Danish Institute of
Plant and Soil Science

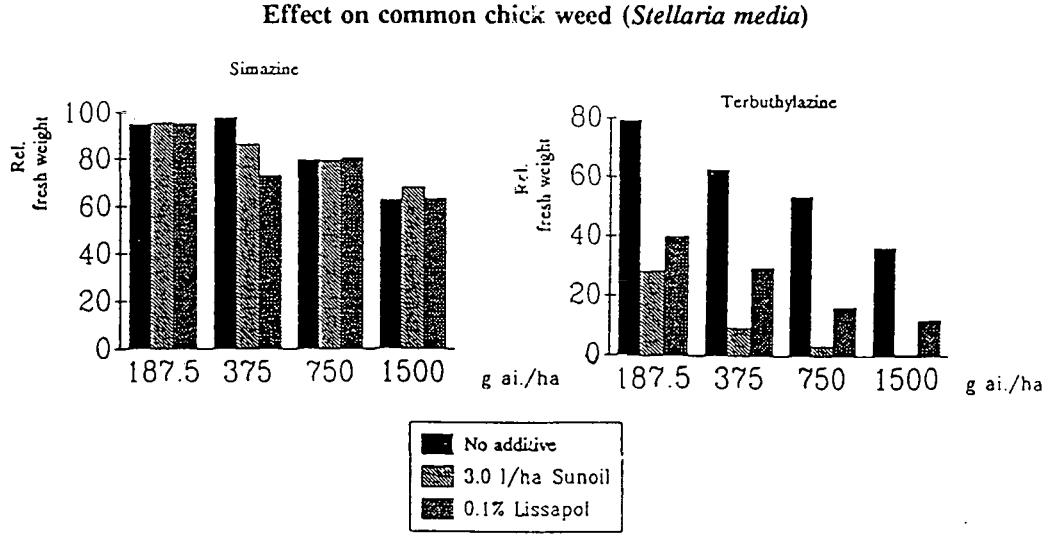
Plant diseases, pests and weeds in Denmark 1991

108th annual report
Compiled by
The Research Centre for Plant Protection

Lyngby 1992

CORRECTION SHEET

Figure page 39



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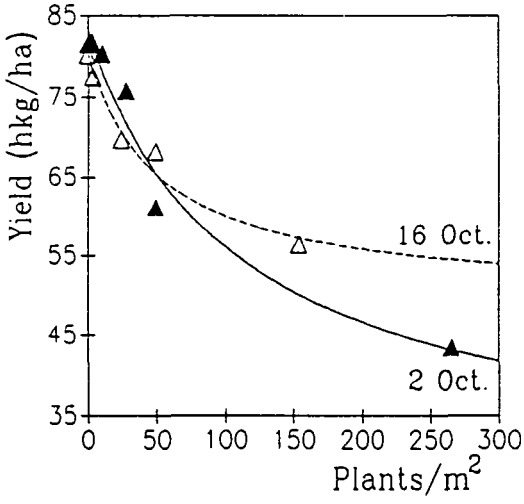

The relationship between density of *Alopecurus myosuroides* and kernel-yield in winter wheat drilled 2nd and 16th October, respectively

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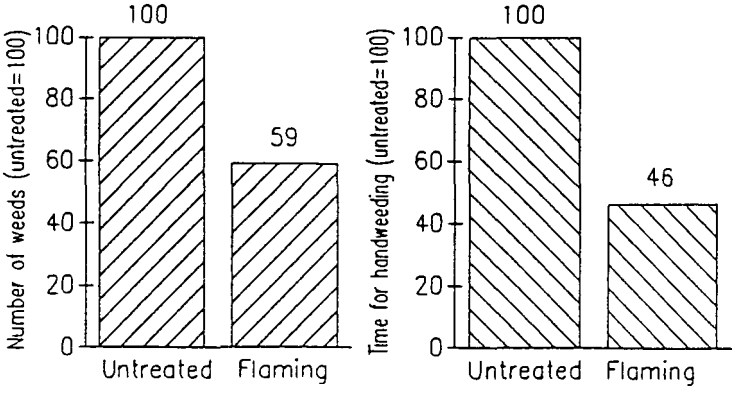

An example with pre-crop-emergence flame treatment in beet

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Contents

A. DANISH RESEARCH CENTRE FOR PLANT PROTECTION

Director: E. Henning Jensen

The Research Centre for Plant Protection is the Ministry of Agriculture's key research institute 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 (until 31.5.91) Ib G. Dinesen (acting from 1.7.91)
Biotechnology Group	Peter Ulvskov
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 concerning 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.

The Research Centre for Plant Protection is hosting the Biotechnology Group, which at the moment employs five 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.

The Centre 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 of Pest Management, respectively.

These reorganizations have already resulted in better utilization of resources and better planning 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.

During 1991, much effort has been put on the elaboration and planning of a new research programme under the Ministry of Agriculture, "Plant Protection towards 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 8th Danish Plant Protection Conference was held on March 5th and 6th, 1991 attracting about 640 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 Institute of 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 the 167 employees, about 104 are located at Lyngby and 63 at Flakkebjerg.

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

	SO	TS	Total
Administration and common functions	3	21	24
Department of Plant Pathology	17	20	37
Department of Pest Management	14	16	30
Biotechnology Group	5	4	9
Advisory Service	3	1	4
Department of Weed Control	21	31	52
Department of Pesticide Analysis and Ecotoxicology	5	6	11
Total	68	99	167

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 1991, the total expenses of the Research Centre for Plant Protection amounted to about 48 mio. DKK.

C. DEPARTMENT OF PLANT PATHOLOGY

Head of Department: **Arne Jensen** (until 31.5.91)
Ib G. Dinesen (acting from 1.7.91)

Scientific staff:

Karen Bech: Bacteria in meristem cultures.
Lars Bødker: Root pathogenic fungi in peas.
Ib Dinesen: Bacterial diseases.
Mogens S. Hovmøller: Virulence analysis of mildew and yellow rust of barley and wheat.
Hanne Lipczak Jakobsen: Diseases in 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 for 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 for 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)

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 3) are described the regulatives concerning pesticides.

In 1991, 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 24) and a number of experiments with decision models for control of leaf diseases of barley and wheat. Furthermore a number of experiments were carried out 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 maintenance 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 are 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.

1. DISEASES OF CEREALS

Virulence surveys of pathogenic fungi on cereals (Mogens S. Hovmøller and Boldt Welling)

The virulence surveys continued in 1991 and comprised the pathogens *Erysiphe graminis* f.sp. *hordei*, *Erysiphe graminis* f.sp. *tritici*, *Puccinia striiformis*, and *Puccinia hordei*. The surveys were carried out based on random samples of aerial powdery mildew spores, and random isolates of yellow rust and brown rust obtained from specific wheat and barley varieties, respectively. A total of 235 isolates of barley powdery mildew, 70 isolates of wheat powdery mildew, about 100 isolates of wheat yellow rust, and 65 isolates of brown rust were assayed by differential sets of varieties possessing known genes for resistance to the different pathogens.

Barley powdery mildew: Only minor changes in virulence gene frequencies occurred during 1991. The frequency of isolates virulent on varieties possessing *Mla3* (V_{a3}) and *Mla13* (V_{a13}) increased to a level of 30% and 40%, respectively. The virulences V_{a7} and V_{a12} matching to the most frequent resistances in barley cultivars grown in Denmark were observed in

frequencies from 70-85%, whereas the frequency of V_{La} was about 40%. Virulence on 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% .

Wheat yellow rust: Isolates of the yellow rust pathogen were collected at 4 localities from the varieties Sleipner possessing *Yr9*, and Kosack and Anja apparently without specific yellow rust resistance. The preliminary results show only minor differences in virulence spectra between isolates within each locality. The most common phenotype possessed the virulences *VYr2*, *VYr3a+4a*, *VYr3b+4b*, and *VYr9*. A few isolates possessing the virulences *VYr6* and *VYr9* were found as well. Virulence on varieties possessing *Yr5*, *Yr7*, *Yr8*, or *Yr10* was not observed.

Barley brown rust: Brown rust on barley occurred late and very sporadic in the growth season 1991, and therefore only a few isolates were collected. Virulence on varieties possessing *Pa1*, *Pa2*, *Pa4*, *Pa6*, *Pa8* or *Pa9* was observed in high frequencies, while 13% and 40% of the isolates were virulent on varieties with *Pa5* and *Pa3*, respectively. All isolates were avirulent on the differential variety with *Pa7*.

Identification of race-specific resistance to brown rust in Danish spring barley varieties (Boldt Welling)

Race-specific resistance to brown rust was investigated in 73 commercial spring barley varieties by use of 7 differential isolates of *Puccinia hordei*. A total of 39 varieties were susceptible to all isolates, whereas the two varieties Canut Carlsberg and Dorret were resistant to all isolates. The remaining part of the varieties possessed different number of known and unknown resistance genes. The work will be continued in 1992 by use of additional differential isolates for a better discrimination of resistance genes in the varieties.

