Pesticides Research Nr. 65 2003
Bekæmpelsesmiddelforskning fra Miljøstyrelsen

Deposition of Pesticides on the Soil Surface

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Contents

CONTENTS 3

PREFACE 5

SAMMENFATNING OG KONKLUSIONER 9

SUMMARY AND CONCLUSIONS 11

INTRODUCTION 13

MATERIALS AND METHODS 15

RESULTS 23

1.1 CROP COVER IN 8 CROPS IN THE 1998-1999 GROWING SEASON 23
1.2 DEPOSITION OF SPRAY LIQUID ON THE SOIL BELOW FOUR CROPS 29
1.2.1 Winter wheat, spring barley, sugar beet and potato 1998/1999 30
1.2.2 Winter wheat 1999/2000 and 2000/2001 32
1.2.3 Spring barley 2000 and 2001 34
1.2.4 Sugar beet 2000 and 2001 36
1.2.5 Potatoes 2000 and 2001 38
1.3 INTERACTION OF SPRAY QUALITY AND SPRAY FORMULATION ON DEPOSITION OF SPRAY LIQUID ON THE SOIL 40

DISCUSSION & CONCLUSIONS 45

REFERENCES 49

SOIL DEPOSITION VALUES 53

WINTER WHEAT 54
SPRING BARLEY 55
SUGAR BEET 56
POTATOES 57

Preface

The project "Model Based Tool for Evaluation of Exposure and Effects of Pesticides in Surface Water", funded by the Danish Environmental Protection Agency, was initiated in 1998. The aim of the project was:

> To develop a model-based tool for evaluation of risk related to pesticide exposure in surface water. The tool must be directly applicable by the Danish Environmental Protection Agency (DEPA) in their approval procedure. As part of this goal, the project had to:
>
> - Develop of guidelines for evaluation of mesocosm experiments based on a system-level perspective of the fresh water environment
> - To develop models for deposition of pesticides on vegetation and soil.
> - To estimate the deposition of pesticides from the air to the aquatic environment.

The project, called "Pesticides in Surface Water", consisted of seven subprojects with individual objectives. The sub-projects are listed in Table 1.

Table 1. Sub-projects of "Pesticides in Surface Water".
Tabel i. Oversigt over delprojekter i "Pesticider i overfladevand".

	Title	Participating institutions
A	Development and validation of a model for evaluation of pesticide exposure	DHI Water & Environment
B	Investigation of the importance of plant cover for the deposition of pesticides on soil	Danish Institute of Agricultural Science
C	Estimation of addition of pesticides to surface water via air	National Environmental Research Institute Danish Institute of Agricultural Science
D	Facilitated transport	DHI Water & Environment
E	Development of an operational and validated model for pesticide transport and fate in surface water	DHI Water & Environment National Environmental Research Institute
F	Mesocosm	DHI Water & Environment National Environmental Research Institute
G	Importance of different transport routes in relation to occurrence and effects of pesticides in streams	National Environmental Research Institute County of Funen County of Northern Jutland

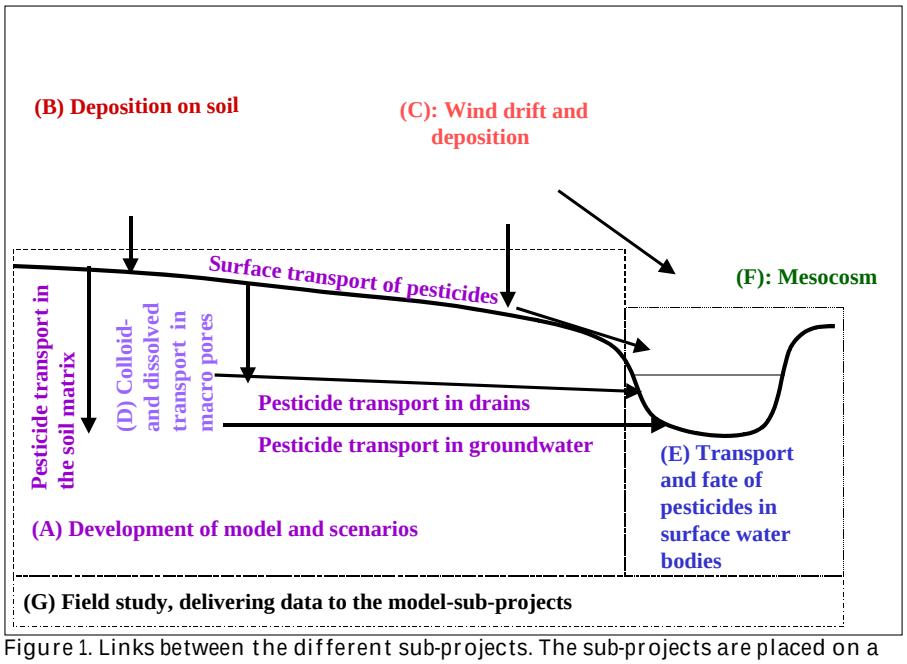


Figure 1. Links between the different sub-projects. The sub-projects are placed on a cross-section of the catchment to illustrate interactions.
Figur i. Sammenhæng mellem delprojekterne. Delprojekterne er placeret på et tværsnit af en opland for at illustrere interaktionerne.

Figure 1 describes the relationship between the sub-projects. Sub-project 1 models the upland part of the catchment, while sub-project 5 models surface water bodies. Sub-project 8 delivers data to both modelling projects. Sub-project 2 and 3 develops process descriptions for wind drift, dry deposition and deposition on soils. Sub-project 4 builds and tests a module for calculation of colloid transport of pesticide in soil. The module is an integrated part of the upland model. Sub-project 6 has mainly concentrated on interpretation of mesocosm-studies. However, it contains elements of possible links between exposure and biological effects.

The reports produced by the project are:

- Styczen, M., Petersen, S., Christensen, M., Jessen, O.Z., Rasmussen, D., Andersen, M.B. and Sørensen, P.B. (2002): Calibration of models describing pesticide fate and transport in Lillebæk and Odder Bæk Catchment. - Ministry of Environment, Danish Environmental Protection Agency, Pesticides Research No. 62.

- Styczen, M., Petersen, S. and Sørensen, P.B. (2002): Scenarios and model describing fate and transport of pesticides in surface water for Danish conditions. - Ministry of Environment, Danish Environmental Protection Agency, Pesticides Research No. 63.

- Styczen, M., Petersen, S., Olsen, N.K. and Andersen, M.B. (2002): Technical documentation of PestSurf, a model describing fate and transport of pesticides in surface water for Danish Conditions. - Ministry of Environment, Danish Environmental Protection Agency, Pesticides Research No. 64.

- Jensen, P.K. and Spliid, N.H. (2002): Deposition of pesticides on the soil surface. - Ministry of Environment, Danish Environmental Protection Agency, Pesticides Research No. 65.

- Asman, W.A.H., Jørgensen, A. and Jensen, P.K. (2002): Dry deposition and spray drift of pesticides to nearby water bodies. - Ministry of Environment, Danish Environmental Protection Agency, Pesticides Research No. 66.

- Holm, J., Petersen, C., and Koch, C. (2002): Facilitated transport of pesticides. - Ministry of Environment, Danish Environmental Protection Agency, Pesticides Research No. 67.

- Helweg, C., Mogensen, B.B., Sørensen, P.B., Madsen, T., Rasmussen, D. and Petersen, S. (2002): Fate of pesticides in surface waters, Laboratory and Field Experiments. Ministry of Environment, Danish Environmental Protection Agency, Pesticides Research No. 68.

- Møhlenberg, F., Petersen, S., Gustavson, K., Lauridsen, T. and Friberg, N. (2001): Guidelines for evaluating mesocosm experiments in connection with the approval procedure. - Ministry of Environment and Energy, Danish Environmental Protection Agency, Pesticides Research No. 56.

- Iversen, H.L., Kronvang, B., Vejrup, K., Mogensen, B.B., Hansen, A.M. and Hansen, L.B. (2002): Pesticides in streams and subsurface drainage water within two arable catchments in Denmark: Pesticide application, concentration, transport and fate. - Ministry of Environment, Danish Environmental Protection Agency, Pesticides Research No. 69.

The original thoughts behind the project are described in detail in the report "Model Based Tool for Evaluation of Exposure and Effects of Pesticides in Surface Water", Inception Report – J. nr. M 7041-0120, by DHI, VKI, NERI, DIAS and County of Funen, December, 1998.

The project was overseen by a steering committee. The members have made valuable contributions to the project. The committee consisted of:

- Inge Vibeke Hansen, Danish Environmental Protection Agency, chairman 1998-mid 2000.
- Jørn Kirkegaard, Danish Environmental Protection Agency (chairman mid-2000-2002).
- Christian Deibjerg Hansen, Danish Environmental Protection Agency
- Heidi Christiansen Barlebo, The Geological Survey of Denmark and Greenland.
- Mogens Erlandsen, University of Aarhus
- Karl Henrik Vestergaard, Syngenta Crop Protection A/S.
- Valery Forbes, Roskilde University
- Lars Stenvang Hansen, Danish Agricultural Advisory Centre (1998-2001).
- Poul-Henning Petersen, Danish Agricultural Advisory Centre (2002).
- Bitten Bolet, County of Ringkøbing (1988-1999)
- Stig Eggert Pedersen, County of Funen (1999-2002)

- Hanne Bach, The National Environmental Research Institute (1999-2002).

October 2002

Merete Styczen, project co-ordinator

Sammenfatning og konklusioner

Et beslutningsstøtteværktøj som skal anvendes ved miljøstyrelsens vurdering af risikoen for transport af pesticider til vandløb og søer er under udvikling. Udviklingen af dette værktøj koordineres af DHI –Institut for Vand og Miljø i projektet "Udvikling af direkte anvendelig og valideret model for pesticiders transport og skæbne i overfladevand". Nærværende rapport beskriver resultaterne fra delprojektet "Undersøgelser af plantedækkets betydning for afsætning af bekæmpelsesmidler på jord ved behandling af relevante afgrøder på relevante tidspunkter".

Delprojektet har omfattet 3 aktiviteter.
Registrering af plantedækkets udvikling igennem vækstsæsonen i 8 afgrøder.
Afsætning af sprøjtevæske på jorden ved behandling på forskellige vækststadier igennem vækstsæsonen i afgrøderne vinterhvede, vårbyg, sukkerroer og kartofler.
Undersøgelser af betydningen af sprøjteteknik og formulering af sprøjtevæske på afsætning af sprøjtevæske på jord under vinterhvede og vårbyg.

Af ressourcemæssige årsager blev målingerne af afsat sprøjtevæske på jord under afgrøden begrænset til 4 afgrøder. Aktiviteten med registrering af plantedækket i de 8 afgrøder blev gennemført for at fremskaffe data for plantedække på forskellige vækststadier i yderligere en række afgrøder for på denne måde at stille data til rådighed for miljøstyrelsen som vil kunne anvendes til at skønne over mængden af pesticid der afsættes på jorden på forskellige behandlingstidspunkter. Resultaterne fra denne aktivitet er præsenteret sammen med resultaterne fra et review der sammenfatter tilsvarende plantedækkeregistreringer fra en lang række forsøg udført i Nordvesteuropa.

Hovedaktiviteten i delprojektet omfattede målinger af afsætning af sprøjtevæske på jorden ved behandling på forskellige vækststadier i afgrøderne vinterhvede, vårbyg, sukkerroer og kartofler. Denne undersøgelse blev gennemført i 3 vækstsæsoner. I den første vækstsæson blev der anvendt en sprøjtevæske uden tilsætning af overfladeaktive stoffer. Dermed opnås en sprøjtevæske med en høj overfladespænding som vanskeligt afsættes på blade/planter. Resultaterne fra disse forsøg må derfor betragtes som en worst case situation i forhold til mængden af afsat sprøjtevæske på jorden under afgrøderne. De 2 efterfølgende år blev der anvendt en sprøjtevæske tilsat spredemidddel og dermed en sprøjtevæske som må anses for at være mere repræsentativ i forhold til de egenskaber sprøjtevæsken opnår når der anvendes formulerede pesticider. Resultaterne, der viser hvilken andel af sprøjtevæsken der lander på jorden på forskellige vækststadier, er præsenteret i rapporten. Resultaterne er sammenlignet med litteraturværdier som er skønnet ud fra plantedækket i et stort nordvesteuropæisk forsøgsmateriale (Becker ***et al***, 1999). Resultaterne fra Becker ***et al*** (1999) danner sammen med resultater fra Ganzelmeier (1997) og van der Zande (ikke publiceret) baggrund for de værdier for afsætning af sprøjtevæske på jord der benævnes FOCUS værdierne. På baggrund af de 2 års forsøg med formuleret sprøjtevæske er der udregnet gennemsnitsværdier for afsætning af sprøjtevæske på jorden under de 4 afgrøder ved forskellige vækststadier. Disse værdier er anvendt i den

beslutningsstøttemodel som er udviklet i det projektet. I rapporten er værdierne for jordafsætning sammenlignet med FOCUS værdierne for afsætning. Den væsentligste afvigelse mellem de værdier der er fundet i nærværende projekt og FOCUS værdierne findes i de 2 kornafgrøder, og her specielt i vinterhvede. I nærværende projekt er der fundet en betydeligt mindre andel sprøjtevæske på jorden ved behandling i strækningsstadierne (31-39 BBCH) end det FOCUS værdierne angiver. Forklaringen skal primært findes i at FOCUS værdierne i kornafgrøder anvender en fælles værdi for busknings- og strækningsstadierne.

Den sidste aktivitet i delprojektet omfattede forsøg, der skulle belyse hvilken betydning sprøjteteknik (dråbestørrelse) og sprøjtevæskens formulering havde for afsætning af sprøjtevæske på jorden. Der blev gennemført forsøg i 2 år i vinterhvede og vårbyg. Forsøgene viste at begge faktorer havde en signifikant effekt på andelen af sprøjtevæske der blev afsat på jorden under de 2 kornafgrøder.

Summary and conclusions

A decision tool used by the Danish Environmental Protection Agency to evaluate the risk of transport of pesticides to water bodies such as streams and lakes is being developed. The development of this tool is co-ordinated by DHI, Water & Environment in the project "Model based tool for evaluation of exposure and effects of pesticides in surface water". This report describes the results from the subproject "Investigations of the importance of the plant cover for the deposition of pesticides on the soil".

The subproject has included 3 activities:

Measurements of the plant cover during the growth season in 8 crops.
Deposition of spray liquid on the soil surface after treatment at different growth stages during the growth season in winter wheat, spring barley, sugar beet and potatoes
Investigations on the influence of spray quality and pesticide formulation on the deposition of spray liquid on the soil below winter wheat and spring barley.

Due to limited resources measurements of deposition of spray liquid on the soil was limited to four crops. In order to obtain data on a further number of crops measurements of plant cover was carried out in 8 crops during the growth season in order to deliver data to the Danish Environmental Protection Agency that can be used to evaluate the amount of pesticide that will be deposited on the soil at different growth stages. The results from this activity is presented together with results from a review which summarises corresponding plant cover assessments from a large number of experiments under Northwest European conditions.

The primary activity in the subproject consisted of measurements of deposition of spray liquid on the soil surface after treatment at different growth stages in winter wheat, spring barley, sugar beet and potatoes. This part was carried out during 3 years. In the first year a spray liquid without any surface-active ingredients was used. Such a spray liquid has a high surface tension and the deposition of spray is reduced on difficult to wet targets. The results from this year therefore must be considered as a worst-case situation concerning deposition of spray liquid on the ground below the crops. The spray liquid used in the two following years included a surfactant and the properties of the spray liquid are expected to be more corresponding to spray liquids with formulated pesticides. The result, which shows which percentage of the spray liquid that is deposited on the ground, is presented in the report. The results are compared to literature values estimated from plant cover measurements in a large Northwest European dataset from pesticide trials. (Becker ***et al***, 1999). The values from Becker ***et al*** (1999) are together with values from Ganzelmeier (1997) and from van der Zande (not published) the basis for the values on deposition of spray on the ground mentioned the FOCUS values.

