Danish Institute of
Plant and Soil Science

Plant diseases, pests and weeds in Denmark 1990

107th annual report
Compiled by
The Research Centre for Plant Protection

Lyngby 1991

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Contents

A. DANISH RESEARCH CENTRE FOR PLANT PROTECTION

Director: E. Henning Jensen

The Research Centre for Plant Protection is the central research institute of the Ministry of Agriculture in the field protection of agricultural and horticultural crops against diseases, pests and weeds.

The Research Centre for Plant Protection is one of the four centres under the Danish Institute of Plant and Soil Science. The three others are: the Administrative Centre, the Research Centre for Agriculture and the Research Centre for Horticulture.

The research carried out at the Research Centre for Plant Protection is located at Lyngby and Flakkebjerg in the following departments:

Secretariat	Søren W. Bille
Department of Plant Pathology	Arne Jensen
Biotechnology Group	Merete Albrechtsen
Department of Pest Management	Jørgen Jakobsen
Department of Weed Control	K.E. Thonke
Department of Pesticide Analysis and Ecotoxicology	Arne Helweg

The aim of the Research Centre for Plant Protection is to improve the basis for preventing and controlling plant diseases, pests and weeds in agriculture:

- to develop and recommend effective preventive and control measures which are not damaging to the environment
- to implement the results gained from the research and experimental work carried out at the centre and to use results from other national or international research institutes in the advisory work
- to contribute to the creation of a background for national and international plant protection legislation

The research carried out on the application of pesticides plays an important part in the work of the centre. Of primary importance is an agreement with the Danish Agrochemical Association concerning efficiency testing of pesticides. The testing is not required by law, but includes almost all marketed products. A pesticide, which is found suitable for its purpose according to the official testing, is granted an approval. The costs involved are paid by the applicant.

Furthermore, the Research Centre for Plant Protection assists the National Agency of Environmental Protection in the evaluation of suitability of the individual products.

The Research Centre for Plant Protection also performs a number of different research and development tasks in other fields, for which it charges payment. As examples can be mentioned: Production of healthy plant material, testing of bacterial ringrot of potatoes, diagnosis of diseases in plant samples, etc.

For a number of years work has been done to develop biological control methods against pests in glasshouse crops. Several methods are operative.

In recent years, the Research Centre for Plant Protection has hosted a Biotechnology Group, which at the moment employs six scientific officers. The project is a well-defined, educational project, and one of the aims is to develop rational methods of diagnosis.

In the coming years, the Research Centre for Plant Protection will be very much involved in the establishment of an information system on diseases, pests and weeds.

In 1990, the work carried out at the Research Centre for Plant Protection has been characterized by the implementation of the administrative reorganizations decided upon in 1989 and by a number of important changes in the research programmes as compared to previous years.

The work is now concentrated at four departments. The former Department of Virology has been transferred to the new Department of Plant Pathology and the former Pesticide Research Institute has been transferred to the Department of Plant Pathology and the Department Pest Management, respectively.

These reorganizations have already resulted in better utilization of resources and better planing of the research efforts.

Due to continued reductions of public funds available for the Research Centre for Plant Protection it has been necessary to reduce our advisory work regarding pests and diseases in agricultural crops and concentrate our efforts on research activities. As a consequence, our participation in the Plant Advisory Department at Skejby ceased at the end of 1990.

During 1990, many efforts have been put on the elaboration and planning of a new research programme under the Ministry of Agriculture, "Plant Protection toward year 2000". Furthermore, the Research Centre for Plant Protection has contributed to the report regarding "Sustainable Agriculture" which is presently being prepared by the Ministry of Agriculture.

The 7th Danish Plant Protection Conference was held on March 6th and 7th, 1990 attracting about 625 participants.

B. SECRETARIAT

Head of secretariat: Søren W. Bille

The central administration of the Research Centre for Plant Protection lies in the Secretariat.

Furthermore, the Secretariat acts as a link between the individual departments and the other centres under the Danish Research Service for Plant and Soil Science.

In collaboration with the departments the Secretariat performs the following tasks, among others:

Administration of the financial circumstances
The annual plant protection conference
Management of common facilities, i.e. maintenance of buildings, official cars and cultivation of fields
Planning and execution of meetings and conferences
Production of written material

Of about 183 employees, approx. 112 are located at Lyngby and about 71 at Flakkebjerg.

The distribution of the staff at the departments will appear from the following:

	SO	TS	Total
Administration and common functions	3	26	29
Department of Plant Pathology	17	22	39
Department of Pest Management	13	16	29
Biotechnology Group	6	5	11
Advisory Service	3	1	4
Department of Weed Control	22	35	57
Department of Pesticide Analysis and Ecotoxicology	5	9	14
Total	69	114	183

SO: Scientific officers
TS: Technical-administrative staff

Financing and staff
Approximately 55 per cent of the activities of the Research Centre for Plant Protection are being financed by way of the government budget. The remaining part of the funds are being provided by way of research programmes financed publicly or privately as well as by different forms of economic activity. In 1990, the total expenses of the Research Centre for Plant Protection amounted to about 48 mio. Dkr.

C. ADVISORY WORK

Scientific staff:

Lyngby:
Ghita Cordsen Nielsen: Pests and diseases of agricultural crops
Lars A. Hobolth: Pests and diseases of horticultural crops

Skejby:
A. From Nielsen: Head of Department, Pests and diseases of agricultural crops

Department of Weed Control, Flakkebjerg:
O. Permin: Weeds in agricultural crops

Advisory work concerning plant diseases and pests is carried out from the Research Centre for Plant Protection at Lyngby and from the Plant Advisory Department at Skejby, Aarhus.

Weather conditions in 1989-90:

		Temperature °C		Precipitation	
		average	normal	average	normal
September	1989	13,5	13,1	38	72
October	-89	10,3	8,7	92	70
November	-89	4,4	4,9	27	60
December	-89	2,7	2,2	60	55
January	1990	4,1	-0,1	83	55
February	-90	5,4	-0,4	93	39
March	-90	6,0	1,7	32	34
April	-90	7,4	6,2	36	39
May	-90	12,2	11,1	24	38
June	-90	14,3	14,5	80	48
July	-90	15,5	16,6	44	74
August	-90	16,6	16,3	68	81

During 1990, 56 Plant Protection Bulletins (a leaflet sent to advisers and growers concerning warning and prognosis on pests and diseases) were sent out dealing with different subjects.

SURVEY OF MAIN DISEASES AND PESTS IN AGRICULTURAL CROPS IN 1990

Cereals

Eyespot (*Pseudocercosporella herpotrichoides*) was favoured by the mild winter and was found widespread in the spring. The dry weather in May prevented the development somewhat, and the damage therefore was less than expected.

Take all (*Erysiphe graminis*) in winter barley, rye and wheat developed strongly during the mild winter and rather severe attacks occurred during May and June.
Also in spring barley mildew occurred rather widespread.

Brown rust of barley (*Puccinia hordei*) was very widespread with severe attacks in winter barley, especially in the variety Andrea.
The disease was also commonly found on spring barley. Severe attacks occurred especially in fields close to winter barley.

Yellow rust of wheat (*Puccinia striiformis*) was found all over the country and severe attacks occurred especially in the varieties Kraka, Anja and Sleipner. The latter, which is the main variety, has shown an increasing susceptibility.

Brown rust of wheat (*Puccinia recondita*) was of no importance in wheat. In rye, however, severe attacks were observed through July.

Speckled leaf spot (*Septoria tritici*) was favoured by the mild winter and occurred commonly in spring, but neither speckled leaf spot nor glume spot became of any importance.

Barley yellow dwarf virus was observed in several fields with winter barley and wheat, but only in a few fields the attacks were of economic importance.

Cephalosporium stripe of wheat (*Cephalosporium gramineum*) was more widespread than usual but, in general, the attacks were weak.

Bunt (*Tilletia caries*) was observed in several fields. Severe attacks occurred only where untreated or very poorly treated seeds were used.

Loose smut of barley (*Ustilago nuda*) occurred more frequently than usual, but in general the attacks were of no economic importance.

Shoot fly (*Opomyza florum*) was widespread in wheat, but the attacks were weak.

Leaf beetle (*Lema melanophus*) was very common and severe attacks occurred.

Aphids (*Rhopalosiphum padi, Sitobion avenae, Metopolyphium dirhodum*) were observed in barley and wheat in early spring and developed somewhat through May. Also in spring barley aphids occurred frequently, but, generally, the attacks were weak.

Grass

Mildew (*Erysiphe graminis*) was widespread, but the attacks were weak.

Crown rust (*Puccinia coronata*) occurred more frequently than usual, and severe attacks were seen in some fields.

Cephalosporium stripe (*Cephalosporium gramineum*) occurred in several fields with perennial ryegrass, but only in few cases with severe attacks.

Ryegrass mosaic virus on Italian ryegrass. Severe attacks and heavy yield loss occurred in several fields for seed production.

Leatherjackets (*Tipula paludosa*) were more widespread than usual and severe damage occurred. Also the Fever fly (*Dilophus febrilis*) was very common.

Legumes

Downy mildew (*Peronospora vicia* s.sp. *pisi*) became widespread through July, but the attacks were weak. Leaf and pod spots were without importance.

Pea enation mosaic virus was shown for the first time in DK. A few infected plants were found in several fields.

Pea Weevil (*Sitona lineatus*) occurred from early April and became widespread in peas and beans. During August heavy populations occurred in fields with clover.

Pea aphid (*Acyrthosiphon pisum*) occurred early and became widespread through June and July.

Rape

Stem rot (*Sclerotinia sclerotiorum*) was of no importance whereas leaf and pot spot (*Alternaria* spp.) occurred with rather severe attacks on some winter rape fields in July. Neither light leaf spot (*Cylindrosporium concentricum*) nor *Phoma lingam* were of any importance.

The blossom beetle (*Meligethes aeneus*) occurred early and heavy populations developed through May and June in spring rape. Also the seed weevils (*Centorrhynchus assimilis*) occurred commonly, but the attacks were weak.

Brassica pod midge (*Dasineura brassicae*) occurred very early, but the resulting damage was without importance.

Slugs (*Derocera* spp.) were not a problem - severe attacks occurred but only at a few localities.

Beet

Beet leaf miner (*Pegomyia hyoscyami*) was widespread in May, but the attacks were generally weak.

Peach potato aphid (*Myzus persicae*) had excellent surviving conditions in the sugar beet clamps. The first aphids occurred in sugar beet fields in early May, and warning on spraying was sent out on 21st May. The symptoms of Virus Yellows occurred widespread in July.

Black bean aphid (*Aphis fabae*) occurred commonly, but the attacks were, generally, weak.

Rust (*Uromyces betae*) developed somewhat through September. Also leaf spot (*Ramularia beticola*) was found, but these diseases were of limited importance.

Potatoes

Late blight (*Phytophthora infestans*) was more widespread than usual in July, but due to the dry weather conditions in late July and August, the attacks became of no importance.

Virus Y was more widespread than usual because of the heavy spread in 1989.

Cutworms (*Agrotis segetum*) appeared already in early May, but the damage on tubers was of no importance.

Aphids (*Myzus persicae, Aulacorthum* and others) were only of limited importance and the resulting spread of virus diseases was very low.

SURVEY OF MAIN DISEASES AND PESTS IN HORTICULTURAL CROPS IN 1990

In 1990, the horticultural advisory department received 1073 samples. The distribution according to crops and according to group of pathogen will appear from the following table, in per cent:

	Physiological	Mycological	Bacteriological	Virological	Zoological	Unexplained	Total
Swede and other cruciferous crops	0,2	2,1	0,3		0,2		2,8
Potatoes		0,2		0,2	0,3		0,7
Fruit bushes and trees	0,6	1,5	0,3	4,7	1,4		8,5
Vegetables	1,0	8,3	0,3	0,6	0,6		10,8
Ornamental	4,9	49,1	3,1	12,5	5,1	0,1	74,6
Without host plant		0,2					0,2
Total	6,7	61,3	3,9	18,0	7,5	0,1	97,5

Sundry 2,5

In 1990, the number of inquiries concerning virus in ornamentals increased somewhat. One explanation might be fear of attacks by the tomato spotted wilt virus, which has been registered in several countries.