Modelling the dynamics of gene frequencies in populations of *Erysiphe graminis* (Mogens S. Hovmøller)

Models were developed to investigate observed and predicted changes in virulence gene frequencies in a local aerial powdery mildew population subject to selection by different host cultivars in a local barley area. Gene frequencies in the pathogen population were estimated from 11-locus virulence genotypes assayed through a virulence survey. Predictions were based on a model system, where selection forces were estimated through detailed mapping of host cultivars in the area considered, and taking into account the changes in distribution of host cultivars during the year due to growth of both autumn sown and spring sown host crops. For most samples, the observed virulence gene frequencies were in accor-

dance with the gene frequencies predicted. For the remaining samples, differences between observed and predicted gene frequencies could be explained to a large extent by discrepancy between the relative acreage on which the cultivars were sown and the actual amount of green foliage of different host cultivars being substrate for the pathogen, and difficulties in collecting spore samples being representative for all the powdery mildew sub-populations produced on the host cultivars. The results emphasized the importance of knowledge about sources of samples when analyzing changes in gene frequencies in an aerial powdery mildew population.

Seed borne diseases in cereals (Bent J. Nielsen and Lise Nistrup Jørgensen)

Bunt of wheat (*Tilletia caries*)

For the past three years (1989, 1990, 1991) there have been several reports on attacks of *Tilletia caries* in wheat. To prevent an epidemic to break out only products with very high efficacy will be recommended for control of Tilletia. Trials with artificial inoculation (5 g spores per kg wheat) and different dose levels of seed treatment gave only 86% control of *Tilletia* with 200 ml Panoctine 30 (21 trials 1975-1991, 60 g guazatine/100 kg), while 100 ml Sibutol LS 280 gave 100% control. With a dose of 50 ml the effect of Panoctine decreased to 61%. Sibutol LS 280 gave at that level still 100% control. In trials with lower disease levels (under 10% plants attacked) the effect of Panoctine 30 was 95%. Sibutol gave 100% control even at disease levels above 30% plants attacked. Trials with Neo-Voronit gave the same results as with Panoctine 30. From 1992 the *biological approval* of Panoctine 30 (and other products containing pure guazatine) and Neo-Voronit for control of Tilletia caries has been withdrawn. These products will be recommended only for seed treatment against *Fusarium* spp. and *Septoria nodorum*. The only liquid formulation with approval against *Tilletia caries* is Sibutol LS 280 (100 ml/100 kg). Different formulations of Beret (fenpiclonil) has an approval but is not on the market yet. The only powder formulation with approval is Derosal M, 150 g/100 kg (carbendazim + maneb).

Stripe smut of rye (*Urocystis occulta*)

Field trials with artificial inoculations are carried out as routine, but the disease is rarely seen in Danish agriculture, although it can be seen when rye has been grown for several years without treatment. Control is easy and the approved products have an efficacy level about 100% (e.g. Sibutol LS 280, 100 ml; Beret 050, 200 ml and Beret Combi, 200 ml).

Loose smut of barley (*Ustilago nuda*)

Ustilago nuda has been seen in many barley varieties especially in winter barley (e.g. the variety Trixi). In winter barley the control of Ustilago with carboxin is only at the 90%-level, whereas the control in spring barley is about 99%. Development of fungicide resistance is being investigated. Many new products has been approved against *Ustilago nuda*, but they are not yet registered for use (Ferrax, Vincit, Raxil and Beret FS 285).

Leaf stripe on barley (*Drechslera graminea*)

Because of efficient seed treatment stripe diseases are now rare in Denmark, but occur where seeds are sown for several generations without treatment. The efficacy level of the approved products is 99-100%. In many products imazalil is standard with 5 g/100 kg. Several new products have been approved in combinations with imazalil (flutriafol + imazalil, tebuconazol + imazalil and fenpicolnil + imazalil).

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

Trials were carried out in glasshouse compartments and in semi-field trials outside. Plants were artificially inoculated with either *Septoria tritici* or *Septoria nodorum*. Folicur 250 ew and Sportak 45 ec showed good preventive and curative effect in the trials. The use of reduced dosages (½ and ¼ of the normal rate) shows that the period for optimal control is reduced considerably. Application should not take place before rainy periods have taken place as the trials show lower efficacy when fungicides are used prior to inoculation. Knowledge of the latent period of the diseases is necessary in order to adjust time and dosage for an optimal curative treatment.

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

Eyespot (*Pseudocercosporella herpotrichoides*)

The mild winter 90/91 and the cold and wet June were favourable to the development of eyespot. Chemical treatment with half dose was recommended in 25 per cent, and with full dose in 25 per cent of 113 examined wheat fields. The summer estimates showed moderate-severe attacks, over 40 per cent straw with moderate-severe attacks in more than half of the 97 examined fields.

In 1991, the first observations of *Tapesia yallundae* were made in Denmark, the telemorph of *Pseudocercosporella herpotrichoides* on wheat straw, in a field in Jutland. In 1991, many mixed infections of eyespot, sharp eyespot and Fusarium were observed.

Sharp eyespot (*Rhizoctania cerealis*) was widespread in 1991 but with weak infections.

Take all (*Gaeumannomyces graminis*) occurred in 1991 with moderate-severe attacks only in 15 per cent of the 98 examined wheat fields. Especially in the 2nd of two successive years with wheat on light clay soils severe attacks were found.

Control of fungal diseases in winter wheat (Lise Nistrup Jørgensen, Bent J. Nielsen, S. Stetter and Jørgen Simonsen)

A total of 30 trials were carried out in winter wheat in 1991 in order to test different fungicides applied for different purposes.

All tested fungicides contained ergosterol inhibitors. The trial plans were designed to provide background for approval of products, to give information on reduced dosages and to test different spraying strategies, including PC-Plant Protection, which is a computer model developed by the Research Centre for Plant Protection.

In spring, moderate attacks of eyespot (*Pseudocercosporella herpotrichoides*) were found. A single application of Sportak 45ec in spring gave, on average, 32% control and increased yield by 2.7 hkg/ha. Split application of Sportak using 0.5 l/ha in the autumn and 0,5 l/ha in the spring improved the effect somewhat as seen before, however, the yield was only increased a little. A late application at g.s. 32 was tested. The effect was similar or better that treatments at g.s. 29-30 and 31.

Septoria spp. The two diseases *S. nodorum* and *S. tritici* were widespread in 1991. As an average of the trials 26% of the green leaf area was attacked at g.s. 75-85. Most severe attacks were seen in the varieties Sleipner and Pepital. *S. tritici* dominated during most of the season but *S. nodorum* was seen in several fields late in the season. Good control of *Septoria* was obtained by several products containing tebuconazol, propiconazol, prochloraz or flusitazol using split applications (g.s. 37 and 55) 2 x 0.3 l of normal dose/ha. One application at g.s. 55 using only 0.3 l/ha gave too poor control of *Septoria* because of a too late application (close to symptom expression). PC-Plant protection was tested in 6 field trials and gave satisfactory disease control and yield response compared to 4 x 0.3 and 3 x 0.3 l/ha Tilt-top. Dosages below 0.25 gave unacceptable control when only 2 or 3 applications were used.

Wheat powdery mildew (*Erysiphe graminis* f.sp. *triticum*). The disease was found in 24 of the trials but the level of attack was low - 7.2% on average. Triadimenol and Tebuconazol used alone or in mixture; propiconazol + fenpropimorph in mixture or fenpropimorph used alone all gave good mildew control.

Reduced dosages using 3 x 0.3 or 4 x 0.25 of a normal dose both gave acceptable control.

Dosages below 0.3 l/ha used on established attacks gave unacceptable control.

Yellow rust (*Puccinia striiformis*). The disease was only found in 2 trials and at very low levels (7.2% on average). This was unexpected as most varieties grown were very susceptible and severely attacked in 1990. Late drilling in the autumn 1990 and a relatively cold February are seen as the major reasons for yellow rust not developing epidemically. The attacks were controlled well by all tested products except prochloraz used alone.

The influence of climatic conditions on the spread of *Septoria* spp. in wheat (Lise Nistrup Jørgensen, Bodt 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. These trials will continue.

A simple forecasting model for *Septoria* spp. in wheat was developed based on historical precipitation data, disease data and growth stage (1980-1989). It was found that the number of days with precipitation $\geq$ 1 mm, calculated during a 30 day period with start at the beginning of stem elongation (Zadoks 32), was well correlated to severe attacks of *Septoria* spp. later in the season. A threshold of 8-9 days with rainfall $\leq$ 1 mm was suggested to be a threshold for *Septoria* treatment or not.

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

Immunodiagnostic assay for cereal eyespot (K. Husted, H. Schulz & L. Nistrup Jørgensen)

An immunologically based diagnostic kit for the detection and quantification of cereal eyespot (*Pseudocercosporella herpotrichoides*), the Du Pont Advisor, was investigated under Danish conditions. The correlation in spring between the normal visual assessment and the antigen level was too poor to allow the definition of a threshold value expressed in antigen units. The main reason probably lies in the sample preparation where all leaf sheaths not fully attached to the stem were removed. This has later been changed by Du Pont in that only entirely dead leaf sheaths are removed.

Using the kit it was possible to follow the development of the disease during the growth season and thereby also investigate the treatment effect. The investigations only showed minor correlation between the treatment effect measured in antigen units and the yield increase reached.

