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Working Group "Integrated Control in Oilseed Crops"

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Preface

The sixth meeting of the working group on integrated control in oilseed crops was held in Le Rheu, France, 27-28 February 1992.

At the meeting the results of the collaboration between two major topics were presented and discussed:
1. Monitoring diseases and insect pests - biology of pathogens and insect pests.
2. Disease resistance and integrated control of diseases/ Biological and integrated control of insect pests.

A report on the results of the joint field experiment - IOBC Joint Oilseed Experiment - was given which started in autumn 1990 with different countries participating .

Results of another collaboration in a major subject were presented and discussed: monitoring and potential use of parasitoids against oilseed pests.

For the first time results of research work in linseed, the second oilseed crop, were presented. Linseed plays a significant role as renewable raw material for industrial production and for dietary products in the food industry.

On the 8th and 9th of April 1991 a subgroup-meeting took place in Braunschweig (Germany), where provisional results and further work in the 'IOBC Joint Oilseed Rape Experiment' were discussed.

V.H. Paul
convenor

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Session 5: Biological and Integrated Control of Pests

Session 1

Monitoring Diseases - Biology of Pathogens

REVIEW OF SCLEROTINIA EPIDEMIC IN WINTER OILSEED RAPE IN ENGLAND AND WALES 1991

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Summary

Sclerotinia levels in 1991 were the highest recorded in England and Wales. It was found in 46% of monitored crops at an average level of 5.5% plants affected. Regional differences were apparent with higher levels in the south and west than in the north and east. Weather conditions are thought to have favoured infection in early May and also in early June. Following this increase in Sclerotinia, it is probable that widespread attacks could now occur in oilseed rape throughout England and Wales in favourable seasons. Reliable forecasting systems are required to minimise the use of prophylactic fungicide treatments.

1. Introduction

Although Sclerotinia sclerotiorum is an important pathogen of rapeseed crops in many parts of Europe, problems in England and Wales have been localised in recent years (Jellis et al., 1984). The disease has consistently been of economic importance in parts of Kent and Sussex in south east England but only occasional crops have been severely affected in other areas. In 1991, widespread attacks were reported for the first time in winter oilseed rape. This paper reviews the scale of the problem and its significance for rapeseed production in England and Wales.

2. Methods

Observations on disease incidence and severity in winter oilseed rape have been made by ADAS since 1976. Crops are selected to be representative of the area of production in each ADAS region and they are now sampled in the autumn, spring (stem extension) and summer (pod ripening). Samples of 25 plants are collected on each occasion and assessed for diseases as described by Hardwick et al. (1989). The number of crops sampled each year ranged from 95-125.

The incidence of Sclerotinia was assessed on a range of cultivars in two replicated field experiments in 1991.

Plots at Ashton, Northants were sown on 4 September 1990 on clay loam soil and harvested on 12 August 1991. Treatments were applied according to farm practice and included a spray of prochloraz (as Sportak 45) 0.25 kg a.i./ha with 2.0 l of Codacide oil on 27 March. At Critchel, Dorset cultivars were sown on 3 September 1990 on silty loam and harvested on 13 August 1991. Sprays of prochloraz + carbendazim (as Sportak Alpha) were applied at 0.21 + 0.08 kg a.i./ha on 1 November, and 0.29 + 0.11 kg a.i./ha on 13 April, and followed by iprodione (as Rovral Flo) 0.50 kg a.i./ha on 15 June. The incidence of Sclerotinia was assessed on 100 plants/plot on 24 July at Ashton and on 15 July at Critchel. Only records from cultivars common to both sites are presented (Table 4).

3. Results

Table 1. Incidence of Sclerotinia in winter oilseed rape England and Wales 1986-1991

Year	% Crops affected	Mean % plants affected
1986	12	0.7
1987	5	0.2
1988	4	0.3
1989	4	0.2
1990	9	0.7
1991	46	5.5

Table 2. Regional incidence of Sclerotinia in winter oilseed rape in England and Wales 1991

Region	Number of crops monitored	Mean % plants affected
Northern	23	4
Midlands & Western	20	10
Eastern	53	2
South Eastern	16	7
South Western	9	12
Wales	2	16
Total England & Wales	123	5.5

Low levels of Sclerotinia have been recorded during the 1980's but in 1991 its incidence in terms of the proportion of crops affected and the mean level of plant infection were the highest ever recorded (Table 1). Rather higher levels of infection were found in the south and west than in the north and east (Table 2). In monitored fields, Sclerotinia affected 1-20% plants in 50 crops, 21-40% plants in 4 crops and 2 crops showed › 61% plants affected. In all areas however, some (non-monitored) crops with more than 50% plants affected were reported.

Further analysis of the survey results showed small differences between the most widely grown cultivars (Table 3) with the lowest levels being recorded on cv. Libravo. However, significant differences between cultivars (P = 0.001) were detected in two cultivar trials (Table 4). The incidence of Sclerotinia was much lower in cvs Libravo and Lincoln than other cultivars.

Typical rainfall records for April-June 1991 in the south west (Lyneham, Wilts), north (Funningley, Yorks) and east (Stansted, Essex) are illustrated in Figs 1-3 respectively.

Table 3. Effect of cultivar on the incidence of Sclerotinia in monitored crops 1991

Cultivar	Number of crops	Mean % plants with Sclerotinia
Falcon	38	3.5
Libravo	22	2.7
Lictor	22	3.5

Table 4. Incidence of Sclerotinia in various cultivars of winter oilseed rape, 1991

Cultivar	Mean % plants affected (July)
Cobra	16.5
Envol	15.1
Eurol	16.3
Falcon	21.3
Idol	15.3
Libravo	6.4
Lictor	14.0
Lincoln	7.3
Samourai	19.0
Tapidor	25.4
SED (54 df)	2.70

Mean of 2 sites, Northants and Dorset

4. Discussion

Although the average levels of Sclerotinia recorded in 1991 would not have warranted specific spray treatment, significant losses are likely to have occurred in the 5% (6) crops where more than 20% plants were affected (Kruger, 1984). As samples of 25 plants are examined in our monitoring studies the results are likely to under-estimate the proportion of crops where Sclerotinia was present at low or very low levels.

The most important feature of the 1991 epidemic is that the numbers of sclerotia returned to soil at harvest may well be sufficient to initiate widespread epidemics

throughout most of England and Wales in future, given suitable weather conditions during flowering. There will undoubtedly be greater pressure to use fungicides to control Sclerotinia. There is therefore an urgent need to provide forecasts or risk assessment for Sclerotinia attacks.

Although 74% of monitored crops received a fungicide treatment in 1991, most were applied at early stem extension. Only 18% crops were sprayed with fungicide during flowering (Gladders et al., 1992) and in these crops some control of Sclerotinia may have been achieved (Kruger 1984). Sclerotinia was recorded in 51.5% of fungicide- treated crops and 40.7% unsprayed crops monitored in 1991. This suggested fungicides had little effect on disease incidence. However, a significant increase from 5% plants affected in untreated to 10% plants affected by Sclerotinia was detected in Wiltshire following an application of prochloraz on 27 March to cv. Lictor (ADAS unpublished results). This was an unexpected result and further observations are needed to substantiate stem extension sprays as a factor aggravating Sclerotinia in 1991.

Results from the two variety trials (Table 4) lent credibility to field reports that cv. Falcon was more severely affected than cv. Libravo. These differences were evident within a local area but not from the national summary of monitored crops (Table 3). The cultivars showed a similar ranking to those of Pope et al. (1992) although disease incidence was much lower in our experiments.

Rainfall during April-June 1991 (Figs 1-3) suggested that there was adequate moisture for the development of apothecia during April. Flowering started in early crops in the south in mid April but occurred more generally during 23-30 April. Flowering was more prolonged than usual in some areas where it continued up to 20 June. Alternating wet and dry periods in late April/early May coincided with early petal fall and are likely to have been conducive to Sclerotinia attacks (Gohari & Ballester, 1991; Kruger, 1984). Rainfall in early June may also have enabled late infection to take place. Field reports suggested that Sclerotinia control had been achieved with sprays applied about 10 May in the South East and occasionally from sprays applied as late as 31 May in the North.

Unfortunately there were no regional depots of sclerotia of Sclerotinia as had been monitored previously (Gladders et al., 1990). The widespread distribution of Sclerotinia indicates that inoculum was present and suggests that this might have been more closely synchronised with flowering than in previous years (Gladders et al., 1990).

Rainfall data from the synoptic stations used for Figs 1-3 can be used to calculate two of the criteria used by Gohari & Ballester (1991) in their analysis of Sclerotinia epidemics in oilseed rape in Cher. Flowering started on 23 April at Lyneham and on 30 April at Stansted and Finningley.

The criteria examined were (1) the number of periods of 4 consecutive days without precipitation (<0.1 mm) from 1 March to one week after the beginning of flowering, (2) a rain index calculated on the number of rain days (days > 0.1 mm rain) multiplied by total precipitation in mm during the 2 weeks after the start of flowering divided by 14. These values are shown in Table 5.

Table 5. Rain criteria for Sclerotinia attack, England 1991

Site	Region	Number of periods of 4 consec. days without rain (A)	Rainfall in 14 days after early flowering (mm)	Number rain days in 14 days after early flowering	Rain Index (B)
Lyneham	South West	13	31.6	8	18.1
Finningley	North	18	8.3	5	3.0
Stansted	East	14	19.7	8	11.3

(A) 1 March to one week after early flower.
(B) For 14 day period after early flowering, Rain Index =

$$\frac{\text{Total Rainfall} \times \text{Number of rain days}}{14}$$

Direct comparison of results from Table 5 with those quoted by Gohari & Ballester (1991) suggest that conditions in 1991 were highly conducive for a Sclerotinia epidemic (if we assume that it is valid to use criteria derived under French conditions). Criteria for these 3 sites in England were within the values of <25 for number of dry periods and of <40 for the rain index calculated by Gohari & Ballester (1991) for sites with significant levels of Sclerotinia in France. Selection of flowering data had a major influence on the rain index values as heavy rain (15-25 mm) fell in most areas on 29 April but this was excluded from calculations for Finningley and Stansted. In 1990, rainfall was very low after early flowering at Lyneham (2.4 mm) and Finingley (1 mm) but comparable to 1991 at Stansted (16.5 mm). This appears to account for the low level of Sclerotinia encountered in 1990 (Table 1).

Overall we have concluded that weather factors in 1991 were conducive for Sclerotinia attack at the early to full flower stage and at late flowering in some crops. Inoculum of Sclerotinia had been increasing slowly over the past 15 years of oilseed rape production in many areas and this contributed to the problem. Both peas and potatoes have also contributed to Sclerotinia problems (Davies, 1991).

Given that only a few severe attacks occurred in the east and north, it is likely that low inoculum levels limited the severity of the epidemic in these areas. Detailed studies of the epidemiology for Sclerotinia in oilseed rape and other arable crops are needed urgently so

that losses from this disease can be minimised in future (Hardwick et al. 1991). Reliable forecasts or risk assessments would enable fungicides to be used selectively against a disease which, in Europe, reaches epidemic proportions once very 5-10 years. Further detailed monitoring of crops will enable high risk areas and more specific strategies to be developed.

Acknowledgments

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Fig.1 Daily rainfall at Lyneham, Wilts. April - June 1991

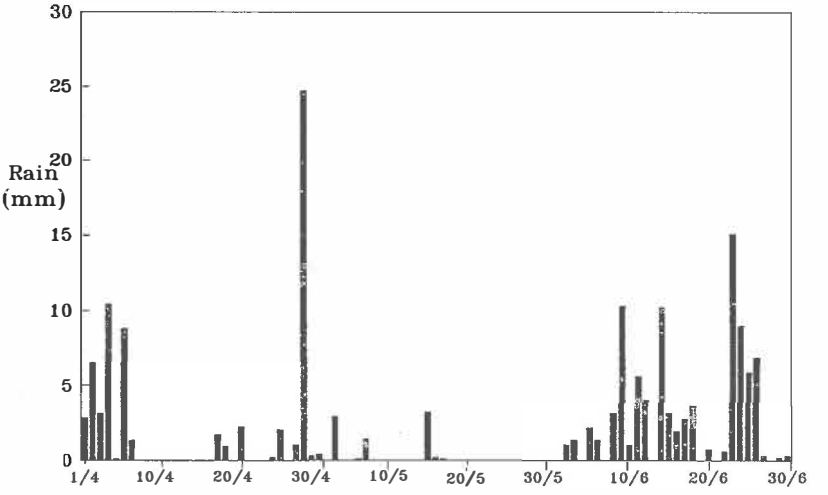


Fig.2 Daily rainfall at Finningley, S Yorks. April-June 1991

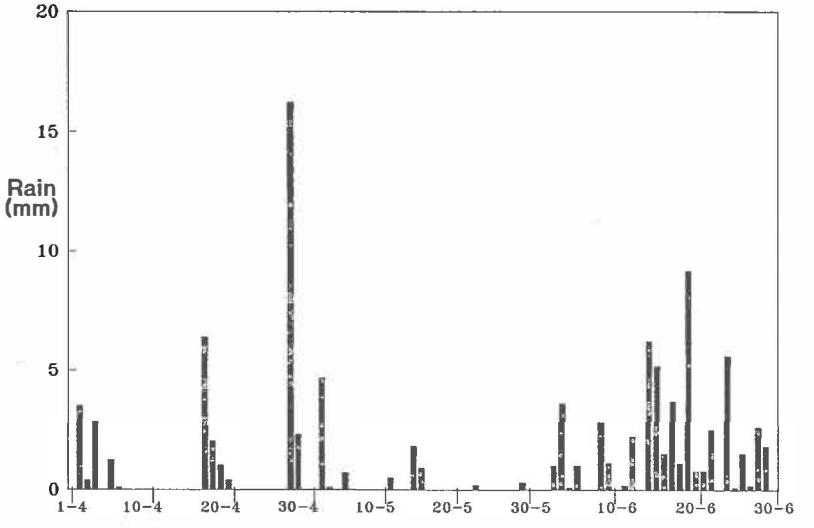
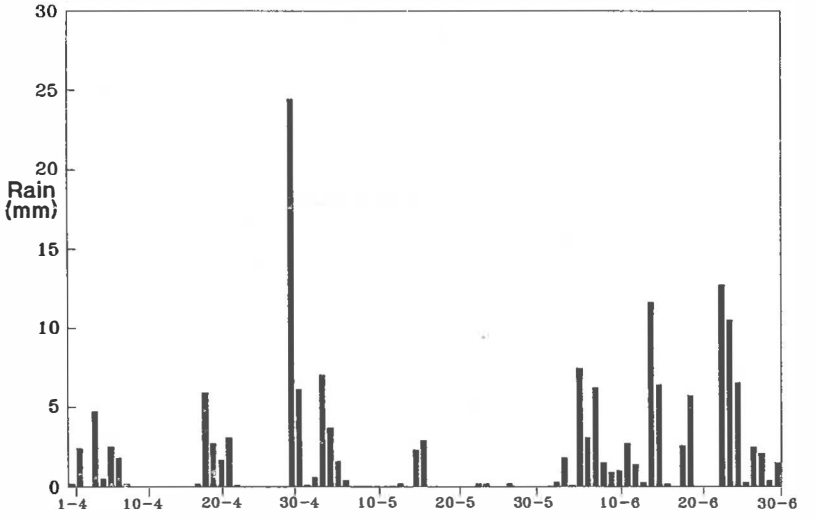


Fig.3 Daily rainfall at Stansted, Essex. April -June 1991



OBSERVATIONS ON RINGSPOT (MYCOSPHAERELLA BRASSICICOLA) IN WINTER OILSEED RAPE IN SOUTH WEST ENGLAND

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Summary

Ringspot has been found in 20-50% of winter oilseed rape crops in July since 1986. It was most common in 1987 and 1991. Leaf symptoms were detected in the spring during 1989-91 at low levels and were first seen in the autumn in 1990. In some cases, ringspot appeared to have spread from adjacent areas of kale. Ringspot increased rapidly during stem extension in some years, its incidence declining as infected lower leaves were lost. Good control of ringspot on foliage was achieved with prochloraz sprays in the spring but end of flowering treatments did not provide control of ringspot on pods. Whilst ringspot is generally present at low levels, there is now potential for ringspot to spread between oilseed rape and other brassica crops.

1. Introduction

Ringspot caused by Mycosphaerella brassicicola is an important disease of vegetable brassicas in England and Wales (Wafford et al., 1986) particularly in western and coastal areas. This disease is also important in forage brassicas, notably in kale (Brassica oleracea). Ringspot is now being found commonly in oilseed rape in South West England where it is largely confined. This paper reviews records of the incidence and development of ringspot in winter oilseed rape and discusses opportunities for control.

2. Methods

The incidence and severity of diseases in winter oilseed rape has been assessed by ADAS plant pathologists since 1976. Samples of 25 plants have been collected from commercial crops at the early stem extension stage (March) and again at the pod ripening stage (July). Crops harvested in 1990 and 1991 were also sampled in the autumn (November-December). Assessments were carried as described by Hardwick et al. (1989).

Ringspot has also been detected in crops used for various field experiments with fungicides. Samples of 25 plants were collected at intervals from an unsprayed area and examined for diseases. Ringspot development in comparison to that of light leaf spot is shown for 1988/89 (Fig. 1) and 1990/91 (Fig. 2).

The site in 1988/89 was at Spaxton, Somerset on cultivar Libravo sown on 30 September 1988 on clay loam soil and harvested on 26 July 1989. During 1990/91 observations were made at Corsham, Wiltshire on cv. Lictor sown on 21 August 1990 on a sandy clay loam soil and harvested on 8 August 1991. In a replicated fungicide experiment (Table 2) in the crop cv. Lictor sprays of prochloraz at 495 g a.i./ha (as Sportak 45) were applied as single sprays on 27 November, 1 March, 14 March and 27 March, in 250 litres of water/ha and on 26 April and 31 May in 350 litres water/ha by Oxford Precision sprayer operated at 200 kPa. Sprays of iprodione + thiophanate-methyl at 500 + 500 g a.i./ha (as Compass) were applied at the end of flowering (31 May) at the higher spray volume following either 27 March or 27 November + 27 March sprays of prochloraz. Plot size was 46 m^2. Disease assessments were made on 10 plants/plots on 26 April (early flowering stage) and on 25 plants/plots in July.

Table 1. Incidence of ringspot in winter oilseed rape 1986-1991

Harvest year	Number of crops sampled	% Crops affected		Mean % plants affected	
		March	July	March	July
1986	12	0	25	0	1.0
1987	14	0	50	0	21.4
1988	5	0	20	0	5.6
1989	8	25	50	1.0	2.9
1990	8	13	25	1.5	1.0
1991	9	44	33	12.9	14.7

3. Results

Symptoms of ringspot were typical of those described on other brassicas (Punithalingam & Holliday, 1975) although affected plants frequently had only simple leaf lesions. Care was needed to distinguish symptoms of ringspot from those of Phoma lingam. Ringspot was characterised by the presence of numerous small black fruiting bodies (spermagonia and ascomata) whereas Phoma leaf spots had more widely spaced brown pycnidia. Ringspot was also found on pods particularly in 1987 and 1991. Pod symptoms were often greyish green on immature pods with numerous black fruiting bodies. Extensive pod spotting seen in 1991 was dark grey to black and could be confused with alternaria pod spot unless examined closely for the presence of fruiting bodies.

Symptoms of ringspot on pods during July have been recorded since 1987, occasionally leaf symptoms were also present at this stage as occurred in 1986 (Table 1). The highest levels of ringspot were found in 1987 and 1991 when 0.1% and 1.5% pod area (respectively) was affected overall. Ringspot was found on samples in autumn for the first time in 1991 (see Fig. 2) but has been found more consistently in the spring (Table 1). Samples with ringspot have been collected

from the counties of Devon, Dorset, Gloucestershire, Wiltshire and Somerset during 1986-1991.

Table 2. Effect of sprays of prochloraz and iprodione + thiophanate-methyl on ringspot, 1991

Treatment applied on						Mean % plants with ringspot	Mean % pod area with ringspot
27/11	1/3	14/3	27/3	26/4	31/5	27 April	19 July
-	-	-	-	-	-	60 c	32.5
P	-	-	-	-	-	35 b	31.2
-	P	-	-	-	-	25 b	28.7
-	-	P	-	-	-	5 a	23.2
-	-	-	P	-	-	0 a	30.0
-	-	-	-	P	-	-	27.5
-	-	-	-	-	P	-	25.0
P	-	-	P	-	-	5 a	31.2
-	-	-	P	-	Co	-	25.5
P	-	-	P	-	Co	3 a	12.5
					SED	6.2 (18 df)	5.64 (27 df) NS

P - prochloraz
Co - iprodione + thiophanate-methyl
Treatment means followed by the same letter do not differ significantly

Monitoring of ringspot development (Figs 1 & 2) showed that leaf spotting increased rapidly during early stem extension (late February/early March) in 1989 and 1991. Further disease development on leaves occurred up to early flowering in 1989 but not in 1991. Ringspot developed extensively on pods in July in 1991 but was not detected on pods in 1989. Development profiles for light leaf spot on leaves in these crops (Figs 1 & 2) show the greater persistence of its leaf symptoms. Light leaf spot was present on pods but data have been omitted from Figs 1 & 2. It was found on 84% plants on 28 June 1989 and on 16% plants on 22 May 1991 increasing to 20% plants affected by 19 July 1991.

In 1988 and 1990 ringspot occurred on 4-8% plants in the spring but did not develop further on experimental sites. Good control of ringspot on leaves with prochloraz was demonstrated on 27 April 1991 (Table 2), 4-6 weeks after spring sprays were applied.

Partial control was achieved with sprays applied in the autumn and 8 weeks prior to assessment (1 March application). There was no significant control of pod infection which developed rapidly during July. Only the two-spray programmes

which included iprodione + thiophanate-methyl gave significant yield increases of 0.47-0.50 t/ha over untreated yield of 3.11 t/ha. A complex of diseases was present and at least partially controlled at this site and it has not been possible to establish the benefits of controlling ringspot.

4. Discussion

Ringspot is now established, albeit at low levels, in oilseed rape in England. At several sites, ringspot is thought to have spread to oilseed rape from adjacent small areas of infected kale used as cover for pheasants and other game. This is, therefore, an example of disease interaction between fodder brassica crops and oilseed rape (Gladders, 1984). In other areas ringspot may spread from vegetable brassicas to oilseed rape (Wafford et al., 1986) and there should be concern that oilseed rape could now be a source of ringspot for other brassicas. Interactions between cabbage and oilseed rape have been noted in Schleswig Holstein (Zornbach, 1991) but similar interactions have not been reported in England. The current distribution of ringspot in oilseed rape suggests that climatic conditions are particularly critical for its establishment. The South West has a mild, wet climate more favourable for ringspot development throughout the year than other districts.

Diagnosis of ringspot may require microscopic examination particularly if several diseases are present on leaves and pods. Following the recent discovery of the teleomorph of the white leaf spot pathogen, Mycosphaerella capsellae (Inman et al., 1991) careful examination of ascospores or culturing may be necessary to distinguish ringspot from white leaf spot on senescent pods. Ringspot usually occurred on the older leaves during the winter and spring whereas light leaf spot was frequently associated with young and partially expanded foliage. This contrast accounted for the greater persistence of foliar symptoms of light leaf spot. Spread of ringspot to the pods occurred most widely in 1987 and 1991 and was associated with high rainfall in late June and July.

The severity of ringspot has generally been low and the disease has probably had little or no effect on yield. Severe foliar ringspot was controlled in winter oilseed rape in Devon in 1987 with two sprays of tebuconazole (Kaspers & Siebert, 1989), but yield benefits from this control could not be determined because control of moderate levels of light leaf spot and alternaria pod spot was also achieved. Ringspot appears to have potential to cause yield reductions through less of photosynthetic tissue in both leaves and pods in the U.K. For ringspot control in the crop, prochloraz and also benzimidazole fungicides may be considered as benzimidazole-resistant strains of ringspot are uncommon (Gladders & Jones, unpublished data). Non-chemical control measures, including isolation of oilseed rape from known or potential sources of ringspot, and ensuring that brassicas are not cropped continuously in close proximity to each other should also be beneficial.

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Fig.1 Development of ringspot and light leaf spot. Spaxton 1988–89

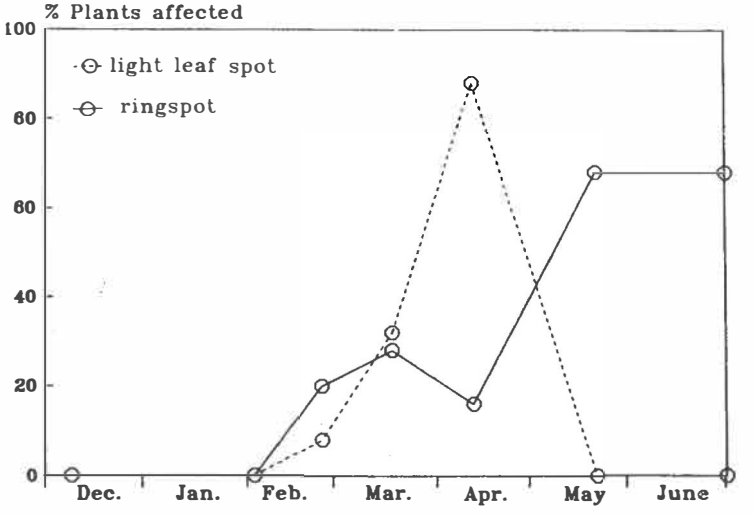
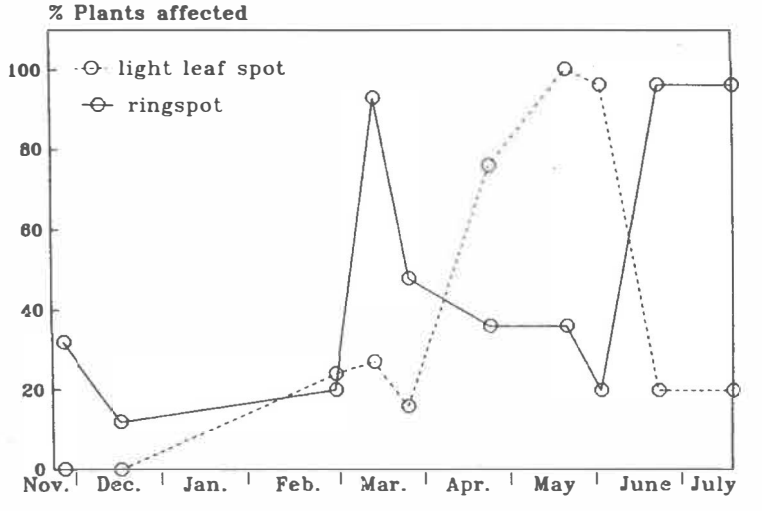


Fig. 2 Development of ringspot and light leaf spot. Corsham 1990/91.