On the basis of the experimental deposition values obtained in this subproject with the formulated spray liquid mean values for deposition of spray liquid on

the ground under the four investigated crops at different growth stages are given. These values are used in the decision support model developed in the overall project. In the report the experimental values are compared to the FOCUS deposition values. The main deviations between the experimental values found in this project and the FOCUS values are the values in the two cereal crops, but especially in winter wheat. The percentage of spray liquid on the ground found during stem elongation (31-39 BBCH) in this work is significantly below the FOCUS values. The explanation for this is that FOCUS uses only one value covering both the stem elongation and the earlier tillering growth stages.

The last activity in the subproject consisted of experiments with the purpose to investigate the influence of spray quality and pesticide formulation on the deposition of spray liquid on the ground. Two experiments in winter wheat and two in spring barley were carried out during two years. The general conclusion on these experiments was that both factors had highly a significant influence on the percentage of spray liquid that was deposited on the soil below the two cereal crops.

Introduction

The conventional technique used to apply pesticides to agricultural crops is by diluting the pesticide in water. The spray solution can then be distributed evenly on the target crop by boom sprayers equipped with an atomiser system. The commonly used atomiser system is hydraulic nozzles where the spray liquid is atomised into droplets forming a spray with a pattern, which enables the even distribution of the spray on the intended target. The boom and nozzles are typically at a height of 0.4-0.5 meters above the crop/soil. When the spray cloud passes the crop a proportion of the droplets are deposited on the crop. However some of the droplets are not deposited during the journey through the crop. Others might be reflected from the leaves or deleted through run-off from the leaves. Therefore, even in dense crops a proportion of the spray liquid will be deposited on the soil below the crop.

A number of factors affect the deposition of pesticide on the crop and hence the partition between plant/crop deposit and soil deposit. The surface structure of the crop interacts with spray application factors and properties of the spray in retention. Large droplets with a high surface tension are not retained on the waxy leaves found on many important crop plants to the same extent as on plants with little or no wax layer (Bengtsson, 1961; Welker, 1979).

Retention may be affected by other spray application factors such as electric charging of the droplets (Göhlich ***et al***, 1985; Hislop ***et al***, 1983) and air-assistance to hydraulic boom sprayers (Cooke ***et al***, 1990; Hislop ***et al***, 1993). Retention may also be affected by leaf morphological features such as shape (Tu ***et al***, 1986), leaf orientation (Davies ***et al***, 1967; de Ruiter & Uffing, 1988) and leaf age (Anderson ***et al***, 1987).

A part of the spray can be lost during the application before the droplets are deposited on plants or soil. Droplets can be transported out of the sprayed field by spray drift. This loss however is under normal climatic conditions negligible. Another loss comes from evaporation during the travel from nozzle to target. This part is not quantified but theoretical considerations suggest that it can be of significant importance under some climatic conditions with high temperature and low humidity (Reichard ***et al***., 1992; Kaul ***et al***., 1996). The proportion of the spray, which is not deposited on plants parts during the travel through the crop, will be deposited on the soil surface. From the short introduction above it can be understood that ground deposit is a function of the collection efficiency of the canopy. Some investigations have measured soil deposition of pesticides on the soil surface. The typical aim has however been to investigate the influence of different changes in application variables, canopy density or pesticide formulation on the qualitative and quantitative deposit in crop and on the ground. The investigations therefore typically include only one or a few crop growth stages.

The aim of this study was to describe the deposition of pesticides on the ground in four crops covering all relevant applications from very early growth stages and until near maturity. The four crops involved were winter wheat, spring barley, potatoes and sugar beet. The influence of droplet size and

pesticide formulation on deposition in winter wheat and spring barley was tested in a separate investigation covering only one growth stage.

Figure 1a. Overview of deposit experiment in a cereal crop.
Figur 1a. Oversigtsbillede fra afsætningsforsøg i en kornafgrøde.

Materials and methods

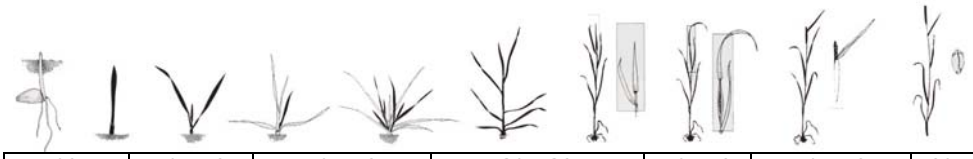
Field experiments were carried out in three growing seasons from 1998 to 2001 on Research Centre Flakkebjerg near Slagelse. The soil type is classified as a sandy loam in all fields used for the experimental work.
In the growth season 1998-1999, eight different crops were followed during the growing season with measurements of growth stage, crop height, and a measurement of percent of soil surface covered by the crop. The crops were grown according to normal practice. Table 2 shows details on cultivation.

Table 2. Cultivation details of crops used to assess crop cover, and other characteristics at various growth stages in the 1998-1999 season.
Tabel 2. Dyrkningsoplysninger for afgrøder der blev anvendt til at bedømme udvikling af plantedække, vækststadier mm i 1998-1999 sæsonen.

Crop	Cultivar	Row distance (cm)	Sowing date	Sowing rate (kg ha^{-1}) (plant spacing)
Fodder peas	-	12	7/4	250
Spring oilseed rape	-	12	7/4	4
Silage maize	10/25	75	6/5	15 cm
Spring barley with undersown perennial ryegrass	Alexis Borvi	12	8/4	120 6
Perennial ryegrass sown in pure stand	Borvi	12	August	6
Perennial ryegrass undersown in spring barley	Borvi	12	8/4	6
Meadow grass 1. year undersown in winter wheat	Balin	12	Autumn 1997	7
Meadow grass 2. year undersown in winter wheat	Balin	12	Autumn 1996	

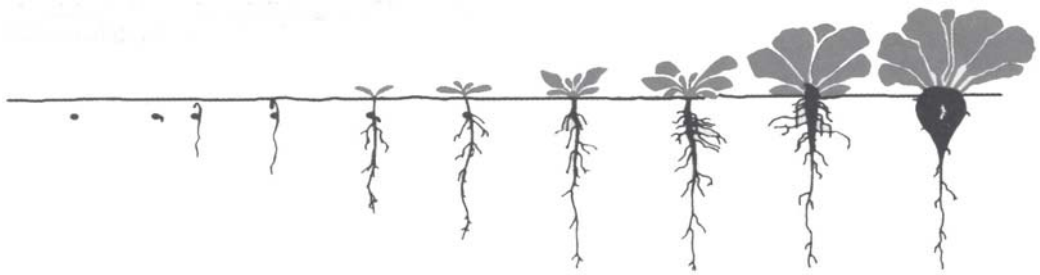
The growth stages are given according to the BBCH scale (Meier, 1997). Figure 2 show the principal growth stages for the four crops included in the depostion studies. Danish translations are available for the general growth scale (Skovbo ***et al***., 1995) and for some crops (Bromand ***et al***., 1995; Schulz ***et al***., 1995; Skovbo ***et al***., 1995; Fertin ***et al***., 2002).

Cereals



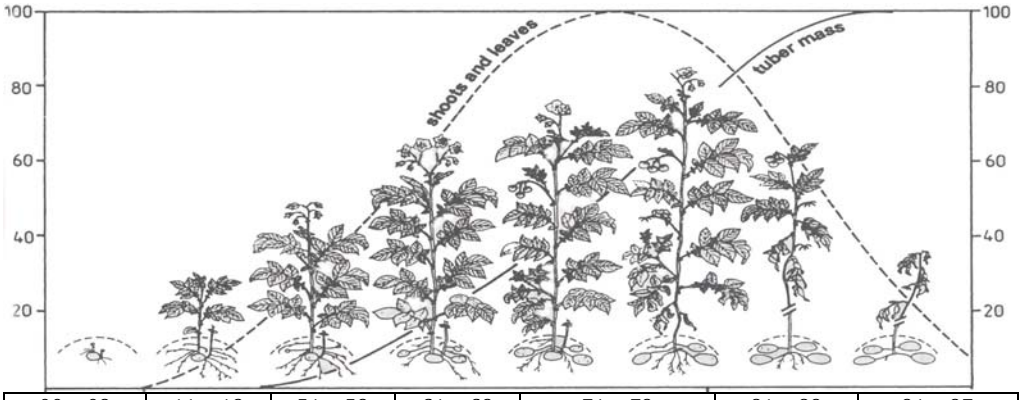
09 Germina-tion	10 – 19 Leaf develop-ment	20 – 29 Tillering	30 – 39 Stem Elongation	40 - 49 Booting	50 – 59 Inflorescence emergence	80 - 89 Ripe-ning

Beet



00 – 09 Germination	10 – 19 Leaf development	30 – 39 Rosette growth	49 Harvestable size

Potato



00 – 09 Sprout-ing	11 – 19 Leaf develop-ment	51 – 59 Inflore-scence emergence	61 – 69 Flowering	71 – 79 Development of fruit	81 – 89 Ripening of fruit and seed	91 – 97 Senescence
		Tuber formation 40	43	45	47 48	49

Rape

10 Germina-tion	11 – 19 Leaf develop-ment	30 – 39 Stem elongation	50 – 59 Inflorescence Emergence	60 – 69 Flowering	70 – 79 Develop-ment of fruit	80 - 89 Ripening

Figure 2. BBCH growth scale for cereals, beet, potatoes and oilseed rape.
Figur 2. BBCH vækstskalaen for korn, roer, kartoffel og raps.

The vertical projection of ground cover by the crop was measured analysing digital phtographies of plots covering 50-33 cm. The photographies was analysed with the GIPS image-processing program (Gade data/Image house A/S, Copenhagen). Additionally a non-destructive measurement of plant canopy reflectance in the red and the near-infrared spectrum was taken. The reflectance measurements were converted to vegetation indices that measure the photosynthetic size of plant canopies. A close correlation between plant biomass and vegetation index has been demonstrated (Jensen & Christensen, 1993). All measurements were taken on 4 replicates.

The aim of this part of the project was to give estimates of plant cover at various growth stages for crops not included in the deposition studies. This part of the project was stopped after the first year due to the fact that a literature review on the same topic was published by Becker ***et al*** (1999). Data from this review fulfils the same purpose as intended by our study and the data is presented in the report.

The second part of the project includes simultaneous measurements of soil deposits of spray and measurements of crop characteristics. Crop measurements included crop height, crop cover measured by photography, and crop growth stage based on the BBCH scale. Additional measurements included the vegetation index measurements in the first growing season. In the last growing season, canopy density was measured non-destructively by using a portable device (LAI-2000, LI_COR, Inc Lincoln, USA), measuring the diffuse light transmission through the canopy followed by a calculation of an approximate LAI (m^2 m^{-2}). LAI-2000 should only be used in diffuse light, and measurements were therefore carried out at dawn or dusk or under cloudy conditions. This part of the project was carried out during three growth seasons in winter wheat, spring barley, sugar beet and potatoes. The four crops were grown according to normal agricultural practice and

Table 3. Cultivation details of crops used in the experiments with measurement of deposit of spray liquid on the soil surface.
Tabel 3. Dyrkningsoplysninger for de afgrøder der blev anvendt i forsøgene hvor afsætning af sprøjtevæske på jorden blev undersøgt.

Year	Crop	Cultivar	Row distance (cm)	Sow-ing date	Sowing rate (kg ha^{-1}) (plant spacing)	Fertilizer (kg ha^{-1} NPK)
1998-1999	Winter wheat	Ritmo	12	17/9	170	160-22-76
1999-2000	Winter wheat	Ritmo	12	15/9	170	160-22-76
2000-2001	Winter wheat	Ritmo	12	5/9	165	160-22-76
1999	Spring barley	Barke	12	12/4	165	80-11-38
2000	Spring barley	Barke	12	10/4	165	80-11-38
2001	Spring barley	Barke	12	9/4	165	80-11-38
1999	Sugar beet	Manhattan	50	20/4	17 cm	80-11-38
2000	Sugar beet	Manhattan	50	11/4	17 cm	80-11-38
2001	Sugar beet	Manhattan	50	10/4	17 cm	80-11-38
1999	Potatoes	Dianella	75	12/5	33 cm	180-44-134
2000	Potatoes	Bintje	75	12/5	33 cm	130-32-97
2001	Potatoes	Bintje	75	9/5	33 cm	130-32-97

recommendations. This included a general weed control in all plots at an early growth stage. This means that the crop was kept weed free during the growing season and that weed plants did not contribute significantly to the plant cover

measured at any application date. For details on cultivar, sowing date etc, see Table 3.

The spray application followed by a conventional technique, which is used for, most applications in agricultural crops in Denmark. A self-propelled plot sprayer equipped with hydraulic flat fan nozzles with drop size characteristics normally recommended for the purpose was used. For details see Table 4. The sprayer used a driving speed of 6 km h^{-1} and the plots treated were 2.5 x 3 m.

Table 4. Details on application techniques used in the deposition experiments.
Tabel 4. Oplysninger om sprøjteteknik anvendt i forsøgene hvor afsætning af sprøjtevæske på jorden blev undersøgt.

Year	Nozzle	Output (litres min^{-1})	Driving speed (km h^{-1})	Application (litres ha^{-1})	Spray quality (BCPC)
1999	Hardi 4110-14	0.82	5	200	Fine
2000	Hardi ISO F02	0.75	6	150	Fine
2001	Hardi ISO LD015	0.55	6	110	Fine/medium

The spray solution used was water with addition of the tracer in the 1998-1999 season. In the two following seasons, 1999-2000 and 2000-2001 a non-ionic surfactant was added at a concentration of 0.1% to the spray solution of water and tracer. The tracer used was brillantsulfoflavin at a dose of 100 g ha^{-1}. The product was delivered by Chroma-Gesellschaft with catalog number C.I. nr. 56205 1F 561. The surfactant used was a non-ionic linear alcohol polyethoxylate (Lissapol Bio, Zeneca, Denmark). The tracer was used at a dose of 100 g ha^{-1}. Just prior to spray application, paper objects were placed in the plots in order to collect the spray. In winter wheat and spring barley the following technique was used throughout the season and the same technique was used in sugar beets and in potatoes after the time when these crop had reached a crop cover exceeding 50% of the soil surface. Four rectangular paper objects with a size of 1.8 x 12 cm were placed just above the crop and 3 x 4 objects at the same size was placed at the soil surface. The paper objects were placed on metal rods in order to obtain a horizontally oriented object, and in order to avoid contamination with soil on the objects placed at soil level.

Figure 3. Placement of objects to catch spray at the soil surface and above the crop in winter wheat.
figur 3. Placering af de objekter der blev anvendt til at opfange sprøjtevæske på jordoverfladen samt over afgrøden i vinterhvede.