Comparison between the field test and the ELISA-test showed reasonable good correlation.

Research concerning MBC-resistance and prochloraz-resistance of eyespot fungi (*Pseudocercosporella herpotrichoides*) (H. Schulz and L. Nistrup Jørgensen)

In July 1991, straw with symptoms of eyespot were collected randomly from several fields throughout Denmark. Isolates are tested on prochloraz (0.01, 0.1, 1.0, 10.0 ppm). So far no indication of resistance to eyespot has been found, despite the fact that the effect of prochloraz in the fields is low. The level of MBC-resistance is still very high in Danish winter wheat fields.

Disease control in barley (Bent J. Nielsen and Lise Nistrup Jørgensen)

Typhula (*T. incarnata*) and snow mould (*Gerlachia nivale*)

The winter 1990/91 was very mild and Typhula was only detected in a few trials. As expected a good control was obtained after spraying with triadimenol + prochloraz, tebuconazol + triadimenol and tebuconazol. Triadimenol alone gave a weaker control. There was no attack of *Gerlachia nivale.*

Scald (*Rhynchosporium secalis*) and net blotch (*Drechslera teres*)

Scald could be seen in winter barley from April and throughout the season and was the dominating disease. Field trials where split applications were tested gave good results. A satisfying control and net yield was obtained with 2 x 0.5 l in many situations. Where scald appeared early in April, 3 x 0.5 l gave the best result. Concerning *Rhyncosporium* the effect level of the tested products used in the normal dose were DPX H6573 (Lyric): 86%, Tiptor: 80%, Sportak 45ec: 78%, Tilt top: 77%, Matador: 72%, Corbel 68%, Alto 240 SL: 36%, Bayfidan: 33%.

Net blotch were only seen with mild attacks, especially late in the season.

Powdery mildew (*Erysiphe graminis* f.sp. *hordei*)

Winter barley was attacked moderately by mildew in May and June. In spring barley the epidemic started in early June and only developed moderately. In winter barley split applications with reduced rate (2 x 0.15 l, 3 x 0.15 l Tilt top, Tilt turbo, Matador or Pluton) gave good control. In spring barley one spray with 0.67 l (Pluton, Folicur, Tilt top, Tilt turbo or Matador) effectively controlled the mildew, but the results from split application trials showed that totally 0.3 l divided into 2-3 sprayings (e.g. 3 x 0.1 l) gave optimum control and net yield.

Concerning powdery mildew the effect level of the tested products used in the normal dose were Matador 98%, Tilt top 97%, Folicur 95%, DPX H6573 (Lyric) 91%, Corbel 91%, Tilt 250 EC 83%, Sportak 45ec 68% and Bayfidan 51%. The efficacy of Bayfidan against

mildew i barley has decreased during the last years and the biological approval against barley mildew has been withdrawn. The effect against wheat mildew is still high.

Brown rust in barley (*Puccinia hordei*)

Contrary to 1990 brown rust only developed late and only at a moderate level. Split application trials confirmed results of previous years that 2 x 0.5 l of effective fungicides controlled the disease.

Barley yellow mosaic virus (BYMV (Arne Thomsen)

Using an ELISA-test and an antiserum from Braunschweig, BYMV was detected in a sample of barley collected on the basis of visual symptoms in early spring in South Jutland. The find was not verified, however, in plant samples from the same field collected later in the spring. Attempts will be made in 1992 to verify the find.

II. DISEASES OF PEA, RAPE, BEET AND POTATO

Root diseases of pea (Lars Bødker)

A three year disease survey of the root diseases of vining and combining peas has shown that *Aphanomyces euteiches* is the most destructive pathogen.

In addition *Fusarium oxysporum* f.sp. *pisi*, *Fusarium solani* f.sp. *pisi*, *Phoma medicaginis* var. *pinodella*, *Mycosphaerella pinodes*, *Pythium* spp. and *Chalara elegans* were commonly isolated from root and epicotyl lesions.

Because of a dry summer in 1991 *A. euteiches* was of less importance than in 1990 where the fungus caused total loss in individual fields with short intervals between pea crops in the crop rotation. Especially *P. medicaginis* var. *pinodella* was in 1991 very frequently isolated from vining and combining pea.

A new genetic variant of *F. oxysporum* f.sp. *pisi* with race 6 phenotype was isolated from two widely separated geographical regions. *F. oxysporum* f.sp. *pisi* race 6 is until now only found to be endemic in North America. The Danish race 6 is on the basis of RFLP (Restriction Fragment Length Polymorphism) and test for VCG (Vegetative Compatibility Grouping) distinctly different from the American race 6, but gives a similar reaction when inoculated on a set of host differentials.

Leaf and pod diseases of pea (H. Schulz)

Severe outbreaks of leaf and pod spot caused by *Ascochyta* spp. occurred only on isolated locations. Grey mould (*Botrytis cinerea*) was prevalent at the end of June but caused only a slight damage. Likewise was downy mildew (*Peronospora viceae* f.sp. *pisi*) more widespread than in 1990 but caused only weak to moderate attacks depending on the location.

In 1991, 5 field trials with seed treatment against soilborne diseases were carried out with KVK Thiram F bejdse (Thiram 4 ml/kg seed), Apron TZ 69 WS (metalaxyl + thiabendazole 1.2 g/kg seed) and Beret MLX 360 FS (fenpiclonile + metalaxyl 1.75 ml/kg seed). There was a good effect against the complex of soilborne diseases and a yield increase was obtained, especially with Beret MLX in fields with intensive pea growing.

Control of fungal diseases in oilseed rape (Hanne Lipczak Jakobsen)

In 1991, 16 trials were carried out testing various fungicides against fungal diseases in oilseed rape.

After germination of the winter rape attacks of dark leaf spot (*Alternaria* spp.) and Phoma canker (*Phoma lingam*) on leaves were widespread. Prochloraz 655 g/ha and 330 g/ha (Sportak 45 EC) and iprodion 500 g/ha (Rovral Flo) applied in October showed good effect on these attacks when assessed one month later. Yield increase was found in the trials due to effect against attacks of Phoma canker at the stem base.

Grey mould (*Botrytis cinerea*) was found in winter rape in several fields mainly because of cold and rainy weather conditions in May and June. All tested fungicides showed good effect when applied at the time of full flowering.

Heavy attacks of dark leaf spot (*Alternaria* spp.) on the pods were common in spring rape at the time of harvest. Spraying with iprodion 500 g/ha (Rovral Flo) or tebuconazole 375 g/ha (Folicur 250 EW) when flowering was terminated (growth stage 5.1-5.2) showed good effect and resulted in yield increases of around 10-14%.

Stem rot (*Sclerotinia sclerotiorum*) was not seen in the trials, but this disease was common in some fields of winter and spring rape in 1991.

Forecasting of stem rot (*Sclerotinia sclerotiorum*) in oilseed rape (Hanne Lipczak Jakobsen)

A forecasting system is 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 1991, the percentage germination varied from 0-15% (very few localities with 16-35%) in 136 depots in winter rape and from 6-45% (few localities with 0-5%) in 65 depots in spring rape at the time of full flowering.

In spite of the relatively low germination in winter rape, severe attacks were reported in some fields where the flowering was late. In spring rape the incidence was unexpectedly low because of a dry period during the flowering.

To improve the forecasting of stem rot a forecasting scheme that makes it possible for the grower or the adviser to make decisions on field level was tested in approximately 400 fields. Only 127 usable answers were returned. Very few fields in this test were attacked by stem rot and therefore the validation of the model was very difficult. The forecasting scheme will be tested again in 1992.

Pea enation mosaic virus (PEMV) (Niels Paludan)

The resistance to a Danish isolate of PEMV was investigated on main Danish pea varieties and resistant pea varieties received from H.E.Schmidt, Aschersleben.

The resistance was based on a 9-1 scale and calculations following a modified formula described by H.E. Schmidt and L. Schubert 1980.

The German canning varieties were highly resistant ('Boretta', 'Bornella' and 'Regina' all 100 degree and 'Sima' 96) while the Danish varieties achieved a lower degree (canning varieties 'Polar' 85, 'Tristar' 78 and 'Uniroy' 72, field peas 'Bodil' 73, 'Bohatyr' 84 and 'Solara' 93). The resistance degree achieved for 'Polar' and 'Solara' might even be too high due to biological conditions.

Infected plants showed a high degree of deformed pods from 71 to 100 per cent, and furthermore, many undeveloped pods, 16 to 45 per cent.

Seed infection trials were carried out with seed harvested from pea plants infected with a sap transmittable PEMV strain received from C. Adam, Braunschweig. No true seed infection occurred in 600 seedlings of each of the varieties 'Dark Skin Perfection' and 'Solara' respectively, based on symptom expression.

Rhizomania in sugar beets (Arne Thomsen)

By means of a modified Bemster method a number of soil samples were in 1991 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 98 soil samples from 5

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 43 % of all soil samples. The common vector for both viruses, the fungus *Polymyxa betae*, was found in 81 % of the soil samples examined.