METHODS FOR DETECTION OF EARLY INFECTION BY PYRENOPEZIZA BRASSICAE (LIGHT LEAF SPOT) ON WINTER OILSEED RAPE IN THE UK.

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Summary

Methods for the detection of early infection by P.brassicae, cause of light leaf spot on winter oilseed rape, were examined. The presence of inoculum was detected by bait plants and by a Burkard spore sampler before the disease was observed in the crop only in those crops following oilseed rape in which inoculum concentrations and consequently disease incidence were high during the autumn. Inoculated plants exposed in the field did not develop symptoms until the daily leaf wetness duration recorded was > 13 h. The disease could be seen on plants in the field before it was detected on bait plants or by a Burkard sampler in a first oilseed rape crop with a low disease incidence. Clearing and staining tissue did not improve detection of light leaf spot. A polyclonal antiserum produced against P. brassicae was not specific enough to be useful.

1.Introduction

Light leaf spot (LLS), caused by Pyrenopeziza brassicae, is considered the most damaging disease of winter oilseed rape in the UK (Hardwick et al., 1991). Autumn infection may cause damaging epidemics later in the season, although symptoms are not easily observed until spring (Rawlinson & Cayley, 1984; Jeffery et al, 1989). Light leaf spot is best controlled by fungicides applied in autumn if the disease is already established then. Therefore, a practical technique for the early detection of the disease would help growers to determine the need for application of fungicides in the autumn. This paper describes methods tested for detecting early infection by P.brassicae in crops. These included bait plants, monitoring airborne spores, detection of weather periods favourable for infection, direct assessment of plants from the field, clearing and staining plant tissues, and polyclonal antibodies.

2.Materials and methods

The studies were done in four oilseed rape experiments with plots of 3 x 21 m, arranged in randomised blocks or split plot designs at Rothamsted. Experiment A (7500 m^2 , cv.Cobra) and experiment C (4000 m^2, cv.Envol) were sown, respectively, on 31 August 1990 and 11 September 1991, following oilseed rape. Experiments B and D (1000, 1000 and 8000 m^2, cvs Falcon, Capricorn and Cobra, respectively) were sown, respectively, on 1 September 1990 and 6 September 1991 following cereals.

2.1 Bait plants

Healthy glasshouse-grown oilseed rape plants (cv. Cobra, GS 1.5-1.6; Sylvester-Bradley, 1985) were exposed in experiment A from 31 August to late December 1990, and in experiment D from mid-September until mid-February 1992. Twice weekly groups of 8 pots with 3 plants per pot were exposed in experiment A; once weekly groups of 24 pots with 3 plants per pot were exposed in experiment D. A half of the pots was placed in the crop and the rest on a grassed area 6 m from the crop. One week later, a half of the pots from each group was transferred to a glasshouse and the other half was left in the field on the grassed area. All plants were assessed for LLS symptoms every 1-3 days for 5 weeks.

2.2 Monitoring inoculum and infection conditions

Concentrations of airborne spores were monitored with a Burkard spore sampler from sowing until March 1991 in experiment A and from mid-September until mid-February 1992 in experiment D. To identify periods favourable for infection, three groups of pot-grown oilseed rape plants were inoculated with conidial suspensions of P. brassicae twice weekly from early September 1990 to late April 1991 and from mid-September 1991 to mid-February 1992. Two groups were kept at 100% r.h. for 48 h after inoculation; one was then placed in a glasshouse and the other outside. The third group was placed next to experiment A or experiment D immediately after inoculation. Every 1-3 days for 6 weeks the incidence and severity of LLS on the plants in each group were assessed. An automatic weather station connected to a Campbell 21x data logger recorded leaf wetness duration and air temperature above and within the crop.

2.3 Assessment of disease on field samples

In November 1990, four assessments of LLS incidence were done in experiments A and B. On 1 and 7 November, samples of 20 plants from the experimental plots and volunteer plants in the surrounding areas were taken at random and assessed directly in the field. On 16 and 19 November, samples of 50 plants were assessed in the field and then incubated in polythene bags at 3°C for 7-10 days before reassessment. In experiment C, from 9 October 1991 onwards, four samples of 100 plants were taken monthly at GS 1.7, 1.9, 1.10 and 1.12, respectively. The plants were incubated and assessed for LLS infection. Four large samples (480 to 2000 plants) were taken from experiment D at GS 1.2, 1.4, 1.6 and 1.07 respectively. Some leaves from plants inoculated with conidial suspensions of P. brassicae and from plants sampled from the crop that were showing LLS-like symptoms were cleared by boiling in ethanol and staining with trypan blue in lactophenol. They were then examined microscopically to determine if the fungus was present.

2.4 Polyclonal antiserum

A polyclonal antiserum against P. brassicae was prepared by using conidia obtained from a 60-day-old single spore culture of P. brassicae grown on 2% malt extract agar. A conidial suspension in sterile distilled water was centrifuged for 10 min. The pellet was resuspended in 0.5 ml saline solution (0.85% w/v sodium chloride) and then mixed with an equal volume of Freund's complete adjuvant. A rabbit was immunised intramuscularly at two sites with 0.5 ml of the antigen (10^8 spores) per site. The serum was collected from the rabbit a month later, then at c. 2 wk-intervals. Since the titre of the serum was low, a second immunisation without adjuvant was done. Antiserum from the sixth bleed had a titre of

1/6400. Using ELISA, this antiserum was tested against plant tissue artificially infected with isolates of P. brassicae, Pseudocercosporella capsellae, Phoma lingam, Peronospora parasitica or Erysiphe cruciferarum from UK oilseed rape crops and against spore suspensions of Alternaria brassicae or Botrytis cinerea.

3.Results

3.1 Bait plants

The bait plants in the crop and on grass 6 m from the edge of the crop first became infected between 3-5 October 1990. The incidence of LLS was low (two out of 24 plants infected) (Fig.1). In autumn 1990, all plants exposed from late October to late December became infected but amounts of disease on plants exposed in the crop were greater than on those outside the crop. In 1991-92 (experiment D), the disease had not been detected by mid-February although a larger number of bait plants was used.

3.2 Monitoring inoculum and infection conditions

Airborne inoculum of P.brassicae, as conidia and ascospores, was present above the crop in experiment A from late September 1990 onwards (GS 1.04) (Fig.2). In experiment D, spores were collected from late December 1991. Ascospores of Unguicularia cfr. raripila similar to those of P. brassicae were also collected by the Burkard sampler from late December onwards in experiment A and from late September in experiment D.

Inoculated plants exposed in experiment A developed LLS symptoms from October 1990 onwards (Fig. 3) when measured daily leaf wetness periods frequently exceeded 13 h, which was shown in controlled environment experiments to be the minimum leaf wetness period required at 12 or 18°C. In 1990, plants inoculated, kept at 100% r.h. for 48 h and then placed outside the glasshouse all developed symptoms from early September onwards. However, the latent period was longer and disease severity was less on those plants when temperatures were low from November onwards. In autumn 1991, the pattern of disease severity and latent period on plants inoculated with conidial suspensions was similar to that on those inoculated in autumn 1990, with the only difference being that in 1991 favourable conditions occurred from late September throughout October.

3.3 Assessment of disease on field samples

In both experiments A and B, LLS was present on volunteer plants by early November 1990, but was not detected on plants in experimental plots until mid-November (Table. 1). The incidence of recorded LLS was greater when plants were incubated in polythene bags for 10 days at 3°C. In 1991, disease progress in the autumn was slower than in 1990. The incidence of LLS in experiments C was greater than that in experiment D. Clearing and staining tissue could not distinguish P. brassicae from the other pathogens until later stages of infection when conidiomata or other typical structures had developed.

3.4 Polyclonal antiserum

The polyclonal antiserum produced against P. brassicae cross-reacted with all the fungi tested and against the sap of healthy plants.

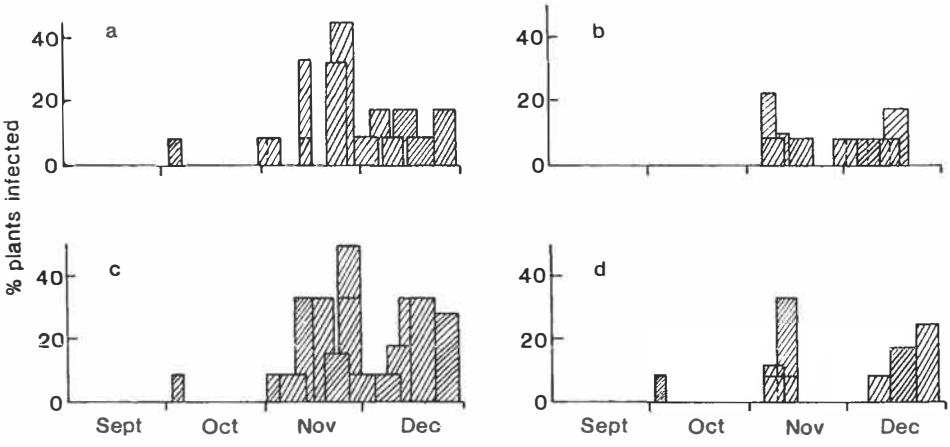

Fig. 1. Incidence of light leaf spot on bait plants incubated under field (**a,b**) and glasshouse (**c,d**) conditions after one week of exposure in experiment A (oilseed rape following oilseed rape) (**a,c**) or on grass outside the crop (**b,d**).

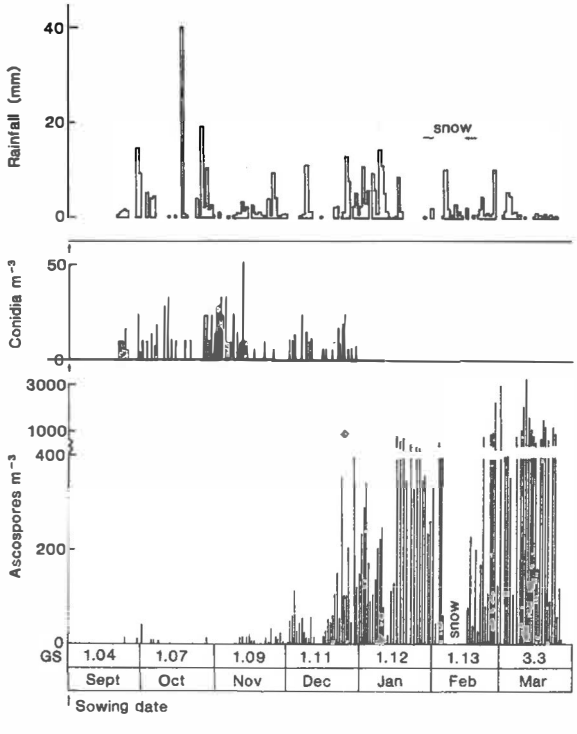

Fig. 2. Daily concentrations of airborne spores (conidia and ascospores) of P.brassicae and daily rainfall from September 1990 to March 1991 in experiment A.

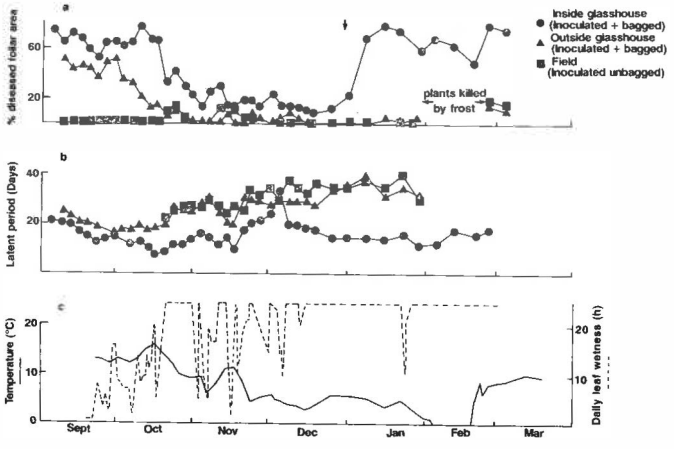

Fig. 3. Light leaf spot severity (a) and length of latent period (b) in relation to air temperature (c) on pot grown oilseed rape plants (cv. Cobra) inoculated with spore suspensions, kept at 100% r.h. for two days and then transferred to a glasshouse ( ) or kept outside the glasshouse ( ) or placed in the field immediately after inoculation ( ).
( ) From this day onwards, temperature in the glasshouse was maintained between 10-15°C.

Table 1. Incidence of light leaf spot on volunteer and crop plants in first and second successive oilseed rape crops in 1990 and 1991-1992.

Sample date	% plants infected					
	Volunteer	Crop	Cultivar	Volunteer	Crop	Cultivar
	Experiment A			**Experiment B**		
1 Nov. 1990	5	0		0	0	
7 Nov.	10	0		5	0	
16 Nov.	10(12)	4 (6)	Co	4(4)	0(2)	F+C
19 Nov.	10(12)	12(16)	Co	4(6)	2(4)	F+C
	Experiment C			**Experiment D**		
1 Oct. 1991	-	-		-	0.1	Co
9 Oct.	7 Co	4	E	-	-	
29 Oct.	-	4	E	-	0.1	Co
17 Nov.	-	-		-	0.2	F+C
7 Dec.	-	8	E	-	-	
16 Dec.	-	-		-	0.2	F+C
6 Jan. 1992	-	16	E	-	-	

Numbers in parentheses indicate disease incidence after incubation at 3°C for 10 days.
Co= Cobra, F+C= Falcon or Capricorn, E= Envol.

4. Discussion

Bait plants and the Burkard sampler detected the presence of inoculum in the field before the disease was observed on oilseed rape following oilseed rape but not on oilseed rape following cereals. This suggests that bait plants and Burkard samplers might detect the presence of the inoculum before symptoms appear in crops, provided that the numbers of airborne spores are large or a large number of bait plants is used. Ascospores of Unguicularia cfr. raripila may also be present as early as late September in an oilseed rape crop, making the identification and estimation of P.brassicae inoculum with the Burkard sampler uncertain (Inman et al., 1992).

Inoculated plants exposed outside the crop did not show symptoms until the leaf wetness duration recorded was commonly more than 13 h per day. Therefore, in addition to the detection of the inoculum in the field it may be necessary to monitor leaf wetness and/or rainfall. When leaf wetness duration is above 13 h, inoculum is present and there is substantial rainfall before temperature drops, severe early infection is likely. However, with the present data it is not possible to determine whether the disease incidence in autumn was lower 1991 than in 1990 because there was less inoculum or because the long dry period in October 1991 made the secondary dispersal of spores inefficient, despite the adequate infection conditions prevailing during October.

Disease severity on the inoculated plants was low at low temperatures, suggesting that the efficiency of the inoculum is likely to be lower during the winter. Therefore, the minimum concentrations of airborne inoculum to cause infection during the periods of low temperature would need to be known when using spore samplers to monitor airborne inoculum as an early detection method. Furthermore, the difficulty in distinguishing some ascospores of Unguicularia cfr. raripila from those of P. brassicae should be taken into account.

These results suggest that visual examination of plants for LLS symptoms may indicate the presence of the pathogen before bait plants or Burkard spore samplers, even in a first oilseed rape crop, provided that a large sample of plants is examined very carefully. Clearing and staining tissues did not improve detection of LLS. The polyclonal antiserum was not specific enough to detect the presence of the fungus, but the development of monoclonal antibodies may eliminate the problem of cross reactivity.

The incidence threshold in the autumn above which fungicide treatment is on average economically justified on a specific cultivar is unknown. Moreover, the threshold seems likely to be a few per cent, and therefore, if the fungus can be detected in the crop by immunological or other means before symptoms are clearly visible, the method will need to use large samples of plants to enable the infection to be detected at a low incidence in the autumn. Although some of the methods investigated were able to detect the pathogen before the symptoms were easily observed in the crop, most of them are labour intensive and time consuming. None of them can be recommended as practical for use in first oilseed rape crops where the incidence of the disease is usually low.

5.Acknowlegement

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CULTIVATION, PRESERVATION, AND HOST-RANGE OF PERONOSPORA PARASITICA FROM CAPSELLA BURSA-PASTORIS

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Summary

The downy mildew, Peronospora parasitica, is common on the wild crucifer shepherd's-purse (Capsella bursa-pastoris) in Alberta, Canada. A method has been developed to grow this downy mildew on seedlings of shepherd's-purse on moistened vermiculite in deep Petri dishes. A number of different methods of freezer and liquid nitrogen storage of this pathogen are being investigated. Brassica napus ssp. oleifera cv. Westar, B. campestris ssp. oleifera cv. Tobin, B. juncea cv. Pusa Bold, Sinapis alba cv. Gisilba, and Eruca sativa (local strain Morena, India) were all highly resistant to this collection of P. parasitica.

1. Introduction

The downy mildew, Peronospora parasitica (Pers. ex Fr.) Fr. is known to occur on canola (Brassica campestris L. ssp. oleifera and B. napus L. ssp. oleifera) and a number of other crucifers in Canada (Conners, 1967; Tewari, 1985; Ginns, 1986; Martens et al., 1988) but no detailed studies have been carried out in this country. In western Canada, where only spring-sown canola is grown, downy mildew infections are often seen on the cotyledons, adult leaves, stems, and siliqua, and more commonly on the stagheads on B. campestris ssp. oleifera caused by Albugo candida (Lev.) Kunze. In this area, certain cruciferous weeds which grow in and around canola fields are also infected with P. parasitica. At present, the downy mildew disease of canola is not considered to be economically important in western Canada. This is unlike the situation in some other parts of the world (Kolte, 1985; Sadowski, 1989). However, fall-sown canola cultivation is presently increasing in eastern Canada, and it remains to be seen if this disease will eventually become economically important in that region.

Among the wild crucifers in central Alberta, Capsella bursa-pastoris (L.) Medic. (shepherd's-purse) is one which is most affected by P. parasitica. This weed is very common in and around canola fields in this area. The downy mildew on shepherd's-purse has been studied by a number of researchers in the past (Gäumann, 1918; Wang, 1944; Yerkes & Shaw, 1959; McMeekin, 1969; Sansome & Sansome, 1974; Dickinson & Greenhalgh, 1977) but the reactions of currently grown cultivars of canola and mustards to this strain of the pathogen are not known. The results presented in this paper are the first part of a continuing investigation on the downy mildew of crucifers in Canada and present information on cultivation and preservation of P. parasitica, using the shepherd's-purse downy mildew as the test organism. Information on reactions of some currently grown cultivars of canola, mustards and an exotic oliferous crucifer is also presented here. Some information presented is of preliminary nature.

2. Materials and methods

2.1 Plant materials

Seeds of shepherd's-purse collected from Edmonton area were treated with gibberellic acid (1000 mgL^{-1} in water) for 24 h, sown in clumps in sterilized vermiculite moistened with water or Hoagland's solution in 7.5 cm deep Petri dishes with lids, and placed at 15° C and 16 h light (62-72 $\mu Em^{-2}s^{-1}$) period. The relative humidity in these Petri dishes was very high and condensation of water was observed on inside of the Petri dishes including the underside of the lids. Gibberellic acid treatment was used to break the dormancy of shepherd's-purse seeds (Corns, 1960).

Seeds of B. napus ssp. oleifera cv. Westar, B. campestris ssp. oleifera cv. Tobin, B. juncea (L.) Cosson cv. Pusa Bold (Indian mustard), Sinapis alba L. cv. Gisilba (white mustard), and Eruca sativa (Miller) Thell., local strain Morena, India (taramira, garden-rocket) were obtained from the department of Plant Science, University of Alberta seed collection and grown as described above.

2.2 Pathogen collection and inoculation experiments

P. parasitica-infected material of shepherd's - purse was collected from Edmonton area during the late summer of 1991. This material contained abundant conidia of the downy mildew. Cultures of P. parasitica were initiated by dusting the conidia directly onto the seedlings of shepherd's-purse. Similarly, the seedlings of other plants were inoculated by dusting the conidia from the infected shepherd's-purse seedlings directly on to their previously moistened cotyledons. All inoculated plants were kept at 15^{o} C with 16 h light period.

2.3 Cryostorage

Materials for cryostorage were prepared by 5 different methods. Two ml cryotubes were sterilized empty (dry treatment) or containing 1 ml water or 20% glycerol in water. Infected cotyledons of shepherd's-purse were placed in these cryotubes using sterile forceps. All cryotubes were precooled for 1h at 4^{o} C before freezing by two different methods. The first method involved placing the cryotubes (dry and water treatments) in a freezer at -20^{o} C. This subjected the cryotubes to an undetermined slow rate of cooling. In the second method the cryotubes (dry, water and glycerol treatments) were placed on level 2 of a Handi Freezer tray (Union Carbide Model P/N R036-8C15). This tray was placed into the neck of a Union Carbide 35VHC Cryogenic Refrigerator, previously filled with liquid nitrogen at -196^{o} C. These loaded cryotubes remained overnight exposed to the nitrogen vapor, cooling at the rate of 6^{o} C/min. The next day, frozen cryotubes and labelled aluminium canes were placed into liquid nitrogen held in a large thermos bottle. Wearing protective cotton gloves and using long metal forceps, the cryotubes floating in liquid nitrogen were picked up and loaded onto canes. Each cane holding 6 cryotubes, was then placed into a numbered canister in the Cryogenic Refrigerator. During the thawing and viability testing procedures one cryotube was carefully removed from the cane using long forceps and cotton gloves. Thawing was done quickly under running tap water at 30^{o} C, holding the cryotube at an angle to allow the stream of water to run over the frozen pellet only. As soon as all ice crystals were melted, the cryotube was set aside. If glycerol had been used, a sterile water wash of the stored cotyledons were carried out. Otherwise, they were applied directly to clumps of shepherd's-purse seedlings.

3. Results and discussion

3.1 Growth of P. parasitica on shepherd's-purse

Shepherd's-purse seedlings grown in vermiculite moistened with water were ready for inoculation in 4-5 days after sowing and upon inoculation with P. parasitica, showed sporulation of the pathogen in another 4-5 days. By about 7-8 days of inoculation, a profuse sporulation of the pathogen was observed. The seedlings grown in vermiculite moistened with water grew very slowly and produced only a few true leaves in the next few weeks. Often these true leaves also got infected and showed sporulation of the pathogen. In this manner, once inoculated, sporulating material in a Petri-dish was available for about 6 weeks. In contrast to this, seedlings grown in vermiculite moistened with Hoagland's solution grew rapidly and profusely and got tangled together filling the whole Petri-dish. These seedlings did get infected upon inoculation but the infection was confined to the lower part of the seedlings and was hard to observe without untangling the seedlings. Therefore, in most experiments only water was used for moistening the vermiculite.

3.2 Preservation of P. parasitica

This work is still continuing and only preliminary results are presented here. Infectivity of freezer and liquid nitrogen stored materials was tested after 2 months and only dry- and water-freezer treatments and glycerol-liquid nitrogen treatments have so far shown any viability in some experiments.

3.3 Host-range of P. parasitica from shepherd's-purse

The cotyledons of all plants screened (cvs. Tobin, Westar, Pusa Bold, and Gisilba and the accession of E. sativa) were highly resistant to P. parasitica and did not reveal any infection and

sporulation of the pathogen. Most inoculated cotyledons revealed hypersensitive response as indicated by necrotic flecking.

Future studies will include some other Canadian, European and Oriental cultivars of canola/rapeseed and mustards, and vegetables and wild crucifers.

4. Acknowledgments

Mrs. Shirley Brezden provided some technical assistance required for this investigation.

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FIRST RESULTS FROM SIMPLE METHODS OF PRESERVATION OF *Peronospora parasitica*

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Summary

Laboratory-tests were conducted to find simple methods of preservation of conidiospores of downy mildew, (*Peronospora parasitica*). Using a number of different additives samples of a conidia suspension were frozen at -21°C. First results about the germination-rates of conidiospores in dependence on different periods of preservation in a freezer are presented.

1. Introduction

Research on resistance of the obligate pathogen *Peronospora parasitica* requires a high expenditure for the preservation of isolates. Different in vitro tests were conducted to limit this routine work and to provide infected material in abundance at any time. Methods for preserving different oomycetes in liquid nitrogen (Bromfield & Schmitt, 1967; Dahmen et al., 1983) or after lyophilization in a freezer (Staffeldt, 1961) were unsuccessful. However preliminary tests on conidiospores at -21°C without prior lyophilization gave promising results.

The objective of this study was to examine systematically the cryoprotective effect of different additives on the survival of conidiospores of *P. parasitica* after storage at -21°C.

2. Material and Methods

For research in the laboratory and in the greenhouse with *P. parasitica,* leaves and pods of the winter-oilseed rape *Brassica napus* ssp. *oleifera* infected by the downy mildew were collected around Kiel, Düsseldorf and Soest. Spores from infected material were used to inoculate cotyledons of the *P. parasitica*-susceptible oilseed rape variety Diadem. Cotyledons were put into plastic boxes on moist filter paper and incubated at 15°C and 70 - 80 % relative humidity. Under these environmental conditions conidiospores could be harvested 6 days after inoculation. For each variant 5 cotyledons colonized with fresh conidiospores were collected in a glass vial.

Fig. 1 Germination-rates of *P. parasitica* after a storage interval of 2 days at -21°C using different cryoprotectants

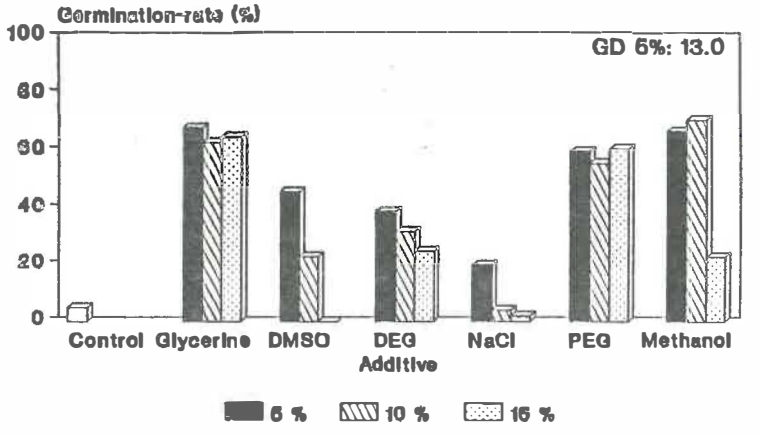
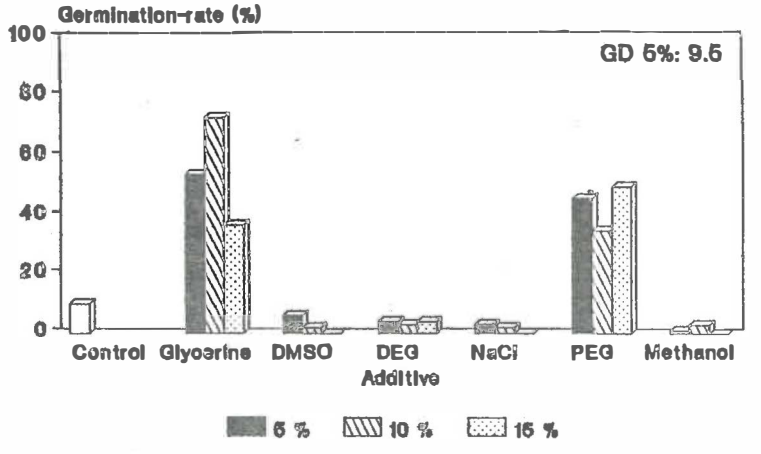


Fig. 2 Germination-rates of *P. parasitica* after a storage interval of 8 days at -21°C using different cryoprotectants



As suspension media the following cryoprotectants were added in a concentration of 5, 10 and 15 % (v/v): diethyleneglycol (DEG), dimethylsulfoxide (DMSO), glycerine, methanol, sodium chloride (NaCl) and polyethyleneglycol (PEG). As control a conidiospore suspension in aqueous solution was used. For each variant 6 glass vials were filled with the conidia suspension and immediately stored in a freezer at -21°C.