D. DEPARTMENT OF PLANT PATHOLOGY

Head of Department: Arne Jensen

Scientific staff:

Karen Bech: Bacteria in meristem cultures.
Lone Buchwaldt: (until 1/7 - 90) Sclerotinia stem rot in oil seed rape
Lars Bødker: Root pathogenic fungi in peas.
Bent Engsbro: (until 1/5 - 90) Virus diseases in agricultural crops
Ib Dinesen: Bacterial diseases.
Mogens S. Hovmøller: Virulence analysis of mildew and yellow rust of barley and wheat.
Hanne Lipczak Jakobsen: Diseases in peas, oil seed rape, testing of fungicides.
Lise Nistrup Jørgensen: Fungicides in cereals.
Bent Løschenkohl: Fungal diseases in horticulture, potato wart testing.
Bent J. Nielsen: Fungicides in cereals, fungicide resistance.
Steen Lykke Nielsen: Viruses of potatoes; potato micropropagation programme.
Niels Paludan: Viruses of horticultural plants, peas and cereals. Production of healthy nuclear stocks of horticultural plants.
Hellfried Schulz: Root and foot rot of cereals, leaf and seed borne diseases of peas.
Jørgen Simonsen: (stationed at the Research Centre of Agriculture, Foulum) Testing of fungicides in cereals, peas and potatoes.
Sten Stetter: Threshold values for leaf diseases of cereals.
Kirsten Thinggaard: (stationed at the Research Centre of Horticulture, Årslev) Root diseases in glasshouse crops, biological control and *Phytophthora fragaria.*
Arne Thomsen: Rhizomania in beet, viruses of woody plants.
Boldt Welling: Leaf diseases of cereals and grasses.

GENERAL REPORT (Arne Jensen)

All the plant pathology diciplines (viruses, bacteria, fungi and disease control) are now incorporated in the department with a view to increasing flexibility, co-operation and utilization of facilities.

The main tasks of the department are investigations, surveys and experimental work, testing for disease resistance and testing of fungicides in agricultural crops. In the general part of the annual report (p 4) is described the regulatives concerning pesticides.

In 1990 great effort has been put into work which aim at the reduction of the use of pesticides. This work comprises the built up of an information database (see page 31) and a number of experiments with decision models for control of leaf diseases of barley and wheat. Furthermore a number of experiments were done with reduced amounts of fungicides, both in the field and in pot experiments.

The virulence gene survey for leaf diseases in barley and wheat was continued, concentrated on mildew and rust.

In order to build up a network for registration of diseases observations have been made of cereal diseases, pea leaf diseases and Sclerotinia stem rot in rape. The information obtained has been spread to agricultural advisers through "Plant Protection Bulletins" (see page 6). - Root pathogens of peas were studied and a soil test method worked with.

In agricultural crops especially the virus disease Rizomania was investigated, which has not yet been found in Denmark, and with regard to viruses in potatoes there is still a big job to be done in the maintainance of a meristem culture bank.

In horticultural crops the main work has been concentrated in glasshouse crops where virus diseases of Dipladenia, Kalanchoë and Pelargonium were investigated. Root pathogenic fungi is a problem in crops grown in recirculating irrigation systems, methods for quick detection are being worked with. Thermal control strategies are investigated in order to reduce the risk of leaf diseases. Preliminary work is done on the development of test methods for disease resistance of horticultural crops.
Diagnostic work comprises both routine identification of virus, bacteria and fungi and development of new methods. An EEC project has been started on the development of DNA technique and protein electrophoresis for rapid and reliable detection of quarantine bacteria. A project is continued on finding better ways of detection of bacteria in meristematic tissues. As part of the MSc thesis work 6 agricultural students have been working at the department. The subjects comprised club root of oilseed rape, leaf diseases in wheat under different fungicide treatments, compost as possible source for transmitting diseases.

I. DISEASES OF CEREALS

Virulence surveys of barley and wheat powdery mildew (Mogens S. Hovmøller)

A virulence survey was carried out based on random samples of aerial powdery mildew spores. About 700 isolates of barley powdery mildew and 150 isolates of wheat were assayed. Virulence alleles were identified based on infection types on a differential set of various possessing known genes for powdery mildew resistance.

Barley powdery mildew: A large increase in the frequence of isolates virulent on varieties possessing Mla13 (V_{a13}) occured (from 5% in spring to 28% in autumn on average). The frequencies of V_{a1} and V_{a3} increased to a level of 30-35%. The virulence V_{a7} and V_{a12} matching to the most frequent resistances in barley cultivars grown in Denmark were observed in frequencies from 60-80%. Virulence for varieties possessing Mlo resistance was not observed.

Wheat powdery mildew: Only minor changes in virulence frequencies matching to resistances present in commercial wheat varieties grown in Denmark, were observed. Virulences on varieties possessing Pm2, Pm5, Pm6 and/or Pm8 were observed in frequencies from 80-100%, whereas virulence matching to Pm4b was observed in a frequency of about 25%.

Modeling the dynamics of allele frequencies in biotrophic pathogen populations (Mogens S. Hovmøller)

Models were developed to investigate the possibilities of predicting the dynamics of virulence allele frequencies in an aerial population of *Erysiphe graminis* f. sp. *hordei* in relation to selection and recombination. Selection is induced only by resistance genes in the host varieties, leading to field specific powdery mildew subpopulations with different virulence gene frequencies. Recombination occurs within the subpopulations on single varieties, and reassortment takes place only between alleles being "unnecessary" on varieties. In general, the prediction of virulence allele frequencies based on the models were in accordance with those observed. The selection induced by host resistance genes will finally lead to fixation of all the virulence genes selected for. Further, the selection will generate gametic disequilibrium (linkage disequilibrium) between virulence genes in the aerial population, even when there is gametic equilibrium in the previous generation. The sign of the gametic disequilibrium can be predicted in specific cases in relation to the distribution of host resistance genes in the varieties. Selection forces induced by two resistance genes present predominantly in different varieties is likely to generate negative gametic disequilibrium, whereas selection induced by two resistance genes present predominantly in the same variety is likely to generate positive gametic disequilibrium. These predictions are in accordance with observed gametic disequilibria in Danish barley powdery mildew populations.

Virulence spectrum of brown rust (*Puccinia hordei*) in barley under Danish conditions (Boldt Welling)

The severity of brown rust in barley in 1990 was obvious after the mild winter. Very early attacks were observed in winter barley and later in neighbouring spring barley fields.
It was the aim of these experiments, initiated in 1990, to study the virulence spectrum of the Danish population and the relative effectiveness of the resistance genes in barley varieties.
Collection of isolates began in May/June 1990.

From the susceptible variety Jenny single leaves with pustules were multiplied on Jenny in the greenhouse so that later it was possible to multiply a single spore population.

The inoculation and incubation technique was adapted to our conditions. Inoculation is carried out in a settle tower on a differential set and incubated in darkness at 17-20^0 at high humidity (95-98%) followed by an incubation period from 10-14 days in spore tight growth chambers.

Assesments of infection type is based on a scale from 0-4.

A differential set is used consisting of 10 varieties with Pa genes 1-10 supplied with some commercial varieties. The variety Jenny is used as a "control" as this variety is fully susceptible without any known resistance genes.

Temporary results show virulence to most of the Pa genes except for the Pa_7 gene where all the tested isolates are avirulent. Total avirulences to this gene are also found by colleagues in other countries. Also many of the isolates show avirulence to the corresponding Pa_5 gene.

Next step in the programme is to identify resistance genes in the commercial varieties and for that purpose there is a possibility to find some isolates suitable as differentials in our isolates.

Diseases in relation to "green fields" (Jørgen Simonsen and H. Schulz)

Plant pathological observations were made in a number of fields mainly with grain crops. The project mainly aims at minimizing the nitrogen loss by maximum percentage of overwintering crops or catch crops in the autumn. A public order was issued 1989 which prescribes 65 per cent green fields on each farm.

The influence of climatic conditions on the spread of *Septoria* spp. in wheat (Lise Nistrup Jørgensen, Boldt Welling, Jens Grønbech, Bo Secher)

The aim of the project is to investigate the influence of different rain forms on the spread of *Septoria* spp. and the influence of spore germination in fields and in rain simulators under controlled conditions. The importance of variety, number of plants, growth stages, size of rain drops-intensity are some of the factors that should be studied.

In growth chambers the disease intensity will be assessed in relation to simulated climatic variation during day and night, relative humidity and temperature.

The results will give good basis information to develop a prognosis/warning model for *Septoria* and other rain splashed diseases.

Eyespot and other root and foot diseases (H. Schulz)

Eyespot (*Pseudocercosporella herpotrichoides*)

The mild winter 89/90 was favorable for the development of eyespot - chemical treatment was necessary in 60 per cent of the examined fields. The summer estimates showed moderate-severe attacks. In 40 per cent of the examined fields 40 per cent of the straw were attacked by eyespot.

Sharp eyespot (*Rhizoctonia cerealis*) was more widespread and with a higher infection-rate than in 1989.

***Fusarium* spp.** attacks on the stem base were present in 67 per cent of the examined fields in 1990. A higher rate than in the previous years.

Take all (*Gaeumannomyces graminis* (H. Schulz)
The disease was widespread in 1990 but generally with moderate attacks. In fields where cereals as preceding crop severe attacks were often found. The attacks were often limited to single plants with totally damaged roots.

Immunodiagnostic assay for cereal eyespot (Hellfried Schulz & Lise Nistrup Jørgensen)

Samples from different fields of wheat and rye with different intensities of attack were tested in the ELISA-test. No direct correlation could be found between the antigen units measured from 10 plants per field and the visual assessment measured as per cent plants attacked.

Research for MBC-resistance of eyespot fungi (*Pseudocercosporella herpotrichoides*) in Jutland (H. Schulz and Lise Nistrup Jørgensen)

In July 1990, straw with symptoms of eyespot were collected randomly from 45 wheat fields throughout Jutland.

345 different isolates were tested in our laboratory for MBC resistance. 71 per cent of all isolates showed MBC resistance. In 22 fields, where MBC spraying was carried out in 1990, 90 per cent of all tested isolates were resistent. In the other 23 fields, which were not treated with MBC, only 51 per cent of the isolates were resistent.

Control of fungal diseases in winter wheat (Lise Nistrup Jørgensen, Bent J. Nielsen, S. Stetter and Jørgen Simonsen)
A total of 45 trials were carried out in winter wheat in 1990 in order to test different fungicides applied for different purposes.

In spring, severe attacks of eyespot (*Pseudocercosporella herpotrichoides*) were found. A single application of Sportak 45ec in spring gave between 30-50% control and increased yield by 2.7 hkg/ha (10 trials). Split application of Sportak using 0.5 l/ha in the autumn and 0,5 l/ha in the spring improved the effect significantly, however, the yield was only increased a little. A late application at G. S. 32 was tested for the first time. The effect was similar to treatments at G. S. 29-30 and 31. Yield had increased, however, to 5.3 hkg/ha, because other diseases were controlled better at this growth stage (in particular yellow rust). A new formulation of prochloraz which containes mancozeb increased the effect on eyespot compared to the old formulation.

Yellow rust (*Puccinia striiformis*) dominated most trials in 1990. Control of leaf diseases in 45 trials increased on average yield by 27.1 hkg/ha. As an average of 18 trials in the variety Sleipner yield were increased by 42.7 hkg/ha, which was around half of the total yield. By the end of June 65% of all green parts of the crops were covered by yellow rust in the untreated plots of the varieties Anja, Kraka and Sleipner. Many azole-fungicides gave very good control of yellow rust. Four applications of a quarter of the dose of e.g. Tilt top (1 N=1 titer) (propiconazol 125 g/l and fenpropimorph 375 g/l) gave acceptable control of these severe rust attacks. The timing of the applications, when using reduced dosages, is very important. 2-3 weeks are the maximum time allowed between sprayings.