Virus diseases of potato (Steen Lykke Nielsen)

Potato mop-top (PMTV)

24 potato cultivars were tested for their sensitivity to develop spraing (rust coloured spots, arches and rings) by growing them in a PMTV infected field in Central Jutland. The sensitive control cultivars 'Saturna' and 'Minea' showed spraing symptoms in 77 % and 3 % of the tubers respectively. The reason for the very low level of spraing in 'Minea' is not known.

Development of spraing was investigated during storage and the influence of different temperatures. 7 potato cultivars from a PMTV infected field were inspected for spraing at harvest and stored at 3 °C and 8 °C. At intervals of one month, spraing in the tubers was registered.

Attempt to isolate PMTV from soil samples using a Finish method with bait plants was not successful.

Tobacco rattle virus (TRV)

44 potato cultivars of which 30 are not-released cultivars from the Potato Breeding Station in Vandel were tested for their sensitivity to develop spraing (rust coloured spots, arches, and rings) by growing them in a TRV infected field at Lundgård Research Station in South Jutland. The sensitive control cultivar 'Nicola' showed spraing in 12 % of the tubers.

Soil samples from 10 potato farmers were tested for presence of TRV by the bait plant method. The farmers had had problems with spraing in the previous harvest. TRV was found in 7 of the fields.

Establishment of disease-free stocks of potatoes

In the meristem culture program 9 potato cultivars have been established as pathogen-free stocks. One cultivar remains because of heavy infection with potato virus. It will be heat treated before new meristems are cut.

Micro tubers

Ivan Simko, post graduated student from the University of Agriculture in Nitra, Czechoslovakia, worked 3 months on the effects of paclobutrazol on microtuberization of potato stem segments cultured in vitro. Paclobutrazol increased micro tuber formation.

Fungicides and potato diseases (Jørgen Simonsen)

For treatment of seed potatoes against black scurf (*Rhizoctonia solani*) two compounds were tested and approved: Rizolex 50 FW (tolclofosmethyl, 50% a.i.) 30 ml/hkg tubers before storage and Moncut 6 (flutoluanil, 6% a.i.) 140 g/hkg before planting.

Tattoo (248 g propamocarb + 301 g mancozeb/1) was tested and approved for control of late blight (*Phytophthora infestans*) with 4 l/ha. 4 treatments were made in July and August, with intervals of 2 weeks. Satisfying control was also obtained with 3 l/ha and 2 l/ha. A sporangial solution applied along newly irrigated plots medio July caused a heavy uniform infection in untreated plots within 3-4 weeks.

III. DISEASES OF HORTICULTURAL CROPS

Virus diseases in fruit trees and bushes (Arne Thomsen)

Prunus ringspot virus (PRV): 300 *Prunus avium* seed plants imported as virus-free seeds were tested for infection of PRV. PRV was detected in 6 plants.

Black currant reversion disease: In connection with the increased growing of black currant numerous tests of black currant reversion disease have been made. Reversion disease seems to be widespread in Denmark.

Virus diseases of ornamental plants (Niels Paludan)

Begonia elatior

Experiments with leaf curl infected varieties of the 'Nixe' group were carried out comprising heat treatment at 30°C and 34°C for 5½ and 4 months respectively in combination with tissue culture.
The established meristem plants were scored for the leaf symptoms vein clearing, chlorotic vein bands and rugosity during a period of 18 months.

Tissue culture without prior heat treatment did not give any convincing results, and nor did a combination with the mentioned heat treatment, the percentage of symptomless plants decreased constantly during the registration period.

Kalanchoë blossfeldiana

The mosaic disease, which causes dark green, raised areas in leaves of sensitive *Kalanchoë* varieties, e.g. 'Charme' is called Kalanchoë green island mosaic (KGIM) in Denmark. Earlier experiments have shown that the KGIM is easily transmitted amongst *Kalanchoë*, both with infectious plant sap and peach aphids using short time feeding.

Healthy *Kalanchoë* plants of the varieties 'Attraction' and 'Charme' have been used in infection experiments, comprising both sap and graft transmissions in order to find the best test method and indicator plant.

Grafting to 'Attraction' caused the clearest symptoms including spoonlike top leaves followed by a mosaic and later on a green island mosaic. Symptoms occurred after 5 to 6 weeks. Sap inoculation gave the same result, but with less clear symptoms against a less vigorous KGIM-strain. Symptoms occurred after 3 to 4 weeks.

Sap inoculation to 'Attraction' was used as a first screening for KGIM, the experiment comprised 66 different varieties and clones from Danish nurseries. 35 per cent of the plants were infected, many did not show any leaf symptoms (latent infection).

Tomato spotted wilt virus (TSWV) (L-strain) was sap transmitted to healthy *Kalanchoë* plants of the variety 'Attraction'. Chlorotic vein clearing and vein band occurred in the youngest leaves within 1 - 1,5 months followed by a yellow mottling along the leaf edge. After 4 months chlorotic and necrotic sunken spots, 5-10 mm, occurred at the leaf basis and later on along the edges and the whole leaf. After 5-6 months the plant was symptomless except for a very few older leaves showing the mentioned symptoms.

TSWV was diagnosed both by the indirect ELISA method and the indicator plant *Nicotiana tabacum* 'Samsun'.

Using young leaves without symptoms the virus was only shown in approximately 50 per cent of the samples, irrespective of the used method. Using older leaves with symptoms the virus was shown in all the samples by ELISA, but only in 33 to 40 per cent using indicator plants.

New virus attacks 1991 (Niels Paludan and Arne Thomsen)

Canna indica hybr.	Canna mosaic virus
Datura sp.	Datura mosaic virus
Iris germanica	Tomato black ring virus
Heracleum pubescens	Tobacco rattle virus

IV. DIAGNOSTIC WORK

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

The project on spread of *Erwinia chrysanthemi* in *Kalanchoë blossfeldiana* was terminated in 1991.

Manuscipts on bacterial infection compared to size and location of meristems and in situ detection of the bacteria are under preparation.

Prognosis-warning systems in sour cherry (Bent Løschenkohl and Karen Bech)

Cherry leaf spot disease (*Blumeriella jaapii*) was monitored during spring and summer 1991. Ascospore ejection was registered in the period 12-15 May and 1-16 June when leaves were drying after a shower.

Symptoms were monitored weekly in a field trial in the cultivar 'Stevnsbær' and 'Kelleriis 16'.

Sprayings were made in the following 3 ways: after a warning system for apple scab, without spraying from bloom to harvest and according to experienced fruit growers practice in cooperation with the Institute of Pomology, Årslev.

Extensive data on climate are analyzed to permit a prediction of epidemic disease development and improve the warning system.

D. BIOTECHNOLOGY GROUP

Head of group: Peter Ulvskov

Scientific staff:

Merete Albrechtsen
Bernhard Borkhardt
Elisabeth Johansen
Søren V.S. Nielsen
Gert B. Poulsen

Use of molecular tools and transgenic plants in breeding

Research in biotechnology is expected to influence strategies for breeding for better crop plants. This research activity will also produce a number of molecular tools for the diagnosis of plant pathogenic microorganisms. Used in combination with tissue culture methods strains of certified pathogen-free stock plants can be produced.

The aims of this project are to:

- Develop new and introduce well known molecular methods
- Establish strategies for the manipulation of important crop plants *in vitro*
- Identify genes for traits agronomic importance
- Develop methods for the rapid and efficient diagnosis of plant pathogens

These objectives are pursued in the following research activities:

- Methods for the transformation and regeneration of pea, rape, and potato are developed using gene transfer with the soil bacterium *Agrobacterium tumefaciens* as well as transfer using direct up-take of DNA into protoplasts.
- The molecular basis of silique opening in rape is investigated in an attempt to engineer a shatter resistant rape plant.
- Plant virus genomes are analyzed in a number of relevant viruses. The genetic information is used for the development of specific probes for virus diagnosis. The introduction of virus resistance in crop plants is pursued using the coat protein mediated virus resistance strategy.
- Fundamental research in the molecular basis of virus host recognition is undertaken in an attempt to discover new avenue towards engineered virus resistance in crop plants.
- Methods based on antibodies or DNA-probes are developed or used routinely for the detection of vira, viroids, and plant pathogenic fungi.

E. DEPARTMENT OF PEST MANAGEMENT

Head of Department: Jørgen Jakobsen

Scientific staff:

Bent Bromand: Insecticides for agricultural purposes
Jens Bligaard: Pests on field vegetables (from 15 December)
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
Mette Kjøbek Petersen: Sustainable agriculture (temporary)
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

* PhD-students
5 MSc-students

GENERAL REPORT (Jørgen Jakobsen)

The main objectives of the department are development of integrated pest management programmes. Testing of pesticides for official efficiencey approval and the impact of pesticides on beneficials are also important activities of the department.

On the basis of results from biological and chemical research the department is involved in developing a computer-based advisory progamme, "PC-Plant Protection".

In agricultural crops including field vegetables, the emphasis of integrated pest management is put on prognosis and warning models, economic injury thresholds and tactical use of insecticides.

The aim is to reduce the dependence on insecticides to support a reduction compared to normal practice. Therefore, the department is engaged in research estimating the importance of naturally occurring beneficials and the influence on the beneficials induced by farming practices.

In glasshouse crops, integrated pest management includes biological control by released beneficials.

The department has for many years been involved in research on development of biological control methods. This research is concentrated on development of biological control in ornamentals, especially against western flower thrips and cotton white fly.