After a storage interval of 2 or 8 days respectively samples were taken from the freezer and thawed at room-temperature (20°C). After thawing for 10 minutes 2 ml of the conidiospore suspension were applicated on each petri-dish containing 15 % (w/v) water-agar using an Eppendorf-pipette. As an indicator for the viability of the stored conidiospores, germination-rates were recorded. This was done after 24-hours at 15°C. The percentage of germination for each variant was assessed with nine counts of 100 conidiospores each.

The statistical analysis was done by a multifactorial variance analysis with a subsequent LSD-test.

3. Results

After a storage interval of 2 days 10% methanol gave the highest germination-rate of 71 % (Fig. 1). All samples of glycerine, 5% methanol and PEG also gave high germination-rates. All the other variants had germination-rates of less than 50 %. In the case of 15 % (v/v) DMSO and 10, 15 % (v/v) NaCl germination was lower than the control rate of 5 %.

After a storage interval of 8 days the highest germination-rate of 73 % was assessed for 10 % (v/v) glycerine (Fig. 2). The second-best result was recorded with 5 % (v/v) glycerine which gave 54 % germination. All PEG samples and the 15 % (v//v) glycerine samples had germination-rates lower than 50 % after 8 days storage. All DMSO, DEG, methanol and NaCl samples had germination-rates of 0 - 6 % even lower than the control with 10 %.

4. Discussion

The use of cryoprotective additives increased the survival of conidiospores of *P. parasitica* after a freezing-storage at -21°C. Although several treatments were effective after two days, germination-rates had declined by 8 days. A sufficient cryoprotective effect was only given by 5 and 10 % (v/v) glycerine which had germination-rates of more than 50 %. The most effective protection is given by 10 % (v/v) glycerine which enabled 73% of conidiospores to survive 8 days at -21°C.

This high cryoprotective effect of 10 % (v/v) glycerine was subsequently confirmed by preservation tests over several weeks. In one experiment an average germination-rate of 80 % could be achieved after 5 weeks in a freezer. A decelerated drop in temperature by an isolation of the glass vials had no effect on the survival rate of the conidiospores. In a further experiment using 10 % (v/v) glycerine more than 50 % germinated conidiospores could be counted after 13 weeks.

Experiments using 10 % (v/v) glycerine will be continued to investigate how long viable conidiospores of *P. parasitica* can be recovered after storage at -21°C.

5. References

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Session 2

Disease Resistance and Integrated Control of Diseases

DISEASE RESISTANCE IN OILSEED RAPE AND LINSEED CULTIVARS IN U.K. TRIALS TO 1991

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Summary

Oilseed rape and linseed cultivars in UK performance trials were evaluated for their resistance to a range of diseases by assessing visual symptoms. For oilseed rape, the majority of cultivars were either moderately or very resistant to downy mildew (Peronospora parasitica). Approximately half of the new cultivars entered in National List trials were moderately susceptible to stem canker, (Leptosphaeria maculans) and about one third were moderately susceptible to light leaf spot (Pyrenopeziza brassicae). Very few cultivars were classified as very susceptible to any of these three diseases. For linseed cultivars, significant differences were found in resistance to powdery mildew (Oidium lini) and grey mould (Botrytis cinerea). There was a weak correlation between powdery mildew and cultivar maturity, but a much stronger correlation between time of flowering and incidence of B.cinerea in the field.

1. Introduction

Resistance to light leaf spot (Pyrenopeziza brassicae), stem canker (Leptosphaeria maculans) and downy mildew (Peronospora parasitica) is assessed routinely in winter oilseed rape cultivars undergoing performance trials in the U.K. at the National Institute of Agricultural Botany. Resistance is evaluated by estimating the severity and incidence of disease symptoms, and the resulting data are converted to resistance ratings for statutory (National List) and advisory (Recommended List) purposes (Sweet & Beale, 1991).

Recently, performance trials for linseed have been carried out in the U.K., and preliminary observations on the incidence and severity of powdery mildew (Oidium lini) and grey mould (Botrytis cinerea) have been made (Beale, 1991).

This paper reviews the levels of disease resistance in oilseed rape and linseed cultivars in trials during 1990 and 1991, and assesses the potential of resistance as a disease control measure.

2. Materials and methods

Diseases in oilseed rape trials were assessed using established protocols (Anon, 1985). Resistance ratings (on a 1-9 scale) were calculated by converting % infection data, or disease indices in the case of stem canker, to ratings using a straight line relationship. The position of the line was fixed each year by assigning the same standard ratings for control cultivars with well established disease reactions and setting a rating of 9 equivalent to 0%, or 0 disease index. For all diseases, infection data were the means derived from a fitted constants analysis over years and sites.

Methods of assessing linseed diseases, linseed agronomic characters and for inoculated tests with B.cinerea have been described by Beale (1991).

3. Results

Resistance ratings for cultivars currently on the U.K. Recommended List are summarised in Table 1. The distribution of resistance ratings for cultivars newly entered in U.K. National List trials for 1990 and 1991 is given in Table 2. None of the cultivars on the Recommended List is classified as very susceptible to any disease, and only one cultivar in National List trials was found to be very susceptible to light leaf spot. The majority of cultivars in National List trials were classified as moderately resistant to light leaf spot, though about 50% of cultivars were moderately susceptible to stem canker. As on the Recommended List, most cultivars were moderately or very resistant to downy mildew.

Most cultivars were at least moderately resistant to more than one disease (Table 3) and only one was classified as susceptible to all three.

Differences between ratings of 3 points or more were statistically significant (Table 4), though for stem canker, 2 point differences were significant in 1990. There was considerable variation in overally disease levels between trials, with high levels of infection occasionally occurring on some cultivars regarded as moderately resistant (Table 5).

There were significant differences in the level of infection with *Oidium lini* on linseed cultivars in all four trials (Table 6). Antares was the most susceptible cultivar, while cv. Norman was the most resistant using fitted constants adjusted means. Using a larger number of cultivars, Beale (1991) reported a weak correlation between susceptibility and earliness of maturity. However, cv Norman, an early maturing type, was resistant, and this is again indicated in recent additional data (Table 6, trial 4).

There were also significant differences in the level of infection with *B.cinerea* in the field, and in inoculated tests (Table 7). Early flowering cultivars tended to be most severely infected in the field, but this was not the case in inoculated tests.

4. Discussion

Some of the oilseed rape cultivars entering National List trials in 1990 have recently been added to the Recommended List, while those entering in 1991 may be recommended for 1993. Since resistance ratings are comparable from year to year *via* the use of control cultivars, it appeared that levels of resistance were generally being maintained, and in some cases improved, with an increasing proportion being moderately and very resistant to light leaf spot and downy mildew respectively. Resistance to stem canker was of more concern, since over half of the new entries were moderately susceptible, and chemical control methods may be only partially effective.

The relationships between disease incidence and yield loss for the oilseed rape diseases discussed here are not well understood (Hardwick *et al.*, 1991). However, in a series of fungicide trials carried out with a number of cultivars with different resistance ratings larger yield responses were generally obtained with those cultivars which were most disease susceptible (Sweet & Beale 1991), though more resistant cultivars also showed some response to fungicide treatment. While this indicates that available levels of resistance offer an effective disease control measure, the levels of disease which sometimes developed on moderately resistant cultivars suggest that resistance alone will not provide adequate disease control in all situations especially for light leaf spot and downy mildew. Whether the high levels of these diseases observed on moderately resistant cultivars were due

to local inoculum pressure or the development of more adapted pathotypes is not known.

Initial observations on the incidence of powdery mildew and grey mould on linseed suggested that resistance to these diseases is available in current material (Beale, 1991). Though the occurrence of grey mould in the field was closely correlated with earliness of flowering, there appeared to be differences in the resistance of cultivars to foliar infections. Further investigation on the rate of development of powdery mildew on different cultivars and on the relation between pre-flowering foliar infections and post flowering capsule infections of grey mould is required so that resistance to these diseases can be fully exploited.

5. Acknowledgements

Part of this work has been funded by the HGCA Oilseeds Levy. The help of NIAB Trials Officers with disease assessments is gratefully acknowledged.

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Table 1. Resistance ratings for light leaf spot, stem canker and downy mildew in currently recommended cultivars of winter oilseed rape in the U.K.

Cultivar	Light leaf spot	Stem canker	Downy mildew
Falcon	6	6	7
Libravo	7	6	8
Samourai	5	4	7
Envoi	6	5	8
Eurol	7	5	8
Idol	7	5	8
Apache	5	6	6
Bristol	5	6	8
Cobol	5	5	8
Lineker	6	5	8
Rocket	6	4	7
Cobra	4	4	7
Lictor	6	5	7
Tapidor	6	5	8

* 1-9 scale where 1 is susceptible, 9 resistant.

Table 2. Number of cultivars in four resistance rating categories in 1990 and 1991 U.K. National List trials for light leaf spot, stem canker and downy mildew.

Resistance category 1-9 rating	"Very susceptible" 1-3	"Moderately susceptible" 4-5	"Moderately resistant" 6-7	"Very resistant" 8-9
1990				
Light leaf spot	0	14	26	0
Stem canker	0	20	19	1
Downy mildew	8	0	29	3
1991				
Light leaf spot	1	10	31	0
Stem canker	0	25	17	0
Downy mildew	0	3	24	15

Table 3. Number of cultivars with multiple disease resistance or susceptibility in U.K. performance trials for 1990 and 1991.

Diseases	Susceptible *	Resistant *
light leaf spot + canker	9	25
light leaf spot + downy mildew	3	56
canker + downy mildew	2	31
light leaf spot + canker + downy mildew	1	23

* susceptible classified as ratings 1-5, resistant classified as ratings 6-9.

Table 4. Average levels of infection * corresponding to selected resistance ratings for light leaf spot, stem canker, and downy mildew in U.K. National List trials during 1990 and 1991.

Disease rating	Experiments in 1990			Experiments in 1991		
	Light leaf spot	Stem canker	Downy mildew	Light leaf spot	Stem canker	Downy mildew
1	-	-	-	13.9	-	-
4	10.2	54.8	9.0	8.3	44.9	11.0
7	4.1	31.1	4.0	3.4	18.5	4.4
9	-	18.0	-	-	-	2.2
LSD (P = 0.05)	4.76	10.8	2.94	3.50	10.71	2.76

* Light leaf spot and downy mildew figures are % leaf area infected, stem canker is a disease index (0-100 scale). Means are derived from a fitted constants analysis over years and sites.

Table 5. Maximum levels of infection* observed on any cultivar with selected resistance ratings for light leaf spot, stem canker and downy mildew during 1990 and 1991.

Disease rating	Experiments in 1990			Experiments in 1991		
	Light leaf spot	Stem canker	Downy mildew	Light leaf spot	Stem canker	Downy mildew
4	20.0	66.7	-	8.7	77.0	25.0
7	12.0	24.5	12.7	2.0	12.4	18.0

* Light leaf spot and downy mildew figures are % leaf area infected, stem canker is a disease index (0-100 scale).

Table 6. Percentage leaf area infected with powdery mildew in performance trials of linseed cultivars on the U.K. Descriptive List.

Cultivar	Trial number[a]				Cultivar maturity[b]	Mean	Unadjusted mean[c]
	1	2	3	4			
Antares	100.0	72.5	80.0	88.3	6.0	85.2	85.2
Atalante	87.5	13.5	47.5	46.7	5.6	48.8	48.8
Barbara	100.0	74.5	*	76.7	5.9	83.6	83.7
Blue Chip	2.5	7.5	14.3	58.3	4.8	20.6	20.6
Lidgate	*	8.0	*	25.0	3.6	22.7	16.5
McGregor	43.5	15.0	25.0	11.7	6.4	23.8	23.8
Norlin	90.0	47.5	82.5	70.0	8.2	72.5	72.5
Norman	20.0	13.0	*	26.7	8.1	19.8	19.9
LSD (P = 0.05)	36.61	34.15	24.13	25.77	2.5	15.01	

[a] Trials 1-3 abstracted from Beale (1991). Trial 4 at Cambridge 1991 assessed on 1 August.

[b] 1-9 scale, 9 = very early.

[c] Fitted constants adjusted mean.

* Cultivar not in trial.

Table 7. Percentage infection with *B. cinerea* in linseed cultivars on the U.K. Descriptive List in field trials and inoculated tests in relation to earliness of flowering (data abstracted from Beale, 1991).

Cultivar	Earliness of flowering[a]	Botrytis infection (field)[b]	Botrytis infection (artificial inoculation)[c]
Lidgate	5.6	23.0	37.2
Barbara	5.5	5.5	*
Antares	5.1	6.5	49.4
Atalante	5.1	5.0	66.3
Norman	4.8	8.0	*
Blue Chip	4.2	3.0	69.8
Norlin	4.1	1.0	97.6
McGregor	4.1	4.5	*
LSD (*P* = 0.05)	0.29	7.37	16.06

[a] 1-9 scale, 9 = very early,
[b] % of plants infected,
[c] % of plants infected
* not tested

STUDIES OF SCLEROTINIA SCLEROTIORUM INFECTION OF LINSEED (LINUM USITATISSIMUM) AND OILSEED RAPE (BRASSICA NAPUS S.SP. OLEIFERA) CULTIVARS.

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Summary

Oilseed rape and linseed cultivars were artificially inoculated with mycelium and ascospores of Sclerotinia sclerotiorum. Significantly different levels of infection developed on linseed cultivars but not on oilseed rape cultivars. Field trials were established at different locations in England and different levels of disease developed on cultivars. The differences in found in artificial inoculation. The levels of disease in flowering and were inversely correlated with cultivar height.

1. Introduction

Stem rot of oilseed rape caused by Sclerotinia sclerotiorum is a very important disease in a few areas in the south of England and occurs sporadically and occassionally at significant levels in other regions (Jellis et al, 1984). In Eastern and Southern Europe the incidence of S. sclerotiorum in oilseed rape and sunflowers is high, resulting in extensive fungicide usage to prevent crop losses (Regnault & Pierre, 1984). In linseed and flax, stem rot incidence is generally low and crop losses have been rarely reported (Mitchell et al., 1986).

Resistance to S. sclerotiorum has been reported in sunflowers (Tourvieille & Vear, 1986) and oilseed rape (Newman & Bailey, 1987), and breeders have incorporated this resistance into breeding lines. Commercial varieties of sunflowers with partial resistance are now being produced in Europe and resistant oilseed rape varieties are being evaluated (R. Jennaway pers. comm.).

This paper describes studies of the resistance in some oilseed rape and linseed cultivars submitted to NIAB for National List and Recommended List testing in 1987-1991.

2. Materials and Methods

A range of oilseed rape and linseed cultivars were selected annually and subjected to artificial inoculation tests with mycelium or ascospores of S. sclerotiorum. In addition cultivars were grown in field trials at various locations in England.

2.1 Inoculated Tests

An isolate of S. sclerotiorum from oilseed rape was cultured on weak potato agar for 2-3 weeks and 5mm diameter pieces of agar were placed on detached leaves of oilseed rape plants. The levels were placed on paper and incubated at 20°C in the dark for 4 days in a sealed plastic box to maintain a high relative humidity. Lesion diameter was measured.

Stem pieces of oilseed rape and linseed, 10cm in length, were similarly inoculated and incubated.

An isolate of S. sclerotiorum from oilseed rape from the Chichester area of Sussex, England, was cultured in potato dextrose broth for four days at 20-25°C. The mycelial suspension was homogenised and sprayed to 'run-off'. Control plants were sprayed with potato dextrose broth only. Seedlings were grown in pots 12.75 cm in diameter, each surrounded with a polythene sleeve to maintain high humidity. Plants were assessed for disease symptoms at weekly intervals.

Ascospores of S. sclerotiorum were produced by Dr S. Mitchell of Imperial College from another oilseed rape isolate using the method described by Mylchreest and Wheeler (1987). Pots of plants were sprayed with ascospore suspensions with concentrations of either 20,000 or 37,000 spores/ml in distilled water in two separate experiments. The plants in pots were sleeved to maintain humidity as above and disease symptoms recorded at weekly intervals. Control plants were sprayed with distilled water only.

2.1 Field Tests

Linseed field trials were established in the South of England near Chichester in 1988-1990 and at NIAB, Cambridge in 1990. Varieties of linseed were drilled in 2 x 10 m pots in randomised blocks in four replications. The Cambridge trial site had been inoculated with sclerotia

incorporated into the soil surface the previous autumn at a density of approximately 5/m² and was sown on 15.4.90. Two replicates of this trial were also sprayed with a mycelial suspension of S. sclerotiorum as described above and the trial was irrigated with water for periods of 10 minutes four times per day to increase humidity in the plots. In all trials the incidence of stem rot (number of infected plants in 4 x 1 m row samples) was recorded and the incidence of apothecia was assessed in 4 x 1 m inter-row samples. Flower maturity was recorded on a 1-9 scale where 1 = green bud, 2 = commenced flowering, 5 = mid-flower, 7 = late flowering, 9 = flowering completed . Height eg to top of the main raceme, was measured at flowering, and flowering records were taken at late flowering of Antares.

Oilseed rape trials were established in Hampshire and Sussex (Chichester) in the South of England and at Cambridge variously in different years. Trials at Cambridge were inoculated with buried sclerotia at a density of 5/m² in the autumn, and had plot sizes of 2 x 10 m. Apothecia occurring in several of the trials were recorded. Trials in Chichester had plots of 24 x 2 m, and were arranged in randomised blocks in four replicates.

Sclerotinia was also recorded in a National List oilseed rape trial at ADAS Experimental Husbandry Farm, Rosemaund, Herefordshire in the west of England in 1991. The height and time of flowering of cultivars was recorded and the effect of the disease on the yield of cultivars was assessed at this site.

3. Results

3.1 Linseed

The incidence of infected stems two weeks after inoculation in the trials inoculated with mycelium and two trials inoculated with ascospores is recorded in Table 1. No infection was observed in uninoculated tests. In addition the length of the stem lesions was recorded on 25 infected plants per plot in two of the trials (Table 2). Subsequent to 2 weeks secondary spread occurred to previously uninfected stems.

Table 1. The percentage infection of linseed plants following inoculation with mycelial suspension or ascospores of S. sclerotiorum

Cultivar	Mean	No of Experiments
Amazon	46.79 a	10
Blue Chip	35.15 ab	10
Vimy	34.95 abc	5
Atlante	34.29 bc	5
Lidgate	32.06 bc	2
Tadorna	31.67 bc	10
McGregor	29.04 bcd	5
Linda	28.00 bcd	5
Beryl	27.03 bcd	5
Norlin	23.23 cd	10
Antares	18.40 cd	5
Mean	30.96	
L.S.D. (P=0.05)	11.92	

All data angularly transformed. Cultivar means adjusted by fitted constants analysis and ranked.
Figures followed by the same letter cannot be separated statistically. (Duncans Multiple Range Test). LSD calculated from average S.E. (diff) = 5.9393.

Fig 1. Relationship between Sclerotinia infection levels in Linseed cultivars in inoculated tests and a naturally infected field trial

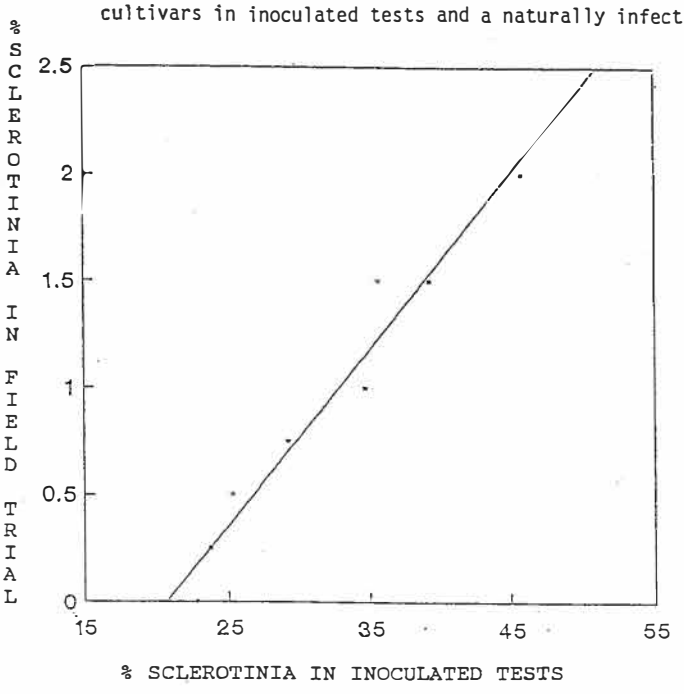


Table 2. Mean length of stem lesions on linseed cultivars inoculated with S. Sclerotiorum

Cultivar	Lesion length (mm)		
	Mean	Experiment 8	Experiment 9
Amazon	133.67	130.00	137.33
Blue Chip	100.59	53.17	148.00
Tadorna	98.86	92.83	104.88
McGregor	93.34	113.67	73.00
Atalante	92.84	73.67	112.00
Linda	60.50	45.33	75.67
Beryl	60.30	26.49	94.10
Norlin	50.06	33.11	67.00
Antares	37.73	29.18	46.28
Mean	80.88	66.38	95.36
S.E.D	NS	NS	NS

NS = Not significant at P=0.05

Table 3. Incidence of S. sclerotiorum infection in linseed cultivars in a field trial, at Chichester, 1990

Cultivar	Mean % plants infected
Amazon	2.00 a
Atalante	1.50 ab
Blue Chip	1.50 ab
Beryl	1.00 bc
Linda	0.75 cd
McGregor	0.50 cde
Antares	0.25 de
Norlin	0.00 de
Mean	0.94
L.S.D.	0.74

Figures followed by the same letter cannot be separated statistically.

Infection levels in all the inoculated tests were high. Infection by ascospores was successful in the absence of petals or other exogenous organic matter on the stems and leaves.

In the Chichester field trial the time of flowering, maturity, height at capsule formation and incidence of stem rot on 8 August were recorded (Tables 3 & 4). Apothecia were present in the Chichester trial during flowering from the 22nd June, but very few were observed in the trial at Cambridge were very little stem rot was observed. Inoculation of the field plots were mycelial suspension induced very little infection at Cambridge (below 0.1% infection) so that data from this trial is not presented.

3.2 Oilseed Rape

Inoculated tests produced high but similar levels of infection in all cultivars with no significant differences being apparent.

Field trials, had very variable levels of Sclerotinia stem rot at different sites in different seasons (Table 5).

However, in the trials where appreciable levels of disease developed, significant differences in disease incidence were recorded between cultivars. Significant differences in height and time of flowering were also recorded. Correlation between height, and incidence of Sclerotinia stem rot were $r = -0.41$ in all the trials, $r = -0.85$ in the 1989 trials with higher levels of infection, and $r = -0.63$ in the Rosemaund 1991 trial.

The numbers of apothecia recorded in plots of different cultivars did not differ significantly.

The correlation coefficient between earliness of flowering and stem rot incidence were -0.62 in the 1989 trials and -0.63 at Rosemaund. However there was also a close negative correlation between height and earliness of flowering ($r = -0.82$ in the 1989 trials and $r = -0.51$ at Rosemaund).

The yield of infected cultivars was reduced in line with the severity of infection (Table 8. Fig 4).

Table 4. Flower maturity and height of linseed cultivars in the Chichester field trial

Cultivar	Flower Maturity (1-9)	Height cm
Antares	7.00 b	56.50 d
Atalante	5.75 c	61.75 b
Norlin	5.25 cd	64.75 a
Amazon	4.50 d	57.50 cd
Blue Chip	3.35 e	61.25 b
Beryl	2.00 f	52.25 e
McGregor	3.00 e	59.75 bc
Linda	8.00 a	48.50 f
Mean	4.84	57.78
L.S.D. (P=0.05)	0.76	0.78

Figures in each column followed by the same letter cannot be separated statistically.