The objects placed above the crop was pooled to one sample and the objects placed at soil level was pooled into 3 samples each consisting of 4 pieces of paper. In the cereal crops, winter wheat and spring barley, a paper object could reach across from the middle of one row to the middle of the next row giving a very representative sample. In sugar beets and in potatoes, the paper objects at the soil surface were placed in such a way that each distance from the middle of the crop row and to the middle of the row between to rows were equally well represented in the samples. In sugar beets with a row distance of 50 cm, 4 papers with a length of 12 cm could be placed as a string from the middle of one row to the middle of the neighbour row. In potatoes with a row distance of 75 cm, the four paper objects were placed between to rows but with a distance of approximately 6-cm between each object. The treatments included each time 4 replicates. The deposit of spray on the soil surface was calculated from the measurements of tracer on the objects per area unit. The deposit is shown as a percentage of the applied per area unit and as a percentage of the spray measured per area unit just above the crop.
In sugar beets and potatoes, at early growth stages until approximately 50% crop cover was reached, another technique was used in the1999-2000 and 2000-2001 seasons. This was done as a consequence of the situation in these crops that consist of very few crop plants per m^2, with a typical recommended plant density in sugar beets of 8-10 plants m^{-2} and 4 plants m^{-2} in potatoes.

Figure 4. Placement of objects to catch spray at the soil surface and above the crop in potatoes when the plant cover exceeded approximately 50%.
Figur 4. Placering af de objekter der blev anvendt til at opfange sprøjtevæske på jordoverfladen samt over afgrøden i kartofler når plantedækket oversteg 50%.

The limited plant density makes it difficult to place paper objects in a representative way at the early growth stages. Instead 6 plants in each plot were randomly selected and paper objects were placed on the soil surface below these plants. The object size used was 21.6, 100 or 200 cm^2, depending on the size of the crop plant. When less than 50% of the paper was visible below the plant, the larger object size was used. Photography was taken of

each individual plant in order to calculate the proportion of the paper which was covered by the crop and which part was visible from a vertical view. Photography was also taken in order to estimate the proportion of the soil with plant cover in the total plot. The filter papers from these six single plants were collected individually in order to calculate the collection efficiency of the individual plants. The deposit on these papers was related to the proportion of the paper covered by the crop. The deposit on the part of the plots with a crop cover was calculated from the mean value collected by the six measured plants. The deposit on the part of the plots not covered with crop was assumed to be equal to 100% of the applied spray.

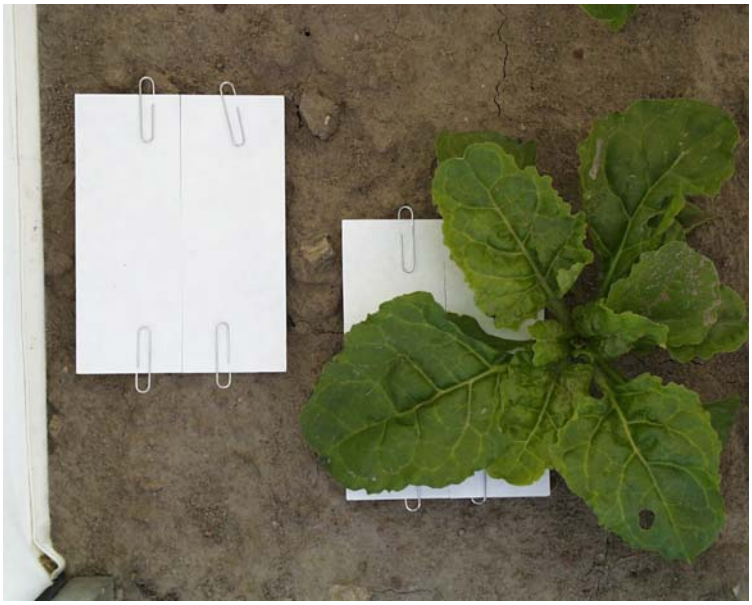


Figure 5. Placement of objects to catch spray at the soil surface and above the crop in sugar beets (picture) and potatoes until the plant cover exceeded approximately 50%.
Figur 5. Placering af de objekter der blev anvendt til at opfange sprøjtevæske på jordoverfladen samt over afgrøden i sukkerroer indtil plantedækket oversteg 50%.

The deposit of spray liquid on the soil surface in the plots was then calculated the following way in a plot with 10% plant coverage and where the deposit of spray below the plant cover was 50%:

90% with no cover and 100% deposit + 10% with plant cover and 50% collection of the spray = 0.9*100 + 0.1*50 = 95% of the spray deposited on the soil surface.

After spraying the filter papers were collected and stored in 100 ml amber glass bottles under dark conditions at 5^0C until the samples were analysed. Samples of the spray liquid were taken and stored the same way. Brillantsulfoflavin is a stable product at 5^0C and storage for several months did not cause loss of activity. The tracer was solved in 50 ml demineralized water and the bottles were shaken thoroughly and a small proportion of the liquid was used for the analysis. The fluorescence analysis was done using a Hewlett Packard HP 1100 system consisting of an auto sampling unit and a fluorescence detector. A sample of 2 µl was injected in a stream of milliQ-water, that with a flow of 0.2 ml min^{-1} leads the sample into the fluorescence detector. The sample was excited at a wavelength of 414 nm and after excitation emission was measured at 505 nm. The content of the sample was

quantified using a number of standard concentrations ranging from 10 to 2000 μg l^{-1}. When the concentration in the samples was below 10 μg l^{-1} further standard concentrations down to 2 μg l^{-1} were included. This was the lower limit for linearity. From the concentration of brillantsulfoflavin in the sample the actual amount of brillantsulfoflavin on the paper objects were calculated. Measurements also included tank samples taken just after the application.

In 2000 and 2001 four experiments two in winter wheat and two in spring barley were used to study the influence of pesticide formulation and application technique on the deposit of spray liquid on the soil surface below the two cereal crops. Four different formulations of a spray liquid were applied to winter wheat at growth stage 38 (BBCH) and to spring barley at growth stage 32-33 (BBCH) using either a fine atomising flat fan nozzle or a coarse atomising air induction nozzle. The formulations used were

- Water
- Water and a non-ionic surfactant. The surfactant used was a non-ionic linear alcohol polyethoxylate (Lissapol Bio, Zeneca, Denmark
- Water and oil additive. The oil additive used was a mineral oil that also includes surfactants (Actirob, Aventis, Denmark)
- Water and recommended dose of the fungicide axozystrobin (Amistar containing 250 g a.i. axozystrobin, Syngenta Crop Protection A/S, Denmark).

The tracer brillantsulfoflavin was added to all formulations at a dose of 100 g ha^{-1} and was used to quantify soil deposits. Paper objects with a size, number and distribution as described above were used to catch the spray liquid above the crop and at soil level. The study included 4 replicates. Details on crop cover at application, characteristics of nozzles used etc are shown in Tables 5 and 6.

Table 5. Details on crop cover in the studies with soil deposit using different formulations and nozzle types.
Tabel 5. Dyrkningsoplysninger for de afgrøder der blev anvendt i forsøgene hvor afsætning af sprøjtevæske på jorden blev undersøgt ved anvendelse af forskellige formuleringer af sprøjtevæske og dysetyper.

Year	Crop	Growth stage (BBCH)	Crop height (cm)	Crop cover (%)
2000	Winter wheat	38	60	100
2001	Winter wheat	51	80	92
2000	Spring barley	32	23	76
2001	Spring barley	34	35	85

Table 6. Details on application technique in the studies with soil deposit using different formulations and nozzle types.
Tabel 6. Oplysninger om sprøjteteknik anvendt i forsøgene hvor afsætning af sprøjtevæske på jorden blev undersøgt ved anvendelse af forskellige formuleringer af sprøjtevæske og dysetyper.

Nozzle	Output (litres min^{-1})	Driving speed (km h^{-1})	Application (litres ha^{-1})	Spray quality (BCPC)
Hardi ISO F02	0.75	6	150	Fine
Hardi Injet 015	0.75	6	150	Very coarse

Results

1.1 Crop cover in 8 crops in the 1998-1999 growing season

The first part of the project included measurements of crop characteristics in some agricultural crops that were not included in the activity with measurements of deposit of spray liquid on the soil below the crop. Results of these measurements are shown in the following tables (7-14). The crops included were grown according to normal practice. The crops included were fodder peas, spring oilseed rape, silage maize and spring barley with undersown grass for subsequent seed production and finally two grasses grown for seed production.

Table 7. Crop cover and other crop characteristics at various growth stages in fodder peas.
Tabel 7. Afgrødedække og andre afgrødekarakteristika på forskellige vækststadier i foderært.

Date	Crop Height (cm)	Growth stage (BBCH)	Canopy reflectance (RVI)	% Crop cover Sd in parenthesis
6/5-1999	1.5	10	1.5	3 (1)
18/5	7	35	1.9	14 (2)
29/5	17	37	3.0	41 (19)
4/6	30	39	8.5	68 (13)
17/6	70	60	13.9	91 (20)

Table 8. Crop cover and other crop characteristics at various growth stages in spring oilseed rape.
Tabel 8. Afgrødedække og andre afgrødekarakteristika på forskellige vækststadier i vårraps.

Date	Crop Height (cm)	Growth stage (BBCH)	Canopy reflectance (RVI)	% Crop cover Sd in parenthesis
6/5-1999	-	-	-	-
18/5	5	12-13	2.2	16 (6)
29/5	14	15	7.0	86 (6)
4/6	25	51	13.0	92 (19)
17/6	90	61	18.2	100 (-)

Table 9. Crop cover and other crop characteristics at various growth stages in silage maize.
Tabel 9. Afgrødedække og andre afgrødekarakteristika på forskellige vækststadier i fodermajs.

Date	Crop Height (cm)	Growth stage (BBCH)	Canopy reflectance (RVI)	% Crop cover Sd in parenthesis
6/5-1999	-	-	-	-
18/5	-	-	-	-
29/5	7	12-13	1.4	2 (-)
4/6	11	14	1.7	3 (-)
17/6	25	14	1.8	8 (2)
23/6	40	18	2.0	17 (4)
19/7	70	36	-	78 (5)

When a cereal crop is undersown with grasses for subsequent seed production the degree of soil covered by the crop increases as the undersown grass increases the total soil cover. The spring barley with undersowing in table 10 was not compared with spring barley without undersowing so the difference cannot be quantified. The increased soil cover in cereal crops is dependent on the type of grass undersown and the way the grass is undersown. Soil cover from ryegrass will generally be larger than from meadow grass. When the grass seed is established in the same row as the cover crop a minor influence on soil cover will be seen as when the grass is established in the centre between the rows of the cover crop as it is possible with some sowing equipment.

Table 10. Crop cover and other crop characteristics at various growth stages in spring barley undersown with perennial ryegrass.
Tabel 10. Afgrødedække og andre afgrødekarakteristika på forskellige vækststadier i vårbyg med udlæg af almindelig rajgræs.

Date	Crop Height (cm)	Growth stage (BBCH)	Canopy reflectance (RVI)	% Crop cover Sd in parenthesis
6/5	7	13	1.8	12 (4)
18/5	13	22	3.8	39 (7)
29/5	14	30	12.5	78 (5)
4/6	25	32	16.0	89 (2)
17/6	65	50	17.5	88 (3)
23/6	80	59	20.7	100 (-)

The two grasses were perennial ryegrass (Lolium perenne L.) and meadow grass (Poa pratensis L.). Perennial ryegrass was established either undersown in spring barley or established in a pure stand in the autumn. Meadow grass was established as an undersowing in winter wheat. Measurements in both grasses started in the autumn when the cover crop was harvested. Perennial ryegrass established undersown in spring barley has a higher coverage in the autumn after harvest of the cover crop than perennial ryegrass established in a pure stand in august. The following spring, the year of seed harvest, there was still a higher crop cover in the perennial ryegrass undersown in spring barley than in the autumn sown crop.

Table 11. Crop cover and other crop characteristics at various growth stages in perennial ryegrass sown in pure stand in the autumn.
Tabel 11. Afgrødedække og andre afgrødekarakteristika på forskellige vækststadier i almindelig rajgræs udlagt i renbestand i efteråret.

Date	Crop Height (cm)	Growth stage (BBCH)	Canopy reflectance (RVI)	% Crop cover Sd in parenthesis
25/9-1998	3	11	1.5	3 (-)
2/10	4	11-12	1.6	4 (1)
9/10	5	12-13	1.5	1 (-)
22/10	6	12-13	1.6	1 (-)
30/10	7	12-13	1.6	8 (5)
21/4-1999	6	24	2.1	20 (13)
27/4	6	29	2.5	-
6/5	14	30	9.2	71 (2)
19/5	22	32	18.3	95 (1)

Table 12. Crop cover and other crop characteristics at various growth stages in perennial ryegrass undersown in spring barley.
Tabel 12. Afgrødedække og andre afgrødekarakteristika på forskellige vækststadier i almindelig rajgræs udlagt i vårbyg.

Date	Crop Height (cm)	Growth stage (BBCH)	Canopy reflectance (RVI)	% Crop cover Sd in parenthesis
25/9-1998	5	22	4.1	51 (3)
2/10	13	23	5.8	50 (3)
9/10	9	25	4.6	20 (3)
22/10	11	25	4.6	42 (1)
30/10	11	25	5.7	53 (4)
30/3-1999	10	25	3.6	21 (1)
21/4	13	27	13.3	71 (1)
27/4	16	30	21	71 (-)
6/5	17	30	26	100 (-)
19/5	26	33	29.9	99 (-)

The two meadow grass crops followed was undersown in winter wheat. There are other recommended ways to establish meadow grass for seed production. Concerning the crop followed in our investigation, it was a rather open crop after harvest of the winter wheat (table 13) but reaching a high ground cover in the following spring. The meadow grass crop that was used for a second harvest was also established from an undersowing in winter wheat. After the first years seed harvest, the straw was removed, and a close cutting was performed. The data for crop cover in the autumn reflects only the “green part” of the crop. The soil cover in the autumn was close to 100% but a large proportion of this cover comes from dead leaves and straw. Burning is often used in meadow grass as an autumn treatment when the crop is used for a second harvest. This leaves the field with no soil cover for a period but the grass typically recovers within a short period and the crop cover in the late autumn will typically be as high as in unburned fields.

Table 13. Crop cover and other crop characteristics at various growth stages in meadow grass in the 1. harvest year. The crop was undersown in winter wheat in the autumn 1997.
Tabel 13. Afgrødedække og andre afgrødekarakteristika på forskellige vækststadier i engrapgræs til 1. års høst. Afgrøden var udlagt i vinterhvede i efteråret 1997.

Date	Crop Height (cm)	Growth stage (BBCH)	Canopy reflectance (RVI)	% Crop cover Sd in parenthesis
2/10-1998	13	13-14	5.9	24 (2)
9/10	7	25	3.0	45 (4)
22/10	9	25	4.0	49 (6)
30/10	10	25	5.9	57 (8)
30/3-1999	8	25	7.2	72 (2)
21/4	18	27	21.5	-
27/4	18	30	26.9	98 (-)
6/5	31	22	22.8	87 (4)
19/5	51	50	29.9	96 (1)

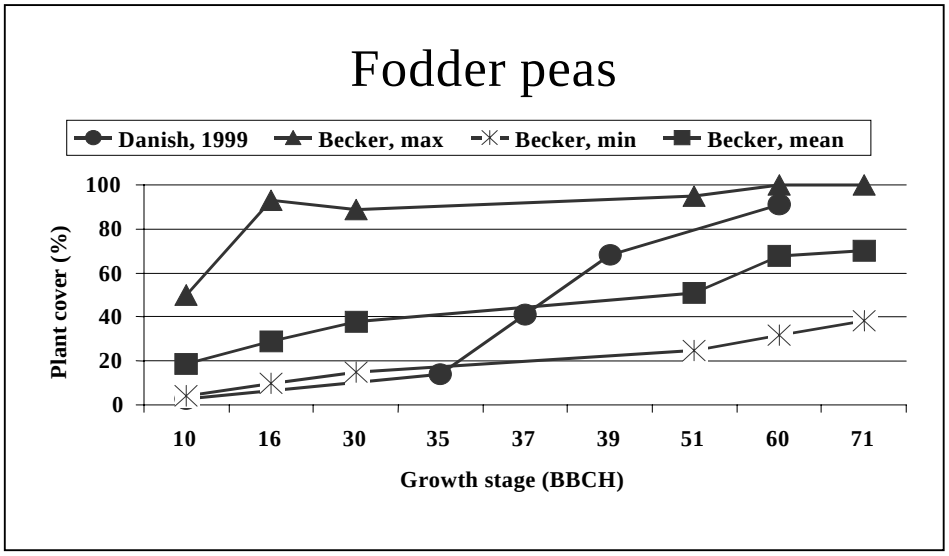
This part of the project was only included one year because a literature review on the same topic was published by Becker et al (1999) during the first year. The data in the paper comes from more than 2000 individual trials carried out under practical conditions by BASF between 1993 and 1996. in Germany, Belgium, the Netherlands, Denmark, Sweden and Great Britain. This review is very comprehensive and includes results on crop cover assessments at various growth stages in the most important agricultural crops. Besides the cereal crops it includes values on beets, potatoes, silage maize, fodder peas and oilseed rape.