Mildew (*Erysiphe graminis*) was found in 23 of the trials, but the attack was generally low (4.6% on average) and could not compete with the severe attack of rust. Tebuconazole, triadimenol and Matador, which is a mixture of the two, gave the best and longest lasting control of mildew.

Septoria tritici was found in 13 of the trials (12.4% on average), but also this disease had difficulties in competing with rust. Tebuconazole, flusilazol, propiconazole and prochloras gave good control of this disease. The two first products mentioned had a longer lasting effect than the two last products. Split application of chlorothalonil (Daconil 500 F) was approved for control of *Septoria* spp. using 2x1.5 l/ha at G.S. 37 and 49-59, and so was a mixture of prochloraz and cyproconazol (CX 061).

Preventive and curative effect of fungicides in cereals (Lise Nistrup Jørgensen)

The effect on *Drechslera teres* of full dose of tebuconazole, prochloraz and propiconazole was good, when application was carried out preventively 2 and 0 days before inoculation and so was the curative effect applied up to 4 days after inoculation. The time interval in which optimal control was obtained was reduced, when a quarter and an eighth of standard dose was used.

A similar response was found for prochloraz and propiconazole when controlling *Rhynchosporium secalis*. The preventive effect (day 0) as well as the curative effect 8 and 11 days after inoculation were less acceptable when half and a quarter of the dose were used. Full dose gave acceptable control from day 0 to day 11 after inoculation.

Rainfastness of fungicides (Lise Nistrup Jørgensen)

By the use of simulated rainfall the rainfastness of propiconazole, prochloraz, fenpropimorph and mixtures of these (Rival and Tilt top) was tested. "Rain" was applied 1/2, 1, 2, 4 and 8 hours after the fungicide treatments. Propizonazole and prochloraz gave significantly lower effect on mildew, if treated with "rain" before 4 hours after application.

Disease control in barley

Net blotch (*Drechslera teres*) and scald (*Rhynchosporium secalis*) (Bent J. Nielsen, Lise Nistrup Jørgensen, S. Stetter and Jørgen Simonsen)

Net blotch and scald were only seen with low level of attack in 1990 in barley. In winter barley the attack of scald developed in May and was controlled by two sprayings with 0.5 l/ha of effective fungicides. This is in accordance with field trials from previous years that diseases developing in winter barley from April can be controlled effectively with 2 x 0.5 l/ha of efficient fungicides.

Barley powdery mildew (*Erysiphe graminis* f. sp. *hordei*).
In winter barley the attack of powdery mildew developed relatively late and at a low level, maybe due to the early and severe attack of brown rust (Puccinia hordei). In spring barley attacks were more severe in susceptible varieties. In trials with pure EBI-fungicides there were only good effect of Folicur (tebuconazol), DPX H6573 (flusilazol), Corbel (fenpropimorph) and Calixin (tridemorph). The best effect was obtain with the mixed products Tilt top (propiconazol + fenpropimorph), Matador (tebuconazol + triadimenol) and Rival (prochloraz + fenpropimorph).

Again this year split application (e.g. 3 x 0.25 l, 3 x 0.15 l or 2 x 0.25 l/ha) showed good results against powdery mildew and there was only a little difference in net yield by reducing the dose to 0,25 l after one spraying. The best yield was obtained with a total of 0.5 - 0.75 l/ha divided in two or three sprayings.

Brown rust of barley (*Puccinia hordei*)
After two mild winters and an unusually early spring, 1990 became a year with early and severe attacks of brown rust especially in winter barley, but also in many susceptible spring barley varieties. In winter barley the epidemic started already in late April and resulted in yield losses of about 20% in the trials.

Many of the tested fungicides were active against brown rust and well-timed applications at the beginning of the epidemic gave good results. In winter barley 2 x 1.0 l of an effective fungicide gave a very good control, but also doses down to 2 x 0.5 l gave satisfying results.

Severe attacks of brown rust usually occur following ear emergence and it is important that the fungicides applied at that time have a long lasting effect.

Several of the tested fungicides gave good control 4 and 6 weeks after application, but with some products, e.g. Rival, the efficacy was too short with low doses.

II. DISEASES OF PEA, RAPE, BEET AND POTATOE

Leaf and pod diseases in peas (*Ascochyta* spp. *Peronospora viciae* f. sp. *pisi* and *Botrytis cinerea*) (H. Schulz)

On 10 different locations all over the country weekly examinations for attacks of leaf and pod spot, downy mildew and grey mould in the cultivars Bodil and Solara (semi leafless) were carried out during the growing season. These observations were incorporate in our advisory leaflets and together with observations over climatic risk periodes sent to the local advisors, firms a.o. with recommendations on control measures.

Spraying against fungal diseases was only necessary on very few locations, where the weather conditions were favorable for the development of the diseases.

Ascochyta spp. occured with very weak attacks in June and July. *Mycosphaerella pinodes* was again the most common fungus on leaves.

Grey mould (*Botrytis cinerea*) were found widespread in July but only with weak-moderate attacks.

Downy mildew (*Peronospora viceae* f. sp. *pisi*) The first attacks were found medio May. In June the disease was more widespread but still with weak-moderate attacks.

Root diseases of pea (Lars Bødker)

1990 was the year of the investigation of the prevalence and importance of root diseases of pea in Denmark.

The disease survey showed that Aphanomyces euteiches, Fusarium oxysporum f. sp. pisi, F. solani f. sp. pisi, F. redolens and Phoma medicaginis var. pinodella were the most prevalent isolated fungi. A. euteiches, F. oxysporum f. sp. pisi and P. medicaginis var. pinodella were the most pronounced in the major pea growing areas and root rot caused by A. euteiches was the most destructive disease. Individual fields suffered a total loss.

A glasshouse test showed a significant correlation between a predicted disease index for soil samples and a disease index scored in the field.

Control of fungal diseases on oilseed rape and peas (Hanne Lipczak Jakobsen)

In 1990, 23 field trials were carried out testing various fungicides.

Oilseed rape: Fungicides for control of stem rot (*Sclerotinia sclerotiorum*) and black spot (*Alternaria* spp.) were tested. Due to the lack of precipitation this season, no attacks of stem rot appeared in the trials. Black spot was widespread during the winter, but only low

incidence was found in the winterrape trials at harvest. More severe attacks of black spot were seen in the spring rape trials. Rovral Flo (iprodione 500 g/ha) and Folicur 250 EC (tebuconazole 375 g/ha) showed good effect on black spot when applied at growth stage 5.2 (filling of pods).

Peas: In 1990 the seeds were without diseases, so the seed treatment trials concentrated only on soilborne diseases. Apron TZ 69 WS (metalaxyl) 0.288 g/kg seed + thiabendazole 0.540 g/kg seed) showed good effect against soilborne Fusarium spp.,KVK Thiram F bejdse (thiram 2.12 g/kg seed), Beret MLX (fenpiclonile 0.28 g/kg seed + metalaxyl o.35 g/kg seed) and Apron TZ 69 WS had only moderate effect against the complex of other soilborne diseases.

Foliar diseases in peas appeared with low incidence and late in the season. Several fungicides were tested, but they showed only moderate to low effect because of the late end weak attacks.

Stem rot (*Sclerotinia sclerotiorum*) in oilseed rape (Hanne Lipczak Jakobsen)

A forecasting system is now in use in Denmark. It is based on registration of carpogenic germination of sclerotia placed in depots in fields of oilseed rape all over the country. In this way the risk of attack by stem rot is assessed on a regional basis, and weekly forecasting bulletins are sent out to the advisers.

In 1990, the percentage germination varied from 0-42% (average 13 %) in 118 depots of winterrape and from 0 - 93 % (average 35%) in 72 depots of springrape at the time of full flowering.

In spite of the relatively low germination in winterrape, severe attacks were seen in some fields, and in springrape the incidence was unexpectedly low because of a dry period immediately before flowering.

Efforts were made to improve the forecasting system. A forecasting scheme has been made to make it possible for the grower or adviser to make decisions of fungicide application on field level. This system will be tested in the following season.

Pea enation mosaic virus (Niels Paludan)

The pea enation mosaic virus (PEMV) has been shown in many pea fields widespread in the country. The spread of the virus in the single fields has been limited to only few plants due to rather late time of infection.

Infection trials with the most common varieties of field pea, using pea aphids as a vector, showed that nearly all varieties were sensitive and developed characteristic PEMV-symptoms.

Rhizomania in sugar beets (Arne Thomsen)

By means of a modified Bemster method a number of soil samples were in 1990 screened for the presence of beet necrotic yellow vein virus (BNYVV), the causal agent of Rizomania, and for an unnamed Swedish virus, isolate 86-lo9. A total of 148 soil samples from six sugar factories were examined by means of ELISA and by sap inoculation. BNYVV was not detected in any samples, while the 86-lo9 isolate was found in 64% of all soil samples. Little is yet known about the agricultural significance of the 86-lo9 virus isolate. The common vector for both viruses, the fungus Polymyxa betae, was found in all soil samples examined.

Mild beet yellowing virus (Steen Lykke Nielsen)

Out of 50 samples of winter oil seed rape collected ultimo November mild beet yellowing virus was established in 2 samples with ELISA.

Virus diseases of potatoes (Steen Lykke Nielsen)

Potato Mop Top

Investigation of sensitivity of potato cultivars to potato mop-top virus was continued in an infected field located in Sunds in Jutland. 24 cultivars were tested. In the sensitive control cultivars 'Minea' and 'Saturna' 10% and 5% of the tubers were found infected respectively. Isolation of potato mop-top virus originating from infected soil was carried out in greenhouse by using bait plants (*Nicotiana debneyi*).

Tobacco rattle virus

Investigation of sensitivity of different potato cultivars to tobacco rattle virus was continued at the experimental station Lundgaard. 25 cultivars were tested. 18% of the tubers of the sensitive control cultivar 'Nicola'were found infected.

Potato virus Y

Several samples of the potato cultivar 'Sava' with round superficial necrotic spots (½ - 3 cm in diameter) on the tuber surface were diagnosed. The causal agent was potato virus Y (necrotic line).

Establishment of virus free stocks of potatoes

In the meristem culture programme 8 potato cultivars have been established as virus- and bacterial-free stocks.

Fungicide effectivity trials in potatoes (Jørgen Simonsen)

Against late blight (*Phytophthora infestans*) 5 compounds were tested in usual 3 step dosage and 5-6 treatments late June to early August. However a hot and dry July kept the infection low. Daconil 5oo F (Chlorothalonil 2,5 l = 0,7 kg a.i./ha) recieved recommendation.

Against black scurf (*Rhizoctonia solani*) 3 compounds were tested by row application or by low volume spray or dust on the seed in the spring. Rizolex 50 FW (Tolcofosmetyl 30 ml = 15 g a.i. /hkg) and Monceren 250 SC (Pencycuron 6 l = 1,5 kg a.i. /ha) were recommended.

Potato wart (*Synchytrium endobioticum*) (Bent Løschenkohl)

The Danish Potato Breeding Station at Vandel sent 307 tuber samples, and the Swedish Breeding Station Svalöf sent 330 tuber samples to be examined for wart resistance.

III. DISEASES OF HORTICULTURAL CROPS

Test methods for screening of resistances against fungal diseases in horticultural crops (Kirsten Thinggaard)

Development of test methods for use in the laboratory to screen for resistance against root pathogenic *Phytophthora* and *Pythium* were started in 1990.

Root rot (*Phytophthora fragariae* var. *rubi*) in raspberry (Kirsten Thinggaard)

The healthy nuclear stock plants of raspberry were tested for root rot caused by *Phytophthora fragariae* var. *rubi*.

***Phytophthora* and *Pythium* in greenhouse crops (Kirsten Thinggaard)**

Root diseases caused by *Phytophthora* and *Pythium* gave many problems especially in nurseries recirculating the nutrient solutions. Therefore methods to detect the two fungi in samples from the nutrient solutions from commercial nurseries were developed.

Development of thermal control strategies to substitute for pesticide plant disease control in protected cultivation (Bent Løschenkohl)

For 3 weeks 16 climate components were registrered every 10 minutes in a commercial greenhouse, using a climate computer. Airborne fungal spores were measured in 6-hour periods using a Burchard sporetrap. Relative humidity was stronger correlated to the temperature outside than inside the greenhouse. This was mainly because of high

temperatures during the night, resulting in no heating requirement. The relation between the release of fungal spores and climate conditions has yet to be calculated.