Table 5. Sclerotinia stem rot incidence (%) in 6 oilseed rape trials in 1987, 1988 and 1989

	Experiment number						
Cultivar	1 1987	2 1988	3 1988	4 1989	5 1989	6 1989	Mean % infection
Rafal	3.7	7.6	2.5	30.5	56.4	29.4	21.7
Bienvenu	5.4	2.3	6.7				4.8
Ariana	4.5	4.8	3.1	21.4	46.7	25.2	17.6
Mikado	10.6	5.4	3.3	36.5	63.8	34.1	25.6
Pasha	5.0	1.6	3.5	25.0	54.1	22.7	18.6
Libravo	1.1	8.9	4.6	18.5	33.7	17.1	14.0
Cobra	4.3	5.4	7.7	24.3	40.7	19.2	16.9
Karma	5.5	8.0	3.6	-	-	-	5.7
Lictor	0.9	6.4	3.5	21.3	39.9	20.9	15.5
Liquanta	5.3	7.3	4.1	-	-	-	5.6
Doublol	1.7	3.3	2.4	17.8	28.1	11.7	8.9
Payroll	1.8	3.9	2.9	-	-	-	2.9
Corvette	4.9	0.7	3.9	35.0	66.9	31.9	23.9
Score	6.1	6.3	4.2	32.1	57.0	30.6	22.7
Capricorn	16.2	5.7	4.2	-	-	-	8.7
Susana	3.1	4.6	4.7	18.2	37.8	21.0	14.9
Link	3.6	2.5	2.4	-	-	-	2.8
Tapidor	-	7.7	5.4	37.9	67.4	35.1	30.7
Liborius	-	7.5	3.2	18.8	30.4	13.2	14.6
Semudnk 1023	-	10.3	3.9	16.1	33.6	16.3	16.0
Samourai	-	3.2	2.5	34.0	60.4	31.9	26.1
Falcon	-	15.6	5.4	24.5	47.0	25.8	23.7
Mean % plants affected	5.2	5.8	4.1	25.7	47.7	24.1	25.3
SED							4.5

Fig 2. Relationship between Sclerotinia infection levels and height of oilseed rape cultivars in 1989 trials

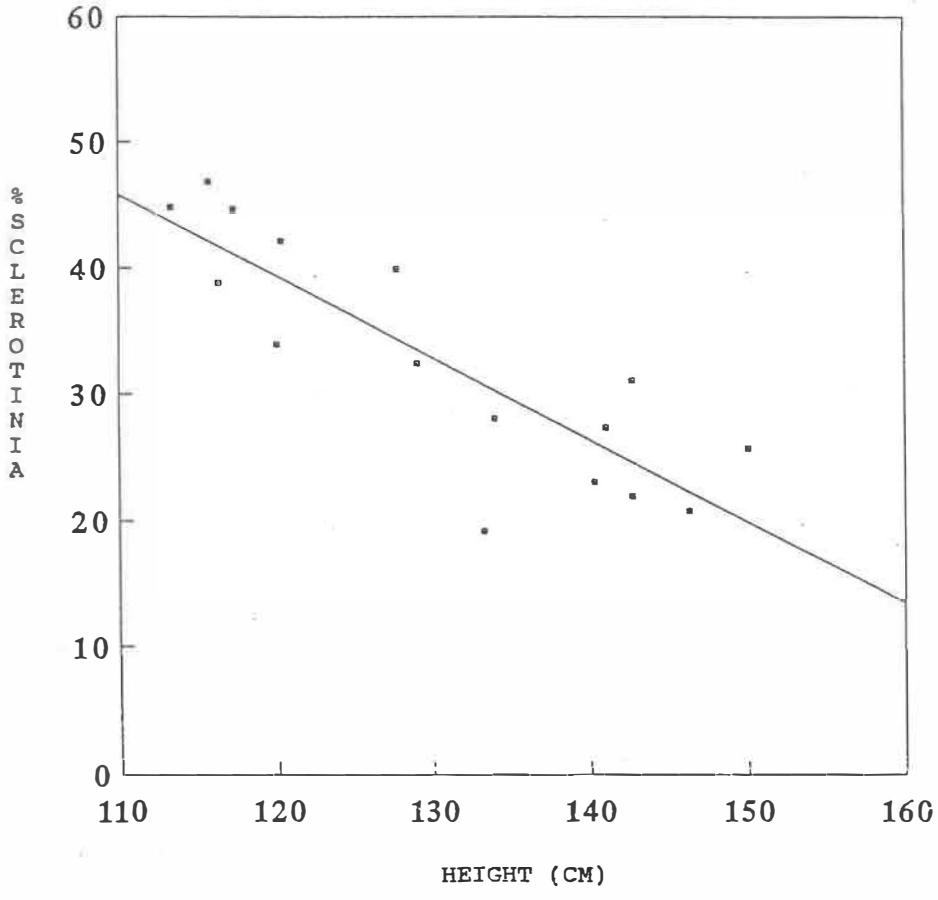


Table 6. Height in cm of oilseed rape varieties in trials in 1987-1989

Cultivar	Mean height (cm)	Experiment number 1 1987	2 1988	3 1988	4 1989	5 1989	6 1989
Rafal	118.3	121	127	113	106	123	120
Bienvenu	125.0	127	137	111	-	-	-
Ariana	141.8	146	158	119	121	168	139
Mikado	114.2	115	124	106	97	128	115
Pasha	120.0	128	128	104	107	137	116
Libravo	141.3	139	153	117	130	156	135
Cobra	137.1	136	148	119	119	149	134
Karma	133.0	139	144	116	-	-	-
Lictor	142.1	142	152	116	131	158	134
Liquanta	147.0	142	169	130	-	-	-
Doublol	133.0	136	140	122	126	143	131
Payroll	120.7	138	121	103	-	-	-
Lecor	118.5	117	134	108	103	128	121
Score	128.5	126	143	119	114	138	131
Capricorn	123.7	119	143	109	-	-	-
Susana	150.0	155	166	129	130	172	148
Link	153.7	146	176	139	-	-	-
Tapidor	116.6	-	127	109	105	124	118
Liborius	146.8	-	172	123	125	167	147
Semudnk 1023	139.4	-	147	122	130	163	135
Samourai	124.7	-	136	109	111	128	122
Falcon	132.5	-	146	110	113	146	128
Mean	134.6		146	116	117	145	130
SED	3.8						

- = Cultivar not in trial

Fig 3. Relationship between Sclerotinia infection levels and time of flowering in oilseed rape cultivars

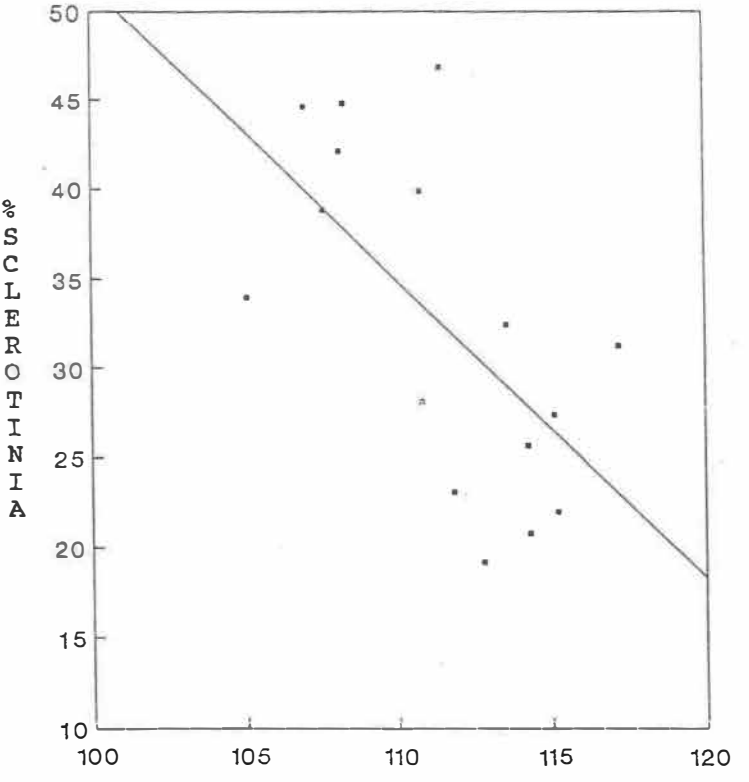


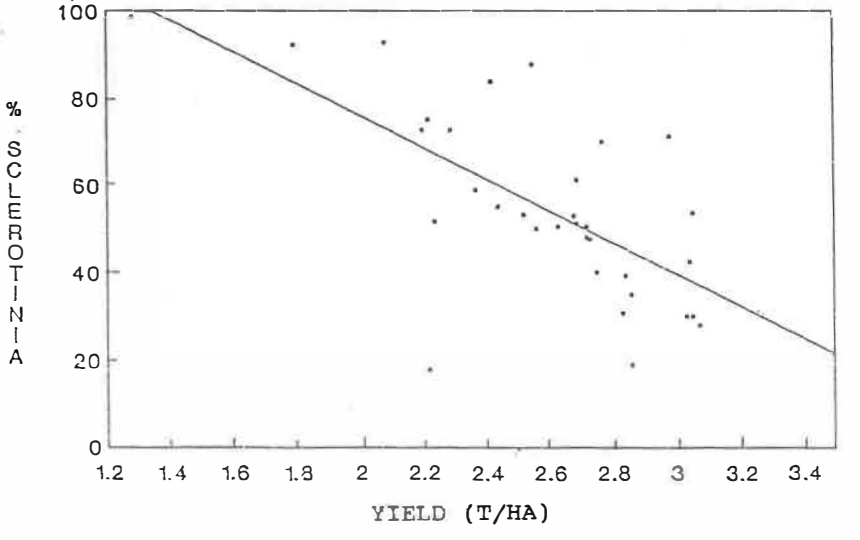
Table 7. Flowering, height and sclerotinia incidence in winter oilseed rape trial, ADAS Rosemaund, 1991

Cultivar	Index of Flowering 1-9 (9=early)	Height at flowering (cm)	% Plants with Sclerotinia at pod ripening
Control varieties			
Libravo	4.2	159	42.5
Cobra	3.8	155	50.5
Tapidor	4.4	139	98.7
Falcon	4.0	152	72.5
Additional varieties			
Lictor	2.9	162	39.2
Samourai	7.5	142	87.5
Year 3 evaluation			
SE	3.1	156	53.0
Eurol	6.8	148	92.5
Idol	6.6	150	83.7
Envol	6.2	149	70.0
Aztec	4.1	143	53.2
Lincoln	4.0	159	40.0
Limerick	3.5	161	30.0
Rocket	5.4	140	75.0
Dragon	6.4	149	92.0
Year 2 evaluation			
29	3.4	154	50.0
PR	5.1	152	58.7
AN	6.4	153	53.7
Bristol	5.7	150	71.2
AS	3.5	161	30.0
NP	4.5	146	55.0
LI	2.5	161	19.0
Lineker	2.8	165	30.7
B7	3.4	162	47.5
LD	3.6	144	48.0
AR	3.4	161	50.5
Cobol	3.2	160	28.0
DI	2.3	162	51.7
R9	5.8	151	51.2
IN	5.0	145	61.2
Apache	4.0	151	72.5
CP	1.5	159	18.0
LSD (P=0.05)	0.76	6.6	8.6

Table 8. Effects of Sclerotinia infection on the yield of some oilseed rape cultivars at Rosemaund compared with National average yields in 1991

Cultivar	Yield at Rosemaund t/ha	Mean yield over all sites t/ha	% Reduction in yield at Rosemaund	% Plants with Sclerotinia
Libravo	3.04	3.19	4.7	42.5
Cobra	2.60	3.35	22.0	50.5
Tapidor	1.28	3.19	60.0	98.8
Falcon	2.20	3.42	36.0	72.5
Lictor	2.84	3.32	14.0	39.2
Samourai	2.55	3.45	26.0	87.5
Eurol	2.08	3.48	40.0	92.5
Idol	2.42	3.39	29.0	83.7
Envol	2.77	3.49	21.0	70.0
Aztec	2.52	3.39	26.0	53.2
Lincoln	2.75	3.45	20.0	40.0
Limerick	3.03	3.26	7.0	30.0
Rocket	2.22	3.39	34.5	75.0
LSD	0.24	0.16	-	8.6

Fig 4. Relationship between Sclerotinia infection and yield of oilseed rape cultivars at Rosemaund in 1991



4. Discussion

4.1 Linseed

The ascospore inoculations demonstrated that S. sclerotiorum ascospores can infect linseed in the absence of exogenous organic or nutrient material under certain conditions of high humidity, in contrast to the normal requirements for infection by ascospores (Lamarque, 1983).

The inoculated tests consistently induced different levels of infection on cultivars and the severity of infection, recorded as stem lesion length, showed similar cultivar differences, suggesting that cultivars differ in both their resistance to primary infection and to the development of the disease.

J. Hutcheon (personal communication), recorded sclerotinia stem rot in linseed cultivars at Long Ashton Research Station and found highest levels in early flowering varieties. This was attributed to declining numbers of ascospores through the flowering period. In the Chichester area, S.J. Mitchell (personal communication) reported that apothecia and ascospores were present in some crops throughout May and June 1990. However conditions were relatively hot and dry during this period, and were not optimal for infection. Additional field data is therefore required to confirm that the inoculated tests reflect the field resistance/ susceptibility of linseed cultivars (Fig 1). However these tests have produced very consistent results and we feel that they are appropriate for testing the resistance of new linseed cultivars.

4.2 Oilseed rape

Oilseed rape cultivars appeared not to differ in resistance to Sclerotinia infection in inoculated tests. However, incidence of infection in field trials varied between cultivars and appeared to be correlated with height and time of flowering of cultivars (Figs 2 and 3). Souliac (1991) demonstrated that incidence of Sclerotinia increased when oilseed rape was treated with growth regulators that reduced height without affecting flowering time. It could therefore be hypothesised that shorter cultivars are more susceptible due to their reduced height resulting in closer proximity of flower petals to ascospores released by apothecia on the ground. However, since most short cultivars are also earlier to flower, it could also be hypothesised that earlier flowering cultivars have more

petals exposed to infection when ascospore production as at its greatest. Susceptibility of oilseed rape cultivars could thus be associated with a combination of reduced height and earlier petal exposure. Further studies are required which differentiate the effects of height from time of flowering.

It would appear that growing cultivars which are later flowering and of above average height would reduce losses associated with Sclerotinia infection. However, except in areas where Sclerotinia is a perennial problem, U.K. growers are more likely to use criteria for cultivar selection which give priority to other agronomic and disease resistant characters. Thus the scope for exploiting cultivar height and lateness of flowering in integrated control is very limited.

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REACTIONS OF SOME WILD CRUCIFERS TO *ALTERNARIA BRASSICAE*

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Summary

Alternaria brassicae is one of the major pathogens of rapeseed and mustard around the world. All cultivated *Brassica* spp. are essentially susceptible to this pathogen. Some wild crucifers common in western Canada were screened to locate sources of resistance to *A. brassicae*. Certain vegetable and oleiferous crucifers were also screened for comparison with the wild types. *Armoracia rusticana* and an accession of *Brassica campestris* ssp. *rapifera* were more resistant than *B. napus*, showing less necrosis and chlorosis. An accession of *Eruca sativa* showed a hypersensitive response. Some wild crucifers such as *Camelina sativa*, *Capsella bursa-pastoris*, and *Neslia paniculata* were very resistant showing no symptoms on healthy leaves.

1. Introduction

Wild species of crucifers are likely to be valuable sources of genes important in *Brassica* crop improvement (Glimelius *et al.*, 1990; Skoropad & Tewari, 1977; Snogerup *et al.*, 1990). Some studies on wild crucifers have shown that they possess high degrees of resistance to diseases which menace the oil-yielding crucifers in the Canadian prairies (Conn *et al.*, 1991; Jejelowo *et al.*, 1991; Tewari *et al.*, 1988). Some wild crucifers also possess traits such as shattering resistance, pest resistance (for flea beetles) and frost resistance (Bonfils *et al.*, 1991; Mithen & Herron, 1991). Although some studies have been initiated in this direction (Glimelius *et al.*, 1990; Klimaszewska & Keller, 1988; Mithen & Herron, 1991; Toriyama *et al.*, 1978), the wild crucifers have so far remained unutilized for improvement of disease resistance and other traits in oil-yielding crucifers. At the same time genes from alien plants have already been used, for example, in wheat (Dyck *et al.*, 1990).

*Alternaria brassic*ae (Berk.) Sacc. is one of the major pathogens of rapeseed and mustard around the world. All cultivated *Brassica* spp. are essentially susceptible to this pathogen. This project was initiated to locate high degrees of resistance to *A. brassicae* among wild crucifers. A number of oleiferous and vegetable crucifers and two non-host plants were also screened for comparison. Preliminary reports on portions of these results have been published (Conn *et al.*, 1988; Conn & Tewari, 1986; Tewari *et al.*, 1988).

2. Materials and methods

2.1 Plant material

Seeds of various crucifers were obtained from the University of Alberta collection, from other researchers or from fields in central Alberta (see Table 2). Plants were grown in a greenhouse at approximately 18/12°C (day/night) and at a light intensity of 400–600 $\mu Em^{-2}s^{-1}$. Leaves of some crucifers were also collected from fields in central Alberta (see Table 2). Some wild crucifer seeds such as those of *Capsella bursa-pastoris* and *Thlaspi arvense* were soaked in gibberellic acid (1000 mgL^{-1}) overnight in order to get them to germinate (Corns, 1960). Two non-host plants to *A. brassicae* (*Hordeum vulgare* L., barley; *Phaseolus vulgaris* L., bean) were also grown under greenhouse conditions.

2.2 Fungal material

Alternaria brassicae was isolated from an infected rapeseed leaf from central Alberta.

Cultures were grown in dark at room temperature for 8–10 days on V8 juice–rose bengal agar medium (Degenhardt *et al.*, 1974). Conidia were washed off the plates with distilled water, filtered through cheesecloth, centrifuged, washed twice, and resuspended in distilled water to a concentration of approximately 1 x 10^6 mL^{-1}.

2.3 Screening crucifers for resistance to *Alternaria brassicae*

The cruciferous and non–host plants used had a variety of growth habits so it was not possible to always use leaves of the same physiological age. At least 5–10 leaves of each plant type were screened and each plant type was screened at least twice. Plants were not all screened at the same time but in each experiment reference crucifers of known susceptibility were included. Detached leaves were placed in humid chambers and a few droplets of an *A. brassicae* conidial suspension placed on one half of each leaf and drops of distilled water were used as controls on the other half of the leaf. Leaves were incubated for 4–5 days at room temperature under continuous cool white fluorescent light (5.5 $\mu Em^{-2}s^{-1}$). The severity of symptoms was assessed visually and the plants sorted according to susceptibility/resistance. When neccessary, the extent of conidial germination was determined under a light microscope on leaf pieces stained with lactophenol cotton blue. Some plants were also screened against *A. brassicae* using injured leaves. In these experiments droplets of an *A. brassicae* conidial suspension and distilled water were placed on parts of leaves that had been gently scratched with the tip of a pasteur pipette.

3. Results and discussion

3.1 Types of responses to *Alternaria brassicae*

The crucifers screened for resistance to *A. brassicae* were placed in three groups based on the type of response to this pathogen (Table 1). The most common response was necrosis and chlorosis which covered a broad range of symptoms including limited and delayed necrosis and chlorosis (e.g. *Armoracia rusticana*), to moderate necrosis and chlorosis (e.g. *B. napus* and *B. campestris* ssp. *oleifera*), to rapid necrosis and extensive chlorosis (e.g. *B. campestris* var. *yellow sarson*). Another response was a hypersensitive reaction by an accession of *Eruca sativa*. Necrotic flecks appeared within the first day after inoculation and then remained of the same size until the leaves began to senesce after 4–6 days. This occurred only on healthy leaves. Some chlorosis occurred on older leaves or on plants that were not healthy. The most resistant response

Table 1. Response of leaves of some crucifers to *Alternaria brassicae*.

Response of healthy leaves	Code #	e.g.
necrosis and chlorosis*	3	*Armoracia rusticana* *B. campestris* var. *yellow sarson*
localized necrotic flecks**	2	*Eruca sativa*
no symptoms; fungal growth inhibited	1	*Camelina sativa*

* The degrees of necrosis and chlorosis covered a broad range of symptoms from limited and delayed necrosis and chlorosis (e.g. *A. rusticana*), to moderate necrosis and chlorosis (e.g. *B. napus* and *B. campestris* ssp. *oleifera*), to rapid necrosis and extensive chlorosis (e.g. *B. campestris* var. *yellow sarson*).

** Hypersensitive reaction

was one in which no symptoms occurred on healthy leaves and growth of *A. brassicae* was inhibited (e.g. *Camelina sativa*). On *C. sativa* no symptoms appeared until leaves began to senesce after 4–6 days, and then only as localized necrotic flecks. *Camelina sativa* leaves, stems, and siliqua from plants obtained from central Alberta and from seeds originating from Pakistan all showed this type of resistance. The resistant response of these crucifers was not due to a physical barrier because injuring the leaves prior to inoculation with *A. brassicae* did not reduce their resistance. This resistant response was different from that of the two non–host plants (barley and bean) that were screened against *A. brassicae*. They showed an immune response in which no symptoms developed while growth of *A. brassicae* on the plant surface was not inhibited.

3.2 Screening crucifers for resistance to *Alternaria brassicae*

Table 2 shows all the crucifers that were screened for resistance to *A. brassicae*. All *Brassica* spp. showed some degree of necrosis and chlorosis. The ranking of *Brassica* spp. (Table 2) generally agreed with what is known, that *B. napus* ssp. *oleifera* is generally more resistant than *B. campestris* ssp. *oleifera* (Bansal *et al.*, 1990; Conn, 1986; Conn & Tewari, 1989; Degenhardt *et al.*, 1974; Petri, 1973; Skoropad & Tewari, 1977; Singh & Kolte, 1991; Tewari & Skoropad, 1976) which are more resistant than *B. juncea*, *B. nigra*, and *B. campestris* var. *yellow sarson* (Bains & Tewari, 1987; Bansal *et al.*, 1990; Singh & Kolte, 1991). Bansal *et al.* (1990) compared six *Brassica* spp. and found that generally *B. carinata* was the most resistant, followed by *B. oleracea*, *B. napus*, *B. campestris*, *B. juncea*, and *B. nigra*. One *Brassica* sp. of particular interest was an accession of *B. campestris* ssp. *rapifera* that showed a limited and delayed necrosis and chlorosis (Table 2). This was very different from the susceptibility of *B. campestris* in general.

The most resistant crucifers were wild crucifers such as *C. sativa*, *C. bursa–pastoris* and *Neslia paniculata* (Table 2). Resistance to *A. brassicae* has been reported for *C. sativa* (Grontoft, 1986). The very high degree of resistance to *A. brassicae* in these plants may not be transferable to *Brassica* spp. by conventional breeding methods but it may be transferable by biotechnological techniques. One way to obtain new plants could be though the fusion of protoplasts from different plants (somatic hybridization). Such hybridization between species, genera, and tribes of Brassicaceae have been carried out (Glimelius *et al.*, 1990). The wild crucifers resistant to *A. brassicae* described in the present study would involve intertribal hybridization with rapeseed. Resistance in some of these wild crucifers is mediated through elicitation of phytoalexins (Browne *et al.*, 1991; Conn *et al.*, 1988; Jejelowo *et al.*, 1991).

Wild crucifers belonging to the Tribe Brassiceae of the Family Brassicaceae (Gómez–Campo & Hinata, 1980) are phylogenetically closest to the oil–yielding Brassicas and will be most suitable for transferring the required traits to them. There is also potential of utilizing members of the Tribes Lepideae and Arabideae which are related to Brassiceae. Plants belonging to the aforesaid tribes are found in temperate regions around the world but those closely related to crop Brassicas show maximum diversity in areas where the crop Brassicas are thought to have originated. Some of these centres of origin for *B. campestris* are the mediterranean area, central Asia, and north–west India; for *B. napus* the mediterranean area; and for *B. juncea* the Middle–East (Prakash & Hinata, 1980). There are some other suggested centres of diversity as well. Concerted studies on the biology, cytogenetics, and pathology of these crucifers will be most useful in the eventual goal of *Brassica* improvement.

Table 2. **Crucifers screened for resistance to** *Alternaria brassicae*.

Crucifer	Common name	Source	Response code (see Table 1)
Camelina sativa (L.) Crantz	false flax	Pakistan[2]/Alberta[3]	1
Capsella bursa–pastoris (L.) Medic.	shepherd's–purse	Alberta[3]	1
Neslia paniculata (L.) Desv.	ball mustard	Alberta[3]	1
Eruca sativa (Miller) Thell.	garden–rocket	Pakistan[2]	2
Armoracia rusticana Gaertn.	horse–radish	Alberta[3]	3*
Brassica campestris L. ssp. *rapifera*	forage turnip	U of A collection	3
Sinapis alba L. cvs. Gisilba, Kirby, Sabre, Tilney	white mustard	U of A collection	3
Thlaspi arvense L.	stinkweed	Alberta[3]	3
B. napus L. ssp. *oleifera* cvs. Westar, Regent	canola[1]	U of A collection	3
B. napus ssp. *oleifera* cv. Jet Neuf	rapeseed	U of A collection	3
B. napus ssp. *oleifera* line Norin 9	rapeseed	France[4]	3
B. napus ssp. *oleifera* lines DH12209, DH12229, DH12014	rapeseed	Saskatoon[5]	3
Erysimum cheiranthoides L.	wormseed mustard	Alberta[3]	3
B. campestris ssp. *rapifera* cv. Tyfon	turnip	U of A collection	3
B. carinata Braun	abyssinian mustard	U of A collection	3
S. arvensis L.	wild mustard	Alberta[3]	3
B. campestris ssp. *oleifera* cvs. Candle, Tobin	canola[1]	U of A collection	3
B. juncea (L.) Cosson cvs. Blaze, Leth. 22A	Indian mustard	U of A collection	3
B. carinata line R8734, cv. Peela raya	mustard	Pakistan[2]	3
B. campestris var. *toria*	rapeseed	U of A collection	3
B. juncea cv. Domo	Indian mustard	U of A collection	3
B. juncea breeding line 90–131–4	Indian mustard[1]	U of A[6]	3
B. campestris var. *yellow sarson*	rapeseed	U of A collection	3**

* Crucifers with a response code of 3 are listed from most resistant (*) to most susceptible (**).
[1] Seeds low in erucic acid and glucosinolate.
[2] Seeds from Pakistan via U of A collection.
[3] Seeds and leaves collected from central Alberta.
[4] Thanks are due to Dr. M. Renard, I.N.R.A., Amelioration des Plantes, Le Rheu, France, for seeds.
[5] Thanks are due to Dr. G. Séguin–Schwartz, Agriculture Canada, Saskatoon, for seeds.
[6] Thanks are due to Dr. G.R. Stringam, Dept. Plant Science, U of A, Edmonton, for seeds.

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REAPPRAISAL OF FUNGICIDE REQUIREMENTS FOR OILSEED RAPE IN ENGLAND AND WALES WITH EC PRICE REDUCTION

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Summary

Under the new EC regime for oilseed rape the value of harvested seed will fall from £270/t to £130/t. Crop protection inputs need to be reappraised as yield equivalents of input costs will be double those under the old price structure. Analysis of recent fungicide experiments indicates that that although most fungicide treatments give small positive yield responses, routine treatments are unlikely to be cost effective under the new regime. Currently, prochloraz and carbendazim the most widely used fungicides, are applied mainly in spring. However, following the reduction in price of harvested seed and the widespread attacks of Sclerotinia in 1991 there is likely to be a reduction in fungicide usage in the spring and an increase in treatments applied during flowering for Sclerotinia control. Substantial reductions in overall fungicide usage will be dependant upon the operation of reliable forecasts of disease outbreaks.

1. Introduction

The recent decision within the EC to move to an area based payment for oilseed rape and to market seed at world market prices, has major implications for crop protection strategies. Costs and benefits of current inputs have been calculated with harvested seed valued at about £270/t. Under the new regime, harvested seed will be sold at about £130/t.

This paper reviews the current position with regard to diseases and disease control in winter oilseed rape in England and Wales and discusses the implications for disease control under the new EC price regime.