Table 14. Crop cover and other crop characteristics at various growth stages in meadow grass in the 2. harvest year. The crop was undersown in winter wheat in the autumn 1996.
Tabel 14. Afgrødedække og andre afgrødekarakteristika på forskellige vækststadier i engrapgræs til 2. års høst. Afgrøden var udlagt i vinterhvede i efteråret 1996.

Date	Crop Height (cm)	Growth stage (BBCH)	Canopy reflectance (RVI)	% Crop cover Sd in parenthesis
2/10-1998	17	13-14	5.9	24 (-)
9/10	13	25	4.1	45 (9)
22/10	13	25	3.0	41 (3)
30/10	13	25	4.3	47 (6)
30/3-1999	9	25	-	67 (5)
21/4	26	29	27.2	100 (-)
27/4	26	29	31.0	84 (-)
6/5	32	36	29.5	75 (5)
19/5	56	58	25.8	100 (-)

The review also includes estimated crop interception of spray in the same crops. The estimated interception by the crop is obtained assuming that the interception is correlated to the degree of crop cover. In the paper it is suggested that the interception factor should be derived from the area somewhere above the mean value. The range between the mean and the mean + the standard deviation is given in the paper as representative estimates of interception values assuming a correlation between plant cover and intercepted spray. Assuming that the proportion of the spray, which is not intercepted, is lost on the soil values on soil deposition can be calculated from the interception values. These values are shown in the following figures as Becker min and Becker max.

Figures 6-8 show the plant cover measured in our project in 1999 in fodder peas, spring oilseed rape and silage maize compared to the values collected by Becker. The figures also include the calculated soil deposition values based on Becker's figures.



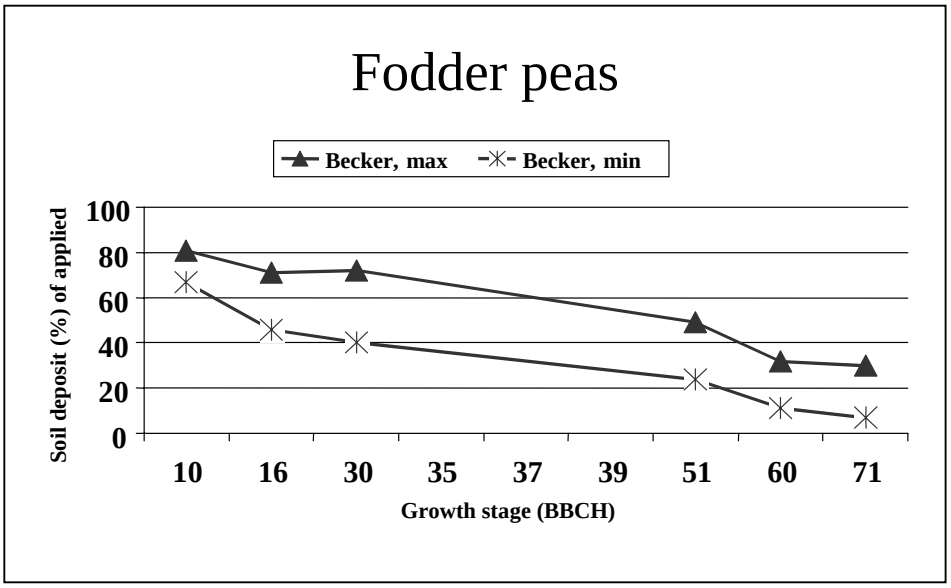
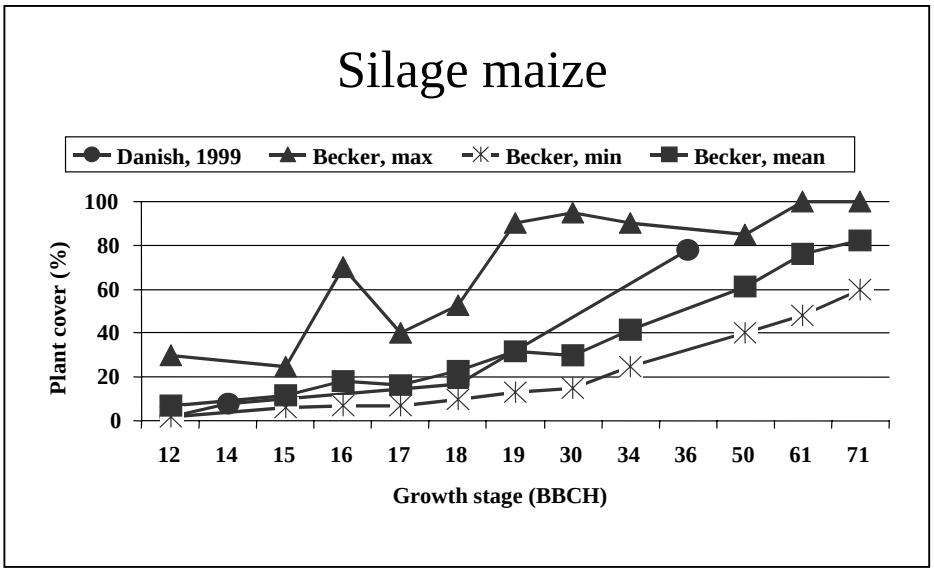


Figure 6. Plant cover and estimated soil deposition of spray at different growth stages in fodder peas. Danish measurements in 1999 and from Becker et al. (1999).
Figur 6. Afgrødedække og estimeret afsætning af sprøjtevæske på jord på forskellige vækststadier i foderært. Danske målinger fra 1999 samt fra Becker *et al*. (1999).



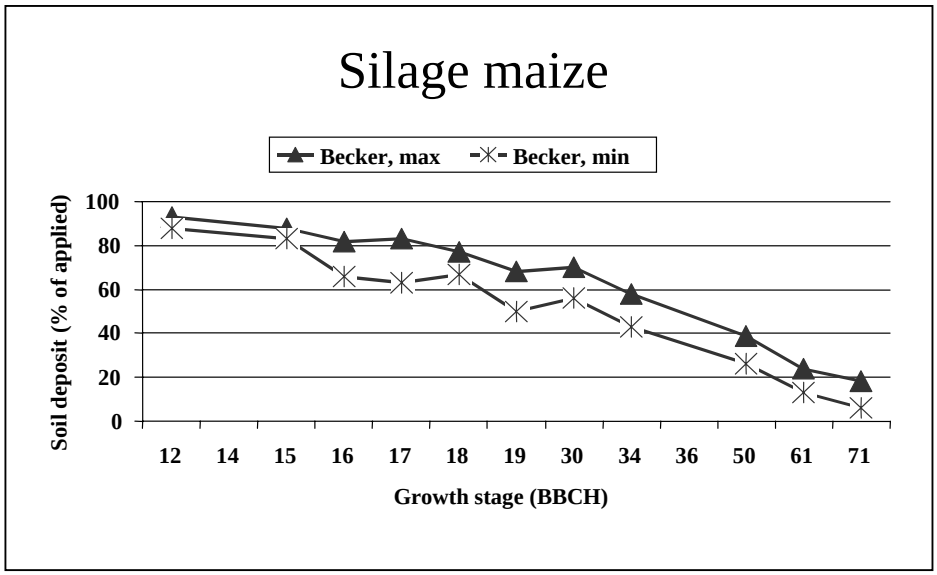
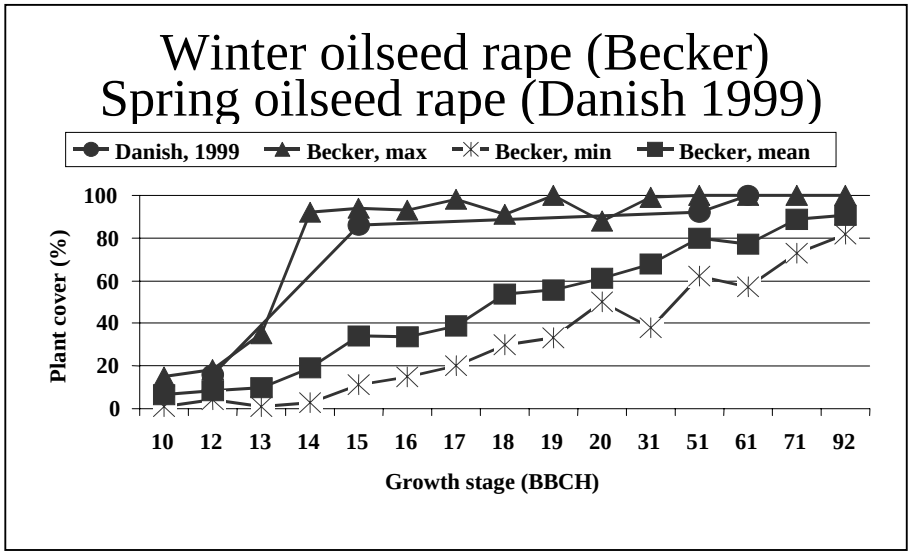


Figure 7. Plant cover and estimated soil deposition of spray at different growth stages in silage maize. Danish measurements in 1999 and from Becker et al. (1999).
Figur 7. Afgrødedække og estimeret afsætning af sprøjtevæske på jord på forskellige vækststadier i fodermajs. Danske målinger fra 1999 samt fra Becker *et al.* (1999).



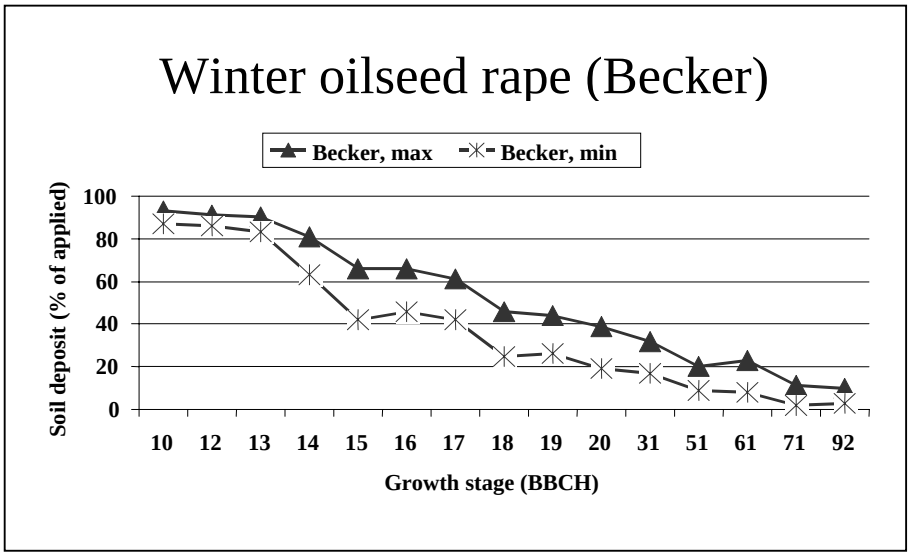


Figure 8. Plant cover and estimated soil deposition of spray at different growth stages in oilseed rape. Danish measurements in spring oilseed rape 1999 and in winter oilseed rape from Becker et al. (1999).
Figur 8. Afgrødedække og estimeret afsætning af sprøjtevæske på jord på forskellige vækststadier i raps. Danske målinger i vårraps i 1999 og i vinterraps fra Becker *et al.* (1999).

1.2 Deposition of spray liquid on the soil below four crops

In this part of the project parallel measurements of crop characteristics and measurements of deposit of spray on the soil surface below four crops was performed through the growing season in three years. The four crops involved were winter wheat, spring barley, sugar beet and potatoes. The crops were grown according to normal good agricultural practice including plant protection.

In the first year, the spray liquid used consisted of tap water and the tracer but without any further additions. This solution was chosen in order to avoid problems in the subsequent analysis of the samples, which eventually could

arise from added surfactants. A spray liquid of water without any further additions has a very high surface tension and the deposition of the droplets on difficult to wet targets will be reduced compared to sprays including adjuvants. From this it follows that the soil deposit of spray on the ground below the crops is higher than can be expected for most formulated pesticides. The results from the 1998-1999 season therefore can be regarded as a worst-case situation concerning pesticide formulation.

1.2.1 Winter wheat, spring barley, sugar beet and potato 1998/1999

The results from the 1998-1999 growing season is summarised in Tables 15-18. The deposit of spray on the ground shown in the tables is calculated as a percentage of the applied dose.

Objects were also placed just above the crop canopy but these objects were primarily used to test whether the actual applied dose was within the expected value. Due to different factors the values found on these objects cannot be expected to be equal to 100% of the applied dose per area unit. When the falling droplets are approaching a horizontal target as these samplers are, a proportion of the spray droplets will follow the air current around the horizontal object. Spray drift is a second factor reducing the theoretic dose to values below 100% although the extent is probably limited in these experiments where a shielded sprayer is used. Another loss comes from evaporation during the travel from nozzle to target. This part is not quantified but theoretical considerations suggest that it can be of significant importance under some climatic conditions with high temperature and low humidity (Reichard ***et al***, 1992; Kaul ***et al***, 1996). The deposit value on horizontal samplers at the top of the canopy is from these reasons expected to be below 100% of the applied pr area unit. The values found at the canopy top varied in a Dutch study from 80-90% of the applied dose (Van de Zande, pers comm).

Table 15. Soil deposit in winter wheat in the 1998-1999 growing season at various growth stages.
Tabel 15. Afsat sprøjtevæske på jorden i vinterhvede i 1998-1999 sæsonen på forskellige vækststadier.

Date	Crop Height (cm)	Growth stage (BBCH)	Canopy reflectance (RVI)	% Crop cover Sd in ()	Soil deposit (% of applied) Sd in ()
9/10- 1998	5	11-12	1.8	4 (1)	-
20/10	6	12-13	2.4	6 (3)	-
11/11	9	14-15	1.9	-	-
8/4 –1999	7	23	3.1	37 (4)	34 (4)
20/4	9	24	3.6	36 (8)	46 (3)
27/4	19	30	6.8	39 (2)	48 (5)
4/5	26	31	10.4	70 (10)	30 (3)
21/5	56	34	19.8	100 (-)	14 (3)
28/5	60	41	20.5	100 (-)	14 (0.4)
2/6	63	46	21.0	100 (-)	10 (2)
15/6	85	60	18.7	100 (-)	7 (2)
17/8	90	90	9.2	72 (18)	19 (3)

The values for soil deposit of spray liquid at the early growth stages in the two cereal crops (Tables 15 and 16) when the crop cover is limited is below what is expected if one assumes that soil deposit values should correspond to 100 -

% crop cover. The results should probably be explained by the way the droplets move when they are approaching the soil level. The droplets are not only falling vertically but also moves in the horizontal direction by turbulence created by the driving speed and the natural wind. Droplets that also has a horizontal movement can be caught by the erect leaves of the crop which acts as a filter before the droplets reach the soil surface.