Virus diseases of ornamental plants (Niels Paludan)

Dipladenia sanderi
Virus-free meristem plants of selected clones comprising four varieties, have been delivered to the nursery industry after a growth and flovering control were carried out at the Horticultural Center, Årslev.

Kalanchoë blossfeldiana
Infection trials with different viruses earlier found in Kalanchoë plants showing mosaic symptoms, were carried out using sap inoculation to healthy plants of the Kalanchoë variety 'Attraction'.

Carnation mottle virus caused infection in Kalanchoë but no symptoms occured during 2 months.

Tobacco mosaic virus (5 different isolates comprising 3 TMV-strains) did not infect the Kalanchoë plants, which were retested twice after periods of one and two months.

Tomato bushy stunt virus caused infection and developed both local and systemic symptoms during a three weeks period as spoonlike chlorotic leaves. Later on no symptoms could be seen.

Pelargonium x hortorum
Inspection trials with six different isolates of tobacco mosaic virus, of which three originated from Pelargonium plants, were carried out using sap inoculation to healthy plants of the variety 'Springtime Irene'.

Three tobacco strains, one MDG-strain and one of two tomato strains did not infect the Pelargonium plants, which were retested twice after periods of one and two months.

The other tomato strain originating from a Danish pepper culture, infected one of 3 Pelargonium plants causing a very low virus concentration. No virus symptoms appeared during two months.

Tomato spotted wilt virus (TSWV)
The virus was shown for the first time in Denmark in 1989 in imported Impatiens plants showing chlorotic, necrosis and wilting. The plants were destroyed and the TSWV was not further spread.

In 1990 a new attack occured in different Kalanchoë varieties from a single nursery. The symptoms varied but consisted mostly of water soaked spots, chlorotic ringformed mosaic in younger leaves and necrotic spots and streakes in leaves and stems.

The virus was diagnosed by ELISA-tests and by sap inoculation to sensitive indicator plants with corresponding results.

By ELISA test positiv reaction was achieved between the mentioned Danish Impatiens and Kalanchoë TSWV-isolates and the following antisera: AGDIA - L, LOEWE - CNPH - L (less sensitive), LOEWE - A5 (with reactions first after 20 hours) and Adams reagents from Braunschweig. Contrary no reaction was achieved with the AGDIA - I antiserum.

A French TSWV - L isolate and a Danish virus isolate from Sinningia, showing TSWV-like symptoms, did not react with any of the mentioned antisera.

TSWV infected *Nicotiana benthamiana* leaves reacted positiv with ELISA after a storage at - 80^0 C during 6 months.

Virus diseases in fruit trees (Arne Thomsen)

Pear vein yellows

Severe attacks of pear vein yellow virus have in 1989-90 been found in the pear cultivar Clara Frijs.

Investigation - by testing a great number of Clara Frijs nurseries trees have shown that the virus infection in all cases was caused by virus in the rootstock and not by scionwood from nuclear stock plant.

New virus attacks 1990 (Niels Paludan and Arne Thomsen)

Brassica napus	beet yellows
Impatiens sp.	tomato spottet wilt virus
Kalanchoë blossfeldiana	tomato spottet wilt virus
Pisum sativum	pea enation mosaic virus

IV. DIAGNOSTIC WORK

Bacterial ringrot of potatoes (*Clavibacter michiganensis* subsp. *sepedonicus* (Ib G. Dinesen)

During 1990 several potato samples from last year's harvest were tested. The total amount of samples tested was about 1000 and it included tubers for seed and consumption.

An EEC-project was started. The title of the project was: Development of DNA technique and protein electrophoresis for rapid and reliable detection and identification of quarantine bacteria in particular the potato ring rot organism *Clavibacter michiganensis* subsp. *sepedonicus*.

In the project 73 bacteria strains of different genera and species have been examined. By using SDS-gelelectrophoresis protein profiles have been analysed of those strains. Typical differences are found between the different species of *Clavibacter, Rhodococus, Erwinia, Pseudomonas* and *Xanthomonas*. Within the genera there are typical differences between the species.

Detection of plant pathogenic bacteria in micropropagated plants (Karen Bech)

The spread of *Erwinia chrysanthemi* in naturally infected 6-8 weeks old plants of *Kalanchoë blossfeldiana* was examined. The bacteria was often isolated just below the apical meristem. Meristems were excised and cultured from 7 infected varieties of Kalanchoë to evaluate the risk of transmission of bacteria with the explants. The results were compared to the size and location of the meristem on the plant. On the average 77% of the explants from infected plants dropped out early because of bacteria. 16% of the meristem plants remained symptom-free and were grown in the green-house for 6 months and subsequently tested for Ec. *Erwinia chrysanthemi* which was not found in these plants.

E. chrysanthemi was detected in situ in fresh cryostat and paraffin embedded sections of infected stems by the indirect immunofluorescence method. Autofluorescense from the plant was eliminated by counterstaining.

V. OTHER WORK

Desinfection trials (Niels Paludan)

Disinfection trials have been continued comprising suspension tests with the tomato strain of tobacco mosaic virus (TomMV).

The most effective disinfection after 5 to 10 minutes of treatment was achieved with respectively brown soap 10 - 25 % concentration, trisodium phosphate 10 % in combination

with the detergent 'Lissapol' 1 %, skim milk 100 %, 'Venno Terra Spray' 100 % and 'Venno Terra Man' 100 %.

Skim Milk and 'Venno Terra Man' are further more usefull as hand disinfectants.

Surface disinfection using long time treatment with and without organic substance added, was carried out with the disinfectant 'Venno Cycla 2' in 1 % concentration. Both TomMV and Pelargonium flower break virus were effective eliminated after 240 minutes even with the presence of organic substance.

Effect of disinfectants (Ib G. Dinesen and Bent Løschenkohl)

Two disinfectants, jodo-cid and Virkon S. were tested and both of them obtained the official approval.

Plant pathogens in compost (Arne Jensen and Bettina Jensen)

The survival of *Rhizoctonia solani, Polymyxa betae, Sclerotinia sclerotiorum, Plasmodiophora brassicae* and *Globodera rostockiensis* have been investigated in a number of big scale composting plants. Infected plant material or resting structures of the organisms were placed in different depths and for 1 to 4 weeks in different compost piles. The results show that the pathogens in most cases are killed after just 1 week when the temperature was more than 55^0C in the compost.

E. BIOTECHNOLOGY GROUP

Head of group: Morten Heide (until 1 June 1990)
Merete Albrechtsen (from 1 June 1990)

Scientific staff:
Merete Albrechtsen: Serological methods and electron microscopy
Bernhard Borkhardt: Molecular biology techniques
Morten Heide: Serological methods and electron microscopy
Karen Husted: Biochemical methods for fungus diagnosis
Elisabeth Johansen: Molecular biology techniques
Søren V.S. Nielsen: Cell and tissue culture technique
Gert Poulsen: Cell and tissue culture techniques

The Biotechnology Group was set up in 1985 in order to develop and implement biotechnological methods of relevance for Danish agriculture and horticulture. The group is geographically situated at the Research Centre for Plant Protection, with close links to the Virology Section.

The main results obtained in 1990 are described below In addition, work has been carried out on protoplast fusion methods applied to *Brassica* species, on *in vitro* selection of rape seed protoplasts for resistance towards *Alternaria brassicae* toxin, and on the molecular biology of plant-virus interactions (the latter is mainly carried out as student projects).

Genetic engineering of virus resistance in pea (Merete Albrechtsen, Bernhard Borkhardt, Morten Heide, Elisabeth Johansen, Søren V.S. Nielsen, Gert Poulsen)

The introduction of agronomically interesting traits into plants by genetic engineering is now technically possible for a number of crops plants. To date, the most promising results have been obtained in the fields of virus resistance and herbicide resistance. The Biotechnology Group is working at applying these new methodologies for the development of virus resistant pea plants. This project comprises two sub-projects: Development of an efficient protocol for genetic transformation of pea, and development of appropriate gene constructs that can confer virus resistance on the transgenic host plant.

In contrast to solanaceous crops such as potato and tomato, leguminous plants are generally difficult to manipulate in tissue culture. Therefore, an efficient regeneration system based on pea hypocotyl explants was first developed. Furthermore, experiments were performed on the use of the soil bacterium *Agrobacterium tumefaciens* for the transfer of foreign genes into pea explants. Transformation frequencies of about 80% have been achieved with wild-type *Agrobacterium*, and after treatment with modified bacteria containing marker genes a few transgenic shoots expressing the marker genes were observed. The optimization of this system continues.

It is known that introduction of virus coat protein genes into plants can make the transgenic plant less susceptible to virus infection. The coat proteins genes of two pea viruses, pea seedborne mosaic virus and pea early browning virus, have been cloned and subsequently modified in a way that should allow them to function efficiently in the transformed host plant. In order to test the gene constructs, these have been transferred to tobacco plants (which are easy to engineer genetically) and the transformed tobacco have been checked for gene expression.

Development of diagnostic tools (Merete Albrechtsen, Bernhard Borkhardt, Morten Heide, Karen Husted)

Two DNA-probes, specific for the barley leaf pathogens *Pyrenophora graminea* and *P. teres* respectively, have been identified. Development of a rapid screening method for these fungi on barley seeds is in progress. A specific and sensitive ELISA-test for pea seedborne mosaic virus has been developed, and a non-radioactive method for DNA-based detection of viruses and viroids has been adapted for use with plant extracts (the latter was done in collaboration with the Genetic Engineering Group at the Technical University). In addition, the Biotechnology Group has participated in a large number of virus and viroid tests throughout the year.

Auxin-binding proteins from rape seed (Søren V.S. Nielsen, in collaboration with Kirsten Jørgensen, Research Centre for Agriculture)

The potential for regeneration of whole plants from single cells or explants varies enormously between different plant species, and between different cultivars of the same species. Likewise, the optimal schedule for plant regeneration *in vitro* is very variable and must today be determined empirically for each new species and cultivar. With the aim of identifying biochemical markers for high and low regeneration potential the auxin-binding proteins of three rape seed cultivars with high or low potential for regenerating from single cell cultures have been studied. Some reproducible differences between the auxin-binding proteins from high and low regenerating cultivars were observed. These proteins are now being characterized further in order to determine, whether they can form the basis for a general method for predicting the regeneration potential of new cultivars.

F. DEPARTMENT OF PEST MANAGEMENT

Head of Department: Jørgen Jakobsen

Scientific staff:

Bent Bromand: Insecticides for agricultural purposes
Henrik Brødsgaard: Biological control of pests in glasshouses
Annie Enkegaard: Biological and integrated control of the cotton whitefly (*Bemisia tabaci*)
Lars Monrad Hansen: Pests on cereals, beet, potatoes. Warning systems
Søren Holm: Pests and diseases of agricultural crops
N.S. Murali and Bo Secher: Computer aided advisory system for pest and disease control
Alex Percy-Smith: Pests on field vegetables and fruit
Hans Peter Ravn: Insect pests in field peas and codling moths in apple orchards
Werner Riedel: Beneficial arthropods in cereal crops
A. Nøhr Rasmussen: Fungicides, insecticides and growth regulators for soft fruit, nursery and glasshouse crops
Lise Samsøe-Petersen: Methods for testing side effect on beneficial arthropods

GENERAL REPORT Jørgen Jakobsen

The department has been reorganized. As per 1st of January, the former Pesticide Research Institute was split up and the activities transferred to the former Department of Botany and the Department of Zoology, respectively.

The activities transferred to the Department of Zoology are: tests of insecticides against pests in agricultural crops and of insecticides, fungicides and growth regulators used in horticulture, fruit productions and in plant nurseries. Also activities formerly situated at "Det Faglige Landscenter" is Jutland have been transferred to the two departments.

As a consequence of these changes the scientific staff now includes Bent Bromand, A. Nøhr Rasmussen and Søren Holm. The name of the department has been changed to: Department of Pest Management.