2. Methods

The incidence and severity of diseases in commercial winter oilseed rape has been monitored by the Agricultural Development and Advisory Service (ADAS) since 1976. Although initially restricted to the main areas of production in Eastern and Southern England, samples are now collected to represent all areas of production (Hardwick *et al*, 1989). Results from 1990 (125 crops) and 1991 (123 crops) are

summarised in Table 1 using observations made at early stems extension (March/early April) and pod ripening (July). Samples of 25 plants were assessed for diseases on each occasion using methods described by Hardwick et al (1989). The mostly widely grown cultivars were Libravo, Lictor, Falcon and Cobra, all "double low" types.

Experiments with fungicides have been carried out using randomised block designs with 3 or 4 replicates. Sprays were applied using hand-held sprayers or

Table 1 **Mean Incidence and severity of major fungal pathogens in winter oilseed rape in England and Wales 1990-91**

Fungal Pathogen	Mean % crops affected	Mean % area affected (stem index)
Stem extension (March/ early April)		
Alternaria brassicae	25	0.1
Leptosphaeria maculans	84	0.5
Peronospora parasitica	55	0.3
Pyrenopeziza brassicae	54	0.9
Total leaf disease	-	2.0
Pod ripening (July)		
Alternaria brassicae (pod)	50	0.2
Botrytis cinerea (pod)	66	0.9
Erysipha cruciferarum (pod)	28	1.2
Pyrenopeziza brassicae (pod)	66	0.6
Total pod disease	-	3.1
Botrytis cinerea (stem)	33	(0.17)
Leptosphaeria maculans (stem)	66	(0.46)
Sclerotinia sclerotiorum (stem)	28	(0.09)

tractor-mounted sprayers in 200-250 litres of water/ha at stem extension and in 200-400 litres of water from flowering onward. Plot sizes were 70-150m^2. Yields were taken by combine harvester and have been adjusted to 91% dry matter.

The main fungicides used were prochloraz 500 g a.i./ha, (as Sportak 40% e.c.) benomyl 550 g a.i./ha (as Benlate 50% w.p.), and iprodione + thiophanate methyl 500 + 500 g a.i./ha (as Compass 167 + 167 g a.i./l, e.c.).

3. Results

The most common diseases recorded in 1990 and 1991 were Phoma leaf spot, light leaf spot, downy mildew and alternaria leaf spot (Table 1). Light leaf spot was more common in 1990 than 1991, the mean leaf area affected was 1.2% in 1990 and 0.5% in 1991. Just prior to harvest the main pod diseases were

powdery mildew, Botrytis, light leaf spot and alternaria (Table 1). Powdery mildew was more prevalent in 1990 when 2.3% pod area was affected. Stem diseases were common but mean severity was low. There were widespread attacks of Sclerotinia in 1991 in contrast to previous years (Gladders et al, 1992).

Analysis of fungicides practice in winter oilseed rape crops monitored in 1990 and 1991 is shown in Tables 2 and 3. Rather fewer crops were left untreated in cropping year 1990/91 than in 1989/90 (Table 2). An average 22% crops received two sprays, but only in 1990/91 were more than two treatments applied. Sprays were predominantly used at stem extension but there was an increase in the use of autumn treatments from 1989/90 to 1990/91.

Table 2 Frequency of fungicide spray treatments on winter oilseed rape in England and Wales 1989/90 and 1990/91

Number of spray rounds	% Crops treated in 1989/90	1990/91
0	42	26
1	40	42
2	18	26
>2	0	6

Source: ADAS

Table 3 Timing of fungicide spray treatments on winter oilseed rape in England and Wales 1989/90 and 1990/91

Timing of application	% Crops treated 1989/90	1990/91
Autumn/winter	6	19
Spring (up to green bud stage	52	56
During flowering	10	9
End of flowering/pod-filling	4	26

Source: ADAS

Alternaria was rather more prevalent post flowering in 1991 than in 1990 and this may have contributed to the higher use of late season sprays (Table 3).

Recent experiments with fungicides have explored the opportunities to improve disease control and increase yield by improved timing of spray application. Prochloraz has been used as the experimental tool because of its broad spectrum activity. Some of the results from 26 experiments carried over 4 years are summarised in Table 4. The mean yield of untreated controls was about 3 t/ha and most sites did not give significant yield responses to treatment. Only 4% of treatment combinations shown in Table 4 were significant ($P = 0.05$) and mean yield responses were small overall. If the size of individual responses are examined in detail, most treatments gave small positive yield increases. Over 60% of sites gave >0.1 t/ha response to a single spray applied between November (autumn) and mid-May (Table 4). However, very few treatments gave responses >0.4 t/ha. There was no evidence of additional benefits from a second spray although at most of these sites disease severity was low.

In a second series of experiments carried out at 25 sites during 1988-90 the responses to single sprays of benomyl and prochloraz have been compared (Table 5). Up to 1988 the main cultivar used was Bienvenu a "single low" type but Cobra and Libravo ("double low" cultivars) predominated in 1989 and 1990. Small positive yield responses which were not statistically significant

Table 4 Yield responses to sprays of prochloraz applied at various times to winter oilseed rape 1988-1991

Timing of prochloraz spray	Mean yield response (t/ha)	% Sites with responses per spray >0.1 t/ha	>0.2 t/ha	>0.4 t/ha
Autumn	0.17	62	50	8
mid February	0.17	69	35	8
mid March	0.14	65	46	0
Stem extension	0.13	65	31	4
Early-mid flowering	0.12	62	31	0
End of flowering	0.06	35	15	4
Autumn + stem extension	0.19	46	4	0
Stem extension + end of flowering	0.15+	38	12	0

+ Iprodione + thiophanate methyl used at end of flowering in 1991

Source: 26 ADAS experiments

Table 5 Relative yields of winter oilseed treated with benomyl or prochloraz at early stem extension 1986 -1990

Year	No of sites	Relative yield+ after spring spray of benomyl	prochloraz
1986	5	103	106
1987	7	101	104
1988	5	101	106
1989	4	105	103
1990	4	103	101

+ Untreated = 100

Source: Hardwick et al (1991)

Table 6 Fungicide usage on oilseed rape in England and Wales
1982, 1988 and 1990

Tear	1982	1988	1990
Area of oilseed rape (ha)	172,834	304,144	343,186
% Crops sprayed with fungicide	52.6	61.8	76.4
% Crops grown from treated seed	95.0	89.6	94.6
Total area sprayed with fungicide (spray ha)	53,571	287,865	431,760

Source: MAFF Pesticide Usage Surveys

Table 7 Fungicide active ingredient used on oilseed rape in England and Wales in 1988 and 1990

Fungicide active ingredient(s)	% Total 1988	Area Sprayed with fungicide 1990
Carbendazim	18.2	17.5
Carbendazim/mancozeb or maneb	4.7	3.5
Carbendazim/prochloraz	0.9	7.6
Iprodione	29.5	10.7
Iprodione/thiophanate methyl	0	7.9
Mancozeb/maneb/zinc	1.9	2.5
Prochloraz	24.4	37.1
Sulphur	4.2	2.6
Vinclozolin	7.4	3.3

Source: MAFF Pesticide Usage Surveys

were also a feature of this experimental series.

Details of pesticide usage in crops in England and Wales is collected at intervals by the Pesticide Usage Survey Group of the Ministry of Agriculture, Fisheries and Food (MAFF). Samples are stratified according to farm size and regional distribution of crops to provide a statistically valid sample. Results from the last 3 surveys on oilseed rape shown in Table 6 show an increasing use of fungicides as sprays. Prochloraz and carbendazim were the most widely used fungicide active ingredients (Table 7). These were used mainly for control of light leaf spot or general disease in the spring.

4. Discussion

Although individual diseases showed seasonal or local variations (Hardwick et al, 1989) there is no firm evidence that the introduction of "double low" cultivars has modified disease patterns in England and Wales. However, the marked increased in Sclerotinia in 1991 is likely to pose a threat to many crops in future and fungicide treatments now need to be considered for this disease (Gladders et al, 1992).

Table 8 Yield responses required to recover costs of fungicide treatment under two price regimes

Fungicide Cost (£/ha)	Yield response (t/ha) required when harvested seed valued at £130/t	£270/t
52	0.4	0.2
26	0.2	0.1
13	0.1	0.05

The yield responses needed to recover the cost of fungicide treatments are illustrated in Table 8. Under the new EC regime yield responses need to be double those required when harvested seed was worth £270/t for the same fungicide treatment. Full rate treatments of prochloraz (500 g a.i./ha) and iprodione + thiophanate methyl (451 + 451 g a.i./ha) cost approximately £26/ha. Benzimidazole fungicides such as carbendazim applied at 500 g a.i./ha are considerably cheaper at £13/ha. A two spray programme of prochloraz in the spring followed by iprodione or iprodione + thiophanate at mid-late flowering would cost £52/ha which equals to 0.4 t/ha yield with seed at £130/t. In calculating the economics of spray treatments, application costs and losses of about 3% from wheelings from sprays applied by ground equipment during the latter part of flowering (Ogilvie, 1989) also need to be taken into consideration. For a typical crop producing 3 t/ha yield a response of 0.1 t/ha or 3% is needed to recoup the cost of a benzimidazole fungicide, 0.2 t/ha or a 6% response is needed where prochloraz or iprodione treatments are used.

It might also be argued that spray treatments should be used only when there is a realistic probability of it being profitable (rather than breakeven).

Recent experiments in commercial crops (Tables 4 and 5) suggest that this is unlikely to be achieved from routine propyhlactic treatments. Sites for fungicide experiments were selected on the basis on known or presumed disease risk and therefore the proportion of sites producing the responses in Tables 4 and 5 may be rather higher than would occur on the 'average' crop.

Further rationalisation of criteria for identifying crops likely to produce a worthwhile response to fungicides is needed. Disease susceptible varieties can give large yield responses (Sweet et al, 1989) particularly where light leaf spot is significant but such cultivars are rarely widely grown. Improvements in the early diagnosis of light leaf spot would be of considerable value in identifying problem fields before the disease became well established. This would offer advantages if more accurate targeting of spray treatments and possibilities for early low dose treatments (Harris et al, 1989) when disease pressure is low. Our own experiments (Table 4) indicate that timing of early sprays (November - mid March) is not particularly critical under low to moderate disease pressure. However there may be opportunities to improve the cost effectiveness of treatments by using reduced closes of fungicide in the autumn (Harris et al, 1989) particularly if crops at risk from disease can be identified reliably.

Under the new EC price regime for oilseed rape many of the fungicide treatments, used recently (Tables 2, 3 and 6) will no longer be cost effective. Even relatively low cost products such as the benzimidazoles have not consistently given yield responses of 3% or more to enable chemical costs to be recovered (Table 5). However, it is of interest to note that benzimidazoles appear to have given rather larger yield responses that prochloraz on "double low" cultivars (used in 1989 and 1990) (Table 5). Fungicide treatments should be used less extensively in future if current disease patterns continue. There will undoubtedly be greater concern over the threat from Sclerotinia which could now cause significant economic losses in epidemic years over much of England and Wales.

This may well generate a shift in emphasis from spring (stem extension) timing to early petal fall (mid flower) timings. Effective forecasting systems for Sclerotinia will be needed if substantial reductions in overall fungicide usage are to be achieved.

Acknowledgements

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RECHERCHE SUR LA PROTECTION FONGICIDE DU COLZA VIS-A-VIS DE *LEPTOSPHAERIA MACULANS*

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Summary

Double low cultivars of winter oilseed rape seemed less resistant to Phoma than single low cultivars.
Studies were conducted to improve disease resistance with early fungicide protection. In field trials where rape was inoculated with infected stalks, triazole fungicides were applied at different stages from one leaf to six leaves. The most efficient treatment occurred at the beginning of ascospore dissemination. In this case, root necrosis was weakly correlated with foliar spotting.
Various seed treatments were tested but their efficacy were low. However, a microgranulated fungicide reduced the number of plants with spots on leaves.
More experiments are carrying out to confirm effects on stem canker.

1. Introduction

Jusqu'en 1985 les variétés inscrites au catalogue français présentaient un niveau satisfaisant de résistance à la nécrose au collet causée par *Leptosphaeria maculans*. Mais la reconversion OO s'est faite avec des variétés de moindre tolérance et s'est accompagnée d'une recrudescence des attaques au collet. Dans le même temps des traitements d'automne ont été pratiqués et ont montré dans certains cas une efficacité contre les macules foliaires de Phoma.

Des études ont été entreprises pour préciser si un traitement d'automne pouvait être efficace non seulement sur les macules foliaires mais surtout sur les nécroses du collet, en se focalisant sur deux points, la date d'application et la nature des traitements d'automne.

2. Matériel et méthodes

Tous les essais sont réalisés au champ, en contamination renforcée sur différents sites 21, 45, 47 et 77. La contamination renforcée consiste à épandre après le semis des pivots nécrosés à raison de 2 à 5 par m^2. Des séquences de brumisation sont appliquées jusqu'aux premières gelées afin de provoquer la dissémination des ascospores de *L. maculans* et favoriser la contamination du colza. Les variétés de colza utilisées sont Jet Neuf en 1989 et Samourai en 1990.

2.1 Dates d'application des traitements en végétation

L'expérimentation 1989 est réalisée suivant un dispositif split-plot à trois répétitions avec comme premier niveau de facteur les fongicides et comme second niveau les stades d'application et un témoin non traité. Trois fongicides, Sportak PF 1.5 l/ha (prochloraze 300 g/l + carbendazime 80 g/l), Punch C 0.8 l/ha (flusilazole 250 g/l + carbendazime 125 g/l), Sumistar 2.5 l/ha (diniconazole 24 g/l + iprodione 160 g/l + carbendazime 80 g/l)

sont appliqués respectivement aux stades B1, B2 et B4. De plus, un capteur de spores Burkard assure le piégeage des ascospores depuis la levée jusqu'au stade 6-8 feuilles.

L'expérimentation 1990 procède selon un dispositif bifactoriel avec en premier facteur les stades - B2, B4, B2+B4 et B6 - et en second facteur les fongicides - Sportak PF 1.5 l/ha (prochloraze 300 g/l + carbendazime 80 g/l), Punch CS 0.8 l/ha (flusilazole 250 g/l + carbendazime 125 g/l), Impact RM 1 l/ha (flutraifol 117,5 g/l + carbendazime 250 g/l) et un témoin non traité.

2.2 Nature des applications fongicides

Les essais sont implantés suivant un dispositif bifactoriel avec en premier facteur les traitements de semences et en second facteur les fongicides appliqués en végétation au stade B2 (stade B4 sur le site 77).

Traitements de semences :	Fongicides appliqués en végétation :
FG 324	Sportak PF 1.5 l/ha
Rovral (iprodione 50%) 10g/kg	Punch CS 0.8 l/ha
Témoin (Talc)	Sumistar 2.5 l/ha
FG 325	Impact RM 1l/ha

2.3 Observations

A l'automne est déterminé un pourcentage de plantes présentant des macules foliaires. Dans 2 essais, trois semaines avant la récolte, 30 plantes par parcelle élémentaire sont réparties en classes selon la gravité de la nécrose au collet (échelle 1-6). Les résultats sont exprimés en % de plantes présentant des nécroses et en une note globale de gravité G2 calculée comme suit :

$$G2 = N2 + 3.N3 + 5.N4 + 7.N5 + 9.N6 \;/\; \text{Nombre de plantes observées}$$

où N2 = attaque faible (simples taches superficielles)
N3 = nécrose inférieure à la demi-section du collet
N4 = nécrose supérieure à la demi-section du collet, le collet résiste à la flexion de la tige.
N5 = nécrose supérieure à la demi-section du collet, le collet ne résiste pas à la flexion de la tige.
N6 = plante sectionnée au moment de l'observation.

3. Résultats

3.1 Date d'application des traitements en végétation

Deux observations ont été effectuées à l'automne 1989, l'une un mois après le traitement stade B2, l'autre 3 semaines après celui réalisé au stade B4. Les résultats sont indiqués Tableau 1.

Tableau I : Importance des macules et des nécroses au collet aprés traitement fongicide à différentes dates.

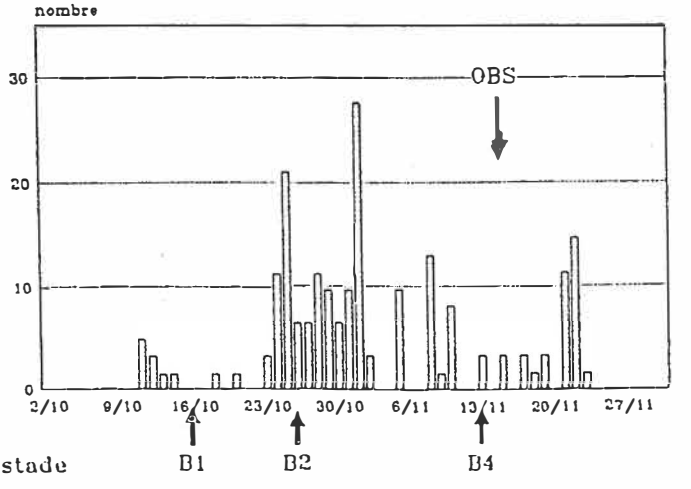
Traitements		% feuilles atteintes		Nécroses au collet	
		15/11/89	7/12/89	% nécroses	G2
Fongicide	Sportak PF	7.1	18.8	22.7 a	2.69 a
	Sumistar	7.9	19.5	17.7 a	2.47 a
	Punch C	7.8	19.2	10.7 b	2.08 b
Date Application	Non Traité	9.0 a	20.6	(31)	(3.13)
	B4 (13/11)	6.4 b	21.8	19.7	2.59 a
	B1 (16/10)	5.7 bc	18.3	18.4	2.51 a
	B2 (26/10)	3.8 c	13	13	2.16 b

a,b,c groupes statistiques différents - Newman & Keuls 5%
() non pris en compte dans la comparaison des moyennes

Seule la première observation fait apparaître des différences au niveau date d'application. Les traitements pratiqués aux stades B1 et B2 qui coïncident avec la première vague de dissémination des ascospores (Fig 1) conduisent aux taux d'attaque les plus faibles. On ne note pas de différences entre les trois fongicides testés.

Concernant les nécroses au collet, le traitement stade B2 se montre le plus efficace, la note G2 différant significativement de celles des deux autres traitements B1 et B4. Punch C se révèle être le fongicide le plus performant.

Figure 1 : Piégeage des ascospores (nombre de spores piégées / m^3 air)



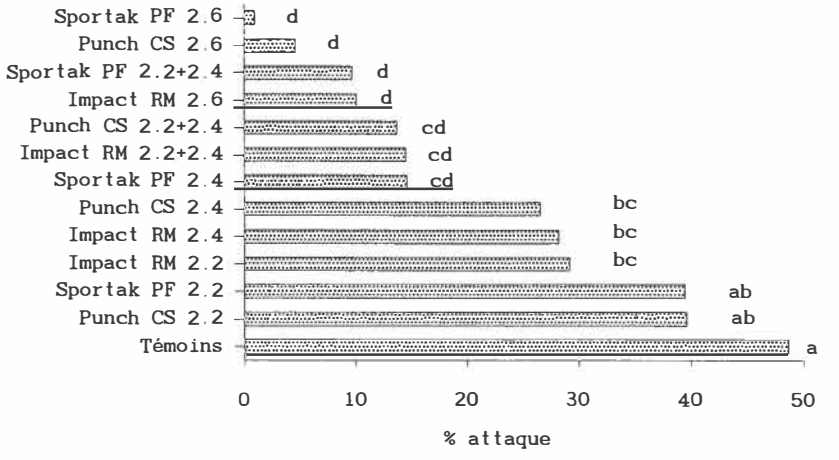
La fréquence des nécroses avant récolte apparaît assez faiblement corrélée à la présence de macules foliaires à l'automne (Tableau II).

Tableau II : Coefficients de corrélation

	% plantes avec macules	% nécroses	note G2
% plantes avec macules	1	0.351	0.358
% nécroses		1	0.965

A l'entrée de l'hiver 1990, 50% des plantes témoins présentent au moins une macule foliaire de Phoma. Les traitements réalisés à B6 et B2+B4 conduisent à une réduction significative des attaques sur feuilles (Fig 2).

Figure 2 : Taux de plantes avec macules en fonction des traitements



Quant aux nécroses au collet (Tableau III), le pourcentage de collets atteints est significativement plus faible lorsque les traitements sont réalisés au stade B6. Les trois fongicides testés permettent de réduire significativement les attaques mais leur efficacité reste faible, au plus 25%.

Quel que soit le stade de traitement, les rendements ne diffèrent pas entre eux de façon significative. Par contre les fongicides ont un effet bénéfique sur les rendements, ce qui conduit à penser qu'ils n'ont pas uniquement controlé le Phoma!

Tableau III : Incidence des traitements sur les nécroses et le rendement

Traitements		% collets nécrosés	Rendement
Stade Application	B2	90.4 a	35.5
	B4	88.3 a	33.2
	B2 + B4	87.1 a	35.8
	B6	71.2 b	36.5
Fongicide	Punch CS	72.9 b	39.9 a
	Sportak PF	87.1 b	36.3 b
	Impact RM	80.8 b	34.8 b
	non traité	96.2 a	30.0 c

a,b,c groupes statistiques différents - Newman & Keuls 5%

3.1 Nature des applications fongicides

Dans 3 sites d'essais, les traitements de semences testés se montrent assez peu efficaces pour protéger le colza des attaques foliaires (Tableau IV). Par contre, un microgranulé codé FG 325 et testé en un seul site, réduit significativement le taux de plantes présentant des macules foliaires.

Les traitements en végétation n'entrainent pas de réduction significative du pourcentage de plantes atteintes à l'automne. Ces traitements ont été appliqués sans connaissance de la libération des ascospores. Sur les sites 21 et 45, le traitement stade B2 aurait été trop précoce pour protéger le colza de contaminations tardives. Au contraire, le traitement stade B4 sur le site 77 aurait été trop tardif, des périthèces libérant des ascospores ayant été observés dès les stade B2. Dans tous les cas , il n'y a pas de différences significatives entre les trois traitements fongicides et le témoin non traité, que l'on considère les macules foliaires ou les nécroses au collet.

Tableau IV : Effets des traitements sur les attaques de Phoma

Traitements		Site 21		Site 45		Site 77	
		% plantes à macules	Rdt (q/ha)	% plantes à macules	Rdt (q/ha)	% plantes à macules	nécroses G2
Trait. Semences	FG 324	22.5	31.35 a	17.2	46.56	50.8 a	-
	Rovral	27.9	31;05 a	14.0	46.54	55.8 a	-
	Témoin	23.2	29.83 b	16.7	46.55	56.4 a	-
	FG 325	-		-		9.6 b	-
Trait. Stade B2	Impact RM	25	30.68	11.9	46.29	86.8	2.7
	Punch CS	21.4	30.83	16.8	46.77	65.8	2.38
	Sumistar	23.1	31.33	18.2	46.73	78.1	2.61
	Non Traité	29	30.15	18.2	46.42	77.5	3.52
	Sportak PF	-	-	-	-	85.8	2.63

a,b groupes statistiques différents (Newman & Keuls 5%)

Au niveau rendements, le traitement de semences permet tout au plus un gain de rendement de 1,5 q/ha (site 21), le traitement en végétation ne procure finalement aucun gain de rendement significatif.

4. Discussion

La lutte chimique peut être intéressante pour assurer une protection précoce du colza, en attendant qu'il mette en place les structures anatomiques lui conférant la résistance au Phoma. Les triazoles se montrent efficaces contre *P. lingam*, à condition de les appliquer au bon moment.

Dans l'expérimentation 1989, la meilleure date d'application se révèle être au stade B2 et coïncide avec celle de début d'émission des ascospores. En 1990, il semble que les meilleurs résultats d'application d'un fongicide surviennent après un traitement au stade B6. Le traitement fongicide en végétation s'avère efficace s'il est appliqué non pas en fonction d'un stade repère du colza mais en fonction de la dissémination des ascospores. Dans la pratique, cela nécessiterait la mise en place d'un dispositif de piégeage et des études épidémiologiques complémentaires conduisant à l'élaboration d'un modèle de prévision.

Les traitements de semences, dont l'avantage serait d'éviter une intervention en végétation, ne semblent pas assurer une protection suffisante des jeunes plantes. Dans certains cas, ils peuvent se révéler phytotoxiques (Ballinger et al., 1988). Par contre, une application fongicide sous forme de microgranulés pourrait se révéler intéressante. Son efficacité mise en évidence sur macules foliaires demande cependant à être confirmée sur les nécroses du collet. En effet, nos résultats montrent qu'il n'existe pas une bonne corrélation entre macules et nécroses au collet et confirment en cela de précédentes observations où le taux de macules ne paraissait pas être révélateur du taux ultérieur de nécroses (Pierre et al., 1982).

Des solutions chimiques apparaissent possibles, leurs mises en oeuvre se traduisent par au moins une intervention à l'automne. D'un point de vue économique, il n'est pas certain que dans le nouveau contexte agricole le coût du fongicide et celui de son application soient compensés par un gain de rendement permettant de dégager un bénéfice. L'amélioration des variétés pour leur résistance au Phoma reste encore le moyen le plus économique de lutter, tout en respectant l'environnement.

5. Remerciements

L'auteur tient à associer à ces résultats pour leur aide technique Mademoiselle Deverchère et Messieurs Caceres, Derosier et Lucas.

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CHEMICAL CONTROL OF SEED-BORNE DISEASES OF LINSEED IN THE UK

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Summary

The most important seed-borne pathogens of linseed in the UK, at present, are *Alternaria linicola* and *Fusarium avenaceum*, although their importance varies from season to season, being much more common when conditions are wet. The pathogens are most damaging prior to emergence and the most effective control measure is seed-treatment, particularly with prochloraz. Fungicide sprays on the growing crop are less predictable in their effect and rarely capable of bringing the level of seed-borne disease down to certification standards. In Britain, sprays can, at times, result in yield increases, probably largely due to control of *Botrytis cinerea*.

1. Introduction

The area of linseed has been expanding so rapidly in the UK in recent years that it can hardly any longer be considered as an alternative crop. This rise in cultivation and the temptation for some farmers to grow linseed on the same land for more than one year, has caused anxiety that diseases of linseed could become factors limiting production as is the case in other parts of the world where flax or linseed are or have been grown.

At present, the major disease problems have been concerned with pathogens with a seed-borne phase, in particular *Alternaria linicola*, *Botrytis cinerea* and *Fusarium avenaceum*. *Phoma exigua* and *Colletotrichum lini* are also found on occasions, but to date, not at damaging levels (Mercer *et al.*, 1991b).

The Plant Pathology Research Division of the Department of Agriculture for N. Ireland (DANI) has, because of its association with the now defunct Irish flax industry, been responsible for the seed-health certification of a major proportion of flax and linseed seed in the UK. Details of disease levels of each sample have been recorded on computer since 1987 and with samples in 1991/92 expected to be close to 2,000, the data-base acts as an accurate monitor of annual seed-borne disease incidence.