Table 16. Soil deposit in spring barley in the 1999 growing season at various growth stages.
Tabel 16. Afsat sprøjtevæske på jorden i vårbyg i 1999 sæsonen på forskellige vækststadier.

Date	Crop Height (cm)	Growth stage (BBCH)	Canopy reflectance (RVI)	% Crop cover Sd in ()	Soil deposit (% of applied) Sd in ()
4/5	7	11	1.6	6 (9)	67 (4)
17/5	10	12-13	2.4	26 (6)	55 (3)
21/5	12	21	3.6	54 (9)	49 (1)
27/5	20	25	5.7	66 (8)	46 (4)
2/6	25	31	10.9	80 (25)	45 (4)
15/6	45	62	15.7	100 (-)	25 (3)
17/8	55	90	10.8	79 (7)	25 (6)

However at later growth stages when the ground cover of the crop exceeds 50% the values are better in accordance with expectations as the sum of % crop cover and % soil deposit exceeds 100%. Values above 100 is expected as the deposition of the droplets on the target is influenced by a number of factors that decrease the deposit values on the crop below the crop cover values.

The 1999 results in the two row crops, sugar beet and potatoes (Tables 17 & 18), are influenced by the methodological problems discussed in the M & M section concerning the early observations when the crop cover is limited.

Table 17. Soil deposit in sugar beet in the 1999 growing season at various growth stages.
Tabel 17. Afsat sprøjtevæske på jorden i sukkerroer i1999 sæsonen på forskellige vækststadier.

Date	Crop Height (cm)	Growth stage (BBCH)	Canopy reflectance (RVI)	% Crop cover Sd in ()	Soil deposit (% of applied) Sd in ()
17/5	2	11	1.4	0-1 (-)	63 (5)
21/5	4	12	1.4	1 (0.4)	59 (3)
27/5	4	12	1.4	1 (0.7)	54 (3)
2/6	7	14	1.4	4 (2)	63 (1)
15/6	6	16	2.1	25 (12)	35 (6)
1/7	30	28	7.6	68 (22)	23 (9)
8/7	45	35	-	76 (11)	8 (3)

Before the 1999/2000 and 2000/2001 growing season, the effects of various additives to the spray solution on the subsequent tracer analysis was investigated and none of the tested adjuvants interfered with the tracer analysis. The non-ionic surfactant was therefore added to the spray solution in both seasons. The surfactant reduces the surface tension of the spray, which is then more comparable to a spray consisting of water and a pesticide that

typically includes surface-active ingredients. In the following tables, results from the last two growing seasons are shown for the four crops.

Table 18. Soil deposit in potatoes in the 1999 growing season at various growth stages.
Tabel 18. Afsat sprøjtevæske på jorden i kartofler i 1999 sæsonen på forskellige vækststadier.

Date	Crop Height (cm)	Growth stage (BBCH)	% Crop cover Sd in ()	Soil deposit (% of applied) Sd in ()
25/6	50	50	79 (-)	-
1/7	75	55	96 (6)	4 (5)
8/7	90	60	99 (1)	4 (4)
6/9	100	70	100 (-)	-

1.2.2 Winter wheat 1999/2000 and 2000/2001

The assessments of crop characteristics and soil deposit values for winter wheat is shown in tables 19 and 20 for the two years. Special attention to the crop development in the autumn should be given. The crop development in the autumn 1999 was limited with a maximum crop cover of 15% whereas the winter wheat in the following seasons had a maximum crop cover of 61% in the autumn. Winter cereals are not fertilised in the autumn and large variations in crop development in the autumn can occur due to effects of the preceding crop, organic manure etc. Despite the vigorous growth in winter wheat in the autumn 2000 the crop development in the spring 2001 did not deviate too much from the former years crop. In both years soil deposit values decreased during the growth season and values below 10% of the applied dose was registered in both years for a period in the late spring.

Table 19. Soil deposit in winter wheat in the 1999-2000 growing season at various growth stages.
Tabel 19. Afsat sprøjtevæske på jorden i vinterhvede i 1999-2000 sæsonen på forskellige vækststadier.

Date	Crop Height (cm)	Growth stage (BBCH)	% Crop cover Sd in ()	Soil deposit (% of applied) Sd in ()
1/10-1999	13	11	7 (-)	-
15/10	15	13	15 (4)	60 (9)
4/4-2000	17	28	33 (6)	50 (8)
10/4	23	30	34 (10)	47 (12)
2/5	47	32	93 (3)	22 (4)
11/5	54	33	100 (-)	12 (2)
16/5	60	38	100 (-)	13 (2)
22/5	62	39	100 (-)	7 (1)
31/5	73	55	100 (-)	1 (0.6)
14/6	95	65	100 (-)	2 (0.8)
20/6	98	67	100 (-)	2 (0.5)
28/6	98	71	100 (-)	6 (2)
4/8	98	87	100 (-)	14 (2)

Table 20. Soil deposit in winter wheat in the 2000-2001 growing season at various growth stages.
Tabel 20. Afsat sprøjtevæske på jorden i vinterhvede i 2000-2001 sæsonen på forskellige vækststadier.

Date	Crop Height (cm)	Growth stage (BBCH)	LAI ($m^2 m^{-2}$)	% Crop cover Sd in ()	Soil deposit (% of applied) Sd in ()
20/9-2000	8	12		5 (1)	-
23/10	17	23		61 (3)	52 (12)
17/4-2001	15	31		42 (4)	45 (2)
2/5	19	32		49 (3)	42 (3)
10/5	32	33		60 (4)	21 (5)
15/5	45	33		63 (7)	30 (12)
22/5	55	34	4.16	84 (1)	22 (3)
1/6	65	45	-	89 (3)	10 (2)
6/6	80	51	5.5	92 (3)	8 (2)
14/6	87	57	5.45	91 (3)	6 (2)
20/6	93	61	5.5	97 (4)	5 (1)
26/6	95	67	5.35	94 (1)	7 (1)
3/7	95	69	5.09	100 (-)	8 (2)
2/8	95	87	3.56	91 (2)	16 (4)

Our results from these two seasons are compared to Becker's values in figures 9 & 10. Concerning plant cover in relation to growth stage, values below the Becker mean values were found at early growth stages in both years whereas the plant covers at late growth stages were above the Becker mean values. Comparing our actual measured deposition values with the values based on Becker show the relation in figure 10. The soil deposition values measured in our study exceeded the Becker max values at some of the early growth stages and were close to or below the Becker min values at late growth stages. The deviation between our results and the values calculated from Becker's estimates reflects the corresponding differences in crop cover between the two investigations.

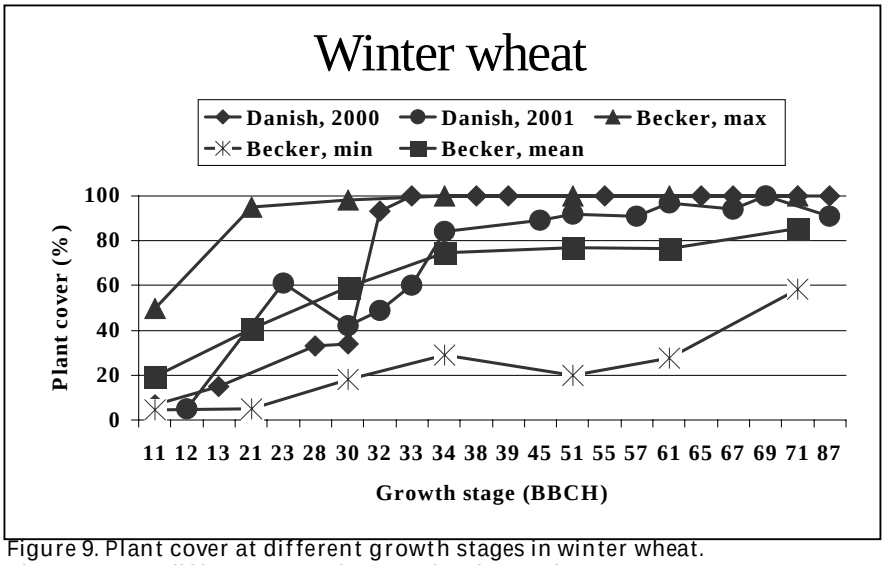


Figure 9. Plant cover at different growth stages in winter wheat.
Plant cover at different growth stages in winter wheat.
Figur 9. Plantedække på forskellige vækststadier i vinterhvede.

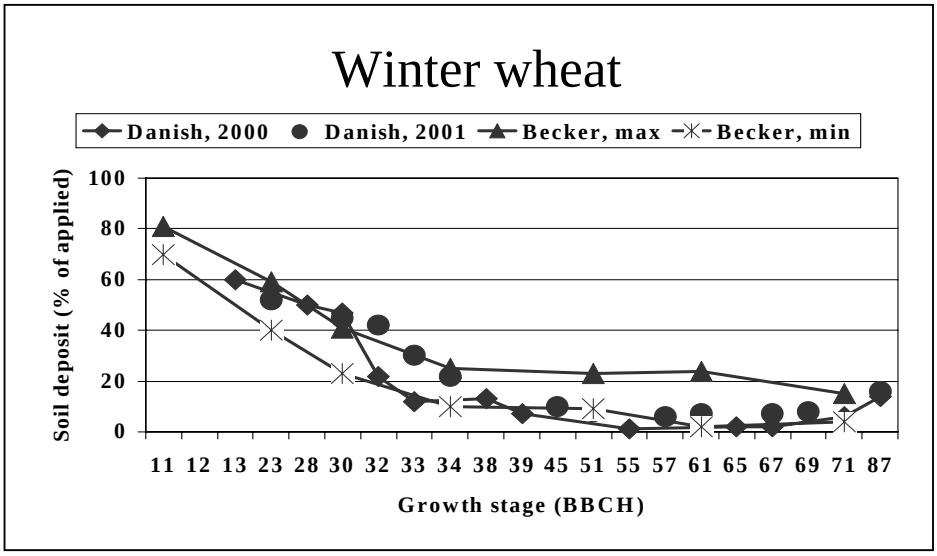


Figure 10. Measured and estimated soil deposition of spray at different growth stages in winter wheat.
Figur 10. Målt og estimeret afsætning af sprøjtevæske på jord på forskellige vækststadier i vinterhvede.

1.2.3 Spring barley 2000 and 2001

The spring barley (tables 21 and 22) did not reach a 100% crop cover at any time during the growth season and the soil deposit values never came below 10% of the applied dose. The cultivar chosen for the study (Barke) is ranked as an average cultivar concerning characteristics such as plant height and plant cover.

Table 21. Soil deposit in spring barley in the 2000 growing season at various growth stages.
Tabel 21. Afsat sprøjtevæske på jorden i vårbyg 2000 sæsonen på forskellige vækststadier.

Date	Crop Height (cm)	Growth stage (BBCH)	% Crop cover Sd in ()	Soil deposit (% of applied) Sd in ()
5/5	11	13	14 (5)	61 (5)
11/5	14	23	40 (2)	37 (3)
18/5	27	32	59 (16)	52 (6)
22/5	24	33	67 (11)	30 (8)
31/5	33	35	76 (8)	34 (13)
10/6	55	50	80 (-)	19 (7)
20/6	62	65	86 (6)	25 (2)
28/6	65	68	61 (13)	18 (3)
4/8	65	87	-	25 (8)

Table 22. Soil deposit in spring barley in the 2001 growing season at various growth stages.
Tabel 22. Afsat sprøjtevæske på jorden i vårbyg 2001 sæsonen på forskellige vækststadier.

Date	Crop Height (cm)	Growth stage (BBCH)	LAI (m^2 m^{-2})	% Crop cover Sd in ()	Soil deposit (% of applied) Sd in ()
10/5	7	11	-	10 (1)	71 (11)
15/5	10	20	-	21 (2)	69 (9)
22/5	15	24	0.37	41 (8)	47 (2)
30/5	25	28	-	71 (5)	42 (6)
13/6	35	34	2.6	85 (2)	18 (6)
20/6	45	49	3.47	89 (3)	15 (4)
26/6	52	59	3.93	92 (4)	12 (3)
3/7	58	59	4.24	93 (2)	14 (5)
2/8	58	89	3.36	81 (4)	17 (5)

It can be seen that the crop development during these two growth seasons was rather parallel. Leaf area index measurements were taken in the last part of the 2001 season but it can be seen from the figures that the soil deposit values are not well related to this parameter.

The comparison to the Becker values is shown in figure 11 and 12. The plant cover results from the two experimental years are close to the mean values given by Becker. Concerning the soil deposition values however, the measured values are closer to the estimated max values given by Becker.

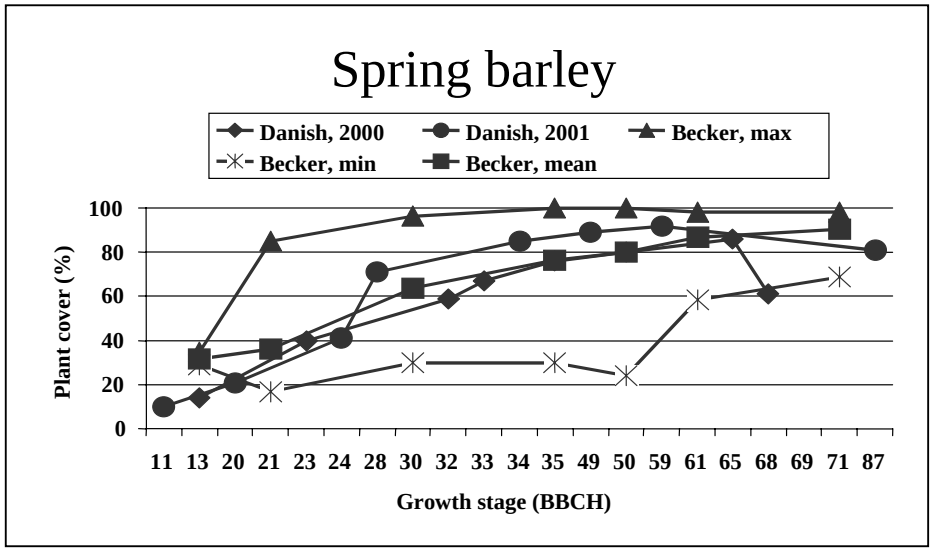


Figure 11. Plant cover at different growth stages in spring barley.
Figur 11. Plantedække på forskellige vækststadier i vårbyg.

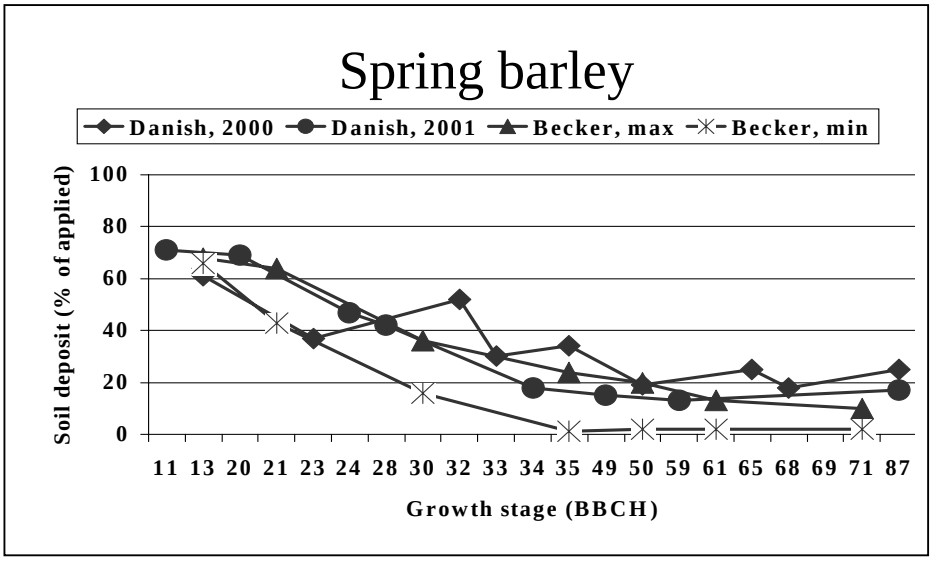


Figure 12. Measured and estimated soil deposition of spray at different growth stages in spring barley.
Figur 12. Målt og estimeret afsætning af sprøjtevæske på jord på forskellige vækststadier i vårbyg.