The official test and approval of pesticides, evaluation and reevaluation of pesticides in connection with the official registration were carried out as usual. The aim of dividing the pesticide testing activities is to integrate this work closer with the biological research. Among the new activities at the department is a survey of pests and diseases in organic farms - and a new project on pests in cabbage. Project leader of this project is agronomist Alex Percy-Smith.

The main activities of the department are still the development of integrated pest management methods for pests in agricultural and horticultural crops with emphasis put on

reducing the use of insecticides and also - in horticulture - on developing methods of biological control.

A special activity of the department is the development of a computer aided advisory system for pests and diseases. This project is carried out in collaboration with the Department of Plant pathology and also with the Department of Weed Control.

In 1990, an initiative was taken, which is a further step towards integrated pest management, to carry out multidisciplinary research on crop production systems in cooperation with the Research Centre for Agriculture. Field experiments with winter wheat are planned and will be initiated in 1991.

The department was organizer of an IOBC-conference about biological control of pests in glasshouse crops held in June in Copenhagen. This conference was attended by about 80 scientists from the Middle East, North America and Europe.

Cereal Cyst Nematodes and Potato Cyst Nematodes (Jørgen Jakobsen)

In autumn 1990, the department made a survey of Cereal Cyst Nematodes in about 200 fields. The previous survey was made in 1983.

For the breeding station Vandel the department tested new potato varieties for resistance to Potato Cyst Nematodes "yellow" Ro-1 and "white" PA-2 and PA-3. About 100 new crossings were tested.

Aphids in cereals (Lars Monrad Hansen)

Aphids are one of our major pests in cereal crops - especially in spring barley and winter wheat. There are great variations in the occurrence between years. Therefore a better method of forecasting and warning has been developed.

The importance of aphids as vectors of barley yellow dwarf virus under Danish conditions was also investigated.

Slugs as a pest (Lars Monrad Hansen)

In recent years, slugs have occurred as a more frequent and serious pest. There is no simple method available for determining the occurrence and the economic injury threshold. Investigations have been made concerning these aspects.

Aphids in beet (Lars Monrad Hansen)

Peach-potato aphid, in particular, is a major pest in beet as vector of Virus Yellows. An improved method has been developed for forecasting this pest. Furthermore investigations have been made to develop methods which more accurately can determine the time invasion into the beet fields.

Survey of pests and diseases in organically grown crops (Søren Holm)

At 15 farms in Jutland, pest and disease attacks were observed in cereals, beet, potatoes, pea and carrot. The crops had been grown organically, i.e. without mineral fertilizers and pesticides, for at least two years according to the rules for organic farming in Denmark. The major pests and diseases found in 1990 were as follows: Thrips in rye, Yellow Rust and Stinking Smut in wheat, Virus Yellows in beet, Aphids in pea, Late Blight, Black Scurf and Wireworms in potatoes and abnormal growth of carrots.

Monitoring of leatherjackets in grass fields

The population densities of leatherjackets were estimated in grass fields in October. *Tipula paludosa* is the most important species in Denmark.

The survey is based on a method where the number of larvae is counted in tubes driven 5 cm into the soil and filled with a 20% salina solution. 20 tubes were used per field. The mean number of leatherjackets was in 1990 about 200 per m^2. The highest number of leatherjackets was found on sandy soils and soil with a high content of organic material.

Information Data Base for Pests and Diseases (N.S. Murali and Bo J. M. Secher)

The project was initiated in 1987 with the aim of developing a PC-based plant protection information system for farmers and agricultural advisors. The system consists of the following modules:

* Optimal plant protection recommendation based on individual field observations
* Information on diseases and pests
* Information on pesticides
* Information on diseases and pests
* Information on beneficial organisms and their sensitivity to pesticides
* Farmers field observations - field log

The present system includes recommendation models for spring barley, winter barley and winter wheat. In 1990, the recommendation models were tested for performance in field trials coordinated by the Research Centre, and a group of agricultural advisors tested the information system for usability and model performance. The system and the models showed good performance. The system is expected to be released in spring 1992. In the coming years other crops will be incorporated.

The field registration system for pests and diseases, which was initiated in 1983, is now coordinated by the Information Data Base Project. In 1990, 390 farmers participated in the registration program. The participants send the recorded field observations to the Centre and received a plant protection recommendation based on their observations and the date of next field registration. These field observations formed a basis for evaluating the national and the regional disease and pest development. The field registration system, in addition to cereals, also include insect pests in sugar-beet, field pea, apple and vegetables. All correspondence between participants and the Centre was by post or telefax.

Investigations on insect pests in field peas (Hans Peter Ravn)

The area grown with field peas is still of considerable dimensions. The use of insecticides on this area is rather intensive. Our knowledge of the importance of insect pests is limited. Due to this, investigations have been continued to clarify the impact of the most common insect pests. It is also the aim to develop simple and safe evaluation methods for practical use by the farmers.

In field studies the spring migration and colonisation pattern of the pea and bean weevil (*Sitona lineatus*) and the pea aphid (*Acyrthosiphon pisum*) into the pea fields have been investigated.

In semi-field facilities controlled outdoor pot experiments have taken place to elucidate the impact of insect pests on pea plant growth and yield. In 1990, experiments with pea aphid and pea and bean weevil were carried out.

Under outdoor conditions the winter survival of the pea and bean weevil has been investigated. Registration of occurrence of the different morphs of the pea aphid in the autumn and winter.

Monitoring and forecasting phenology and damage by Pea Moth (*Cydia nigricana*) (Solveig Kappel*, Jens Bligaard* & Hans Peter Ravn)

The purpose of the project was to evaluate the pheromone traps in relation to the actual damage level and, furthermore, to use temperatures for optimizing the spraying time.

In 9 pea fields the levels and time of attacks have been compared with the catch by pheromone traps. The traps reflected the time of flight very well. The relation between % damaged pods and accumulated catch showed that under a certain catch level the risk of attack is correspondingly limited.

* Students from the Royal Veterinary and Agricultural University

Investigations showed that no particular stage or position of the developing pod seemed to be more attractive to pea moth than others.

In laboratory and semi-field experiments the relationship between developmental rate and temperature was elucidated for eggs, larvae and pupae.

These investigations were carried out as a graduation project from the Agricultural University.

Monitoring turnip moth (*Agrotis segetum*) by means of sex traps and forecasting cutworm attacks (Alex Percy-Smith)

The turnip moth was monitored at 48 localities in Denmark and 30 localities in Skåne, Southern Sweden. Total catch in pheromone traps was about the same as in 1989, but the flight period was slightly longer due to weather conditions. Flight activity was at its highest in the whole of June and was relatively constant in this period.

Precipitation varied considerably from locality to locality. Treatment was generally necessary, although the places where more rain fell treatment was not required. A single, well-timed treatment with a pyrethroid gave good control.

Monitoring carrot fly (*Psila rosae*) with yellow sticky traps (Alex Percy-Smith)

Monitoring was largely decentralised and run by advisors and processing companies. Close contact was, however, maintained between the Research Centre for Plant Protection and the advisors, in order to ensure optimal coordination and to discuss evaluation of catch results.

The flight period of the first generation started in April, which was earlier than in most years.

The second generation varied considerably from locality to locality, but there was generally most activity from the middle of August to the middle of September.

Carrot fly (*Psila rosae*) control strategies (Alex Percy-Smith)

Field trials were carried out to investigate the effect of different combinations of insecticides. In addition, spraying equipment was tested in collaboration with Hardi International A/S.

The results indicated poor control in all treatments.

Monitoring codling moth (*Cydia pomonella*) by means of sex traps (Alex Percy-Smith and Hans Peter Ravn)

Delta traps were used at 54 localities for monitoring codling moth in apple orchards. The main flight period was from the middle of June to the middle of July. The number of treatments was slightly higher than in 1989.

Pests in agricultural crops and field vegetables (Bent Bromand)

In 1989, a total of 51 field trials were carried out and 12 insecticides were given approval. For the first time a trial was carried out testing different spraying techniques against aphids in spring barley. The conventional hydraulic sprayer was compared to 2 air-assisted types of sprayers, the Hardi Twin and the Danfoil sprayer. From the results of this trial it does not seem likely to obtain a better effect on aphids with an air-assisted sprayer-type.

In cereals, trials were carried out against thrips in winter rye and against aphids in winter barley and winter wheat in order to prevent the spread of BYDV.

In sugar beet, trials were carried out with insecticides incorporated in the pellets before sowing. Very promising results were obtained with imidachloprid. Spaying trials were carried out against field thrips, pygmy beetles, Mangol flies, black bean aphids and peach-potato aphids. Spraying techniques with different pressure, driving speed, amount of water and height of spray boom were used.

In oilseed rape, seed treatment was used against flea beetles (*Phyllotreta* spp.) and field thrips. Spraying trials were carried out against the blossom beetle, the seed pod weevil and the brassica pod midge.

In peas, seed treatment or spraying trials were carried out against the pea and bean weevil. Besides, trials were conducted on spraying against pea aphids and pea moths.

In field vegetables, seed treatments, granules and sprayings were applied against the carrot fly and cutworms. A warning system for egg-laying of first and second generation has been developed and is now in operation.

Development of standard methods for determining the effect of pesticides on beneficials (Lise Samsøe-Petersen)

Rearing of the Carabid beetle *Bembidion lampros* was continued during 1990. Late in the year experiments with an artificial diet for larvae were initiated.

A laboratory test for adult females of the Staphylinid beetle *Aleochara bilineata* has been developed earlier in co-operation with the IOBC Working Group "Pesticides and Beneficial

Organisms" (Samsøe-Petersen, 1987) The work on this species, resumed during 1989, was continued in 1990.

The laboratory test was used to perform tests for chemical industries on a contract basis, and the development of other tests was initiated.

To achieve a more comprehensive picture of the effect of pesticides under field conditions it should be possible to conduct additional tests after the initial laboratory test.

Experiments with a test for *A. bilineata* under semi-field conditions were continued in 1990. The set-up for the semi-field test was further developed in the laboratory, but another year is needed to complete the development.

Furthermore experiments were initiated to develop the original laboratory test to take place in different soil types instead of sand. This is also expected to be finished next year.

Thrips in glasshouses (Henrik F. Brødsgaard)

Insecticide resistance tests, using a residue on glass technique, were carried out on different strains of the western flower thrips (*Frankliniella occidentalis*). These tests showed significant differences in resistance to different insecticides from different insecticide groups. Possible cross resistance was also observed.

Biological control experiments using the anthocorid bug *Orius insidiosus* for the control of thrips on glasshouse pot chrysanthemum were carried out. These results showed that this bug is a very efficient biocontrol agent on chrysanthemum.

Cotton whitefly *Bemisia tabaci* (Annie Enkegaard)

Investigations on the biology of the cotton whitefly, *Bemisia tabaci* on Poinsettia was continued. The following parameters have been determined in climate chambers at 16°, 19°, 25° and 28°C: adult female longevity, pre-oviposition period, age specific fecundity, developmental time and developmental mortality from egg to adult and the ratio between males and females in the progeny.

The hymenopterous parasite *Encarsia formosa* has ben chosen for experiments to elucidate its potential as biological control agent of *B. tabaci*. Experiments on the basic biology of *E. formosa* on *B. tabaci* on Poinsettia were carried out in the laboratory at 16°, 22° and 28°C. These included the longevity and fecundity of the parasite, developmental time and developmental mortality from egg to adult and the parasite's preference for host stage. Investigations on others aspects of the aspects of the biology of the parasite are to be conducted.

Finally, a method of distinguishing between live and dead immature individuals of the cotton whitefly has been developed. The method is based on the production of honeydew droplets from the larvae, droplets which are made visible by way of water sensitive paper.

Manipulation of polyphagous predators in cereals (Werner Riedel)

1988, a Nordic project started with the aim of finding methods to enhance the population of naturally occurring enemies of cereal aphids. The Danish part of the project is to create good overwintering sites for beetles and spiders. As indicator organisms two ground beetles *Bembidion lampros* and *Agonum dorsale* as well as some rove beetles within the genus *Tachyporus* were chosen, because they are very common in Danish agricultural land. These beetles are overwintering as adults in field edges and hedges. Therefore a simple grass and herb ridge was created in a winter wheat field in spring 1988.

