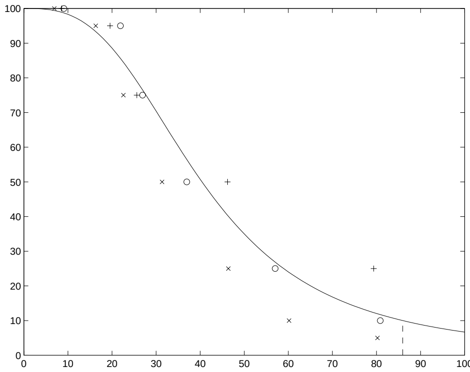
The height of the lower edge of the Släpduk's crop opener was at 2/3 of the canopy plant height in order to have sufficient penetration. The results indicates that it is not preferable to strive for high penetration in potato late blight control, instead it might be better to let the crop



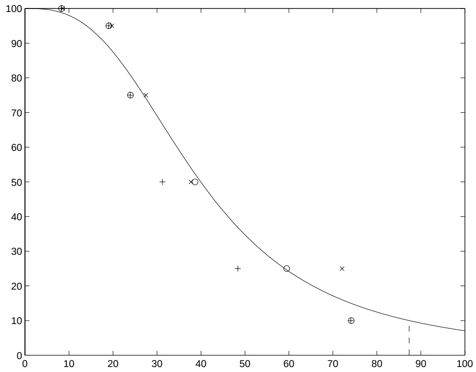
(a). TeeJet XR 150 l/ha



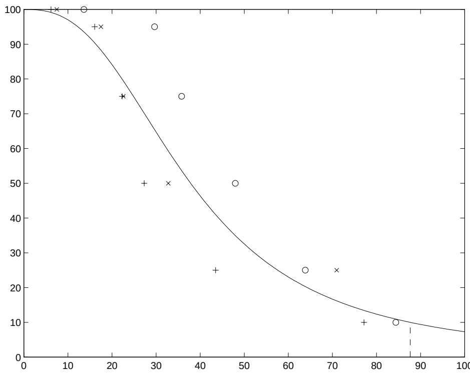
(b). TeeJet XR 300 l/ha



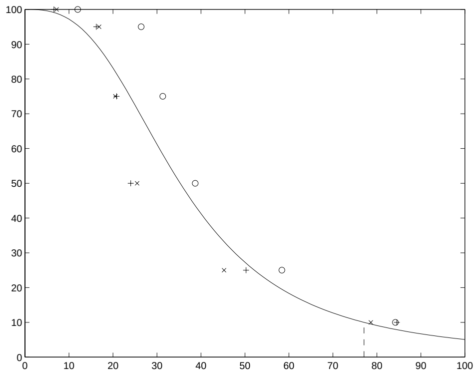
(c). Lechler ID 150 l/ha



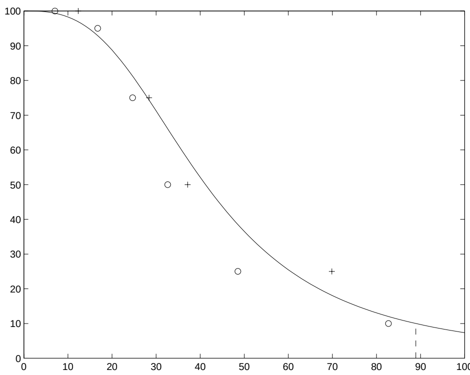
(d). Lechler ID 300 l/ha



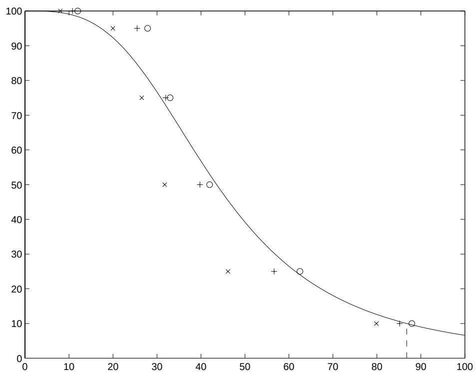
(e). Lurmark DriftBeta 150 l/ha



(f). Lurmark DriftBeta 300 l/ha



(g). AirTec 105 l/ha



(h). AirTec 150 l/ha

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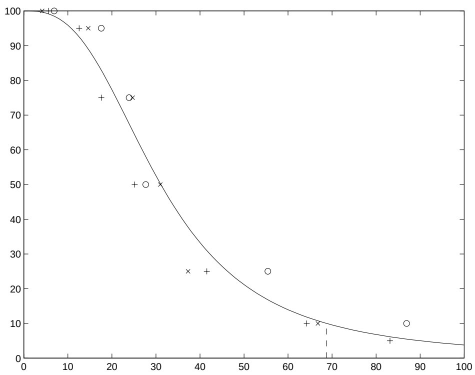
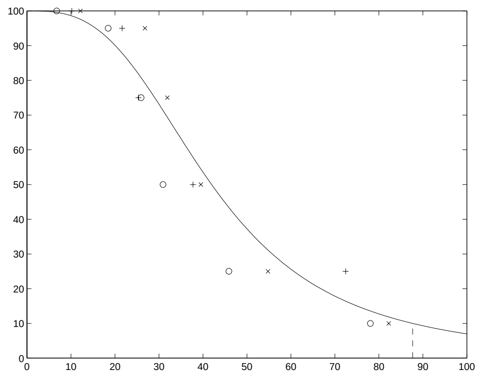