1.2.4 Sugar beet 2000 and 2001

The results from the two last growth seasons are shown in tables 23 and 24. Two different methods were used to evaluate soil deposit in sugar beet in these experiments for reasons discussed in M&M were the methodology is described. Generally, however the values were obtained by a combination of experimental values and calculation considering the values from the first part of the season.

Table 23. Soil deposit in sugar beet in the 2000 growing season at various growth stages.
Tabel 23. Afsat sprøjtevæske på jorden i sukkerroer 2000 sæsonen på forskellige vækststadier.

Date	Crop Height (cm)	Growth stage (BBCH)	% Crop cover Sd in ()	Soil deposit (% of applied) Sd in ()
5/5	3	11	0.2	99.7 (0)
11/5	5	12	1.1	98.7 (0.3)
18/5	7	13	5.1	93.6 (0.6)
22/5	8	13	10	87.2 (1)
31/5	10	15	16	78.9 (0)
9/6	20	16	45	43.3 (7)
20/6	22	22	67 (15)	26.1[1] (4)
28/6	25	35	82 (12)	36[2] (3)
28/6	25	35	82 (12)	21[1] (10)
27/7	38	39	94 (2)	11[1] (7)
9/8	38	39	100 (-)	5[1] (5)

[1] based on the method with deposit evaluation on the whole plot level
[2] based on the method with single plant evaluation and 100% deposit on the uncovered part

Table 24. Soil deposit in sugar beet in the 2001 growing season at various growth stages.
Tabel 24. Afsat sprøjtevæske på jorden i sukkerroer 2001 sæsonen på forskellige vækststadier.

Date	Crop Height (cm)	Growth stage (BBCH)	% Crop cover Sd in ()	Soil deposit (% of applied) Sd in ()
10/5	2	11	0.1	99.9 (0)
15/5	3	12	0.1	100 (0)
22/5	4	14	0.8	99.2 (0)
30/5	8	16	3.3	96.7 (0)
13/6	12	18	12	88.4 (0)
20/6	15	18	22	77.6 (0)
26/6	18	20	44 (8)	56.6[2] (2)
26/6	18	20	44 (8)	47.7[1] (8)
3/7	20	30	69 (10)	31 (4)
2/8	20	39	89 (2)	13 (4)

[1] based on the method with deposit evaluation on the whole plot level
[2] based on the method with single plant evaluation and 100% deposit on the uncovered part

In the last part of the season at high crop cover values, the same methodology as in the cereals was used. At the time when the method was changed an assessment using both methods is included in the tables. Due to the low number of plants per area unit and a slow development in the early part of the season sugar beet constitutes a very open crop in the early crop stages where the weed control is carried out. High crop coverage and low soil deposit values are seen in the end of the season where control of fungi attack and pests can be relevant. There were large differences between the two years in plant cover at a corresponding growth stage in the early part of the season and this is also reflected in the soil deposition values found.

The comparison to the Becker values is shown in figures 13 and 14.

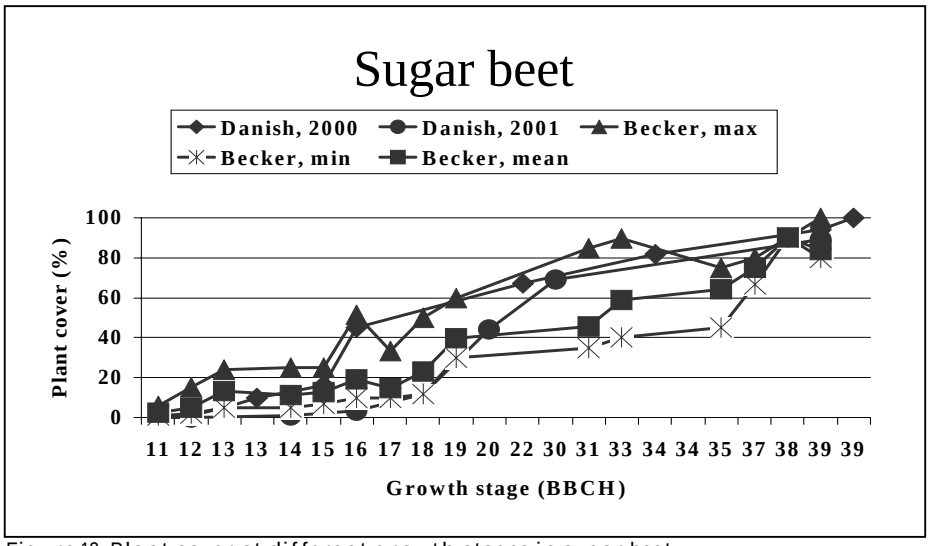


Figure 13. Plant cover at different growth stages in sugar beet.
Figur 13. Plantedække på forskellige vækststadier i sukkerroer.

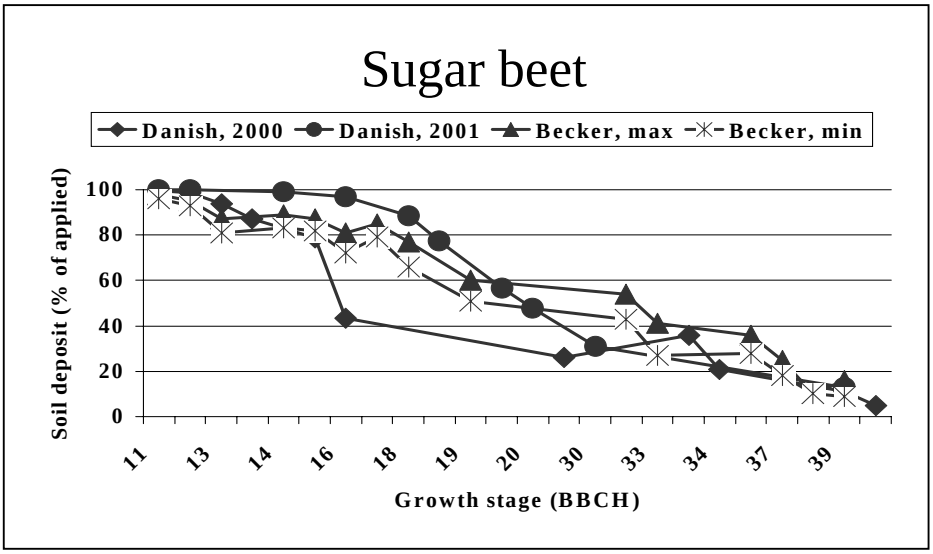


Figure 14. Measured and estimated soil deposition of spray at different growth stages in sugar beet.
Figur 14. Målt og estimeret afsætning af sprøjtevæske på jord på forskellige vækststadier i sukkerroer.

1.2.5 Potatoes 2000 and 2001

The investigations in potatoes in 2000 and 2001 (Tables 25 and 26) were carried out in Bintje, a cultivar used for production of potatoes for human consumption. The canopy development is not as vigorous as in those cultivars that are used for industrial purposes such as Dianella, which was used in the 1999 investigation.

Table 25. Soil deposit in potatoes in the 2000 growing season at various growth stages.
Tabel 25. Afsat sprøjtevæske på jorden i kartofler 2000 sæsonen på forskellige vækststadier.

Date	Crop Height (cm)	Growth stage (BBCH)	% Crop cover Sd in ()	Soil deposit (% of applied) Sd in ()
9/6	10	25	15	85 (0)
20/6	20	32	32	68 (0.3)
28/6	28	35	58 (5)	43[2] (2)
28/6	28	35	58 (5)	35[1] (9)
26/7	55	69	85 (7)	18 (11)
9/8	55	79	88 (-)	4 (3)

[1] based on the method with deposit evaluation on the whole plot level
[2] based on the method with single plant evaluation and 100% deposit on the uncovered part

Table 26. Soil deposit in potatoes in the 2001 growing season at various growth stages.
Tabel 26. Afsat sprøjtevæske på jorden i kartofler 2001 sæsonen på forskellige vækststadier.

Date	Crop Height (cm)	Growth stage (BBCH)	% Crop cover Sd in ()	Soil deposit (% of applied) Sd in ()
13/6	10	18	4	97 (0)
20/6	15	30	19	81 (0)
26/6	21	35	37 (15)	63[2] (1)
26/6	21	35	37 (15)	57[1] (5)
29/6	25	35	51 (25)	52 (10)
3/7	40	40	64 (26)	46 (10)
18/7	45	59	95 (4)	7 (7)
2/8	45	69	100 (4)	10 (12)

[1] based on the method with deposit evaluation on the whole plot level
[2] based on the method with single plant evaluation and 100% deposit on the uncovered part

The investigation in potatoes in 2000 and 2001were carried out as in sugar beets using different methods at early and late growth stages and with one overlapping assessment where both methods were used. At the time of weed control there is a limited plant cover and hence a high soil deposit of spray liquid. Control of fungi attack in the last part of the season is very intensive in potatoes. At the time when the crop canopy had closed in Bintje soil deposit values from 4-18 % of the applied dose was found. Although the spray liquid was used without any surface-active additives in the very dense industrial potato Dianella in 1999 a soil deposit value of only 4% of the applied dose was seen in that cultivar. The measured plant cover values in the two study years was somewhat below the Becker mean values at early growth stages but raised above the Becker values at late growth stages (figure 15 and 16). This was reflected in the soil deposit values where the measured values in our study was above the max values calculated from Becker at early growth stages and fell to levels below the Becker min values at late growth stages.

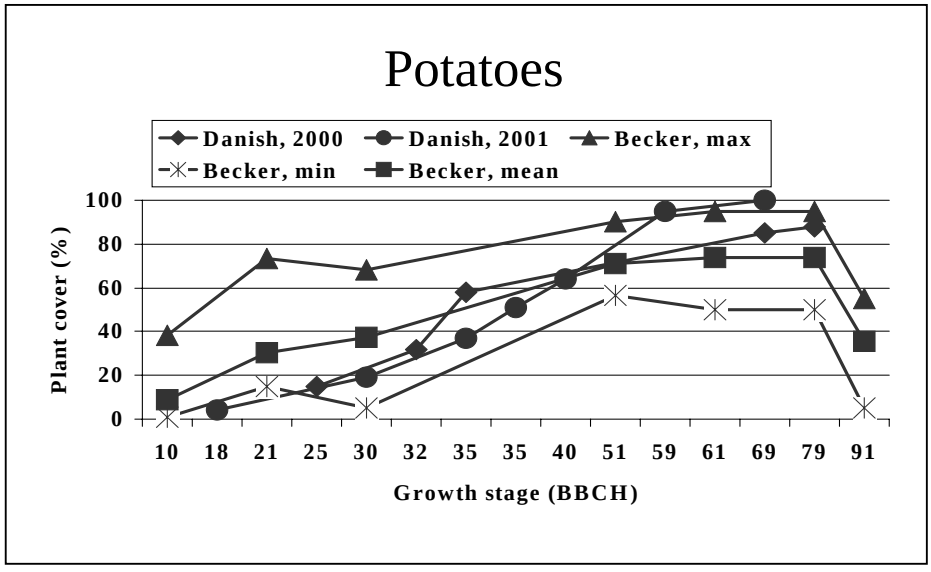


Figure 15. Plant cover at different growth stages in sugar beet
Figur 15. Plantedække på forskellige vækststadier i kartofler.

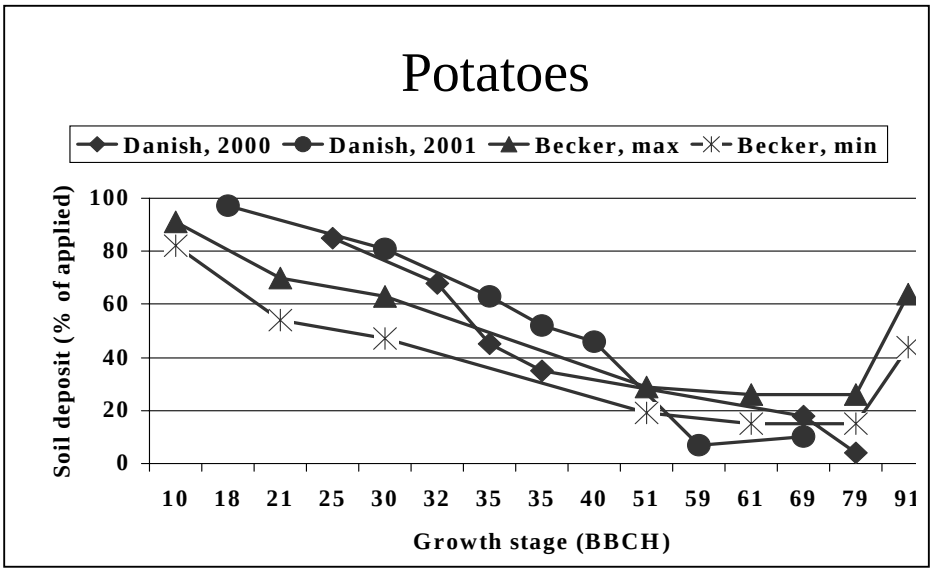


Figure 16. Measured and estimated soil deposition of spray at different growth stages in sugar beet.
Figur 16. Målt og estimeret afsætning af sprøjtevæske på jord på forskellige vækststadier i kartofler.

1.3 Interaction of spray quality and spray formulation on deposition of spray liquid on the soil

This activity was included in the project for two years in 2000 and 2001 in order to investigate how much change in pesticide formulation and application technique can influence the deposition on the soil surface below dense crops. A large number of investigations have shown that formulation and spray quality affects deposition and retention on crop and weeds (Holloway ***et al.***, 2000; Webb ***et al.***, 2000; Taylor & Chambers, 2002). Only a few of those have included soil deposition measurements (Table 17). The investigation included a total of four experiments, two in winter wheat and two in spring barley. The results are shown in figures 17-20.

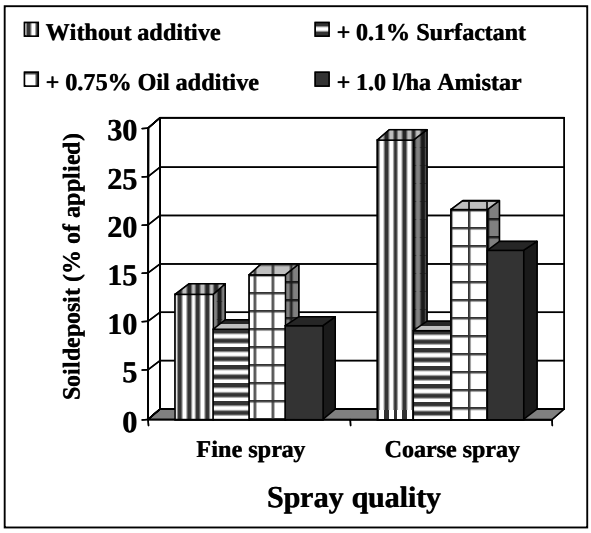


Figure 17. Influence of formulation and spray quality on soil deposition of spray on the ground below winter wheat. Year 2000. $LSD_{0.95}$: spray quality = 5.3, formulation = 7.5, spray quality x formulation = 10.5.
Figur 17. Effekt af formulering og dråbestørrelse på afsætning af sprøjtevæske på jord i vinterhvede. Forsøg i 2000. $LSD_{0,95}$: dråbestørrelse = 5,3, formulering = 7,5, dråbestørrelse X formulering = 10,5.