Densities of overwintering beneficials in the established ridge has been high and rather consistent during the last 3 winters and mortality in the ridge is low. During the early spring catch of the key species *Bembidion lampros* in pitfall traps is several times higher in the surroundings of the raised bank compared to mid field and the predation level of artificial prey has increased correspondingly.

Testing and approval of fungicides and insecticides in horticultural crops (A. Nøhr Rasmussen)

The Danish Research Service for Plant and Soil Science grant approval to chemicals and biological plant protection products for control of plant diseases, pests and weeds when satisfactory trial results are available. The trials are performed according to an agreement between the Danish Agrochemical Association and the Ministry of Agriculture.

As from the 1st January 1991 3 fungicides, 12 insecticides/acaricides were granted approval from the Danish Research Service for Plant and Soil Science. The approved products, dosages, active ingredients, names and the pests and diseases which the products are approved to control are listed below.

Product and a.i.	Approved against	Crop	Dosage
Fungicides			
Ronilan DF*			
vinclozolin 500g/kg	Grey mould	Strawberries	1.0 kg/ha
S-3308L DF*			
diniconazol 500g/kg	Powdery mildew	Apple	0.3 kg/ha
	Apple scab	Apple	0.25 kg/ha
	Am. gooseberry mildew	Black currant	0.25 kg/ha
	Leaf spot Anthracnose	Black currant	0.25 kg/ha
	White-Pine blister rust	Black currant	0.25 kg/ha
Systhane 40WP*			
myclobutanil 400g/kg	Pear scab	Pear	0.3 kg/ha

* Not registered by the National Agency of Environmental Protection by the 1st January 1991.

Product and a.i.	Approved against	Crop	Dosage
Insecticides			
Andalin liq 25*			
flucycloxuron 250g/l	Red spider mite	Fruit trees	1.0 l/ha
Dibeta 25WP*	Red spider mite	Fruit trees	0.5 kg/ha
thuringiensin 250g/kg	Two spotted mite	Fruit bushes	0.3 kg/ha
Dibeta 25WP + Stirrup M*	Red spider mite	Fruit bushes,	0.2 kg/ha +
thuringiensin 250g/kg		Strawberries	0.3 l/ha
	Two spotted mite	Fruit trees	0.3 kg/ha +
			0.3 l/ha
Kelthane E 30	Red spider mite	Fruit trees	1.75 l/ha
dicofol 400g/l	Apple rust mite	Apple	1.75 l/ha
KVK Difluron + Presol*			
diflubenzuron 250g/kg	Pear sucker, nymphs	Pear	0.6 kg/ha +
			4.0 l/ha
Pirimor G	Mealy plum aphids	Plum	1.0 kg/ha
pirimicarb 500g/kg	Cherry aphid	Cherry	1.0 kg/ha
	Green apple aphid	Apple	1.0 kg/ha
	Peach-potato aphid	Ornam. plants	0.05%
Sumirody 10 FW*	Winter moths	Fruit trees	1.5 l/ha
fenpropathrin 100g/l	Leaf rollers	Fruit trees	1.5 l/ha
	Onion thrips	Ornam. plants	0.075%
Midol 2200*			
vegetable oil	Two spotted mite	Glassh. crops	2.0%
SC 128 500 SL*	Peach-potato aphid	Ornam. plants	0.08%
diafenthiuron 500g/l	White fly	Ornam. plants	0.08%
	Two spotted mite	Ornam. plants	0.08%
MicroGermin A			
Verticillium lecani	Two spotted mite	Glassh. crops	3.5 g/l
3×10^8 spores/g			
MicroGermin F			
Verticillium lecani	Two spotted mite	Glassh. crops	3.5g/l
3×10^8 spores/g			

* Not registered by the National Agency of Environmental Protection by the 1st January 1991.

G. DEPARTMENT OF WEED CONTROL

Head of department: K.E. Thonke

Scientific staff:

Peter Kryger Jensen and Svend Christensen; Applied research with chemical weed control in agriculture including work on competition and threshold

Peder Elbæk Jensen and Per Rydahl Nielsen: Testing and approval of herbicides and growth regulators in agriculture

Georg Noyé and Anette Binder: Weed control and approval of herbicides in horticultural crops

Thomas Rubow and Ole Hansen: Weed control and approval of herbicides in forestry and windbreaks

Per Kudsk, Jens Kristensen, Solveig Kopp Mathiasen and Hanne Juul Pedersen: Research on factors affecting the efficiency of herbicides

Bo Melander, C. Holm-Nielsen and Ilse A. Rasmussen: Population dynamics of weeds

Jesper Rasmussen, Jakob Vester and Anders Nemming: Weed control by means of non-chemical methods

Ole Permin and Ebbe Nordbo: Research on spray technique and drift

Ole Permin and Marianne Baandrup: Advisory service

The staff includes 21 scientists and 31 assistents.

The research work concentrated on chemical and non-chemical weed control and population dynamics of weeds.

Testing of new herbicides or older herbicides in new areas of application has been carried out in agriculture, horticulture and forestry. This work was performed at growers´ sites all over the country.

As a result of the reevaluation of older herbicides prepared by the National Agency of Environmental Protection, presumeably 1/3 of the current active ingredients will disappear from the Danish market. There will be a pronounced decrease in the number of cultures, in which herbicides can be applied in future. This will cause large problems for weed control, particularly within horticulture and forestry, and therefore research - looking for alternative herbicides and control methods - has been carried out.

In agricultural crops field trials have been carried out to optimize efficacy of herbicides by:

1. spraying on weeds at different stages of development, including split treatments.

2. relating herbicide treatment to climate (i.a. +/- dew, time of application during the day)

3. tank mixing with other pesticides or additives

4. performing experiments with application technique (spray drift, biological effect of new types of field sprayers)

In addition experiments concerning long-term result of control strategies have been established.

In controlled environments in climate chambers and green houses research work in 1990 centered on: Description of synergistic and antagonistic effects between herbicides and additives including mixtures of pesticides. Studies into herbicide efficacy related to soil and climatic factors concentrated on herbicides used in rape and pea.

In 1990 research has been carried out to identify the microvariation in swath distribution of the spray drops related to speed, nozzle size and wind velocity in the field.

RESEARCH IN MECHANICAL WEED CONTROL CONCENTRATES ON:

1: Development of a spike-tooth harrow, which makes it possible to separate harvest and weed effect.

2: Development of a self steering interrow cultivator.

3: Experiments and demonstrations with weed harrowing, interrow cultivator, flame treatment and use of various cover materiel in different crops under practical conditions.

Population dynamic experiments have been carried out in the areas: weed seed production in relation to chemical control with various doses. Development of models for competition between crop cultivar and weed at different manure levels and different herbicide treatments. Concerning control thresholds work has been carried out to develop models for the species Couch-grass, Black-grass and Silky-bent-grass. An identification key for weed seeds is in preparation.

Publication and advisory activities in 1990 covered lectures for advisers and growers, publications and participation in symposia and conferences. In 1990 great efforts have been made to finish the "PC-Plantevæm" ("PC-Plantprotection"), an advisory system holding an advisory part and a guidance part. PC-Plantprotection" is expected, through the "Integrated Farm Management System" developed by the Danish Agricultural Advisory Center, to be accessible to Danish farmers in the spring 1991.

Applied research on chemical weed control in agriculture including competition and thresholds. (Peter Kryger Jensen)

The field of activity includes a broad spectrum of work on the optimization of herbicide efficiency under field conditions. A major research area has been carried out on the use of split application of herbicides. This method is now recommended for weed control in peas (see below) and research with split application are continued in other crops.
Another major area concerns on herbicide efficacy and crop tolerance at different stages of development of crop and weed.

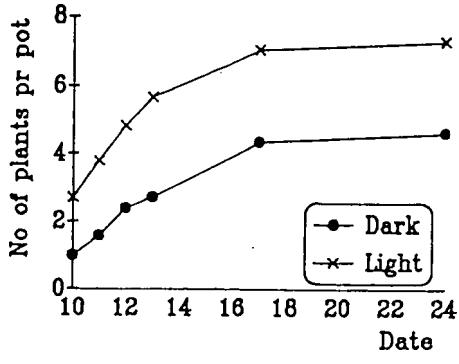
New field sprayers on the Danish market are tested for biological efficacy against weeds, pests and diseases, as well as in drift studies. The new sprayers have been compared to the traditional hydraulic Hardi sprayer with flat fan nozzles and volume rates on 150-250 l/ha. The last years has included trials with two new sprayers, Hardi Twin and Danfoil. Both sprayers are operating with air assistance and with volume rates from 30-100 l/ha.

Split application of herbicides

Split application of herbicides has in the last 3 years proved to improve weed control in peas, when compared to a single application at the same total dose. The trials with split application was extended to oil seed rape in 1990. The use of split application makes it possible to spray at an earlier stage than with single application treatment, because the single application has to await all weeds to have emerged. The first treatment with split application therefore is carried out when weeds are still at the cotyledon stage, and this is on an earlier crop growth stage than normally recommended with herbicide mixtures containing cyanazine. As the improved weed control by split application is primarily obtained because weeds are easier controlled at the cotyledon stage, trials elucidating the crop tolerance at these earlier than normally recommended growth stages has been carried out with cyanazine mixtures.

Light induction of weed seeds under field and laboratory conditions

Seeds of a number of weed species, and among them many important weeds, requires a light induction for germination to take place.
Daylight penetrating the soil decreases rapidly in intensity, and the intensity below a few millimeters of soil is insufficient to induce germination in light dependent weed seeds.
Preliminary trials in the autumn 1990 have shown that the demand for light induction can be fullfilled for a proportion of the seedbank by the short light flash during seedbed preparation in daylight. Both in the field and in pot experiment it was found that the number of emerged weeds were reduced and the emergence time were delayed with seedbed preparation and sowing carried out in darkness, compared to the same treatment in daylight (see figure). Research on this topic will be continued in the spring.



Pot experiment in glass house.
Number of emerged weeds after seedbed preparation either in daylight -x-, or in darkness -•-. All pots were kept under natural day/night conditions in the germination period

Weed suppression by cultivars (Svend Christensen)

Preliminary research at the department showed differences in the competitive ability of spring barley cultivars. Therefore a project with the aim of investigating the correlation between competitive ability and morphological and physiological characters was initiated. The project is founded by the Danish Agricultural and Veterinary Research Council and is part of the efforts of reducing the input of herbicide.

In one field experiment several characteristics are measured, but especially the canopy height, growth habit and light interception are examined. In another experiment the possibilities of using reduced doses of herbicide in different cultivars are evaluated.

Assessing competition between species by spectral reflectance index

Absorption of light, transmittance and reflectance are important crop growth character. In monoculture the reflectance from canopy is correlated to the biomass and leaf area index (LAI). Reflectance from canopies can be measured by a simple sensor technique even from

a far distance (remote sensing from aeroplane or satellite). In experimental work reflectance can be measured by portable equipments. The results with remote sensing have showed that the ratio between red and near infrared reflection from canopies (spectral reflectance index) was the most useful variable, because it was independent of soil type and moisture.

Under favourable growth conditions light is the main factor determining the growth rate of the crop and its associated weeds. The purpose of this experiments is to investigate the possibility of using the spectral reflectance index to describe the competition between species.

Testing and approval of herbicides and growth regulators in agriculture (Peder Elbæk Jensen and Per Rydahl)

Contrary to many other countries, Denmark operate with two independent procedures regarding testing and approval of new pesticides. On one hand, only effective pesticides can be registrated by the environmental authorities. On the other hand, the producers and importers of pesticides have shown interest in achieving approvals (quality-marks for marketing purpose) regarding the effect connected to a specific combination of: dosage, adjuvants, tankmixers, timing and pest spectrum. The criteria for approval implies, that new products must be as least as effective to pests, and still as less harmful to crop, as comparable products in market.