Students doing their Master thesis or PhD thesis at the department are an important part of the department's relations with the Royal Vet. and Agricutlural University and the University of Copenhagen.

Pests in cereals, beet, oilseed rape and potatoes. Forecasting/warning models (Lars Monrad Hansen)

Aphids in cereals

Aphids are one of our major pests in cereal crops. There are great variations in the occurrence between years. In 1991, the aphid populations were very moderate in size and extension.

Slugs as a pest

In recent years, slug occurrences have been more frequent and serious than previously. In spite of this, there exist no reliable monitoring methods or threshold values. Investigations have been made concerning these aspects.

Aphids in beet

Peach-potato aphid is a serious pest in beet primarily due to its role as vector of Virus Yellows. In 1991, peach-potato aphid occurrence was very moderate and a general recommendation to control was not given, as it has been the case in previous years. A method to determine with more precision the time of invasion into beet fields is being developed.

Pests in oilseed rape

Brassica pod midge constitutes one of the most serious pests in oilseed rape. In recent years, apparently, the population has been decreasing. This is primarily due to a a change in rape growing practices from spring oilseed rape to winter oilseed rape. A forecasting/warning method for brassica pod midge in oilseed rape is being developed.

Brassica pod midge was only of little importance in winter oilseed rape in 1991, whereas, in spring oilseed rape, moderate to severe attacks were observed at several locations. The

explanation to this is that comparatively small populations in the winter oilseed rape concentrate in the spring oilseed rape.

Aphids in potatoes

Aphids is of great importance as carriers of serious diseases in potatoes. By means of yellow watertraps and windtraps the approach to the potato fields are followed to decide the risk and time for infection.

Pests and diseases in organically grown crops (Søren Holm)

A monitoring program was performed at 9 farms in cereals, pea and potatoes.

Major pests and diseases found in 1991 were bean weevil (*Sitona lineata*) in pea, late blight (*Phytophtora infestans*), black scurf (*Rhizoctonia solani*) and wireworms (*Agriotes lineatus*) etc. in potatoes, *Septoria* spp. in wheat.

Of minor importance were, on barley: Powdery mildew (*Erysiphe graminis*), leaf blotch (*Rynchosporium secalis*), net blotch (*Drechslera teres*), cereal leaf beetle (*Lema melanopus*) and aphids, - on wheat: Eyespot (*Cercosporella herpotrichoides*), powdery mildew (*Erysiphe graminis*), stinking smut (*Tilletia caries*), shoot fly (*Opomyza florum*) and aphids, - in pea: Leaf and pod disease (*Ascochyta* spp.), downy mildew ((*peronospora viciae*) and aphids.

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.

Different methods for monitoring 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 compared.

In semi-field facilities controlled outdoor pot experiments have taken place to elucidate the impact of insect pests on pea plant growth and yield.

Preliminary investigations on differences in attractance of pea and bean weevil and pea aphids by different varieties of field peas have been carried out.

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 laboratory and semi-field experiments the relationship between developmental rate and temperature for eggs, larvae and pupae have been investigated.

In 1991, an evaluation of the developmental model under field conditions was carried out with success. The thermal sum required for development of the eggs is 80 DD (based on a developmental zero on 10.3°C)

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

The turnip moth was monitored at 56 localities in Denmark and 27 localities in Skåne, Southern Sweden. Due to the extreme wet and cold weather conditions in June the number of moths caught was very low throughout June. In July, some moths were registered but in low numbers.

On Funen, investigations on local variation in catch levels among turnip moth pheromone traps showed large variation between traps from field to field, even when they were situated

* Student at the Royal Veterinary and Agricultural University

rather close to each other. However, conclusions are difficult to draw due to the catch levels, generally, being low in 1991. Together with investigations on carrying capacity in catch by the traps these studies were carried out as a graduation project from the Agricultural University.

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 peaked in late May.

The second generation was most active from the middle of August to the middle of September.

Carrot fly (*Psila rosae*) laboratory rearing (Ole Bloch Hansen* & Karen Eberhardt*)

Different rearing techniques have been tested under laboratory and glasshouse conditions. It has been possible to run the laboratory cultures for several generations and with limited mortality of eggs, larvae and pupae.

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

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

Delta traps were used at 62 localities for monitoring codling moth in apple orchards. The main flight period was from the middle of June to the middle of July. Due to the cold and wet weather conditions in June most of the flight activity took place in July. Control of the codling moth was recommended at approx. half of the localities.

Nordic Project on Brassica Vegetable Pests (Alex Percy-Smith and Jens Bligaard)

In connection with the NKJ project "Reducing the use of insecticides in Brassica vegetable crops" a pilot trial has been carried out with a view to establishing a rearing of the cabbage root fly (*Delia radicum*).

Egg-laying activity has been monitored using egg traps with some 30 growers.

* Student at the Royal Veterinary and Agricultural University
In 1991, a questionnaire investigation was carried out concerning pests in brassica crops. This investigation showed that cabbage root fly is by far the most serious pest in the cabbage production.

Pests in agricultural crops and field vegetables (Bent Bromand)

In 1991, 36 field trials were carried out and 3 insecticides were given approval against 8 different pests, see table below.

Trials with different spraying techniques against aphids in spring barley were continued. The conventional hydraulic sprayer was compared with 2 air-assisted types of sprayers, the Hardi Twin and the Danfoil sprayer. The last two years the attacks by aphids in spring barley have been fairly low. From the results so far it does not seem likely that a better effect on aphids is obtained with an air-assisted sprayer type.

In spring barley and winter wheat, trials were carried out against aphids with different pyrethroids compared with pirimicarb. Split doses and different damage thresholds were incorporated in the trials.

In sugar beet, the trials were carried out with insecticides incorporated in the pellets before sowing. Very promising results were obtained with imidachloprid against pygmy beetles,

mangol flies, black bean aphids and peach-potato aphids. In semi-field trials 100 per cent mortality was obtained on peach-potato aphids 2½ months after sowing sugar beet pellets with imidachloprid.

In oilseed rape pyrethroids gave good effect against the blossom beetles. However, very low yield increases were obtained due to unusual heavy attacks on spring oilseed rape by the brassica pod midge.

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

Newly approved insecticides and insecticides with extended or changed approval (1st January 1992. *= not registered in Denmark.

Products and active ingredients	Company	Dosage	Approved against
Talstar 5* bifenthrin 50 g/l	R-P Agro Norden A/S	0.12 l/ha	*Sitobion avenae* *Rhopalosipum padi* *Metopolophium dirhodum*
		0.6 l/ha	*Oscinella frit*
		0.3 l/ha	*Meligethes aceneus*
		0.3 l/ha	*Ceuthorrhynchus assimilis*
		0.2 l/ha	*Dasineura brassicae*
Pirimor pirimicarb 500 g/kg	ICI A/S	0.25 kg/ha	*Acyrthosiphon pisum*
Pirimor G pirimicarb 500 g/kg	ICI A/S	0.25 kg/ha	*Acyrthosiphon pisum*

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, pests and beneficial organisms
* Information on pesticides and pesticide compatibility
* Spraying technique
* Farmers field observations - field log

The present system includes recommendation models for spring barley, winter barley and winter wheat. In 1991, 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 model showed good performance. The system is expected to be released in autumn 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 system project. The participants send the recorded field observations to the Centre and receive a plant protection recommendation based on their field observations and the next field registration card. These field observations form 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 the participants and the Centre is by post or telefax.

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

A laboratory test for adult females of the Staphylinid beetle *Aleochara bilineata* has been developed earlier according to the principles of the IOBC Working Group "Pesticides and Beneficial Organisms" (Samsøe-Petersen, 1987). The work on this species, resumed during 1989, was continued in 1991.

The laboratory test was used to perform tests for the chemical industry on a contract basis, and for the 6th joint pesticide testing programme of the IOBC WG. Furthermore, 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 1991. 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 continued to develop the original laboratory test to take place in different soil types instead of sand, and to develop a test for effects of pesticides on pupae of *A. bilineata*. These are also expected to be documented during 1992.

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)

The hymenopterous parasite *Encarsia formosa* has ben chosen for experiments to elucidate its potential as biological control agent of *Bemisia tabaci*. Laboratory experiments on the basic biological characteristics of *E. formosa* and *B. tabaci* on Poinsettia were continued.

In addition, experiments were conducted to investigate the searching efficiency and parasite performance in relation to density of host and parasitoid. These experiments were conducted in 0.6 m^3 insectary cages placed in a glasshouse as well as in a large scale glasshouse experiment (14 m^2).

The studies have revealed that the biology of *E. formosa* parasitizing *B. tabaci* is very similar to the biology of *Trialeurodes vaporariorum* with respect to adult longevity, juvenile development, host stage preference and oviposition rate. Juvenile mortality, however, seems to be higher when *E. formosa* develops on *B. tabaci*.

Furthermore, the host-parasitoid interactions and the resultant outcome are very similar to the ones reported when *T. vaporariorum* serves as host.

The prospects for using *E. formosa* as a biological control agent of *B. tabaci*, therefore, seems good - at least in situations where a longer lasting control with a low level of pests in the crops is intended. However, with respect to biological control on ornamentals difficulties may arise due to the low or zero tolerance threshold for pest infestation.