Since the time that the linseed crop began to expand rapidly, DANI has been actively engaged in a research programme which has examined the most effective methods of control of seed-borne pathogens, both as seed-treatments and as sprays applied to the growing crop. Much of the field work has been in cooperation with ADAS, Leeds. This paper records published and unpublished results on chemical control since 1985. Work on biological control is reported elsewhere (Mercer, Mee & Papadopolous, this journal).

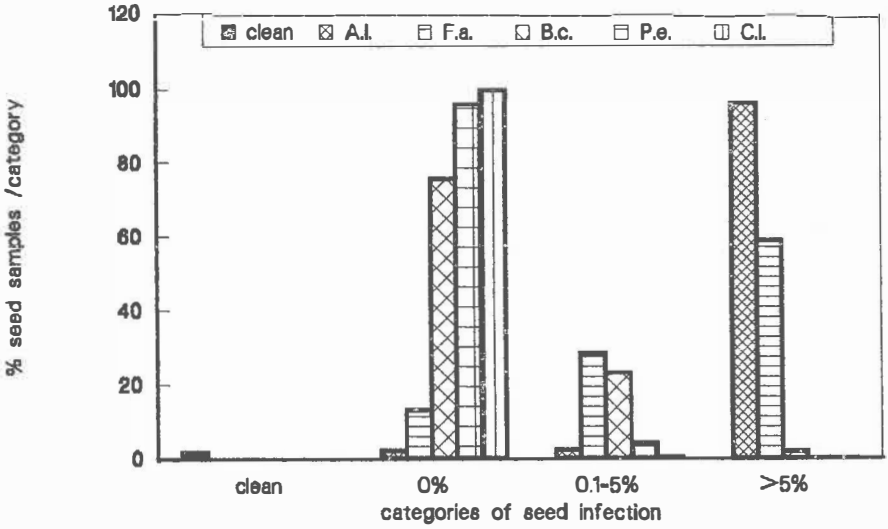

Fig. 1. Frequency of pathogens isolated from samples of untreated linseed in the UK in 1987. (clean - no seed-borne infection; A.l. - *A. linicola*; F.a. - *F. avenaceum*; B.c. - *B. cinerea*; P.e. - *P. exigua*; C.l. - *C. lini*).

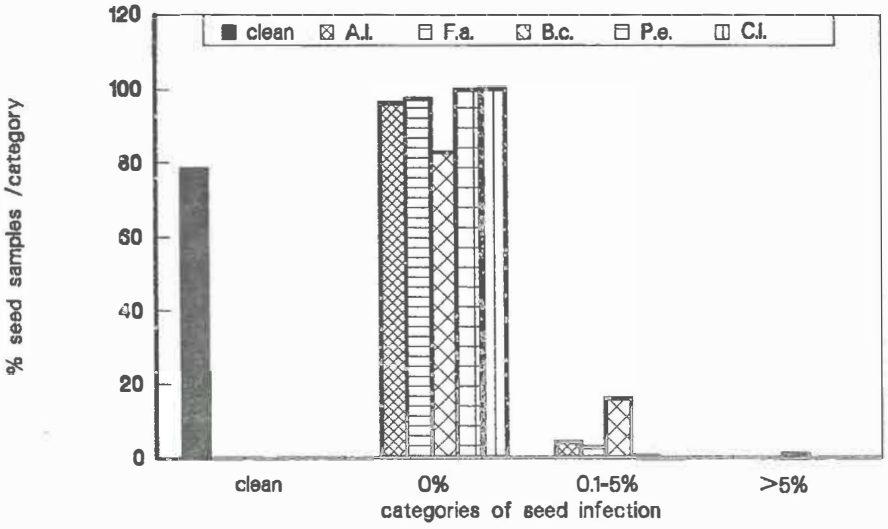

Fig. 2. As for Fig. 1 but for 1990.

2. Experimental

(a) Micro-organisms on the seed. Collation of results from the DANI data-base shows big differences in the frequency of pathogens between years, particularly between wet and dry ones. Seed-borne pathogens, particularly *A. linicola* and *F. avenaceum* tend to have high frequencies in a wet year such as 1987 (Fig. 1), while in a very dry one, such as 1990, the frequency of these pathogens may be practically zero. The frequency of *B. cinerea* does not seem to vary so much between years, being only slightly lower in 1990 than in 1987, although in the latter year the frequency was considerably lower than either that of *A. linicola* or *F. avenaceum*. The frequency of *B. cinerea* on the seed does not necessarily give a true picture of its incidence in the field, as infection on individual capsules is frequently so severe that the capsule and seeds are shed and are not therefore harvested (Mercer & Hardwick, 1991). Frequencies of *P. exigua* and *C. lini* were extremely low in both 1987 and 1990.

As well as pathogens, there is a number of saprophytic fungi - *A. alternata*, Alternaria state of *Pleospora infectoria* (Fitt, Coskun & Schmechel, 1991), *Epicoccum nigrum* and *Stemphylium botryosum*. The growth of such fungi can, at times, make the detection of pathogens difficult.

Much of the early experimental work was involved with electron and light microscopic examinations of whole and dissected seeds in an attempt to discover the manner in which seed-borne pathogens are distributed. This indicated (Mercer & Hardwick, 1991), that most are located as thick-walled resting hyphae in the outer gelatinous layer of the seed-coat and are not normally found infecting the embryo. A seed-treatment that can prevent the hyphae from reaching the emerging seedling should therefore prove highly effective at preventing damge to the seedling, damage that can often prevent its emergence. The degree of transmission is also dependent on temperature, seed lots with varying degrees of infection with *A. linicola*, consistently producing more diseased plants when grown at lower rather than higher temperatures (Fig. 3). After emergence, *A. linicola* and *F. avenaceum* appear to cause little damage. Subsequent to capsule-formation and particularly in a wet season, both pathogens begin to colonise capsules and seeds, inoculum, at least of *A. linicola*, coming from infected lower leaves and stem-bases (Mercer & Hardwick, 1991)

(b) Use of seed-treatments. Initial attempts at control of seed-borne diseases concentrated on the use of seed-treatments. First tests involved screening a small range of these and comparing them with the standard, a mixture of benomyl/thiram (Mercer *et al.*, 1985). Results (Fig. 4) showed that, in a sample which was 41% (arcsin transformation) infected with *A. linicola*, an iprodione powder formulation was the most successful treatment, giving complete control of *A. linicola* and improving % germination. This product was widely adopted as an industry standard.

However, problems arose in 1985 with seed which had a relatively high level of *F. avenaceum* as well as *A. linicola*. As it also appeared that *A. linicola* itself had a controlling effect on *F. avenaceum* (Mercer & McGimpsey, 1987), use of iprodione often resulted in the appearance of previously unsuspected *F. avenaceum* (Fig. 5) and it was therefore necessary for an addition of benomyl to be made in these circumstances.

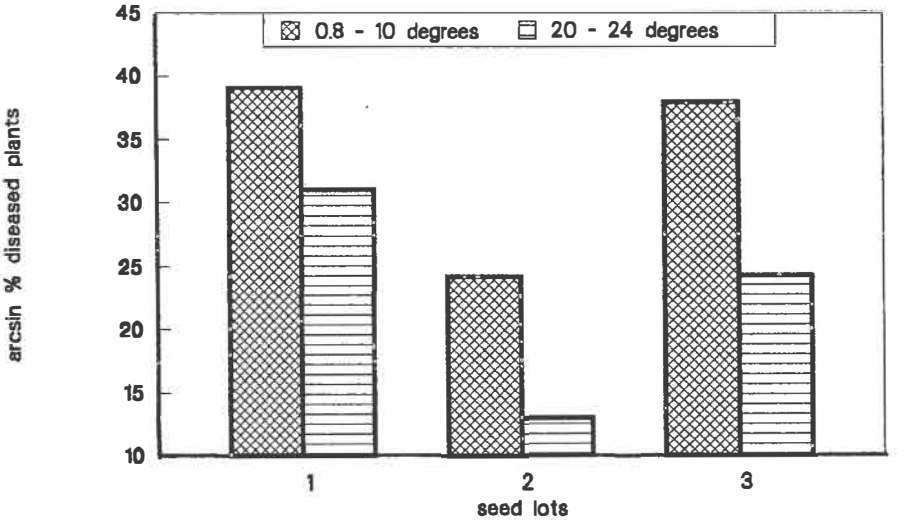

Fig. 3. Effect of growing three seed lots with different levels of infection by *A. linicola*, at two temperature ranges, on % seedlings with *A. linicola* lesions. Assessed at 18 cm height. $P < 0.001$; S.E. (15 DF) = 1.73

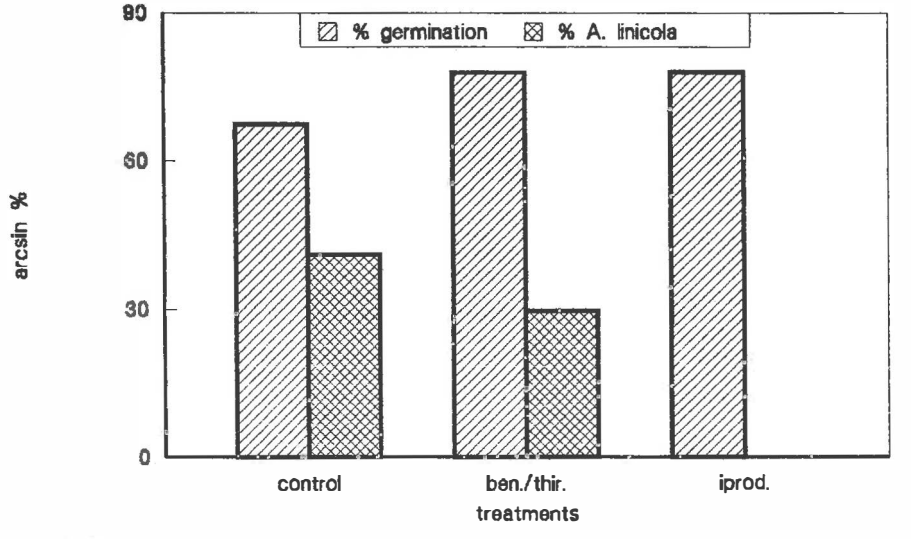

Fig. 4. Effect of seed-treatment with either benomyl/thiram (ben./thir.) or iprodione (iprod.) on % germination and % seeds with colonies of *A. linicola*, 7 days after plating out on 2% malt agar. $P < 0.001$ for both variates; S.E.'s (39 DF) 1.20 (germination), 1.68 (infection).

Table 1 Testing of materials for control of seed-borne diseases of linseed (1986/87).

INGREDIENTS	FORMULATION	g or cc ai/kg or l	MATERIAL	Control of: A.linicola	F.avenaceum	B.cinerea	C.lini	P.exigua	Germination
benomyl	w.p.	500	Benlate	-	+	+	nt	nt	+
benomyl/ thiram	w.p.	210/ 210	Benlate T	+/-	nt	nt	nt	nt	+
captan	w.p.	500	Captan 50	+/-	+/-	nt	nt	nt	+
carboxin	w.p.	750	Vitavax	-	-	nt	nt	nt	+
chlorothalonil	w.p.	500	Bravo 500	-	-	+/-	nt	nt	+
ethirimol/ flutriafol/ thiabendazole	e.c.	400/ 30/ 10	Ferrax	+/-	-	nt	nt	nt	+
fenpropimorph	e.c.	750	Mistral	+	-	+	+/-	+	-?
fenpropimorph/ benomyl	e.c./w.p.	375/ 250	-	+	+	+	nt	nt	+?
fenpropimorph/ iprodione	e.c.	150/ 100	Sirocco	+	-	+	nt	+	+
fenpropimorph/ prochloraz	e.c.	375/ 225	Rival	+	+	nt	+	nt	+
flutriafol/ captafol	e.c.	47/ 375	Impact T	+	+/-	+	nt	+	+
hymexazol	w.p.	700	Tachigaren	-	+?	nt	nt	nt	+
imazalil	e.c.	200	Fungaflor	+/-	-	-	nt	nt	-
imazalil	e.c.	200	-	+	+	nt	nt	nt	+
iprodione	w.p.	500	Rovral	+*	-	+	+	+	+
iprodione	s.	250	Rovral Flo	+*	-	+	+	+	+

Table 1 (continued)

INGREDIENTS	FORMULATION	g or cc ai/kg or l	MATERIAL	Control of: A.linicola	F.avenaceum	B.cinerea	C.lini	P.exigua	Germination
iprodione/ benomyl	w.p.	500/ 500	-	+*	+	+	nt	nt	+
iprodione/ carbendazim	e.c.	167/ 167	Calidan	+/-*	-	nt	nt	nt	+
iprodione/ thiophanate methyl	e.c.	167/ 167	-	+	-	nt	nt	nt	+
maneb	w.p.	800	Plant Prot.	-	+/-	-	nt	nt	+
nuarimol	e.c.	90	Triminol	+	-	-	nt	nt	-
prochloraz	e.c.	400	Sportak	+	+	+	+	+	+
prochloraz/ carbendazim	e.c.	266/ 100	Sportak alpha	+	+	nt	nt	nt	+
propiconazole	e.c.	250	Tilt	+/-	-	+	+	+	+
propiconazole/ tridemorph	e.c.	125/ 250	Tilt turbo	+	+	nt	nt	nt	-
procymidone	e.c.	500	Sumisclex	-	nt	nt	nt	nt	+
pyrazophos	e.c.	300	Missile	-	+/-	nt	nt	nt	+
thiabendazole/ imazalil	e.c.	375/ 175	-	-	+/-	nt	nt	nt	-
thiophanate methyl	e.c.	500	Cercobin	-	-	nt	nt	nt	-
thiram	w.p.	750	Fernasan	+/-	-	nt	nt	nt	+
thiram	w.p.	275	Hexyl	-	+/-	-	nt	nt	+
triadimenol	e.c.	250	Bayfidan	-	-	-	nt	nt	+
tridemorph	e.c.	750	Calixin	+	+/-	+	nt	nt	-
vinclozolin	w.p.	500	Ronilan	+/-	-	nt	nt	nt	+

* - resistant races exist; + (control) - effective control; + (germination) - no deleterious effects

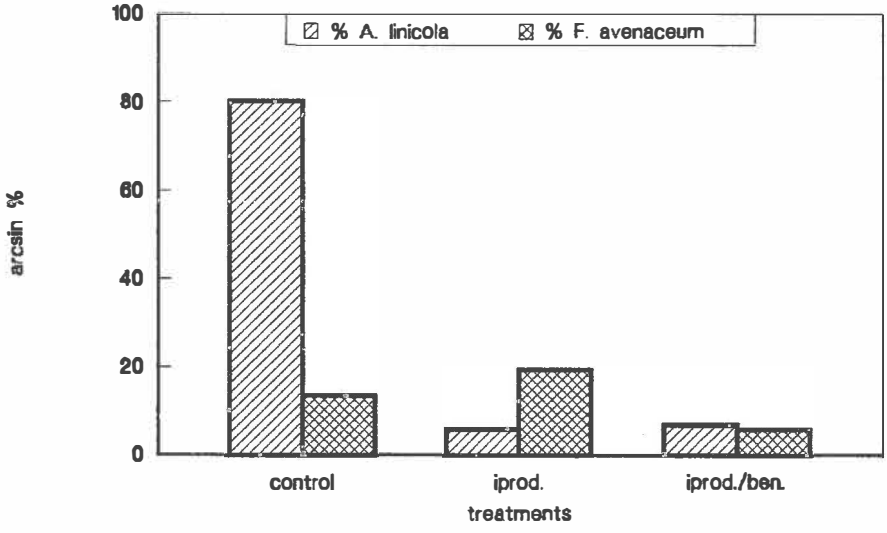

Fig. 5. Effect of seed-treatment with either iprodione (iprod.) or iprodione/benomyl (iprod./ben.) on % seeds with colonies of *A. linicola* or *F. avenaceum* 7 days after plating out on 2% malt agar. $P < 0.001$ for both variates. S.E.'s (6 DF) 3.51 (*A. linicola*), 1.17 (*F. avenaceum*).

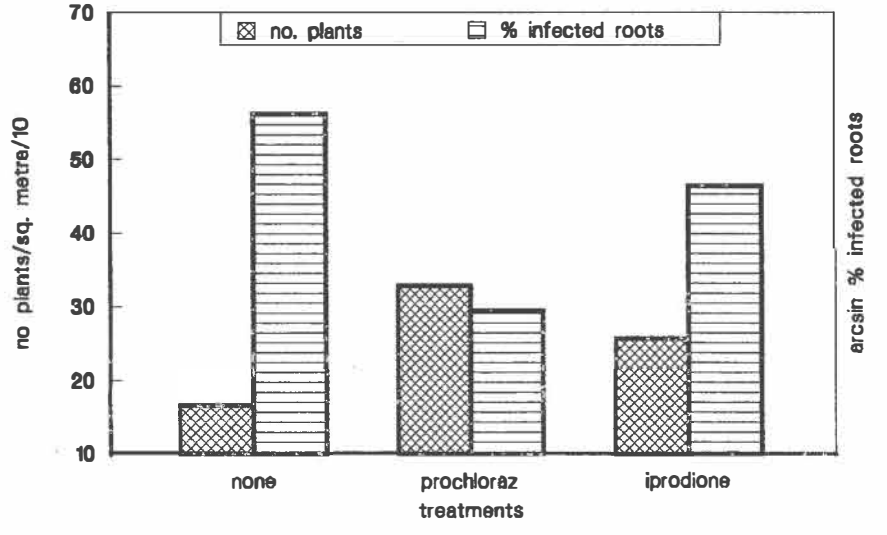

Fig. 6. Effect of seed treatments on emergence and root infection in N. Ireland in 1988. $P < 0.001$ for both variates; S.E.'s (24 DF) 2.10 (no. plants), 3.11 (root infection).

In 1986, there were the first indications of resistance by *A. linicola* to iprodione (Mercer, McGimpsey & Ruddock, 1988) and by 1988, 85% of seed samples received by DANI had at least some of their *A. linicola* population resistant to the fungicide (Mercer & Hardwick, 1991). An intensive search was then made for alternative products. Thirty-four were examined, by treating seed infected with *A. linicola*, plating it out on 2% malt agar and examining it after 7 days' incubation for the presence of *A. linicola* (Mercer & McGimpsey, 1987). A number of products (Table 1), such as fenpropimorph/benomyl and propiconazole/tridemorph showed good control of *A. linicola* and *F. avenaceum*, but they also had a deleterious effect on germination. The most satisfactory, from the point of view of overall disease control and lack of effect on germination, were propiconazole and prochloraz, the latter being more effective at control of *A. linicola* (Mercer, McGimpsey & Ruddock, 1988). Prochloraz also proved effective in field trials at increasing % emergence and reducing numbers of lesions on seedlings (Fig. 6). Estimates were made (Mercer, McGimpsey & Ruddock, 1989) of a loss of 15% in seed yield in one trial due to lack of seed-treatment.

(c) Use of sprays. Although *B. cinerea* is widely distributed in the air-spora, and *F. avenaceum* is found extensively in the soil, it is believed that *A. linicola* is transmitted from one crop to the next mainly via the seed. Mercer, McGimpsey & Ruddock (1991a) compared levels of *A. linicola* in seeds and capsules of a first- and a second-year linseed crop in N. Ireland in 1990. Although the maximum levels of *A. linicola* on capsules and seeds were 25% and 10% respectively higher at the second-year site, levels even at the first site were 65% and 70%. Attempts have been made to prevent, or at least reduce, colonisation of seeds, by spraying fungicides on to the growing crop. These have met with varying degrees of success.

In N. Ireland prior to 1990, the use of a number of different spray types had very little effect on the level of *A. linicola*, even on occasions increasing it (Mercer, McGimpsey & Ruddock, 1990). On the other hand, some control of *B. cinerea* and *F. avenaceum* was achieved. In 1990 (Mercer, McGimpsey & Ruddock, 1991a), some control of *A. linicola* in capsules and seeds was obtained with sprays of iprodione, although the most effective regime required weekly sprays from the time of capsule formation and even then the level of control was not high (Fig. 7). Iprodione tended to increase, and carbendazim decrease, the incidence of *F. avenaceum* in seeds (Fig. 8). There was little effect on *B. cinerea*. In spite of its effectiveness as a seed-treatment, prochloraz performed relatively poorly as a spray. Iprodione sprays produced an increase in thousand grain weight, but no overall increase in yield. In 1991, sprays of iprodione again had an effect in reducing the incidence of *A. linicola* on capsules and seeds, although once more with a multiple spray regime (Mercer, Ruddock & McGimpsey, 1992a). There was a significant reduction in capsule infection with *B. cinerea* at one assessment, but no significant effect on seed infection. There was no effect on either capsule or seed infection with *F. avenaceum*. Although there were marked colour differences between sprayed and unsprayed plots, no yield differences could be detected.

In Britain, a reduction in the level of *A. linicola* was obtained in 1987, although this was not accompanied by a yield increase. Indeed, in a series of seven trials, carried out from 1987-90, yield increases were only obtained in three of them (Mercer & Hardwick, 1991). One to three sprays of iprodione were applied at different timings. Table 2 shows the highest

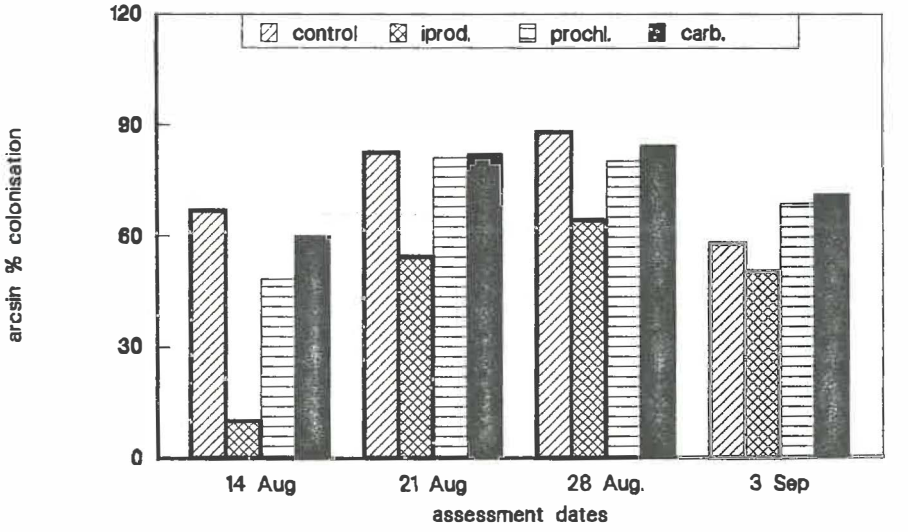

Fig. 7. Colonisation of seeds with *A. linicola* following various spray regimes in N. Ireland in 1990.

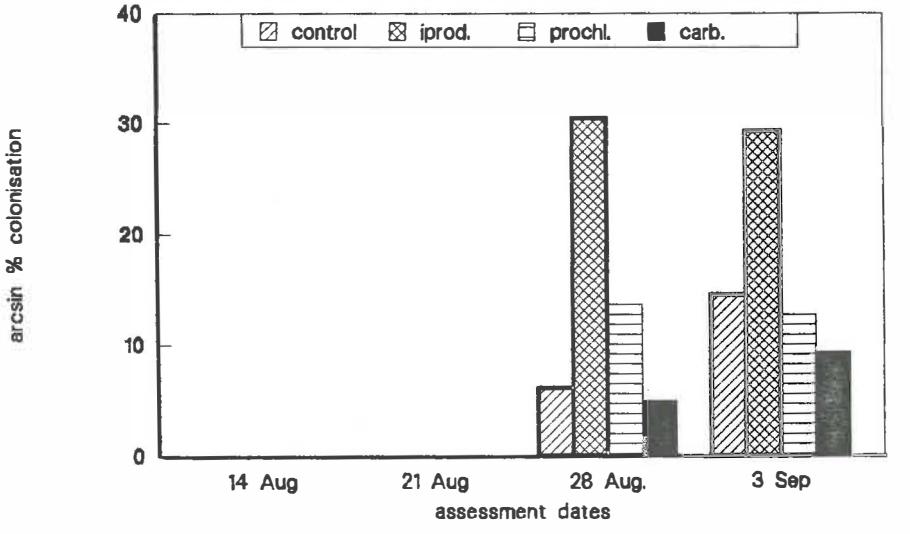

Fig. 8. As for Fig. 7 but colonisation with *F. avenaceum*.

similiar levels of yield increase. The reasons for differences between years in response to disease control, and the effectiveness of different spray regimes is still a matter for clarification. However, spraying of the growing crop with present fungicides is unlikely to become an effective and economic method of reducing the level of seed-borne disease, although it may on occasions result in a significant yield increase.

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SEASONAL DIFFERENCES IN INCIDENCE AND EFFECTS OF DISEASES ON LINSEED AT ROTHAMSTED, 1988 - 1991

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Summary

In experiments at Rothamsted to examine the effects of diseases on linseed (cv. Antares), the diseases were more significant in 1988 and 1991 than in 1989 or 1990 when less rain fell in July and August. The amount of leaf browning, associated with *Alternaria* spp. and *Botrytis cinerea* (grey mould) in unsprayed plots was greater in 1988 and 1991 than in 1989 or 1990 but was decreased most by fungicide sprays in 1988. The incidence of powdery mildew (*Oidium lini*) on leaves was high in 1989, 1990 and 1991 and was decreased by fungicide spray treatments. The incidence of stem browning (*Verticillium dahliae*) was least in 1988 when July/August were colder than in the other years. Numbers of mature capsules were greatest in 1988 and least in 1989 and were increased by fungicide treatments in all seasons. A low incidence of grey mould on capsules was observed in 1988 and 1991 but not in 1989 and 1990. Yields of seed and oil and thousand seed weights were increased by fungicide treatments in all seasons with the greatest responses in 1988.

1. Introduction

The recent increase in the area of the linseed crop (*Linum usitatissimum*) in the U.K., from *c.* 1000 ha in 1984 to 105,000 ha in 1991, may lead to an increase in the severity of disease problems (Mercer *et al.*, 1991). Pathogens such as *Alternaria linicola*, *Botrytis cinerea*, *Fusarium oxysporum* f.sp. *lini*, *Pythium* spp. and *Sclerotinia sclerotiorum*, which occurred on fibre flax cultivars of *L. usitatissimum* when they were widely grown in the UK in the 1940s (Muskett & Colhoun, 1947), have all been reported recently on commercial linseed crops (Fitt *et al.*, 1991; Mercer *et al.*, 1991). *Alternaria* blight can cause yield losses of up to 90% in India (Saharan, 1988) and *F. oxysporum* can greatly decrease yields if the concentration of soil-borne inoculum is high and weather favours the disease (Paul *et al.*, 1991). This paper examines the seasonal differences in the occurrence and effects of diseases on the growth and yield of linseed in experiments at Rothamsted from 1988 to 1991.