The four formulations of the spray solution represents the range of many real spray solutions concerning surface tension of the spray liquid. The two application techniques chosen represents the same way realistic spray quality characteristics although the fine spray quality is the normal recommended and used whereas the very coarse spray quality included represents an extreme with a small actual use at the time.

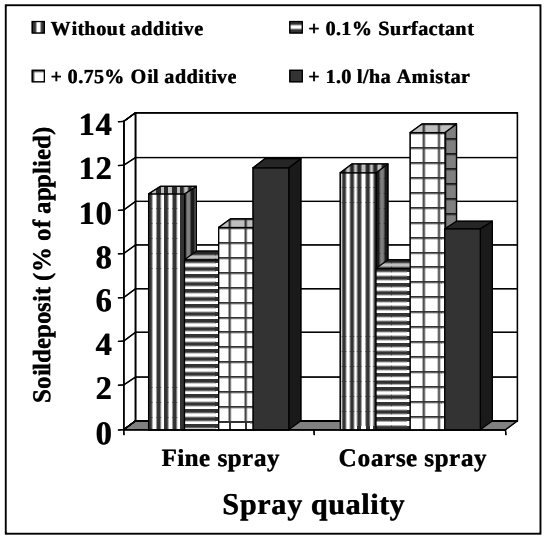


Figure 18. Influence of formulation and spray quality on soil deposition of spray on the ground below winter wheat. Year 2001. $LSD_{0.95}$: spray quality = NS, formulation = 2.4, spray quality x formulation = 3.3.
Figur 18. Effekt af formulering og dråbestørrelse på afsætning af sprøjtevæske på jord i vinterhvede. Forsøg i 2001. $LSD_{0,95}$: dråbestørrelse = NS, formulering = 2,4, dråbestørrelse X formulering = 3,3.

In winter wheat there was a strongly significant influence of both formulation and spray quality on soil deposit values in 2000. Using water without any

additives soil deposit values were more than doubled changing from the fine spray to a coarse spray. Using the coarse spray, addition of surfactant to the spray solution reduced the soil deposit values with a factor three. There was also a significant interaction between formulation and spray quality in this experiment. Such an interaction is described in literature where the influence of spray quality is reduced when the surface tension of the spray liquid is reduced, as it is the case where the surfactant is added and partly where the oil additive and formulated pesticide Amistar is added.

The differences in 2001 in winter wheat were generally much smaller (see y-axis). However there was still a significant influence of formulation and the interaction between spray quality and formulation was also significant.

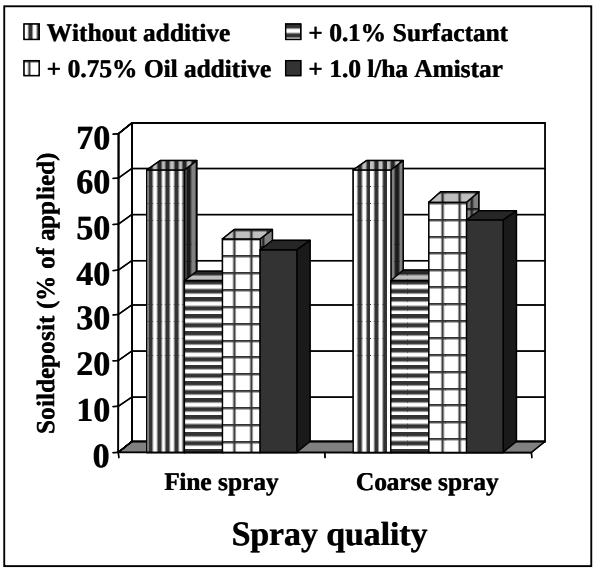


Figure 19. Influence of formulation and spray quality on soil deposition of spray on the ground below spring barley. Year 2000. $LSD_{0.95}$: spray quality = 9.7, formulation = 13.8, spray quality x formulation = NS.
Figur 19. Effekt af formulering og dråbestørrelse på afsætning af sprøjtevæske på jord i vårbyg. Forsøg i 2000. $LSD_{0,95}$: dråbestørrelse = 9,7, formulering = 13,8, dråbestørrelse X formulering = NS.

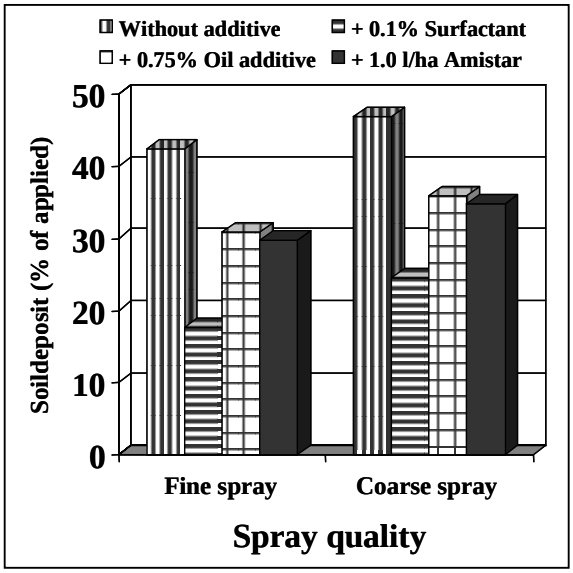


Figure 20. Influence of formulation and spray quality on soil deposition of spray on the ground below spring barley. Year 2001. $LSD_{0.95}$: spray quality = 8.9, formulation = 12.7, spray quality x formulation = NS.
Figur 20. Effekt af formulering og dråbestørrelse på afsætning af sprøjtevæske på jord i vårbyg. Forsøg i 2001. $LSD_{0,95}$: dråbestørrelse = 8,9, formulering = 12,7, dråbestørrelse X formulering = NS.

The spring barley crop used for the application was not as dense as the winter wheat and the values found regarding soil deposits of spray liquid were generally at a much higher level. In the trial in 2000 there was a small but significantly increased soil deposit going from fine to coarse spray. There was a greater and highly significant influence of formulation with water without

Table 27. Three-way (spray quality x formulation x year) ANOVA for soil deposition of spray liquid below winter wheat and spring barley.
Tabel 27. Trevejs (dråbestørrelse x formulering x år) ANOVA test for afsætning af sprøjtevæske på jord i vinterhvede og vårbyg.

	Winter wheat			Spring barley		
Source of variation	d.f.	Mean square	F	d.f.	Mean square	F
Spray quality	1	259.21	46.18***	1	290.13	24.38***
Formulation	3	187.92	33.48***	3	1554.27	130.62***
Year	1	442.00	78.74***	1	4295.89	361.03***
Spray quality x formulation	3	56.86	10.13***	3	14.39	1.21
Spray quality x year	1	197.28	35.14***	1	20.90	1.76
Formulation x year	3	54.45	9.70***	3	2.73	0.23
Spray quality x formulation x year	3	47.45	8.45***	3	21.18	1.78
Error	45	5.61		45	11.90	

***: $P<0.001$

any additions giving the highest values and with the surfactant addition giving the lowest values. No interaction between spray quality and formulation were seen in spring barley in 2000 or in the following experiment in 2001. In 2001 there was a small but significant influence of spray quality and a larger and highly significant influence of formulation again as can be seen in figure 20. The results of a three-way ANOVA test (Table 27) summarises the influence of spray quality, formulation and year on soil depostion of spray liquid in winter wheat and spring barley.

The large influence of year could in both crops to a large extent (seen in an analysis of covariance) be ascribed to a difference in plant cover at the treatment time (see Table 4). From the table it can be seen that spray quality is more important than formulation in winter wheat whereas the opposite is the case in spring barley. Why there is such a difference between these two cereal crops remains a question. In general however these experiments documents that other factors than plant cover/growth stage is of importance when the soil deposition of spray liquid is to be estimated. This is especially of importance at late growth stages/high plant cover where the influence of spray quality and pesticide formulation on plant/leaf deposits indirectly can be very important in changing the absolute values of soil deposition of spray liquid.

Discussion & Conclusions

Measurements of plant cover in relation to growth stage is given for a number of crops and compared to values from a recent review on the same topic. The general impression is that the measurements under Danish conditions show a delayed crop cover at early growth stages compared to the mean review values. At late growth stages on the other hand the plant cover values measured in our study often exceeds the mean values from the review and are close to the maximum review values. Concerning the crop development at different growth stages, however, it seems reasonable to include the information collected by Becker ***et al.*** (1999) in order to have a more robust estimate than can be obtained from the three crops included in this study.
A measurement of soil deposits of spray liquid on the soil surface below the crop was carried out in four crops. The results in the first year were obtained using a spray liquid without any surface-active ingredients. The relation between plant cover and soil deposits found in this year can be regarded as a worst-case situation when considering various pesticide formulations. The influence of formulation is separately documented in the experiments with four formulations and two spray qualities.

The spray liquid included a surface active ingredient in the two following years and the properties of this liquid concerning its ability to be deposited on plant leaves can be regarded as more comparable to spray liquids including formulated pesticides. This was actually seen in the investigation comparing the influence of different formulations and application techniques on soil deposition. Soil deposit values with addition of the surface-active ingredient and the formulated pesticide, Amistar, was closer than soil deposit values using water without any additives.

Relatively few investigations on soil deposition of pesticides below agricultural crops can be found in the literature and the existing investigations typically covers one crop at one ore a few growth stages. Some investigations have measured soil deposition others calculate soil deposition on the basis of crop interception. Table 27 reviews the experimental data and gives the value on soil deposition whether it actually is measured or calculated from crop interception measurements. These data generally give support to the values found in our study. There are nowhere data available to provide a comprehensive overview of deposition values in the major crops in Northern Europe during the growth season. Our measured values can therefore only be compared with these single values at different points and the values calculated from Becker's estimated interception values. The general impression is that deviations between our measured soil deposition values and the values based on Becker's estimates to a large extent can be explained by a corresponding divergence in crop cover between the two investigations. The soil deposition values achieved during the three experimental years demonstrate the level of soil deposit which can be expected below crops grown according to normal good agricultural practice under Danish conditions.

Table 28. Literature references on deposition of spray liquid on the soil in various crops.
Tabel 28. Litteratur referencer vedrørende afsætning af sprøjtevæske på jord ved behandling i forskellige afgrøder og stadier.

Crop	Timing (BBCH)	Soil deposit (%)	Other treatments	Source
Winter wheat	14-15	73		Smith ***et al.***, 1986
Winter wheat	14-15	49		Cessna, 1993
Winter wheat	15	48		Grover ***et al.***, 1985
Winter wheat	32	10		Nau & Mittermeier, 1986
Winter wheat	39	2-9	Spray quality and crop density	Bryant ***et al.***, 1984
Winter wheat	41	9-20	Conventional technique at three volume rates	Robinson & Garnet, 1984
Winter wheat	30-85	Related to LAI	Nitrogen rates	Gyldenkærne ***et al.***, 1999
Winter wheat	47-82	16 – 6		Cilgi & Jepson, 1992
Winter wheat	14-22, 45, 85	100, 4-9, 9-16	Spray quality	Taylor & Andersen, 1987
Winter wheat	10-89	<80 –5		Ganzelmeier, 1997
Spring barley	22-75	Related to LAI		Gyldenkærne ***et al.***, 1999
Spring barley	32-37	10-38	Spray quality and crop density	Bryant ***et al.***, 1984
Spring barley	56	20		Jagers op Akkerhuis ***et al.***, 1998
Potatoes	2-4 weeks after emergence	70		Linders & Jager, 1997
Potatoes	Late ?	24		Van de Zande ***et al.***, 2000
Potatoes	Full growth (51-80?)	10		Linders & Jager, 1997
Sugar beet	2-4 weeks after emergence	70		Linders & Jager, 1997
Peas	09-11 and 60-69	80 and 20		Linders & Jager, 1997

The deposition values obtained with a spray liquid without additives in the first year represents a worst case situation whereas the soil deposition values

achieved during the second and third experimental season can be considered more representative concerning the relation between plant cover and soil deposition of spray below the crop. Soil deposition values to be used in the overall decision tool and by the Danish Environmental Protection Agency are shown in appendix 1. The values are obtained by pooling together data from the last two experimental years where the spray liquid included a surface-active ingredient. The data are pooled in such a way that the growth stage intervals represented aimed at including at least one treatment from each of the 2 years.

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Soil deposition values

Soil deposition values to be used in the overall decision tool and by the Danish Environmental Protection Agency are shown in this appendix. The values are obtained by pooling together data from the last two experimental years where the spray liquid included a surface-active ingredient. In general it was intended to have a deposition situation representative to normal practice. This goal was aimed at using a standard practice concerning sowing time, plant density, fertilization and plant protection in order to obtain a crop with a representative development and crop cover. Traditional application techniques with fine atomizing hydraulic flat fan nozzles and a spray liquid including a surface-active ingredient mimicking formulated pesticides was used. The data are pooled in such a way that the growth stage intervals represented aimed at including at least one treatment from each of the 2 years. This ensures that yearly variations are included in the values given. The disadvantage is that the growth stage intervals are not as logical as the way the BBCH growth stage is. Data were log-transformed before the analysis of variance was performed. The values shown in the following are back-transformed values. The mean soil deposition values calculated are given for each growth stage interval together with the 95% upper- and lower-confidence limits for the expected value of the dependent variable (mean) for each observation. It is recommended to use the winter wheat deposition values as representative values for winter cereal crops, and to use the spring barley values as values representative for spring cereals. For those crops where Danish experimental values do not exist it is recommended to use the FOCUS 2002 values. The FOCUS (2002) values are shown in comparison to the experimental Danish values and in Table 5 and 6. Soil deposition values used for insecticide applications in spruce plantations is based on Danish experience (Rubow pers comm.) and is shown in table 7. The time interval were a growth stage (BBCH) was registered during the two growing seasons 2000-2001 is shown in Table 8.

Winter wheat

Table 1. Deposition of spray liquid on the soil surface below winter wheat based on 2000-2001 experiments. The table includes mean values and 95% upper- and lower-confidence limits for each growth stage interval. FOCUS 2002 values are included for comparison.
Tabel 1. Afsætning af sprøjtevæske på jord under vinterhvede baseret på resultaterne fra 2000-2001. Tabellen indeholder gennemsnit, samt 95% øvre- og nedre konfidensinterval for hvert vækststadieinterval. FOCUS 2002 værdierne er inkluderet til sammenligning.

Growth stage interval (BBCH)	Soil deposition (% of applied)			
	FOCUS	95% lower	Mean	95% upper
11-13	75	41.1	59.6	86.7
23-28	50	38.5	50	65.3
30-32	30	30.6	36.9	44.7
33-34	30	14.5	18.4	22.9
38-45	20*	6.4	8.2	10.2
51-57	10	2.7	3.4	4.2
61-71	10	3.5	4.1	4.7
87	10	11.3	14.7	19.1

* FOCUS changes from 30 (BBCH 38-39) to 10 (BBCH 40-45).