Manipulation of polyphagous predators in cereals (Werner Riedel)

A 4-year Nordic project with the aim of finding methods of enhancing the polyphagous predators in cereals have just been finished at the end of 1991. The Danish part of the project was concerned with the establishment of appropriate overwintering sites for these beneficial arthropods within cereal fields.

A simple grass/herb ridge in the middle of a big field provided a successful overwintering site with densities of Carabidae, Staphylinidae and Araneae of up to 1400/m^2. Highest densities were seen on the south side of the ridge in the grass *Festuca rubra* although some species seem to prefer the northern side as overwintering site. A clear soil type preference as well as vertical distribution in the soil profile was observed for some species. Low winter mortality was recorded. The spring migration to the surrounding field was pronounced for the dominating carabid species *Bembidion lampros* and *Agonum dorsale*. Overwintering *B. lampros* from the established ridge contributes markedly to the total field population in the spring.

Testing and approval of fungicides, insecticides and plant growth regulators in horticultural crops (A. Nøhr Rasmussen)

The Danish Institute of Plant and Soil Science grant approval to chemical and biological plant protection products for control of plant diseases, pests and weeds, when satisfactory trial results are available. The trials are carried out as a result of requests from chemical companies and they are carried out according to Danish guidelines for testing pesticides.

With validity from the 1st January 1992 several new fungicides, insecticides and plant growth regulators have been granted an approval. The approved products with dosages, active ingredients and the plant diseases and insects pests which they have been approved against are listed below.

Product and a.i.	Approved against	Crop	Dosage
Fungicides			
Midol 2200* vegetable oil 677 g/l	Powdery mildew	Cucumber, glasshouse	2.0%
Ronilan DF vinclozolin 500 g/kg	Grey mould	Cucumber, tomatoe, glasshouse	0.1%
Insecticides/acaricides			
Dimilin diflubenzuron 250 g/kg	Apple leaf miner	Fruit trees	0.6 kg/ha
MicroGermin Plus *Verticillium lecanii* $5x10^9$ spores/g	Peach-potato aphid Whitefly	Glasshouse crops Glasshouse crops	3.5 g/l 3.5 g/l
S-71639 10 EC* pyriproxyfen 100 g/l	Whitefly Tobacco whitefly	Glasshouse crops Glasshouse crops	0.0025% 0.0025%
Safer Insektsæbe* kaliumoleat 470g/l	Peach-potato aphid Whitefly Two-spotted mite	Glasshouse crops Glasshouse crops Glasshouse crops	2.0% 2.0% 2.0%
Siva 50 Insektsæbe kaliumoleat 470 g/l	Tobacco whitefly	Glasshouse crops	2.0%
Talstar 5* bifenthrin 250 g/kg	Red spider mite	Fruit trees	1.0 l/ha
Vectobac 12 AS *Bacillus thuringienses* H14 1.2%	Sciarid flies	Ornamental plants	5.0 g/m²
Plant growth regulators			
Sumagic* uniconazol 1 g/l	*Dendranthema Indicum hybrid* *Euphorbia pulcherrima* *Kalanchoë blossfeldiana* Pot-roses		0.5-4.0% 0.05-0.15% 0.15-0.3% 0.3-0.15%

* Not registered by the National Agency of Environmental Protection by the 1st January 1992.

F. DEPARTMENT OF WEED CONTROL

Head of Department: K. E. Thonke

Scientific staff:

Peter Kryger Jensen and Svend Christensen (PhD student): Applied research with chemical weed control in agriculture including work on crop and weed competition and control thresholds.

Peder Elbæk Jensen and Per Rydahl Nielsen (PhD student): 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, Solvejg Kopp Mathiassen 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 assistants.

The research work focused 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, presumably, 1/3 of currently active ingredients will disappear from the Danish market. As a consequence the number of cultures in which herbicides can be applied will markedly decrease in future. This will cause large problems for weed control, particularly in horticulture and forestry, and a search for alternative herbicides and integrated control methods, therefore, has been carried out.

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

1. spraying with herbicides on weeds and crops at different stages of development, including split treatments.

2. tank mixing with other pesticides or additives

3. influence of cultural methods on germination of weed seeds under field conditions.

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

In controlled environments in climate chambers and greenhouses research work in 1991 focused on: Description of synergistic and antagonistic effects between herbicides and additives including mixtures of pesticides. Studies into herbicide efficacy in relation to uptake through foliar and/or soil were investigated as well as experiments to analyse resistance and cross-resistance of a sulfonylurea-resistent biotype of *Stellaria media.*

In 1991, research has been carried out to identify the microvariation of spray drop distribution within the swath, related to speed, nozzle size and wind velocity in the field.

Research in mechanical weed control concentrated on:

1: Development of a model for predicting the optimum intensity of harrowing.

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

Population dynamics 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 fertilization 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.

In 1991, planning and set up of an experiment concerning integrated crop production programme for winter wheat was carried out in collaboration with the Research Centre for Agriculture.

Publication and advisory activities in 1991 covered lectures for advisers and growers, publications and participation in symposia and conferences. The department was organizer of a Nordic workshop in June. "PC-Plant Protection" holding an advisory part and a guidance part was made accessible to Danish farmers in 1991 through the "Integrated Farm Management System" developed by the Danish Agricultural Advisory Centre.

Applied research on chemical weed control in agriculture and weed biology (Peter Kryger Jensen)

The field of activity includes a broad spectrum of work on the optimization of herbicide efficacy under field conditions. A major research topic has been the use of split application of herbicides. This method is now recommended for weed control in peas (see below) and research on split application continues in other crops.

Another major area of concern is the herbicide efficacy and crop tolerance at different stages of development of crop and weed.

New field sprayers on the Danish market have been 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. During the last years trials have included two new sprayers, the Hardi Twin and the Danfoil. Both sprayers operate through air assistance and with volume rates from 30-100 l/ha.

Split application of herbicides

Split application of herbicides has, in three years investigations, shown to improve weed control in peas, as compared to one single application at the same total dose. Trials with split application were extended to oil seed rape from 1990 . The use of split application makes it possible to spray at an earlier stage than with single application treatment, which has to await until all weeds have emerged. The first treatment with split application is therefore carried out when weeds are still at the more easily controlled cotyledon stage. This timing implies an earlier crop growth stage than normally recommended with herbicide mixtures containing cyanazine and trials elucidating the crop tolerance at these earlier stages therefore have been carried out with cyanazine mixtures.

Light induction of weed seeds under field conditions

Seeds of a number of weed species, many of them being important weeds, require light induction for germination to take place. Daylight penetrating the soil decreas es rapidly in intensity, and the intensity below a few millimetres of soil is insufficient to induce germination in light dependent weed seeds. Investigations in the autumn 1990 and in 1991 have shown that the light requirement can be met for a proportion of the seedbank by the short light flash during seedbed preparation in daylight. The number of emerged weeds were reduced and the emergence time delayed when seedbed preparation and sowing was carried out in darkness, as compared to the same treatment in daylight.

Weed suppression by cultivars (Svend Christensen)

Three years experiments with different cultivars of cereals showed significant varietal

differences in weed suppression. Varying spacious light interception (shading ability) in the period from stem elongation until heading caused this variation. Canopy heights of the cultivars were the main character of the competitive ability and a regression model was used to describe the correlation between straw length and weed biomass (U_{index}).

Experiments in spring barley and winter cereals showed that the dose-response curves of the cultivars could be derived from the weed biomass assessed in untreated plots. Further, aiming at the same level of control (gram weed dry matter per m^2) the required herbicide dose could be calculated from the U_{index}. In strongly competitive spring barley and winter wheat cultivars the herbicide doses could be reduced by 20 % compared to cultivars with a moderate competitive ability. In weak spring barley and winter wheat cultivars doses should be increased by 10 and 30 % respectively to achieve the same level of control as in moderate cultivars.

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 registered by the environmental authorities. On the other hand, the producers and importers of pesticides have shown interest in achieving approvals (quality-marks for marketing purposes) regarding the effect resulting from 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 against pests, and still as little harmful to crop, as comparable products on the market.

Herbicides containing new active ingredients are tested 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 recommendations. 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 m^2 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 legislative demands for reducing pesticide use. New herbicides containing known active ingredients are normally tested to a minor 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´ sites, 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 1990/91 indicate, that acceptable effects can be achieved with reduced dosages by early autumn applications. Tests concerning control of *Aethusa cynapium* and *Amsinckia intermedia* are successfully

made in sugar beets and peas respectively.

In 1990/91 the Department of Weed Control was requested to conduct test concerning 58 approvals. As some products were notified for various purposes, the number products/combination of products were only 49. By the end of 1991, 21 approvals had been granted. Not all of these products have been registered yet.

The new active ingredients approved 1991 are listed in the Table below.

New ingredients for weed control approved 1991

Active ingredient	Crops	Selected "problem" Weeds
aclonifen	potatoes peas	2 cotyledon 2 cotyledon
carbetamid	winter rape	1+2 cotyledon
diflufenican*	winter crops	1+2 cotyledon
fenaxaprop-ethyl	barley	wild oat-grass
prosulfocarb	winter crops	1+2 cotyledon
quimerac	sugar beets	*Galium aparine*

* Co-formulated with other active ingredients.