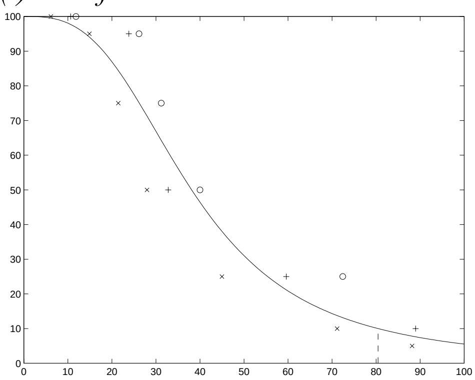


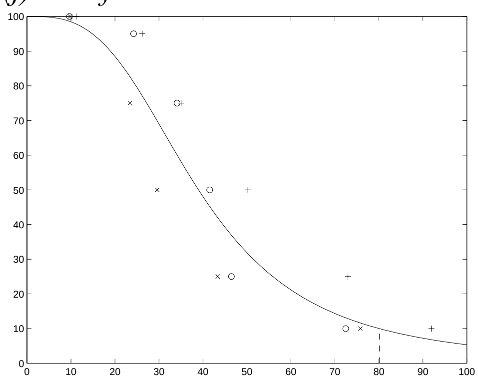
(i). Danfoil 30 l/ha



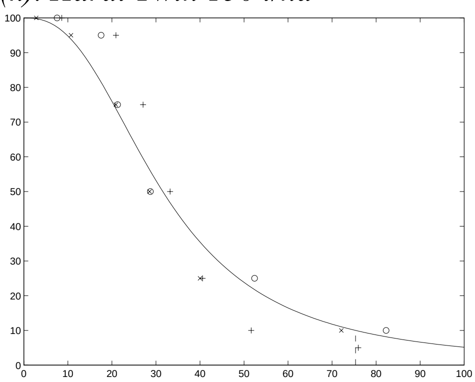
(j). Danfoil 50 l/ha



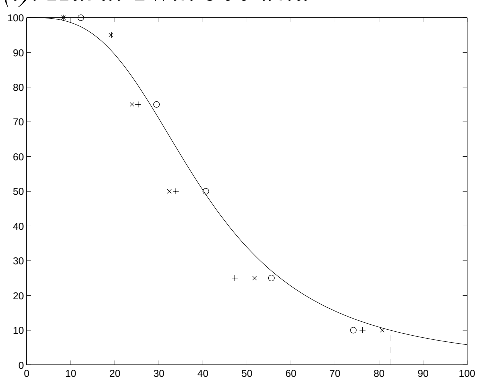
(k). Hardi Twin 150 l/ha



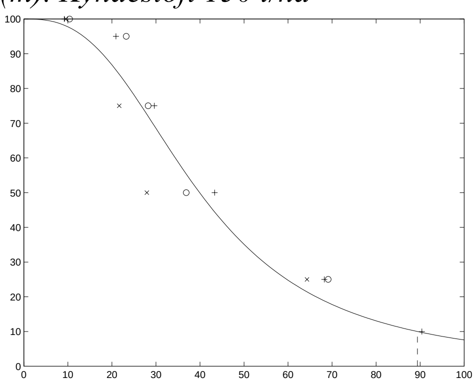
(l). Hardi Twin 300 l/ha



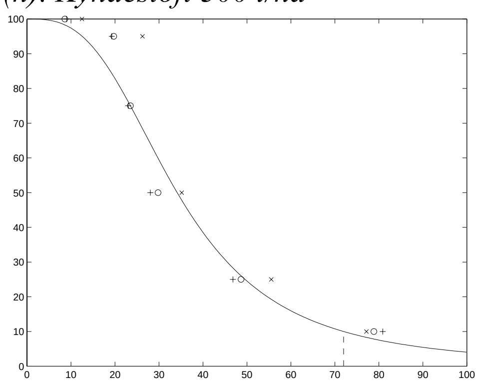
(m). Kyndestoft 150 l/ha



(n). Kyndestoft 300 l/ha



(o). Släpduk 150 l/ha



(p). Släpduk 300 l/ha

*Figure 8 (a-p). The charts show the results from the potato late blight control. The y-axis is the percentage necrosis on leaves in the canopy and the x-axis is the dose percentage relative to recommended dose, where 100% is 0.4 l/ha Shirlan. "**x**", "**o**" and "**+**" is the three repetitive samples in each treatment and the line is the fitted dose response function. The dashed line shows ED90, i.e. the dose required to achieve 90% of full effect.*