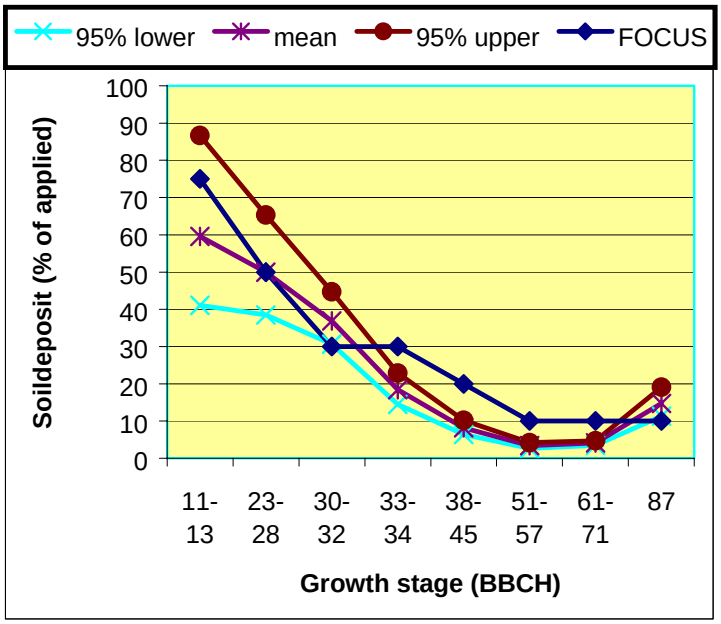

Figure 1. Deposition of spray liquid on the soil surface below winter wheat based on 2000-2001 experiments. The figure includes mean values and 95% upper- and lower-confidence limits for each growth stage interval. FOCUS 2002 values are included for comparison. FOCUS changes from 30 (BBCH 38-39) to 10 (BBCH 40-45).
figur 1. Afsætning af sprøjtevæske på jord under vinterhvede baseret på resultaterne fra 2000-2001. Tabellen indeholder gennemsnit, samt 95% øvre- og nedre konfidensinterval for hvert vækststadieinterval. FOCUS 2002 værdierne er inkluderet til sammenligning. FOCUS skifter fra 30 (BBCH 38-39) til 10 (BBCH 40-45).

Remarks: The most pronounced deviation between the Danish values and FOCUS 2002 values is seen at growth stages from 38-71 (BBCH) where the Danish deposition values are below the FOCUS values. FOCUS uses the same values for winter and spring cereals.

Spring barley

Table 2. Deposition of spray liquid on the soil surface below spring barley based on 2000-2001 experiments. The table includes mean values and 95% upper- and lower-confidence limits for each growth stage interval. FOCUS 2002 values are included for comparison.
Tabel 2. Afsætning af sprøjtevæske på jord under vårbyg baseret på resultaterne fra 2000-2001. Tabellen indeholder gennemsnit, samt 95% øvre- og nedre konfidensinterval for hvert vækststadieinterval. FOCUS 2002 værdierne er inkluderet til sammenligning.

Growth stage interval (BBCH)	Soil deposition (% of applied)			
	FOCUS	95% lower	Mean	95% upper
11-13	75	53.7	65.1	79.8
20-24	50	41.7	49	57.5
28-32	40*	34.2	38.9	44.7
33-35	30	19.7	23.8	28.8
49-50	10	13.0	15.8	19.5
59-68	10	14.1	17.3	21.3
87-89	10	16.6	20.4	24.9

* FOCUS changes from 50 (BBCH 20-29) to 30 (BBCH 30-39).

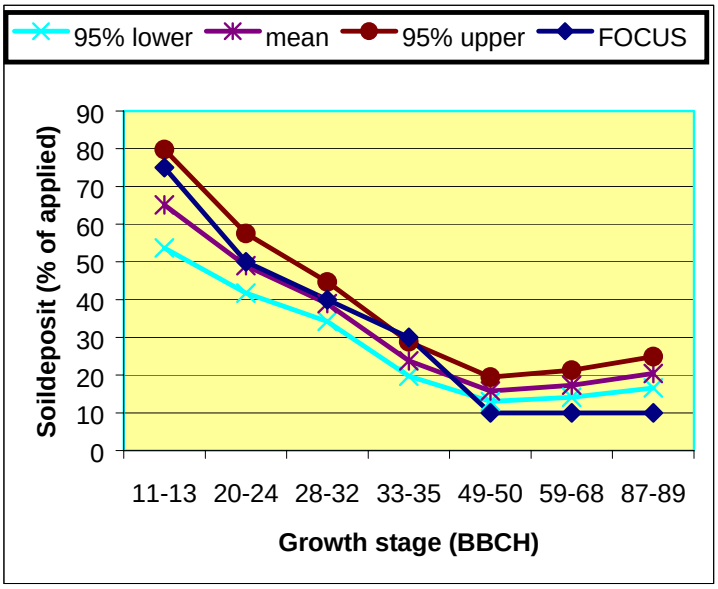

Figure 2. Deposition of spray liquid on the soil surface below spring barley based on 2000-2001 experiments. The figure includes mean values and 95% upper- and lower-confidence limits for each growth stage interval. FOCUS 2002 values are included for comparison. FOCUS changes from 50 (BBCH 20-29) to 30 (BBCH 30-39).
Figur 2. Afsætning af sprøjtevæske på jord under vårbyg baseret på resultaterne fra 2000-2001. Tabellen indeholder gennemsnit, samt 95% øvre- og nedre konfidensinterval for hvert vækststadieinterval. FOCUS 2002 værdierne er inkluderet til sammenligning. FOCUS skifter fra 50 (BBCH 20-29) til 30 (BBCH 30-39).

Remarks: The Danish values and the FOCUS values are in good accordance. The Danish deposition values are above the FOCUS values at growth stages above 49 (BBCH). FOCUS uses the same values for winter and spring cereals.

Table 3. Deposition of spray liquid on the soil surface below sugar beet based on 2000-2001 experiments. The table includes mean values and 95% upper- and lower-confidence limits for each growth stage interval. FOCUS 2002 values are included for comparison.
Tabel 3. Afsætning af sprøjtevæske på jord under sukkerroer baseret på resultaterne fra 2000-2001. Tabellen indeholder gennemsnit, samt 95% øvre- og nedre konfidensinterval for hvert vækststadieinterval. FOCUS 2002 værdierne er inkluderet til sammenligning.

Growth stage interval (BBCH)	Soil deposition (% of applied)			
	FOCUS	95% lower	Mean	95% upper
11	80	84.3	99.8	100
12	80	84.1	99.3	100
13-14	80	81.3	93.1	100
15-18	80	69.2	76.4	84.1
20-22	30	36.6	42.7	49.9
30-35	30	24.7	28.9	33.7
39	30	6.4	7.6	8.9

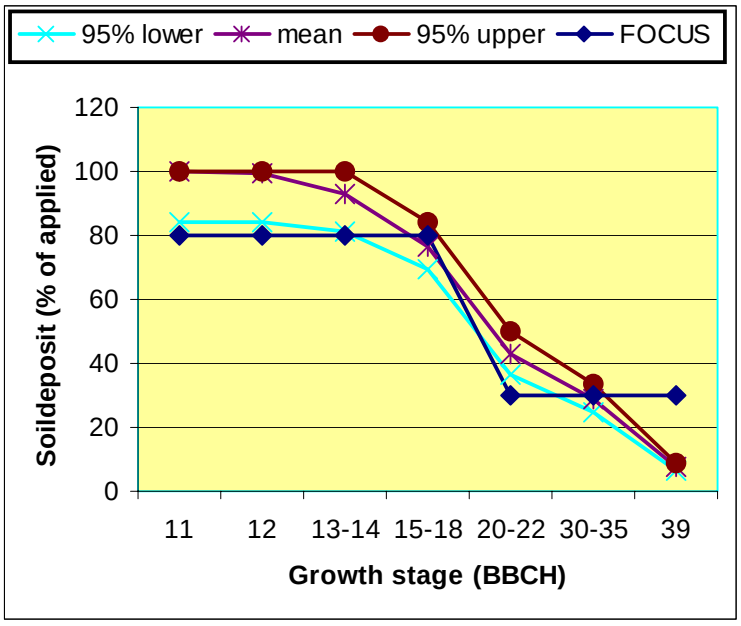

Figure 3. Deposition of spray liquid on the soil surface below sugar beet based on 2000-2001 experiments. The figure includes mean values and 95% upper- and lower-confidence limits for each growth stage interval. FOCUS 2002 values are included for comparison.
Figur 3. Afsætning af sprøjtevæske på jord under sukkerroer baseret på resultaterne fra 2000-2001. Tabellen indeholder gennemsnit, samt 95% øvre- og nedre konfidensinterval for hvert vækststadieinterval. FOCUS 2002 værdierne er inkluderet til sammenligning.

Remarks: Good accordance between Danish values and FOCUS values at early growth stages. Lower Danish values at the late growth stage (39 BBCH).

Potatoes

Table 4. Deposition of spray liquid on the soil surface below potatoes based on 2000-2001 experiments. The table includes mean values and 95% upper- and lower-confidence limits for each growth stage interval. FOCUS 2002 values are included for comparison.
Tabel 4. Afsætning af sprøjtevæske på jord under kartofler baseret på resultaterne fra 2000-2001. Tabellen indeholder gennemsnit, samt 95% øvre- og nedre konfidensinterval for hvert vækststadieinterval. FOCUS 2002 værdierne er inkluderet til sammenligning.

Growth stage interval (BBCH)	Soil deposition (% of applied)			
	FOCUS	95% lower	Mean	95% upper
10-19	85	-	100	-
18-25	70*	67.6	90.4	100
30-32	50	56	74.6	99.5
35-40	50	40.3	48.5	58.4
59-79	20	5	6.4	8.2

* FOCUS changes from 85 (BBCH 10-19) to 50 (BBCH 20-39).

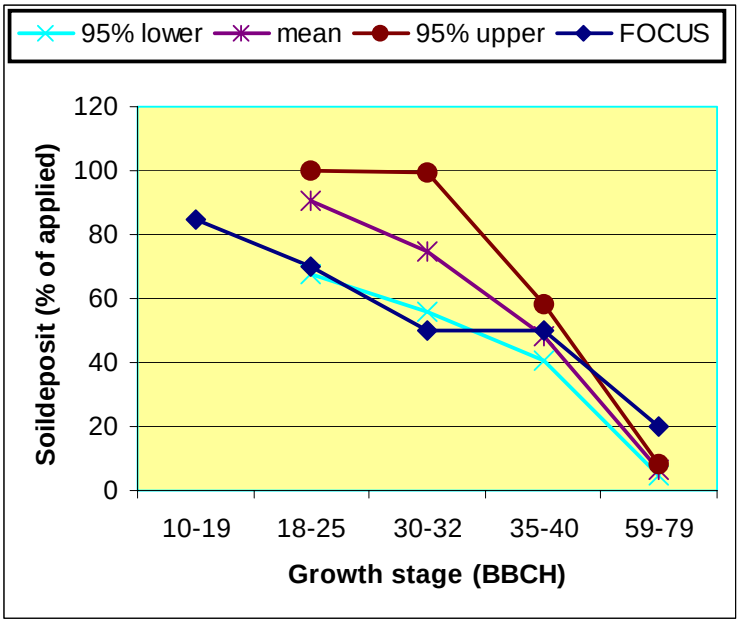

Figure 4. Deposition of spray liquid on the soil surface below potatoes based on 2000-2001 experiments. The figure includes mean values and 95% upper- and lower-confidence limits for each growth stage interval. FOCUS values are included for comparison. FOCUS changes from 85 (BBCH 10-19) to 50 (BBCH 20-39).
Figur 4. Afsætning af sprøjtevæske på jord under kartofler baseret på resultaterne fra 2000-2001. Tabellen indeholder gennemsnit, samt 95% øvre- og nedre konfidensinterval for hvert vækststadieinterval. FOCUS 2002 værdierne er inkluderet til sammenligning. FOCUS skifter fra 85 (BBCH 10-19) til 50 (BBCH 20-39).

Remarks: Higher soil deposition values in Danish investigation at early growth stages (10-32 BBCH) than the estimates/experimental FOCUS values. Lower Danish values at late growth stages (59-79 BBCH).

Table 5. Deposition of spray liquid on the soil surface (% of applied) in different agricultural crops according to FOCUS 2002.
Tabel 5. Afsætning af sprøjtevæske på jorden (% af udsprøjtet mængde) I forskellige afgrøder ifølge FOCUS 2002.

Crop	Bare – Emergence	Leaf develop-ment	Tillering & stem elongation	Flowering	Senescence Ripening
	BBCH				
	00-09	10-19	20-39	40-89	90-99
Beans (field + vegetable	100	75	60	30	20
Cabbage	100	75	60	30	10
Carrots	100	75	40	20	20
Cotton	100	70	40	25	10
Grass*	100	60	40	10	10
Linseed	100	70	40	30	10
Maize	100	75	50	25	10
Oil seed rape (summer)	100	60	20	20	10
Oil seed rape (winter)	100	60	20	20	10
Onions	100	90	75	60	40
Peas	100	65	45	15	15
Potatoes	100	85	50	20	50
Soybean	100	65	45	15	35
Spring cereals	100	75	50 (20-29) 30 (30-39)	10	10
Strawberries	100	70	50	40	40
Sugar beets	100	80	30 (rosette)	10	10
Sunflower	100	80	50	25	10
Tobacco	100	50	30	10	10
Tomatoes	100	50	30	20	50
Winter cereals	100	75	50 (20-29) 30 (30-39)	10	10

* A values of 10 is used for applications to established turf.

Table 6. Deposition of spray liquid on the soil surface (% of applied) in tree- and bushfruit according to FOCUS 2002.
Tabel 6. Afsætning af sprøjtevæske på jorden (% af udsprøjtet mængde) I træ- og buskfrugt ifølge FOCUS2002.

Crop	Stage				
Apples	Without leaves 50	Flowering 35		Foliage development 30	Full foliage 20
Bushberries	Without leaves 50	Flowering 35		Flowering 35	Full foliage 20
Citrus	All stages 30				
Vines	Without leaves 60	First leaves 50	Leaf development 40	Flowering 30	Ripening 15

Table 7. Crop cover development and deposition of spray liquid on the soil surface (% of applied) in spruce plantations (Rubow pers comm.).
Tabel 7. Udvikling af afgrødedække samt afsætning af sprøjtevæske på jord (% af udsprøjtet mængde) in juletræskulturer. (Rubow pers comm.).

	Age of culture							
	0	1	2	3	4	5	6	7
% crop cover	1-2	2-3	5	10	20	33	45	55
Soil deposit (% of applied)						25	25	25

Table 8. Time interval were a growth stage (BBCH) was registered during the two growing seasons 2000-2001.
Tabel 8. Tidsinterval indenfor hvilket det pågældende vækststadieinterval (BBCH) blev registreret I vækstsæsonerne 2000-2001.

Winter wheat		***Spring barley***		***Sugar beet***		***Potatoes***	
G.S. (BBCH)	Time interval	G.S. (BBCH)	Time interval	G.S. (BBCH)	Time interval	G.S. (BBCH)	Time interval
11-13	15-oct	11-13	5/5-10/5	11	5/5-10/5	10-19	-
23-28	23/10-4/4	20-24	11/5-22/5	12	11/5-15/5	18-25	9/6-13/6
30-32	10/4-2/5	28-32	18/5-30/5	13-14	18/5-22/5	30-32	20/6-20/6
33-34	10/5-22/5	33-35	22/5-13/6	15-18	30/5-20/6	35-40	26/6-3/7
38-45	16/5-1/6	49-50	10/6-20/6	20-22	20/6-26/6	59-79	18/7-9/8
51-57	6/6-14/6	59-68	20/6-3/7	30-35	28/6-3/7		
61-71	14/6-3/7	87-89	2/8-4/8	39	27/7-9/8		
87	2/8-4/8						

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