<u>Weed control and approval of herbicides in horticultural crops -including vegetables, fruit growing and nursery culture (Georg Noyé and Anette Binder).</u>

In 1991, the work has focused on testing of herbicides and developing new strategies for weed control; especially in crops where the herbicides are revoked by the reevaluation (carried out by the National Agency of Environmental Protection).

This year we launched a research program on weed control for use in an integrated vegetable production systems. Eight combinations of band spraying, inter-row cultivation and flaming have been tested in onions. The efficiency of weed control was relatively high in the experiment.

17 herbicides were applied for testing in the growing season of 1991. The distribution according to crop was 4 in onions, 4 in carrots, 3 in green peas, 4 in sweet corn, 1 in cabbage, 3 in different nursery crops, 1 in lawns and 1 in black current.

The chemicals listed below all obtained an approval for use. Products with * has not yet been registered.

* 1. Aclonifen (aclonifen) 600 g/l) was approved for use in pea.

2. Afalon disp.(linuron 475 g/l) was approved for use in carrots. Good results with split application.

3. Karmex DF (diuron 800 g/kg) had the approval extended to include weed control in nursery crops of maple, june berry, beech, lime tree, *Ligustrum vulgare*, *Pinus mugo* and *Forsythia.*

* 4. Marksman (atrazin 250 g/l + dicamba 132 g/l) was approved for use in corn.

* 5. Ravine (napropamid 190 g/l + trifluralin 240 g/l) is a new formulation of Treflan Plus. Ravine was approved for use in cabbage.

6. Stomp SC (pendimethalin 400 g/l) had the approval extended to include carrots. Lower dose on humic soils.

<u>Weed control and approval of herbicides in forestry and windbreaks (Thomas Rubow).</u>

The consumption of herbicides for forestry purposes is moderate and the number of applied herbicides limited.

Consumption per year: 25,000 kg a.i.
Total forest area: 500,000 ha.
Application frequency: 0.03.

Area for production of Christmas trees and decoration greenery: 35,000 ha.
Application frequency: 0.3-1.0

Number of important herbicides: 6
Herbicides for occasional use: 6

The herbicides used up till now are for a great part originally developed as total herbicides, and the most important are broad-spectrum soil acting herbicides with high persistence. These are of the very type of agents, that are to be removed or further restricted by the ongoing reevaluation process.

During 1990 and 1991 the reevaluation has been finished for some important forestry herbicides. The complete ban on future use of atrazine in forestry has worried cultivators,

especially as typical substitutes like simazine and terbuthylazine have been put under such restrictions for maximum dose as to make them less suitable under most forestry conditions.

Because of the small number of relevant herbicides such limitations hit very severely. The forestry trade therefore has provided an economical basis for an intensification of testing of new herbicides for forestry purposes. The work has been shared out to the Danish Forest and Landscape Research Institute and the Department of Weed Control.

The work includes:

1) Investigation of herbicidal efficiency and crop tolerance for new herbicides.
2) Tank mixtures of new and well known herbicides.
3) Use of additives in order to enhance the effect of soil acting herbicides as to compensate for dose restrictions.

One example is given below demonstrating results from pot experiments in greenhouse including 3 weed species. This work was carried out by Solvejg Kopp Mathiassen.

Effect on common chick weed (*Stellaria media*)

Complementary studies concerning tolerance of conifers (*Abies procera*) have been established as field experiments.

RESEARCH ON FACTORS AFFECTING THE EFFICIENCY OF HERBICIDES

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

Soil and foliar activity of grass weed herbicides

In a series of trials the soil and foliar activity of grass weed herbicides was investigated. The effect of isoproturon, methabenzthiazuron, cyanazine, pendimethalin and trifluralin on various grass weed species at the 1-2 leaf stage and *Stellaria media* at the 4 leaf stage was examined in pot trials. The herbicides were applied as an overall spray, only to the foliage or only to the soil to assess the foliar- and soil-activity, respectively. On *Poa annua* all herbicides, except methabenzthiazuron, exerted their main activity through the soil, while the foliar-activity contributed significantly to the overall effect of methabenzthiazuron. On *S. media* isoproturon and cyanazin was mainly soil-active whereas methabenzthiazuron, pendimethalin and trifluralin was mainly foliar-active. Addition of an anionic surfactant improved foliar-activity of isoproturon on *P. annua*. *Apera spica-venti*, *P. annua* and *P. pratensis* were inherently more susceptible to the herbicides than *Lolium multiflorum* and *Alopecurus myosuroides*. Incorporating trifluralin into 1 cm depth provided generally a better control of *L. multiflorum* than when applied to the soil surface, irrespectively of sowing depth. Delaying application from the 1-2 to the 3-4 leaf stage reduced the effect of isoproturon and cyanazin.

Resistance of sulfonylurea herbicides in *Stellaria media*

A sulfonylurea-resistant biotype of *S. media* was found in a field which had been grown continuously with spring barley for 8 years. The field had been treated with mixtures of chlorsulfuron+MCPA for 7 years and metsulfuron+MCPA for 1 year. In whole plants bioassays the resistant biotype was found to be more resistant to chlorsulfuron (R/S>270) than to other sulfonylurea herbicides (R/S=63-89). The degree of cross-resistance to imazapyr was much lower than to sulfonylurea herbicides. No cross-resistance to herbicides with different sites of action was observed.

Efficacy of selective graminicides on volunteer cereals at different growth stages.

At the 3-leaf stage of winter barley, winter wheat and rye the efficacy of selective graminicides differed more between the species than after tillering. Winter barley was more susceptible to fluaxifob-p-butyl and alloxydim than was winter wheat and rye, whereas the susceptibility of winter wheat to the haloxyfobethoxy-ethyle, propaquixafob and cycloxydim was lower compared to that of winter barley and rye.

Efficacy and rainfastness of mechlorprop-p and fluroxypyr on *Galium aparine*

In pot trials the efficacy on *G. aparine* of mecoprop-p formulated as an amine and ester

and fluroxypyr in relation to growth stage, temperature and soil moisture was examined. In general, the activity of mecoprop-p ester was lower compared to the amine and fluroxypyr. The efficacy at plants which had developed 2-3 whorls was higher than at plants with 1-2 whorls or 6-8 whorls. At a temperature of 18°C the performance of the 3 herbicides was similar, while at 4°C the efficacy of mecoprop-p ester was significantly lower compared to the amine and fluroxypyr. Low soil moisture significantly reduced the activity of the herbicides. Whereas the mecoprop-p ester was rainfast 2 hours after application, rain applied 5 hours after application reduced the efficacy of mecoprop-p amine.

Influence of environment and additives on the performance of glufosinate

The influence of environment on the performance of glufonisate applied alone and in mixture with 0.5% Genapol LRO was examined at 6 climates in climatic simulators on outdoor grown barley plants. Increasing temperature and humidity enhanced the activity of glufosinate whether 0.5% Genapol LRO was added or not, however humidity seemed to affect the activity more than temperature. Addition of 0.5% Genapol LRO improved the activity at all 6 climates.

The performance of glufosinate in mixture with various additives was examined on different plant species and the rainfastness was examined on *Sinapis alba* and barley.

Influence of temperature and humidity on the activity of foliar-applied herbicides

In climatic simulators the efficacy of 9 foliar-applied herbicides was examined at 9 climates with natural cycling temperature and humidity. Preliminary results show an enhanced activity of glyphosate, fluazifob-p-butyl and phenmedipham with increasing temperatures, whereas the influence of temperature on the activity of phenmedipham+ethofumesat, metamitron, bentaxone, cyanazin and MCPA seems small. Further statistical analyses are necessary to reveal the influence of humidity due to strong interactions between relative air humidity and temperature.

Influence of soil type on the activity of soil applied herbicides

Soil type has a pronounced influence on the activity of many soil applied herbicides, but little is known about the required dose on various soil types. A 5-year project therefore was initiated in 1990 with the objective to quantify the differences in activity of soil applied herbicides on various soil types. With the knowledge about the relative dose requirement on different soil types factor adjusted doses of herbicides can be calculated.

Bioassays are carried out with various soil applied herbicides on 6 different soil types and a reference soil (=sand, where no adsorption of herbicide occurs). The results from the first years have shown significant differences in activity of most herbicides, closely related to the content of organic matter in the soil types.

The investigations will continue in the coming year.

POPULATION DYNAMICS OF WEEDS

Grass weeds population dynamics and thresholds (Bo Melander)

Biology 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*).

Since 1989 research work on the competitive ability of *Elymus repens* in rye, wheat, winter barley, spring barley, peas and oilseed rape has taken place. So far the results from 3 years work have shown severe yield reductions in peas, oilseed rape and partly spring barley. In contrast the winter cereals were far less affected by competition from *Elymus repens*.

The investigations on *Elymus repens* infestations also give information about other biological aspects like emergence patterns of shotts, production of secondary shotts, influences on the yield components of the crops, etc.