2. Materials and Methods

Experiments were sown as second or third linseed crops (cv. Antares) on 13 April 1988, 21 April 1989, 22 March 1990 or 10 April 1991 at seed rates of 600 seeds m^{-2} (1991) or 1100 m^{-2}. Plots (area 30 - 45 m^2) were arranged in randomized block designs with 4 or 8 plots per block and 3, 4 or 6 blocks. In the first three years, fungicide and insecticide treatments were applied to cv. Antares and in 1991 fungicide treatments only were applied to four cultivars. Results are only presented for fungicide treatments and for cv. Antares.

Fungicide treatments were a seed dressing with prochloraz (0.4g per kg^{-1} seed) in 1989, 1990 and 1991 followed by fungicide spray treatments during flowering in all seasons. These were benomyl (550g) and, separately, iprodione (500g) each in 200 l ha^{-1} three times in 1988, prochloraz (500g in 200 l ha^{-1}) and iprodione once each in 1989, and iprodione, prochloraz and carbendazim (280g) + maneb (1600g) in 300 l ha^{-1} in 1990 and 1991. All plots received nitrogen fertilizer and were treated with herbicides to control weeds. Crops were desiccated with diquat (0.6kg ion ha^{-1}) or glyphosate (1.4kg ha^{-1}) when seeds were ripe and combine harvested on 28 October 1988, 4 September 1989, 23 August 1990 and 10 October 1991.

Regular samples, generally of ten plants, were taken from each plot. Plant height, crop growth stage (GS, Turner, 1987) and numbers of leaves, flowers or capsules were recorded. The incidence of diseases on cotyledons, leaves, flowers and capsules was assessed and the % of plants affected calculated. Sometimes the severity of disease was assessed on a 0-5 severity scale or as the numbers of leaves or capsules affected. Seed yields were calculated at 90% dry matter and the % oil in seeds was measured by nuclear magnetic resonance so that the oil yield (kg ha^{-1}) could be calculated. Thousand seed weights were measured. Temperature, rainfall and other meteorological records were obtained from a meteorological station 0.5 - 1.0 km from the sites. The effects of treatments on the variates measured were estimated by analysis of variance.

3. Results

3.1 Crop growth and disease incidence.

Crop height was greater in 1988 and 1991 than in 1989 and 1990, which were both dry years when less rain fell in July/August than in the other two years (Table 1). Seasonal differences in numbers of leaves per plant reflected these differences in crop height. The proportion of the leaf area which was dark brown at GS10 after flowering was greatest in untreated plots in 1991 and 1988 and these symptoms were less frequent in the two dry years. *Alternaria* spp. and *Botrytis cinerea* (grey mould) were isolated from leaves with these symptoms, although it was difficult to distinguish between symptoms caused by these two pathogens. Fungicide treatments decreased the incidence of leaf browning greatly in 1988 and less in 1991. The incidence of *Oidium lini* (powdery mildew) at GS10 on unsprayed plots was high in 1989, 1990 and 1991 and was decreased by spray treatments in 1990 and 1991 (mildew incidence was not assessed in 1989).

The incidence of plants at GS11 with dark brown stems, from which *Verticillium dahliae* was isolated consistently, was greater in the dry years than in the wet years and was not much affected by fungicide treatments (Table 1). The proportion of flowers aborting was greater in 1990 than in 1989 or 1988 and was slightly decreased by fungicide treatments in 1988 and 1990 (Table 2). The number of mature capsules was greatest in 1988 and smallest in 1989 but was increased by fungicide treatments in all years. There was a low incidence of capsules with sporulating *B. cinerea* in 1988 and 1991 but not in 1989 and 1990 and brown stem bases from which *Fusarium oxysporum* was isolated were observed at a low incidence in 1990.

Table 1. Number of leaves, crop height, incidence of browning (*Alternaria* spp. and *Botrytis cinerea*) and of powdery mildew (*Oidium lini*) on leaves and incidence of browning on stems and branches (*Verticillium dahliae*) in linseed (cv. Antares) plots with or without fungicide treatments in relation to July/August mean temperature and total rainfall in 1988, 1989, 1990 and 1991.

		1988	1989	1990	1991
No. of leaves/plant		-[1]	46	50	56
Crop height(cm)	Nil	65	39	43	69
	Fung.	65	42	45	72
	SED (df)	0.9 (6)	0.8 (15)	0.9 (15)	1.7 (21)
% leaf area dark brown after flowering (GS10)	Nil	61	12	-	72
	Fung.	11	7	-	61
	SED (df)	4.8 (6)	2.0 (15)		6 (21)
% plants with mildew after flowering (GS10)	Nil	<5	*c.*100	97	90
	Fung.			48	68
	SED (df)			7.8 (15)	14.0 (21)
% plants with dark brown stems (GS11)	Nil	12	80	51	40
	Fung.	10	79	32	70
	SED (df)	-	5.8 (15)	7.1 (15)	16.1 (21)
Mean temp. (°C)		15.0	17.5	17.3	17.1
Total rainfall (mm)		155	85	71	119

[1] Not measured

Table 2. Incidence of aborting flowers, number of mature capsules and incidence of grey mould (*Botrytis cinerea*) on capsules in linseed (cv. Antares) plots with or without fungicide treatments in 1988, 1989, 1990 and 1991.

		1988	1989	1990	1991
% flowers aborting (GS10)	Nil	30	44	79	-[1]
	Fung.	24	46	72	-
	SED (df)	6.0 (6)	3.4 (15)	3.2 (15)	
No. mature capsules (GS11)	Nil	17.4	6.8	8.0	10.0
	Fung.	18.5	8.1	9.8	12.5
	SED (df)	1.59 (6)	0.54 (15)	0.49 (15)	1.94 (21)
% capsules with grey mould (GS10)	Nil	2.4	0	0	0.2
	Fung.	0.3	0	0	0.3
	SED (df)	0.70 (6)			0.23 (21)

[1] Not measured

3.2 Seed and oil yield.

Seed and oil yields were *c.* 50% greater in plots treated with fungicides than in untreated plots in 1988 and 5 - 9% greater in treated than untreated plots in other years (Table 3). Thousand seed weights were slightly increased by fungicide treatments in

1988 but not in other years.

Table 3. Seed yield, oil yield and thousand seed weight of linseed (cv. Antares) in plots with or without fungicide treatments in 1988, 1989, 1990 and 1991.

		1988	1989	1990	1991
Seed yield [1] (t/ha)	Nil	1.9	1.3	1.9	2.2
	Fung.	2.8	1.4	2.0	2.4
	SED (df)	0.24 (6)	0.09 (15)	0.04 (15)	0.18 (21)
Oil yield (kg/ha)	Nil	752	495	713	847
	Fung.	1130	538	782	928
	SED (df)	92 (6)	35 (15)	15 (15)	72 (21)
Thousand seed weight (g)	Nil	7.4	6.6	8.4	7.5
	Fung.	7.7	6.5	8.4	7.6
	SED (df)	0.08 (6)	0.08 (15)	0.03 (15)	0.08 (21)

[1] 90% dry matter.

4. Discussion

In these experiments the seasonal variation in yields of linseed was not clearly associated with the effects of diseases. Yields were lowest in 1989 and 1990 which were exceptionally hot dry years and it seems likely that drought stress decreased them. However, the pathogen *V. dahliae*, which is favoured by high soil temperatures (Schnathorst, 1981), was widespread in these years and since it was unaffected by treatment its effects on growth and yield were unclear. It is possible that root infection by *V. dahliae* aggravated the effects of drought stress on linseed in these experiments. The experiments were all in second or third linseed crops which might have greater amounts of soil-borne inoculum of *V. dahliae* than first linseed crops. Since this pathogen has a wide host range, rotations need to be planned carefully to ensure that amounts of inoculum remain low.

The greatest yield decreases attributable to diseases were associated with leaf browning caused by *Alternaria* spp. and *B. cinerea* in 1988, when fungicide treatments gave a 50% yield response. The effects of these pathogens may have been to decrease numbers of capsules and thousand seed weight which were both increased by fungicide treatments in that year. It is not clear why fungicide treatments were less effective against these pathogens in 1991, when considerable loss of capsules infected by *B. cinerea* was observed. The low incidence of capsules infected by grey mould in that year was an underestimate since it was observed that many infected capsules were lost through shedding.

The yield losses associated with widespread infection by *O. lini* in 1989 and 1990 were much smaller than those associated with infection by *A. linicola* and *B. cinerea*. The fungicide treatments may have delayed leaf senescence through control of mildew so that the number of capsules which set seed was increased. However, other fungicides may be more effective against powdery mildew than those used in these experiments and yield

responses of 18% have been associated with control of this disease (Beale, 1991). Nevertheless, our experiments suggest that use of fungicides is more likely to be worthwhile in seasons which favour *A. linicola* and *B. cinerea* because the period between flowering and harvest is wet, than in seasons which favour powdery mildew because this period is dry.

5. Acknowledgements

I thank S. Burhenne, J.W. Cook, A.W. Ferguson, R.A. Gutteridge and H. Davis for assistance with these experiments and A.D. Todd for the statistical analyses.

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BIOLOGICAL CONTROL OF ALTERNARIA DISEASES OF LINSEED AND OILSEED RAPE

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Summary

Tests on linseed seed and the growing crop showed that a high degree of control of *A. linicola*, sometimes rivalling that obtained with the fungicide iprodione, was achieved by applications of preparations of an isolate of *Trichoderma viride*. Some control was also obtained with an isolate of *Epicoccum nigrum*. Although isolates of *Alternaria alternata* had some effect in Petri dish tests they appeared to have very little in soil-tests. A measure of cultivar resistance to colonisation of developing seeds was apparent in 1991.

Tests on oilseed rape plants showed that a spray of a spore suspension of an *A. alternata* isolate, prior to one of *A. brassicae*, resulted in a considerable reduction in disease on leaves. Spraying *A. alternata* after *A. brassicae* had a lesser effect.

1. Introduction

Alternaria linicola is the most important of seed-borne pathogens of linseed in the UK (Mercer *et al.*, 1991b). It is found in the outer layer of the seed-coat in the form of thick-walled resting hyphae which rapidly resume activity as the seed imbibes water prior to germination (Mercer & Hardwick, 1991). The embryo itself is not normally affected by the pathogen in the ungerminated state, but as germination proceeds, hyphae may grow from the infected seed-coat towards the emerging root, infecting it, producing brick-red lesions and frequently preventing emergence of the seedling.

The disease-free status of the embryo makes it an ideal situation for the use of a seed-treatment, as prevention of hyphal growth from the infected seed-coat will maintain a healthy emerging seedling. Although there is currently a highly-effective chemical seed-treatment in the form of prochloraz (Mercer & Ruddock, this journal), problems have arisen in the past with resistance to another commonly-used seed-treatment - iprodione (Mercer, McGimpsey & Ruddock, 1988) and for this reason, the possibility of biological control was also considered, both as seed-treatments and as sprays of spore suspensions on the growing crop (to control the pathogen in the developing seed).

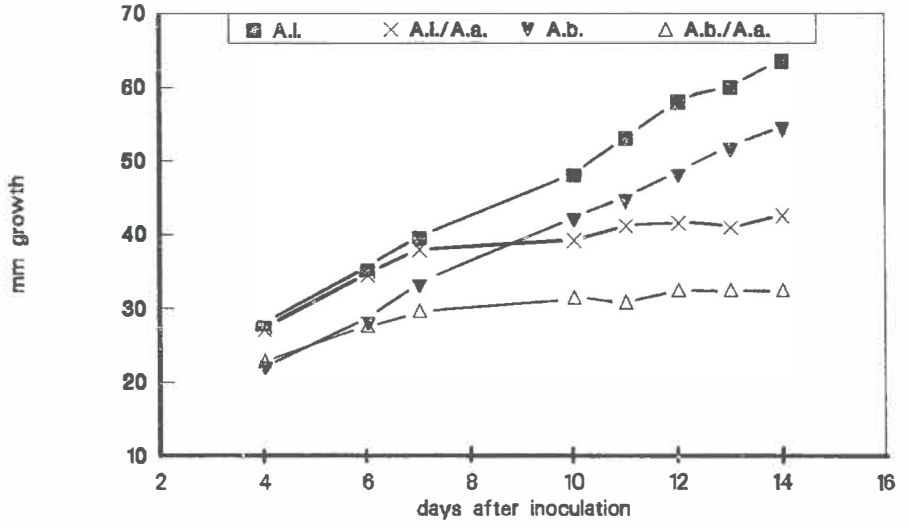

Fig. 1. Growth of cultures of *A. linicola* and *A. brassicae* on 2% malt agar, in the presence or absence of *A. alternata*. A.l. - *A. linicola* alone; A.l./A.a. - *A. linicola* plus *A. alternata*; A.b. - *A. brassicae* alone; A.b./A.a. - *A. brassicae* plus *A. alternata*.

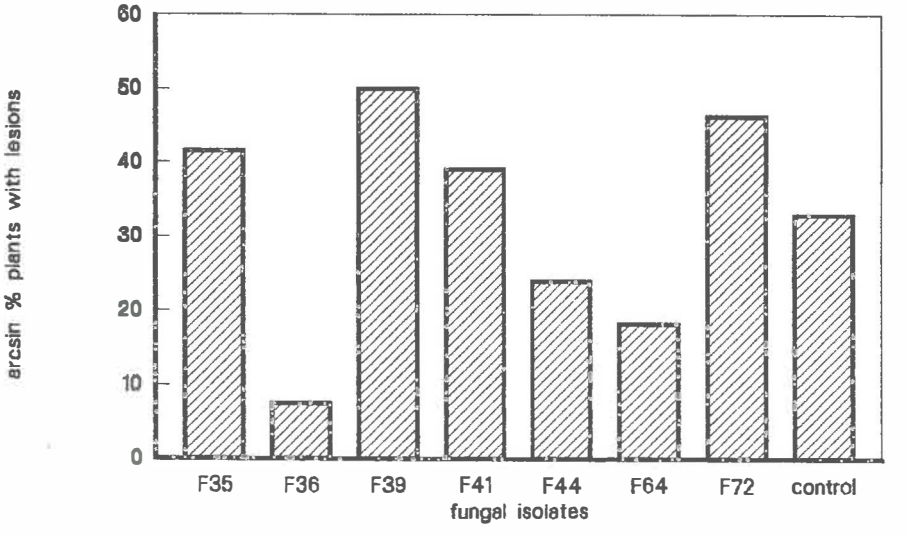

Fig. 2. Effect of treatment with spores of a range of isolates of *E. nigrum* on % seedlings of linseed with lesions caused by *A. linicola*. P = 0.03; S.E. (28 DF) = 5.58.

One of the candidates for this form of treatment was the saprophytic *Alternaria alternata*, and this was also investigated as a control measure for the Alternaria disease of leaves and pods of oilseed rape caused by *A. brassicae*. This paper records published and unpublished results of experiments on both crops.

2. Experimental - *Alternaria linicola* of linseed

Three sets of micro-organisms were examined for biocontrol potential - (a) *Alternaria alternata* and (b) *Epicoccum nigrum*, both commonly-occurring fungal saprophytes on linseed seed, and (c) *Trichoderma* spp., not frequently found on either linseed plants or seeds, but well known for their antagonistic activity. An isolate of a *Corynebacterium* sp. was also found to have some activity (Mercer & Papadopolous, 1990), but discussion in this paper is confined to fungal agents.

(a) *Alternaria alternata*. As this fungus belongs to the same genus as the target pathogen, it was thought that it might be successful at occupying the same ecological niche. Isolates were initially tested against *A. linicola* on 2% malt agar in Petri dishes (5 replicates) and incubated at 22°C. Results (Fig. 1) indicated a degree of antagonism towards the pathogen. Further tests involved taking samples of seed contaminated naturally with *A. linicola* and/or other pathogens, and shaking 100 seeds in sporing cultures of *A. alternata* growing in Petri dishes. These and untreated samples were then plated out (10 seeds/plate), incubated at 22°C under 12 h dark/12 h near ultra-violet light and examined for the presence of pathogens after 7 days. As an example, an untreated sample of one batch showed 71.4% and 42.6% of seed to be colonised by *A. linicola* and *Fusarium avenaceum*, respectively, compared with 10.8% & 14.4% respectively when treated (S.E. = 6.55; 17 DF's). There did not appear to be much difference in activity between isolates of *A. alternata*.

Although these tests showed promise, there appeared to be little effect on *A. linicola* when seed, treated in the same way, was sown out in soil in pots (Mercer & Papadopolous, 1990) and compared with the effects of some isolates of *Trichoderma* spp. (Fig. 7). *A. alternata* has not yet been tested as a field spray.

(b) *Epicoccum nigrum*. Tests with a range of *E. nigrum* isolates, using the same technique as with *A. alternata*, showed a range of activity against *A. linicola* (Fig. 2), isolates F36 and F64 being particularly effective. As F64 spored considerably more profusely than F36, it was used for further tests.

Compared with *A. alternata* as a seed treatment in pot tests (Mercer & Papadopolous, 1990), the *E. nigrum* F64 isolate reduced the level of *A. linicola* in seedlings quite significantly (Fig. 7), although there was some suggestion of phytotoxicity (Fig. 8). However, when used as sprays of spore suspensions on the growing crop in 1990 (Mercer, McGimpsey & Ruddock, 1991a), its effectiveness against capsule colonisation by *A. linicola* (Fig. 3) was much closer to one of the poorer chemical treatments, prochloraz, than to the best, iprodione, and this was achieved at only one assessment. Further, there was no significant effect on the seed. In a similar experiment in 1991, (Mercer, Ruddock & McGimpsey, 1992), which also included the factor of spray-frequency, a single spray of *E. nigrum* at green capsule stage appeared to be much more effective at preventing capsule colonisation than weekly sprays, when assessed at *a* number of dates

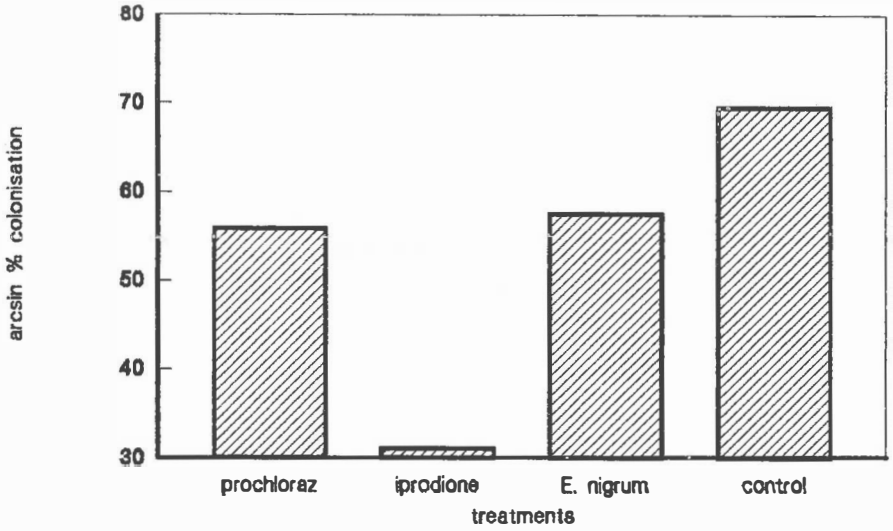

Fig. 3 Effect of sprays of prochloraz, iprodione and a spore suspension of *E. nigrum* on colonisation of linseed capsules in a crop on 14 August 1990. $P < 0.001$; S.E. (33 DF) = 3.90.

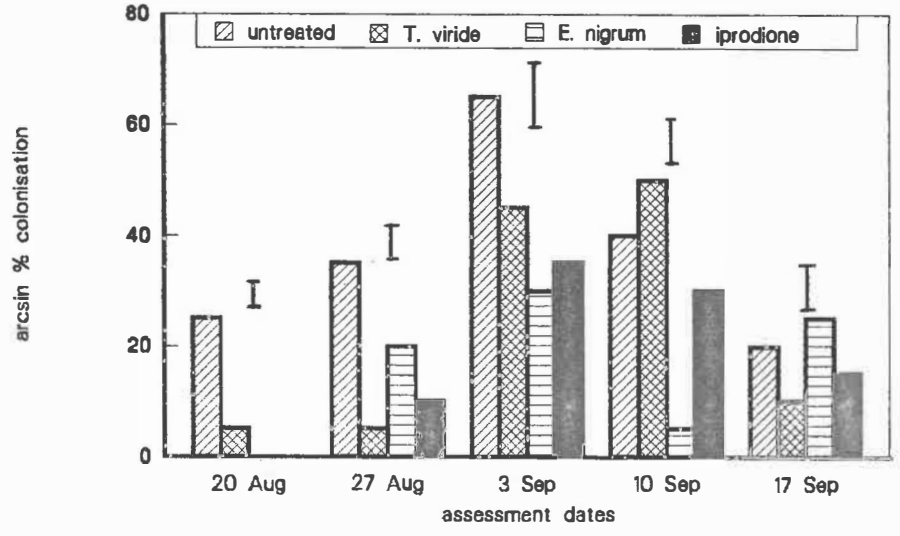

Fig. 4 Effect of a spray at green-capsule formation of iprodione or spore suspensions of *T. viride* or *E. nigrum* on % capsules colonised by *A. linicola*. Bars = S.E.M's (30 DF).

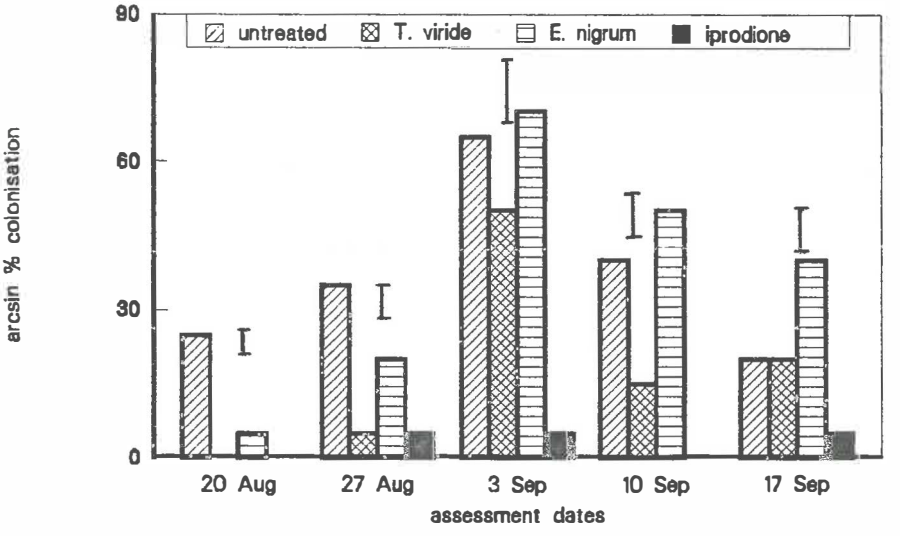

Fig. 5 Effect of weekly sprays, from green-capsule formation onwards, of iprodione or spore suspensions of *T. viride* or *E. nigrum* on % capsules colonised by *A. linicola*. Bars = S.E.M's (30 DF).

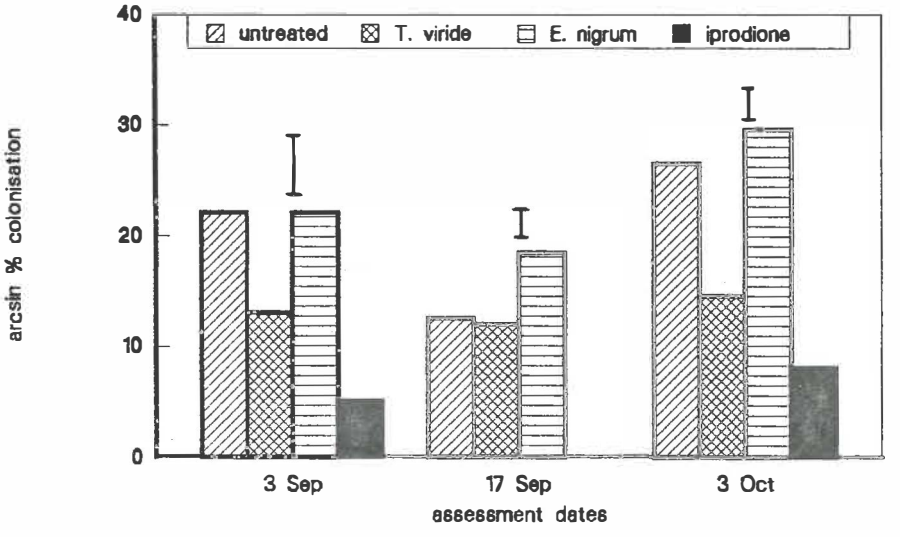

Fig. 6 Effect of weekly sprays, from green-capsule formation onwards, of iprodione or spore suspensions of *T. viride* or *E. nigrum* on % seed colonised by *A. linicola*. Bars = S.E.M's (30 DF).

(Figs. 4 - 5). Its effectiveness also compared well with a single spray of iprodione. Again, however, there was no significant effect on seed colonisation (Fig. 6). Neither *E. nigrum* nor any of the other chemical or biological agents had any significant effect on seed-yield in either 1991 or 1992.

(c) *Trichoderma* spp. A range of 30 isolates of *Trichoderma* spp., mostly obtained from yards of mushroom composters, was assessed for suitability as seed treatments, in a series of tests on Petri dishes and in soil in pots. The treatments were applied to two types of seed - either 85% infected with *A. linicola* (infected) or substantially free of the pathogen (clean). Generally any effects on dishes were reflected by those on pots. Figs. 7 & 8 show a range of isolates from one of the tests in soil (Mercer & Papadopolous, 1990). As with *E. nigrum*, there was a wide range of activity against *A. linicola* (Fig. 7), some such as T7 and T14, completely protecting the emerging seedlings, while others, such as T12 and T17 produced no obvious effect. However, there was also a tendency for the more successful antagonists to damage the seedlings, T5 for example, which had a substantial degree of control of *A. linicola*, had one of the most deleterious effects on the germination of 'clean' seed (Fig. 8). T7 & T14, which had complete control of *A. linicola*, reduced germination to a lesser extent, as did T17 although it had had no obvious effect on control of *A. linicola*. T12 had no significant effect on either *A. linicola* control or germination. The effect on germination was also reflected in general plant growth, those isolates reducing germination also having a stunting effect on shoot growth. Effects on germination and control of *A. linicola* can be examined together by looking at the percentage of healthy seedlings resulting from the total number of seed sown. If this measurement is used as a criterion of success then T1 and T6 were the most successful isolates in that particular test.