Herbicides containing new active ingredients are testet in field trials for two succeeding growth seasons. Each year 6 trials are conducted: 3 trials for harvest, testing the 1/1- and 2/1 dosage according to company recommandations. This is to evaluate any possible damage to the crop. Also 3 so called "effect" trials are conducted, testing 1/4, 1/2 and 1/1 dosage. The effect is evaluated by counting and weighing weeds by species in 3 x 0,25 m2 rings per plot. In this way results of at least 12 trials are achieved. This information is used in database systems (see elsewhere in this paper) in order to guide farmers, and in that way meet the legislation demands of reducing pesticide use. New herbicides containing known active ingredients are normally tested to a reduced extent.

The requests by companies are being still more specific regarding weed spectrum. In order to attain the desired weed populations, most trials are located at farmers', distributed over a rather great territory of Denmark.

This season much effort has been put into the field of annual monocotyledons, eg. *Poa Annua, Alopecúrus myosurídes* and *Ápera spica-vénti*. Results of 1989/90 indicate, that acceptable effects can be achieved with reduced dosages by early autumn applications.

The results of 1989/90 are characterized by the well developed weed in the spring due to a very mild winter. Therefore, particular by spring applications in winter crops, many trials have shown unsatisfactory effects, especially for less susceptible species treated with reduced dosages.

In 1989/90 Institute of Weed Control was requested to conduct test concerning 87 approvals. Some products were notified to various purpose, why the number products/combination of products were 43. By the end of 1990, 63 approvals were granted. These products have not all been registered yet.

The in 1990 approved new active ingredients are listed in table 1.

Table 1.

Approved new ingredients for weed control 1990

Active ingredient	Crops	Selected "problem" Weeds
propaquizafop	broadleaved	*Agropyron repens*
fluroxypyr*)	cereals *Galeopsis* spp. *Veronika* spp. *Matricaria* spp.	*Galium aparine*
imazamethabenz	winterwheat spring wheat spring barley	*Avena fatua*
buminafos	peas potatoes	Dessication of crop
tribenuron methyl (tablet)	cereals *Matricaria* spp. *Polygonum* spp.	*Galeopsis* spp.
sulfosate	spring rape peas *Agropyron repens* cereals	Dessication - -
ioxaben *)	winter barley winter wheat *Veronica* spp. *Myosotis arvensi*	*Matricaria* spp. *Viola arvensis*
fenoxaprop-ethyl	winter wheat *Avena fatua* *Alopecúrus myosu.*	*Apera spica-vent*

*) tankmixed or formulated with other active ingredients

Weed control and approval of herbicides in horticultural crops - including vegetables as well as fruit growing and nursery culture. (Georg Noyé and Annette Binder).

Our work in 1990 has primarily been concentrated finding alternative herbicides and alternative weed control methods to replace the herbicides which are revoked by the reevaluation (carried out by the National Agency of Environmental Protection). At present 15 active ingredients have been prohibited and 9 more are revoked by the reevaluation, but they are appealed to the Environmental Appeal Board.

In the 1990 growing season 31 herbicides and 1 sprout inhibitor (growth regulator) were tested.

The distribution between crops was 3 in onions, 2 in carrots, 2 in cabbage, 4 in green peas, 5 in sweet corn, 1 in beetroots, 3 in strawberries, 1 in lawns, 10 in different nursery crops, 2 in orchards and 5 in fruit bushes.

The chemicals mentioned below has all obtained approval for use, or extended approval for use by the Danish Service for Plant and Soil Science.

Products with * has not yet obtained an approval to be used from the National Agency of Environmental Protection.

1. Agil* (propaquizafop 100 g/l) was given approval for control of couch grass in peas.

2. Antergon MH 180 (maleinhydrazid 180 g/l) was given approval as sprout inhibitor in onions.

3. Basta* (glufosinat 200 g/l) has had the approval extended to include control of suckers in cherries and strawberry runners.

4. Basagran 480+ Stomp SC* (bentazon 480 g+ phendimetalin 400 g/l) given approval for split application in peas.

5. Bentanal Plus (phenmedipham 160 g/l) has had the approval extended to include weed control in beetroots.

6. Dimefuron WP* (dimefuron 500 g/kg) has had the approval extended to also include broccoli and cauliflower.

7. Dual 720* (metholachlor 720 g/l) has had the approval extended to also include broccoli and cauliflower.

8. Fusilade EW 25% (fluazifob-p-butyl 250 g/l) was given the same approval as Fusilade EW 12.5%.

9. Karmex DF® (diuron 800 g/kg) has had the approval extended to also include weed control in nursery crops of oak, Malus sargentii, Pinus spp. and snowberry.

Weed control and approval of herbicides in forestry and windbreaks. (Thomas Rubow and Ole Hansen)

In the autumn of 1989 the seed production of beech was extraordinary rich wich lead to the establishment of several thousand hectars of natural regenerations all over the country. This opportunity was utilized for investigations concerning the effect of weed control carried out during the youngest stages of the regenerations. After one year the observations preliminary spraying with Roundup seems to be of vital importance for the development of weeds regardless of complementary herbicide application. It is clearly demonstrated that preemergence application of propyzamide and terbuthylazine decreases the amount of beech seedlings.

The reevaluation of herbicides (carried out by the National Agency of Environmental Protection) is expected to remove some of the most important forestry herbicides from the Danish market.

Herbicides are mainly utilized for weed control in Christmas tree plantations and in stands for production of decoration greenery. These products are of great importance for Danish forestry and make out an export income of nearly 0,5 mia. Dkr. (1990). The research for the next few years will undoubtly mainly concentrate on finding substitutes for the resigned herbicides.

Plantation forestry in surplus agricultural land

The afforestation on the majority of the area expected to be left out of intensive farming in the future, causes a need for preparing and advising rational, environmentally compatible plans for weed control in plantations on former marginal farmland.

On the basis of this, a research project called "Utilization of pesticides at the establishment of forest on marginal farmland" has been started.
The aim of this project is to develop a system, which can provide a more efficient use of herbicides, as well as information of non-chemical weed control.
The achivement of the aim involves a interplay between the need for weed control, economy and environment.

The system is based on an information data base, which can give information on the preparing weed control at the establishment of the plantation as well as on the use of

pesticides and mechanical weed control in existing plantations. The basis for such an information data base is the content of data comprising results from trials on weed and pest control in forests, windbreaks and first generation of plantations on previous farmland.

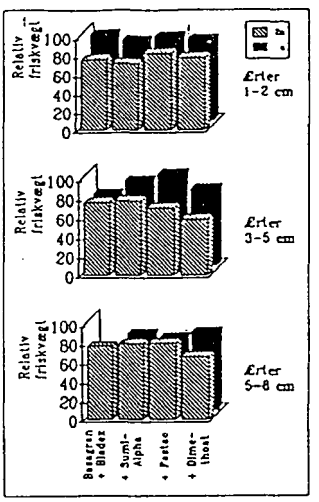
In order to procure supplementary results for the data base, trials in plantations of relevant wood species established on former farmland have been started. The objective of the trials is to test the effect of various soil applied herbicides on weeds and the tolerance of the woody plants in relation to soil cultivation/non-soil cultivation on dry and sandy soils. The experience gained from these new trials will, together with the existing knowledge, form the basis of the input to the system.

RESEARCH ON FACTORS AFFECTING THE EFFICIENCY OF HERBICIDES

Pot and semi-field experiments (Per Kudsk, Solveig Kopp Mathiassen, Jens Kristensen and Hanne Juul Pedersen)

Influence of application variables on the tolerance of pea to herbicides

The tolerance of pea to cyanazine, cyanazine+ bentazone and pendimethalin+bentazone+MCPA was examined in semi-field experiments. Volume rate (150 l/ha using a Hardi 4110-14 flat fan nozzle and 300 l/ha using a Hardi 4110-24 flat fan nozzle) as well as application in mixture with various insecticides had no influence on the tolerance of the pea plants, although more herbicide was deposited on the pea plants using the Hardi 4110-14 nozzle. Growth stage, however, was found to influence the susceptibility of pea; 3-5 cm high plants being more susceptible than 1-2 and 5-8 cm high plants Although significant, these differences were not very pronounced.



Tolerance of peas at 3 growth stages to bentazone+cyanazin applied alone and in mixture with insecticides. The relative fresh weights are shown for normal (n=400 g/ha bentazone + 500 g/ha cyanazin) and double dose. Application technique: 4110-24 nozzle, 250 Kpa and 325 l/ha.

Effect of increasing doses of adjuvants on herbicide activity.

The effect of various herbicides in mixture with 10-12 doses of a recommended adjuvant was examined in pot experiments. The objective of the experiments was to describe the relationship between adjuvant dose and herbicide activity. It was found that the sigmoid curve, previously used to describe herbicide dose-response curves, was applicable when describing the relationship between relative potency of the herbicide and adjuvant dose.

Efficacy and rainfastness of various herbicides in mixture with a series of nonyl-phenol-polyethoxylate surfactants

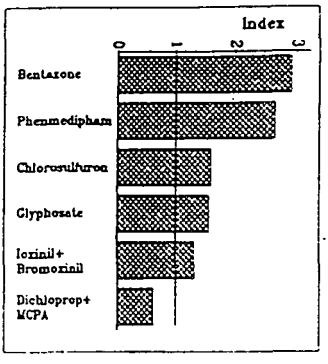
The effect and rainfastness of the sulfonylurea herbicide, tribenuron applied alone and in mixture with 0.1% (w/v) of a series of nonyl-phenol-polyethoxylates (HLB ranging from 8 to 18). Preliminary results on 2 plant species indicate that the surfactant optimizing activity do not provide optimum rainfastness.

Effect of photosystem II inhibiting herbicides on atrazineresistant *Chenopodium album* L

Seeds of atrazine-resistant *Chenopodium album* L biotypes was collected in a maize field treated with atrazine for 7 years. Whereas a susceptible biotype was controlled by 180 g/ha atrazine, 11 kg/ha atrazine had virtually no effect on the resistant biotypes. The resistant biotypes was also resistant to metamitron and methabenzthiazuron (R/S=1.7 to 4.5) whereas a negative cross resistance to dinoseb, bentazone and ioxynil was found (R/S=0.3 to 0.7). In Denmark a mixture of atrazine and bentazone is commonly used to control atrazine-resistant weed species, and the results indicate, that a reduced bentazone dose can be applied.

Influence of soil moisture on the activity of foliar-applied herbicides

A series of experiments have shown that the activity of most foliar-applied herbicides is significantly reduced under low soil moisture conditions. The effect of soil moisture was most pronounced with photosystem II inhibiting herbicides whereas the activity of the phenoxyalkanoic acid herbicides was not affected by soil moisture. Generally, a reduction in herbicide activity was found before any visual effects on plant growth was apparent.
Experiments were initiated to assess whether the effect of soil moisture on herbicide activity could be eliminated by including adjuvants in the spray solution



Effect of water stress on the efficacy of different herbicides.
The index indicates how much the dosage of the herbicide should be increased (index >1) or reduced (index <1) in order to obtain the same effect on water stressed plants as an non stressed plant.

Influence of soil type on the activity of soil-applied herbicides

It is well known that soil type have a pronounced influence on the activity of many soil-applied herbicides. A 5-year project was initiated to quantify the differences in activity on various soil types. The objective is to be able to relate the recommendations for soil-applied herbicides to soil type (factor-adjusted doses). Based on results from pot experiments, relationships between herbicide activity and soil properties will be established and tested in the field. The results from this project will be incorporated in the computer-based advisory system which has been developed at our institute.

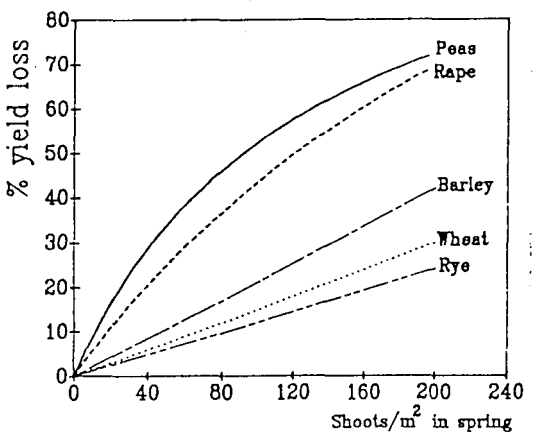
POPULATION DYNAMICS OF WEEDS

Grass weeds population dynamics and tresholds (Bo Melander)

Biologi and control of weeds in crop rotations predominated by winter cereals and winter rape.