opener touch the top of the canopy to achieve a sufficient protection of the youngest leaves. This has resulted in changed recommendation from the manufacturer of Släpduk on how the spray technique should be used in late blight control in potato. Also, the air assistance techniques had high airflows in order to increase the penetration. Whether this is appropriate or not remains to be investigated.

CONCLUSIONS

The experiments in this project have included the distribution of spray liquid on flat surfaces, on the ground, as well as the distribution, with respect to penetration, in fully developed canopies. The biological effect of chemical control of weed control in spring cereals and fungi control in winter wheat and potato has been investigated. In spite of the fact that differences in spray deposition in different levels in canopies, between different spray techniques, has been shown, no significant differences in biological effect have been found. However, this does not prove, in any way, that differences do not exist. Anyhow, it is remarkable that no significant differences were found in any control studies.

It is important to have in mind, however, that the objective with these trials was to investigate the spray techniques under optimal conditions. All trials was executed at practically windless conditions and when other weather conditions and time of spraying etc. was optimal for the object of control at present. The ability to reduce drift, increase capacity or enhance the quality of control in other ways has not been included in this investigation.

Yet, the results imply that, at "optimal" conditions for the situation of control in these investigations, there are no great differences between different spray techniques. The choice of spray technique can be of greater importance in situations where the pesticide is more likely to fail. Spray application in dense crops with typically contact active pesticides could be such a situation. Other such scenarios can be found where the pesticide generally has a poor effect or selectivity than in the present cases.

The ability to reduce drift, increase the capacity in order to treat larger areas under optimal conditions, and improve safety and working environment is important factors to consider when selecting the spray technique. Furthermore one should consider how easy the spray technique is to use and manage. A high number of possible settings makes it possible to adapt the spray technique to different situations, but it also increases the risk of using the wrong setting, which could lead to an inferior treatment effect. In this way, the use of an advanced spray technique demands a higher degree of expertise.

The choice of spray application technique is done with an ambition to achieve high capacity, minimal wind drift, high degree of coverage on the plant or on other objects of control, even spray liquid distribution and low deposition on the ground. The spray technique simply should result in the highest possible effect at minimum dose and with minimum environmental impact in all situations of control. At the same time it should be easy to use an offer a good working environment. These demands can be incompatible and the resulting choice is therefore a compromise that each user have to do out of his or hers own conditions.

REFERENCES

Alness, K., Bengtsson, P., Engqvist, A. & Enfält, P. 1996. A field experimental system for developing methodology for selective plant protection. *The Tenth International Conference and Exhibition on Mechanization of Field Experiments (IAMFE/FRANCE '96), INRA Versailles, France.*

Enfält, P., Alness, K. & Andersson, A. 1995. Spridningsjämnhetens betydelse för val av dos - en modell. *36th Swedish Crop Protection Conference. Uppsala 25-26 January 1995*, 315-324

Enfält, P., Alness, K., Engqvist, A. 1996. A mathematical model of dose response behaviour - depending on the spray liquid distribution. *AgEng Conference, Madrid 23-26 September*

Enfält, P., Engqvist, A. & Alness, K. 1997. Assessment of the dynamical spray distribution on a flat surface using image analysis. *Aspects of Applied Biology, 48. Proceedings, Optimising Pesticide Applications, Long Ashton Research Station, 6-7 January 1997, 17-24*

Halldin, R. 1998. Dose-response curves with application to weed control. *Rapport 44, Avdelningen för statistik, SLU.* Uppsala.

Wretblad, P. 1997. Fördelning av sprutvätska i spannmåls- och potatisbestånd med fyra olika appliceringstekniker. *Rapport 223, Institutionen för lantbruksteknik, SLU.* Uppsala.

Öhlund, L. 1996. Lantbrukssprutors dynamiska spridningsjämnhet – 24 sprutor testade på gårdsnivå. *Institutionsmeddelande 96:03, Institutionen för lantbruksteknik, SLU.* Uppsala.

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