In the autumn 1990 competition studies in the field with *Apera spica-venti* in winter wheat

The relationship between density field of *Alopecurus myosuroides* and kernel-yield in winter wheat drilled 2nd and 16th October, respectively.

and rye drilled at two different dates, and with *Aleopecurus myosuroides* in winter wheat drilled at two different dates were started. Yield losses in the crops, emergence patterns of the grass seedlings, grass seed production in relation to increasing grass density and mortality of grass plants will be of main interest.

Weed biology, distribution and spreading (C. Holm-Nielsen)

Main project
Investigation of methods for seed-identification and quantification of the seed-bank of cultivated soil.

As an implication hereof:
Preparation of a key for weed-seed-identification with specifications and photos.

Secondary project
Investigation of some weed aspects in a continued barley growing system with differing soil cultivation methods and without herbicide sprayings. Weed reproduction rates as well as the relationship between barley grain dry matter and weed green matter are investigated.

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. Experiments are conducted with sown-in weeds in cereals, treated with various herbicides in a range of doses. The seed production is measured, correlated to weed size by harvesting in size-classes, in order to separate the influence of size from that of herbicide use. Seed rain is determined in untreated plots. In some cases, seed viability is tested in germination-tests.

Preliminary results indicate that seed production is related to weed dry weight, and that reducing herbicide dose to an extent where weed control is still satisfying with respect to yield etc., will not cause an increase of the weed seed reserve in the soil.

WEED CONTROL BY MEANS OF NON-CHEMICAL METHODS

Mechanical weed control in agricultural crops (Jesper Rasmussen)

The main activity is to develop mechanical weed control methods of annual weed in cereals and seed legumes. Three different strategies of mechanical control have been examined:
1) harrowings at early crop growth stages,
2) selective inter-row cultivations with finger-weeders and

3) hoeing at narrow row widths.

The main objective has been to develop an analytic framework to enable prediction of the optimum intensity of harrowing. Two sets of models have been suggested. The first is based on the selectivity-concept of harrowing, which expresses the relationship between weed control and crop damage associated with harrowing. The second is applicable to experiments without assessment of the crop damage.

Both modelling approaches have the capability to separate the crop yield response into two parts, one derived from the weed-killing effect and the other derived from the crop damage associated with harrowing.

Further investigation on factors affecting the selectivity between crop and weeds is being carried out. Also dynamic aspects have to be incorporated into the models in order to optimize the time of harrowing.

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

Harrowing is carried out in sown onions and carrots, at different periods and number of times after the emergence of the crop. The crop tolerance is compared with flame cultivation before the emergence and herbicide treatments.

The effect of integrated weed control methods are monitored in four integrated crop rotations. Different ploughing depths, levels of slurry, straw incorporation and nitrogen levels are varied in the experimental area. Weed control is applied in accordance with the actual weed flora and very low doses of herbicides are used.

Supported by the Ministry of the Environment a project demonstrating an integrated plant protection in winter wheat has been initiated in 1991. Weed problems are reduced by late sowing and mechanical weed control by harrowing. In the case of weed problems in the early spring only very low doses of herbicides will be used. 10 fields at different localities in Denmark were chosen in collaboration with farming advisers.

Integrated crop production programme for winter wheat (Jakob Vester, Peter Kryger Jensen & Svend Christensen)

A preparatory project was carried out in the first half year of 1991, during which the literature has been reviewed. The main project was initiated in August, and a number of experiments have been established or are prepared, focusing on important interactions in winter wheat growing. Weed problems and competition in relation to cultivar, sowing time, plant density, nitrogen fertilization, soil cultivation, species and density of weeds will be investigated. The results will be linked to a detailed model system and a crop production programme.

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.

We make trials on weed harrowing in cereals and flame treatment in beet, vegetables and cereals at organic farms.

An example with pre-crop-emergence flame treatment in beet.

The figure shows a reductive effect in number of weed and reduction of time consumption for following hand weeding.

RESEARCH ON SPRAY TECHNIQUE AND DRIFT

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

Following the general trend of reducing pesticide doses for each field a greater concern needs to be given to variability of the spray liquid deposited on each single plant. Continued studies have shown the deposition pr. cm^2 plant surface to range at least a factor 1:10 from the least to the best covered single plant, even under fairly favourable spraying conditions. Also it has been noted how the tractor and spray equipment in meeting the natural wind generates specific spatial patterns of deposition, according to the relative wind

direction. As the over-all control level obtained depends on the frequency of plants having received a certain threshold quantity (and quality) of spray, a major aim of application technique development is to reduce this variability. Investigations continue in order to quantify the major sources of variability, i.e. boom oscillations and the turbulence of natural wind, but also the intrinsic variations at the very droplet formation process.

From a series of investigations it was concluded that wind stress applied to plants before or after spraying with differing foliage-applied herbicides only affected herbicidal efficacy to a minor, yet varying degree depending on the specific combination of plant species, herbicide formula and wind period.

ADVISORY SERVICE

PC-Plant Protection, Weeds (Marianne Baandrup)

Computer-based advisory models have been developed for optimizing weed control and simultaneously reducing the amount of herbicides used.

The PC-based system holds recommendation models for weed control in agricultural crops and general information on herbicides, spray application techniques, tank mixtures and information on weed species.

In cooperation with the Agricultural Advisory Centre PC-Plant Protection was released in 1991 for farmers and advisers.

PC-Plant Protection calculate on the basis of simple user input the optimum control strategy, select herbicides and adjust the dose according to the prevailing conditions. PC-Plant Protection supply the farmer with field-specific recommendation. Research results are being transformed into practical recommendations in the recommendation models and the distance from research to agriculture has become very short.

Results from field trials with recommendation model for spring barley.

	Treatment index	
	Recommendation model (spring barley)	All farmers (cereals)
1991 (14 trials)	0.5	unpubl.
1990 (18 trials)	0.4	1.1
1989 (17 trials)	0.5	1.4
1988 (27 trials)	0.5	1.0

Results from field trials have shown that the recommendation models have proved efficient and well performing during testing for 4 years in spring barley.

The recommendation models have sustained the weed control with considerably lower amounts of herbicides without influencing the yield. The recommendation models hold great potentials for reducing the use of herbicides, achieving sufficient weed control, and maintaining the yield response and can become very useful tools for farmers and advisers.

Weed control (Ole Permin)

The advisory service is primarily a link between research and the advisers employed by the farmers´ union. Participation in meetings and field excursions all over the country provides the opportunity for an exchange of ideas and problems which is necessary in the planning of the research work in the future.

This work enables organisations to bring out new knowledge gained from research to the user without delay. Also the work includes 1) the organizing of advanced courses training advisors in weed control handling, and 2) compilation of new results from research in cooperation with the Danish Agricultural Advisory Centre working out strategies for weed control in different crops.

G. 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
Arne Helweg: Degradation and adsorption of pesticides in soil
Erik Kirknel: Fungicides and insecticides in plants
Peder Odgaard: Lysimeter studies with pesticides

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 objectives 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. Chemical analyses of 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, 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 have been studied. 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 soil for collection of water, leaving the root zone. Samples are taken during the winter and analyzed by GC/MS.

In water samples from the 2 plantations the content of atrazine, hexazinone and degradation products of both has been determined. In water samples from the 3 agricultural soils the content of phenoxy herbicides has been determined.

Run off from arable soil

The pesticide content in run off from a sloping locality grown with winter wheat and sprayed with mechlorprop will be studied.

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

The degradation of ^{14}C-mecoprop (K-salt) has been determined at different soil temperatures and moisture contents and in sterile and non sterile soil. Three soil types have been used and soils were sampled both in the plough layer and down to 1 m. K_d was also determined.

Estimated half life in 3 surface soils was 3 to 4 days at 20°C whereas at 20, 10 and 5°C the half lives were 3, 12 and 20 days respectively. In soil sampled at 0-33, 33-66 and 66-99 cm the half life at 10°C was 7, 70 and 34 days. K_d-values in the soil types were 0.1 to 0.2 with K_{oc}-values of 8, 13 and 5 in the 3 surface soil samples.

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

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

In cooperation with National Institute of Animal Science metabolism of ethephon on barley is investigated. The grain was used in reproduction studies of rats and analyzed for ethephon residues.

Deposition of pesticides on spraying personnel

In cooperation with the Danish Agricultural Engineering Institute research in contamination of spraying personnel continued. This year it was tried to elucidate to which degree contamination was reduced using practical means of protectives. A significant reduction in contamination was obtained using few precautions in changing the machinery and protective clothing.

Decomposition of dithiocarbamates on potato leaves in field experiments

Decomposition studies were mainly concerned with the influence of sunlight i.e. experiments were conducted in period without precipitation. Different formulations of dithiocarbamates were investigated.

Leaching of ^{14}C-labelled pesticides determined in lysimeter experiments (Peder Odgaard & Arne Helweg)

Lysimeter experiments have been carried out to elucidate the leaching of autumn used mecoprop (K-salt).

^{14}C-mecoprop (2 kg a.i./ha) was applied in November to lysimeters with a surface area of 0.5 m^2 and a soil depth of 1-1.1 m (coarse sandy soil).

Until mid-March the following year the accumulated ^{14}C-amounts found in the leachate were 15 and 25 % respectively in the two lysimeters. Between 60 and 95 % of ^{14}C leached was identified as mecoprop.

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