The area with winter crops in Denmark has risen considerably in recent years.
More winter crops are expected to change the composition of weed species in the fields. In order to investigate the changes as well as other aspects concerning weed problems in winter crops a 5-year project was started in 1988. The project will mainly include research into the population dynamics and the economic importance of the weeds: Couch (*Elymus repens*), Silky Bent-grass (*Apera spica-venti*), Cleavers (*Galium aparine*), Annual Meadow Grass (*Poa annua*) and Black Grass (*Alopecurus myosuroides*).

Yield losses in 5 different crops due to competition from Couch is investigated in the field. Results from 1989 and 1990 are shown in the figure as average of the two years.



Yield losses in winter rye, winter wheat, spring barley, spring oilseed rape and peas as a result of competition from Couch (*Elymus repens*).

The trials also will give information about other biological aspects like emergence patterns of shoots production of secondary shoots influences on the yield components of the crops, etc.

In the autumn 1990 competition studies in the field with Silky Bent-grass in winter wheat and rye and Black Grass in wheat were started. Yield losses in the crops, emergence patterns of the weeds, weed seed production in relation to increasing weed density and mortality of weed plants will be of main interest.

Weed seed bank (C. Holm-Nielsen)

Investigation of methods for seed-identification and quantification of the seed-bank of cultivated soil was continued in addition to this.

Preparation of a key for weedseed-identification with specifications and photos are under development.

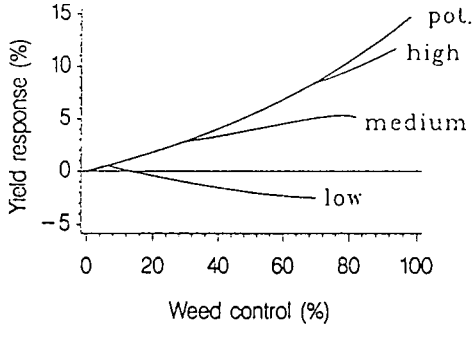
Weed seed production in relation to different methods and intensities of weed control (Ilse A. Rasmussen)

A project supported by the Danish Agricultural and Veterinary Research Council was started in 1989. The aim of the project is to establish the fate of weed seed production as a result of reduced herbicide usage and/or mechanical weed control. Experiments are conducted with sown-in weeds or test-plants in cereals, treated with various herbicides in a range of doses. The seed production and the seed gain is measured and correlated to weed size and treatment. Preliminary results indicate that reducing herbicide dose to an extent where weed control is satisfying with respect to yield and other important factors, will not cause an increase in the weed seed reserve in the soil. Further experiments are planned.

WEED CONTROL BY MEANS OF NON-CHEMICAL METHODS

Mechanical weed control in agricultural crops (Jesper Rasmussen)

The main activity has been to develop the mechanical weed control of seed propagated weeds in cereals and legumes. Two principles have been considered, harrowing and row cultivation. With respect to harrowing the aim has been to develop a model able to describe the crop yield response of harrowing. The modelling approach makes it possible to optimize the application of harrowing because it is able to seperate yield response into two parts, one coming from the positive weed killing effect of harrowing and another coming from the negative effect of crop damage. The crop damage is caused by soil covering of the crop due to harrowing. It has been shown that the ratio between weed control and crop covering is a very important factor. This ratio is defined as the selectivity of treatment. Only when conditions of selectivity are favourable harrowing seems to be an efficient method of weed control. Conversely when selectivity is low harrowing is not a suitable weed control method.



An example of the importance of selectivity in relation to the yield response of weed harrowing. The potential yield response (=pot.) is the yield response without crop damages due to weed control

Further investigations on selectivity have to be carried out before a general evaluation of weed harrowing can be made. In respect to row cultivation the main object has been to develop a steering system for hoes. The project is supported by the Ministry of Environment and made in cooperation with The Royal Veterinary and Agricultural University.

Weed control by means of non-chemical methods (Jakob Vester)

Experiments with synthetic cover materials for weed control in windbreaks were initiated in 1990. Different materials and different widths of coverage are investigated. Different types and treatments of straw for mulching also are investigated.

Flame treatment for desiccation of potato leaves was compared with Diquat treatment and mechanical cutting. In order to save gas the combined effect of flame treatment and root cutting was investigated.

Harrowing for weed control was tried in sown onions and carrots, at different times. The effect was compared with herbicide treatments and flame cultivation. Results so far show that monitoring the effect on weeds from different ploughing depths, levels of slurry, straw incorporation and nitrogen levels are monitored in four different integrated crop rotations. Weed control is applied in accordance with the actual weed flora and very low doses of herbicides are used.

Weed control in organic farming (Anders Nemming)

18 organic farms in Denmark are studied intensively in a cooperation of different research institutes.

Together with The National Institute of Agricultural Engineering, the Institute of Weed Control is following the existing weed situation, the actual aims of weed control and the obtained weed controlling effect.

In 1990 we have started to introduce new machinery, strategies and intensive advisory activity on some of the farms.

We make tests with the new machinery on the farms to show the farmers the potentials of the machinery and how to use it.

RESEARCH ON SPRAY TECHNIQUE AND DRIFT

The influence of wind on spray application efficiency and herbicidal effects. (Ebbe Nordbo)

Though spray application techniques are still being developed world-wide, deposition variability still causes a loss in effectivity, especially troublesome with the dose reductions generally aimed at. Also drift is of major environmental concern.

Studies so far with fullscale field sprayers as well as with smaller boom sections indoor has shown, that the magnitude of plant-to-plant variability is greatly dependent on application technical factors such as nozzle type and driving speed. But also wind plays a major role in these contexts, and more basic studies in this project of wind/application relations hopefully will give clues to improved techniques. It was thus found, that airassisted spraying generally improves efficiency through an increasing of averages and lowering of variability, and especially the application of finer and more biologically effective drop-size-spectra is facilitated.

Also physiological effects of wind are studied, but in experiments so far physiological interactions of wind and herbicide has proven relatively weak.

ADVISORY SERVICE

PC-Plant Protection, Weeds (Marianne Baandrup)

An advisory information system for personal computers has been developed which can help farmers and advisers in the decision-making process concerning herbicide management.

Based on user-input on crop status, weeds present, their number and development PC-Plant Protection, Weeds can select a relevant herbicide for weed problem in the field, adjust (reduce) the herbicide dose according to the weed species and their growth stages, and make more information on weed control available for the user.

"PC-Plant Protection, Weeds" has been developed for weed control in cereals, peas and oilseed rape. The recommendations of the programme have been tested in field trials during the last four years, showing there are great potentials in adjusting the herbicides dose to weed species and growth stages in order to achieve a reduction in the amount of herbicide used.

The system (ver. 1.0) is being released in the spring 1991, as part of the "Integrated Farm Management System" developed by the Danish Agricultural Advisory Centre and can be used by farmers and extension.

Data on how the climatic conditions affect the field performance of the herbicides are needed to refine the advice of the system.

Strategies for weed control in sugar beets and other crops, where a split-application of herbicides is required must be developed for the programme.

Annual updating of the programme is a "must" in order to supply the farmer with new knowledge. An expansion of the information part with hypertext, and pictures of weed species (CD-ROM technology) will be considered, too, as well as expert system technology and the use of intelligent information retrieval system.

II. DEPARTMENT OF PESTICIDE ANALYSIS AND ECOTOXICOLOGY

Head of department: Arne Helweg

Scientific staff:

Susanne Elmholt: Effect of pesticides on the soil microflora
Gitte Felding: Determination of leaching of pesticides
Erik Kirknel: Fungicides and insecticides in plants
Peder Odgaard: Herbicides in plants and soil

The department supports the experimental work at the research centre with chemical analysis of pesticides. Furthermore, the department is using increasing resources on terrestrial environmental research. The main objective are determination of the fate of pesticides in the terrestrial environment and the environmental consequences of the use of pesticides. The experiments are carried out by means of both chemical and biological methods and the main tasks are the following.

1. Residue analysis of pesticides in crops and soils in cooperation with the experimental work at the centre.

2. Determine degradation, adsorption and transport of pesticides in soil.

3. Analyse infiltrated water in field and lysimeter studies to determine the risk of leaching of pesticides out of the root zone.

4. Determine the influence of pesticides on soil microorganisms.

5. Participation in determination of pesticide transport and deposition during spraying and determine exposure of spraying personnel to pesticides.

The department is equipped with analytical instruments: gaschromatographs with EC, NP, HW and FPD-detectors and gaschromatograph with mass spectrometer. To determine drift of pesticides, fluorescent compounds are used, these are determined by fluorometry. Adsorption and degradation and leaching in lysimeter experiments are followed by ^{14}C-labelled compounds and determined by scintillation counting.

The staff consists of 5 scientists, 6 laboratory technicians and 2 to 4 MSc-students.

Effect of pesticides on the soil microflora and on the decomposition of organic material (Susanne Elmholt)

Side-effects of pesticides, especially fungicides, on the composition and the activity of the soil microflora has been studied. As straw burning in the field has been banned, special regard has been paid to the effect of fungicides on straw decomposing fungi. Furthermore, the composition of fungi in organically cultivated soils has been studied with special regard to *Penicillium* and *Fusarium*.

Leaching of pesticides from fields and forestry (Gitte Felding)

On 5 selected localities stainless steeltubes have been set up. The tubes (3 at each locality), have been placed in the soil for collection of water, leaving the root zone. Samples are taken during the winter and analysed by GC/MS.

Until now water has been sampled from 2 clayey localities planted with Christmas trees. The concentration of atrazine, hexazinone and degradation products of both have been determined by GC/MS.

Degradation and adsorption of pesticides in surface and in subsurface soils (Arne Helweg)

Influence of soil temperature, soil type and concentration on pesticide degradation is detemined by use of ^{14}C-labelled pesticides. In the experiments, mecoprop (MCPP) has been used as a model compound.

Degradation of ^{14}C-labelled mecoprop (MCPP) has also been determined in soil cores sampled in the unsaturated zone at 1 meter's depth. In most cases degradation appears, also in these subsurface soils but normally the degradation rate is low and rarely exceeds 1/10 of the degradation rate in surface soils.

Insecticides, fungicides and growth regulators on plants (Erik Kirknel)

Effect of ethephon on rats and residue of ethephon in rat tissue

National Institute of Animal Science is feeding rats with ethephon contained in diet and measuring different biological parameters such as biological value of ethephon sprayed barley. The Laboratory has analysed heart, testicles and muscles for ethephon. No ethephon was found.

Deposition of pesticides on spraying personnel

In cooperation with the Danish Agricultural Engineering Institute it was investigated how the spraying personnel is contaminated in a normal agricultural spraying situation. 90% of

the contamination took place at mixing and loading and only 10% when spraying in the field. Recommendations for spraying personnel regarding protective means have been worked out.

The influence of formulation and additives on rainfastness of dithiocarbamates

In semi-field experiments it was determined that formulation and additives to a very high degree influenced the rainfastness of dithiocarbamates. The experiments were made in pea and potatoes.

Lysimeter experiments and analyses for herbicides and plant growth regulators etc. (Peder Odgaard and Arne Helweg)

6 lysimeters consisting of monoliths of 0,5 m^2 x 1 m were installed according to the principle developed by Prof. Fritz Führ, Institute of Radio-Agronomy, Jülich. The lysimeters are used to determine degradation and transport of pesticides under more natural conditions than in the laboratory. Experiments with clopyralid, isoproturon, mecoprop and atrazine are in progress. The transport of water is determined by ^3H-labelled water.

The analytical work with the growth regulating agent uniconazole has been finished. When determining its relative distribution between soil and water phase, this chemical seems to be relative strongly adsorbed to pot soils.

The distribution between soil and water is also the topic in a series of herbicide analyses. They are carried out mainly to support the interpretation of the biological effect of soil herbicides in different Danish soils.

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