Field trials including sprays of spore suspensions of two *Trichoderma* isolates were performed in 1991 (Mercer, Ruddock & McGimpsey, 1992). The two selected were the *T. harzianum* isolate T1 from the above test and a *T. viride* isolate, T21, which proved very successful at control of *A. linicola* in further tests, although also showing a slight degree of phytotoxicity. When applied as weekly sprays (Fig. 5), there was a substantial reduction in capsule colonisation by T21 at all assessments, except the last, although not generally as large a reduction as with the fungicide iprodione. T1 had no significant effect. The effect of only a single spray (Fig. 4) of T21 was most marked in the early assessments. T21 also significantly reduced the level of *A. linicola* on leaves. On seeds, only weekly sprays had a significant effect (Fig. 6) and again as with capsules the reduction was less than with iprodione. There were no significant effects on yield.

(d) Cultivar resistance. This can also be considered as a form of biological control. Field trials carried out in Britain in 1987 (Mercer & Jeffs, 1988) suggested a measure of resistance to seed colonisation by *A. linicola* by some linseed cultivars, although it was not clear if varying maturity dates were not a confounding factor. Further field trials in N. Ireland in 1991 (Mercer, Ruddock & McGimpsey, 1992b) showed no differences in capsule colonisation amongst cultivars but did show significant differences in seed colonisation (Fig. 9), the level on *cv.* Antares, for example, being 3-4 times higher than on *cv.* Tadorna. There were, however, no differences among cultivars in incidence of *B. cinerea* or *F. avenaceum*.

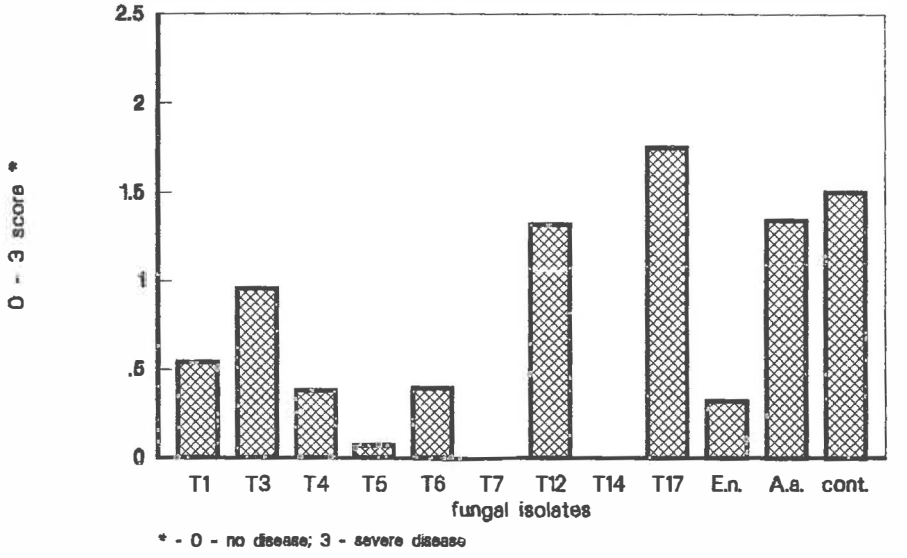

Fig. 7 Effect of treatment with spores of a range of fungal isolates (T1 - T6 - *T. harzianum*; T7 - *T. hamatum*; T12-17 - *T. viride*; E.n. - *E. nigrum* (F64); A.a. - *A. alternata*; cont. - untreated control) on severity of lesions caused by *A. linicola* grown from infected linseed seed, 10 days after sowing in soil in pots. $P < 0.001$; S.E. (72 DF) = 0.16

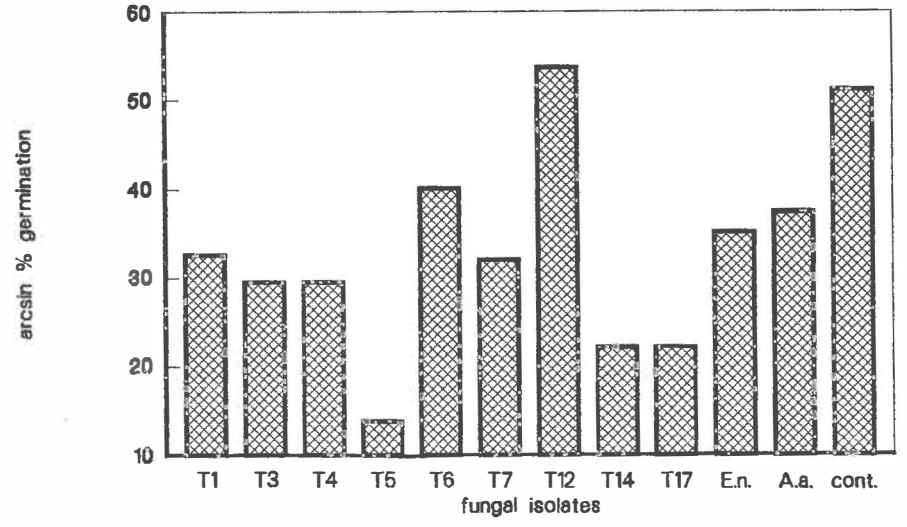

Fig. 8 As for Fig. 7, but effect on % germination on 'clean' seed. $P < 0.001$; S.E. (72 DF) = 0.16.

3. Experimental - *Alternaria brassicae* of oilseed rape.

As with *A. linicola*, initial tests involved plating of paired cultures and again showed (Fig. 1) a measure of antagonism by *A. alternata towards A. brassicae*.

In 1990, a trial was performed on 7 - 10 week old oilseed rape plants growing in pots in the glasshouse (Mee, Mercer & McGimpsey, 1991). A spray of a spore suspension of *A. alternata* was applied either 24 h before or after a similar spray of *A. brassicae*. Single sprays of *A. alternata* and *A. brassicae* were also applied. Results of subsequent lesion scores on leaves (Fig. 10) showed a significant reduction in score by spraying *A. alternata* both before and after *A. brassicae*, although the effect was greater where it was sprayed before.

In the following year a much larger-scale trial was carried out on 0.6 m diam concrete pots situated in the open air (5 plants of *cv.* Topas sown per pot on 21 March; 3 replicates). The trial examined a range of factors which also included those examined in 1990, and only these are reported here. Sprays of suspensions of *A. alternata* (6 x 10^6/ml) and *A. brassicae* (2 x 10^6/ml) were applied, in the same sequence as in 1990, on 24 and 25 June (GS 4.7). Results of estimates of the percentage *A. brassicae* lesions on the upper leaves are shown in Fig. 11 and indicate a similar pattern to the previous year, in that there is a bigger reduction where *A. alternata* was applied prior to *A. brassicae*, than the converse. Unfortunately, due to bird-damage no reliable figures for yield were obtained.

4. **Discussion**

Alternaria alternata had *a* significant effect on the the growth of *A. linicola* and *A. brassicae* in paired-culture tests, suggesting a degree of antagonism. As *A. alternata* is a common occupant of linseed seed-coats, it might therefore have been expected to have had some effect on *A. linicola* in this situation. However, this did not prove to be the case. On the other hand, if niche occupation is a more important factor for *A. alternata* (and the literature does not suggest widespread antibiotic production in *Alternaria* spp.) then it has to be conceded that, in the experiment reported, the seed-coats had already been largely occupied by *A. linicola*, which could have been difficult to displace. If, however, niche occupation were the only method of control, it is surprising that a spray of *A. alternata* following *A. brassicae* on oilseed rape should also have had some effect.

Epicoccum nigrum is also a common saprophyte of linseed seeds, and some isolates showed a high degree of activity against *A. linicola* on linseed seed in pot tests. There was also some effect by one of the isolates on capsule colonisation in field tests. The reason for this being apparently more successful as a single spray rather than a number of sprays, is not clear and needs further elucidation.

Trichoderma spp. had the most striking effects of all the fungal isolates, both in laboratory, glasshouse and field trials. This is rather surprising as *Trichoderma* spp. are not commonly found on linseed seed-coats. There was, however, considerable variation in the behaviour of the various *Trichoderma* isolates. T1 (*T. harzianum*) was one of the most successful isolates in laboratory and glasshouse, in terms of disease

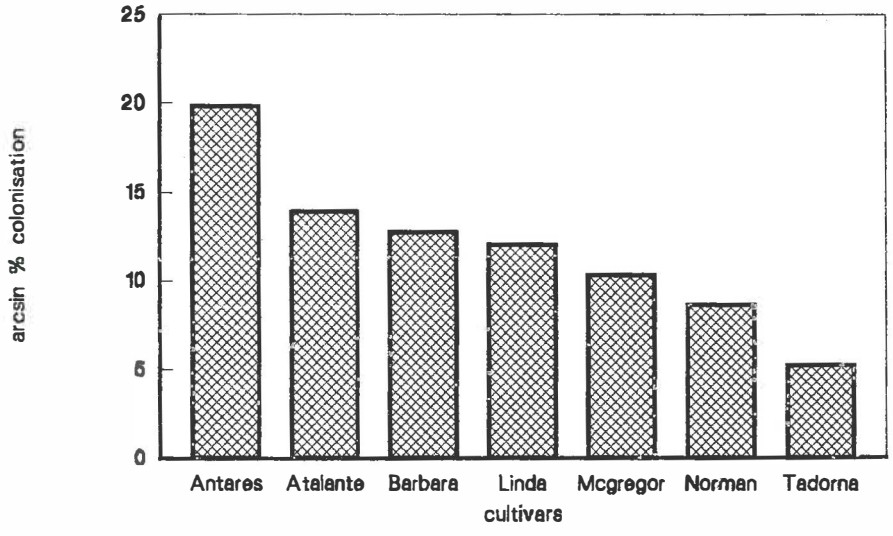

Fig. 9. Colonisation of harvested seed of a number of linseed cultivars by *A. linicola* in N. Ireland in 1991.

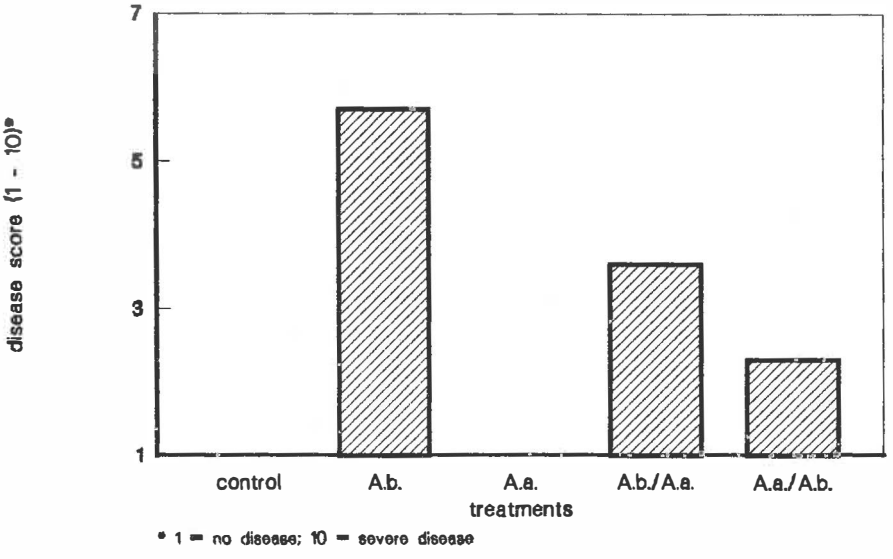

Fig. 10 Effect of sprays of *A. alternata* on level of disease caused by *A. brassicae* on oilseed rape plants in a glasshouse. A.b. - *A. brassicae* alone; A.a. - *A. alternata* alone; A.b./A.a. - *A. brassicae* followed by *A. alternata*; A.a./A.b. - *A. alternata* followed by *A. brassicae*. $P < 0.001$; S.E. (21 DF) = 0.19.

control and lack of harmful efects on the plant, but it had negligible effects in the field. T21, on the other hand, which had established good disease-control although with some accompanying phytotoxicity, was considerably more successful in the field, the degree of control of *A. linicola* at times rivalling that obtained by the fungicide iprodione. Although in practical terms some sort of laboratory/glasshouse pre-screening is necessary, these results indicate that a degree of caution needs to be exercised when extrapolating results of such tests to the field.

Results of the cultivar trial in N. Ireland in 1991 showed a range of seed colonisation amongst different cultivars. As these differences are not all well linked to differences in maturity, they indicate that some cultivars do possess a measure of resistance to colonisation of their seeds by *A. linicola*. This confirms earlier unpublished work by H.C. McGimpsey which indicated significant variation amongst different cultivars in the resistance of seedlings to lesion formation, following sprays of spore suspensions of *A. linicola*.

In spite of some control of *A. linicola* by *T. viride* and *E. nigrum*, there was no effect on the yield of linseed (the effect on yield of oilseed rape has not yet been quantified). Considerably more research is required into timing, delivery systems and choice of isolates before biological control of either *Alternaria* sp. is likely to become a commercial proposition.

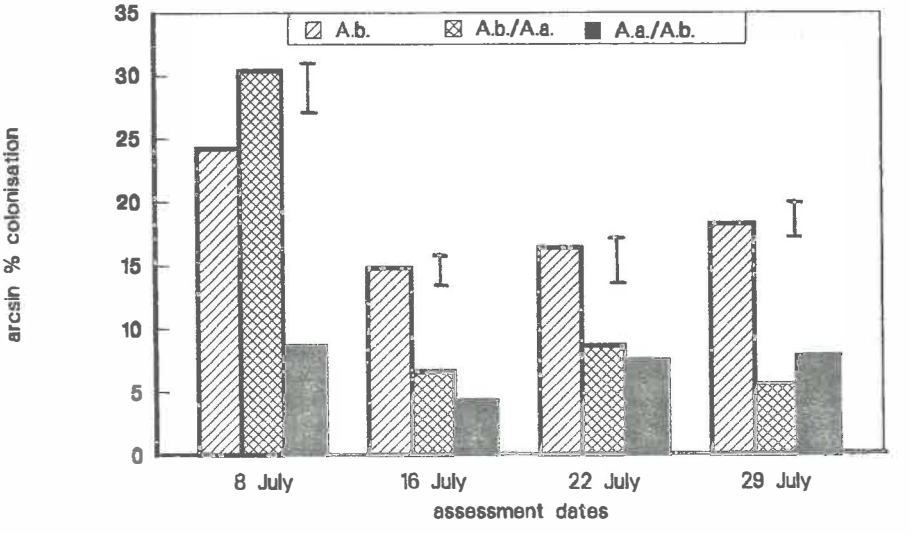

Fig. 11 Effect of sprays of *A. alternata* on level of disease caused by *A. brassicae* on oilseed rape plants in open air in 1991. A.b. - *A. brassicae* alone; A.b./A.a. - *A. brassicae* followed by *A. alternata*; A.a./A.b. - *A. alternata* followed by *A. brassicae*. Bars = S.E.M's (12 DF)

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PATHOGENICITY OF TWO ISOLATES OF *ALTERNARIA LINICOLA* ON 16 CULTIVARS OF *LINUM USITATISSIMUM*

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Summary

Two isolates of *Alternaria linicola* were tested for pathogenicity on 16 cultivars of *Linum usitatissimum* in the greenhouse. They were used in infection experiments on seedlings and young plants. Infection with the isolate from Eichhof produced a higher disease severity on all the cultivars than the isolate from Thüle. Some cultivars had a relatively high level of tolerance, but no cultivar was resistant to either of the two isolates. The variation in tolerance between the cultivars suggests that breeding for resistance to *A. linicola* might be successful.

1. Introduction

Alternaria linicola is one of the most common seed-borne pathogens of linseed and can seriously decrease emergence if infected seed is sown (Mercer et al., 1989). Little is known about the epidemiology of the pathogen between crop emergence and capsule colonisation. On U.K. linseed crops, lesions originating from infected seeds were seen on cotyledons and on the lower leaves at the beginning of the season. However, it is not clear how the pathogen spreads over the plant to reinfect the seeds at the end of the season (Fitt et al., 1991). In field trials at various sites in northern and central Germany from 1989-1991, *A. linicola* could be isolated from cotyledons and stem bases in the seedling stage and from stems, leaves, capsules and seeds in GS 11-12 (capsule senescence), although typical symptoms did not occur. At the seedling stage, *A. linicola* was often isolated from cotyledon and hypocotyl lesions concurrently with other pathogens, typically *Botrytis cinerea*, *Phoma* sp. or *Fusarium avenaceum*. During maturity *A. linicola* was only isolated from lesions caused by other fungi such as *Phoma* sp., *Botrytis cinerea*, *Oidium lini*, *Mycosphaerella linicola* and *Verticillium dahliae*. Screening for resistance/susceptibility of linseed cultivars to natural infection of *Alternaria linicola* in the field in Germany has therefore not been possible so far (Bauers & Paul, 1991).

There have been suggestions that cultivars differ in their susceptibility to *A. linicola* (Mercer et al., 1991) but it is not clear whether these are related to differences in maturity. The dependence on environmental conditions may alter the infection levels of cultivars from year to year. For this reason it is useful to examine the differences in cultivar

susceptibility to disease under controlled environment conditions.

This paper reports results from artificial inoculation experiments on 16 linseed cultivars at three growth stages. Two strains of *A. linicola* were tested to investigate any variability in the plants' resistance/susceptibility to these strains.

2. Materials and Methods

2.1.Isolation and Cultivation of the two Isolates

During 1990 two isolates of *A.linicola* (designated ALT I - Thüle; ALT II - Eichhof) were obtained from infected seeds of linseed plants. The seeds were surface sterilized in ethanol (70%) and then placed on a selective-medium (rote Platte) for incubation, initially at 17°C under alternating 12 h ultraviolet light and 12 h darkness. After 2-3 days monospore lines of the pathogen were obtained from the isolates after transfer of individual spores with a glass needle. For cultivation and to induce maximal production of conidia single spores were transferred under conditions of 20% V-8 juice agar (pH 5,5), alternating temperature (22/12°C) and alternating 12 h UV light/12 h darkness.

2.2 Susceptibility testing

For susceptibility tests to *A. linicola*, 16 cultivars of *Linum usitatissimum* were tested at different growth-stages (seed/GS00, seedling/GS09, plants/GS13-15 (Freer, 1991)). In accordance with a joint experiment of linseed (supported by the Ministry of Agriculture) 1990, 16 cultivars/lines were chosen for the inoculation experiments.

2.3. Seed test

In transparent "Gerda" plastic dishes (5x19x19cm) surface sterilized seeds were laid on wet, folded filterpaper and sprayed with a spore suspension (30 ml) of *A. linicola* (2750 spores/ml) using a Sata-colour spray container (0,5mm nozzle, 2 bar). The seed was germinated at room temperature (20°C) and was subjected to seasonal fluctuations of the photoperiod and light intensity of the room. Air humidity within the plasticdishes reached 97 % relative humidity.

2.4. Seedling test

Seedlings of different linseed cultivars were raised in transparent "Gerda" plastic dishes at constant temperature (22°C) and at the seasonal fluctuations of the photoperiod and light intensity.

When the cotyledons had developed they were sprayed with a spore suspension of *A. linicola* (5266 spores/ml) using a Sata-colour spray container (0,5mm nozzle, 2 bar). After inoculation the boxes were covered with transparent lids and kept for 48 hours at constant temperature (20°C). Air humidity within the plastic-dishes reached 98 % relative humidity. The seedlings were assessed after two days by estimating the percentage hypocotyl area infected.

2.5. Plant test

The test plants were grown in propagators at a temperature of 15 to 20°C by day and of 10°C by night and normal light conditions. The cultivars were grown in a peat-sand compost. When the third pair of true leaves had fully expanded they were sprayed with a spore suspension (30ml) of *A. linicola* (3970 spores/ml) using a Sata-colour spray container (0,5mm nozzle, 2 bar). After inoculation the boxes were covered with transparent domes and kept for 8 days at 18-20°C and 8000 Lux/darkness (12h/12h). Air humidity within the propagators reached 96 % relative humidity. The test was evaluated after eight days with special regard to differences in symptom development on the hypocotyl, cotyledons and stem.

2.6. Disease assessments

The first disease assessment was made on seeds 5 days after inoculation by scoring % seed germination failure. The second disease assessment was made 10 days after inoculation by scoring % seedling death.

Seedlinginfection was recorded as the 2% area of hypocotyl infected two days after inoculation

A range of methods have been used to assess incidence and severity of plant infection:

1. % infected cotyledon area ,
2. % infected leaf area (only the most severely infected leaf was assessed.)
3. % infected stem area .

Table 1. *Alternaria linicola* on linseed : assessment of seedlings and plants after inoculation

Infected area (leaves/stems)	Score	degree of severity
0%	1	no infection
< 10%	2	trace
10 - 25%	3	very slight
25 - 40%	4	slight
40 - 55%	5	moderate
55 - 70%	6	moderate to severe
70 - 85%	7	severe
85 - 99%	8	very severe
100%	9	plants dead

Nine categories were employed for the disease assessment on inoculated seedlings and plants (Table 1).

3. Results and Discussion

3.1 Artificial inoculation experiments in vivo

Symptoms were observed on leaves, cotyledons and stems. The examinations demonstrated, that infection resulted in a decrease of assimilatory leaf surface and damage to stems.

3.2. Seed infection

During the germination the linseed reacted sensitively to *A. linicola*. The germination rate of the linseed was decreased by the inoculation, although the effects were far more pronounced on the subsequent survival of the seedlings after emergence.

Table 2. Germination failure rate (%) and seedling death rate of seeds (%) after inoculation of seeds by two stra ins of *A.linicola* (ALT I; ALT II)

	1.*		2.**	
	ALT I	ALT II	ALT I	ALT II
Liflora	9	10	99	96
Ariane	2	2	93	93
Tadorna	4	1	94	95
Kreola	1	18	100	89
Gießen 464/76	5	18	95	93
Gießen 600/74	-	-	95	81
Gießen 704/74	6	4	83	75
Gießen 1270/73	10	1	100	88
Linda	-	5	90	76
Antares	11	20	98	95
Atalante	8	10	97	87
Norlin	6	2	94	82
McGregor	8	-	90	89
Kiszombori	1	12	88	86
Szegedi 43	14	5	96	88
Szegedi 62	-	-	99	93
Mean			93	87

* = 1st disease assessment in % of not germinate seeds (5 days after inoculation))
** = 2nd disease assessment in % of dead seedling (10 days after inoculation)

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3. Results and Discussion

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Even with low original disease scores both strains under favourable conditions, resulted in a high subsequent mortality, on average 90%.

In comparison with control, the inoculated seed showed a lower germination rate. Comparing the strains based on the cultivar susceptibility, some cultivars showed similar scores (eg. Liflora and Ariane), although others showed weighty variations in scores between strains (eg. Kreola and Gießen 1270/73).

Many seedlings were killed within 10 days of inoculation (Table 2) ALT I gave a mean of 93%, deead seedlings and ALT II 87%. dead seedlings. The cultivars Gießen 704/74 and Linda proved to be the least susceptible of the investigated cultivars. The cultivars Kreola and Gießen 1270/73 proved to be most susceptible to infection with AlT I, and Liflora, Tadorna and Antares to ALT II (Table 2).

3.3 Infection of seedlings

The hypocotyl showed red-brown, longitudinal discolourations (3-20mm). Lesions flow together, when the severity was high. As a result the hypocotyl began to decay and the seedlings died. At severe infection levels the lesions increased in size and caused putrification of the hypocotyl

Table 3. Pathogenicity of two strains of *A. linicola* (ALT I; ALT II) to seedlings of 16 cultivars of linseed (scoring 1-9)

Cultivar	ALT I		ALT II		Mean	
	Score	R	Score	R	Score	R
Liflora	3.2	8	4.0	11	3.6	9
Ariane	4.0	15	3.0	2	3.5	5
Tadorna	2.9	5	4.3	13	3.6	8
Kreola	3.2	7	3.9	10	3.6	6
Gießen 464/76	2.6	2	3.0	2	2.8	2
Gießen 600/74	3.7	14	3.8	6	3.8	13
Gießen 704/74	3.2	9	3.9	9	3.6	9
Gießen 1270/73	2.7	3	3.8	7	3.2	3
Linda	4.0	16	5.5	16	4.8	16
Antares	3.4	12	3.7	4	3.6	11
Atalante	3.3	10	4.4	15	3.8	14
Norlin	3.6	13	3.7	4	3.6	12
McGregor	3.0	6	3.9	8	3.5	4
Kiszombori	3.5	11	4.1	12	3.8	15
Szegedi 43	2.8	4	4.3	14	3.6	6
Szegedi 62**	2.1	1	1.8	1	2.0	1
Mean	3.26		3.90		3.58	
LSD (p=0.05%	0.6					

R = rank,
** = lowest germination rate

and finally led to the death of the seedlings.

The symptoms on cotyledons were small to large, concentric and concave necrotic areas, which were brown at first an becoming grey-brown in the centre.

The cultivars showed a low variability in their resistance to *A. linicola*, but infection levels in this inoculation test were low.

Over all cultivars, the strain ALT I had a higher disease level than the strain ALT II.

The cultivars Szegedi 62 and Gießen 464/76 proved to be the least susceptible of the investigated cultivars. The cultivars Linda, Kiszombori and Atalante proved to be most susceptible to infection with both Alternaria strains (Table 3).

3.4 Infection of plant (GS 13-15)

Compared to the seedling infection scores, the plant assessments showed greater variability between cultivars, with regard both to their overall susceptibility to the pathogen, and to the two Alternaria strains.

On cotyledons Alternaria produced diffuse, concave, lesions with diameter of one to five mm. Spots on the leaves were oval to elongated, blurred at the edges. An expansion of cotyledon and leaf lesions was sometimes observed and this resulted, in extreme cases, of death of the whole leaf area. On stems longitudinal, unilateral, brown discolouration could be observed on the epidermis which later burst. Severe attacks of ALT II may lead to lodging and death of the plants.

The symptoms produced by the two strains were consistently different. ALT I produced diluted-grey lesions whilst ALT II produced evident brown infection areas.

The pathogenicity experiment with the 16 linseed cultivars demonstrated differences between of the two isolates ALT I and ALT II. ALT II was more aggressive than ALT I and this was consistend across all the cultivars tested..

The mean of the assessment notes of stem, cotyledon and leaf (Gesamtpflanzennote) elucidated the susceptibility of the cultivars Gießen 704/74, Gießen 600/74, Kiszombori, Antares, Gießen 1270/76 and Kreola. Norlin, Tadorna and McGregor were the cultivars with the lowest infection level.

In comparison with the suscepibility of the single organs cotyledons, leaves and stems, ALT II produced a higher disease level on the cotyledons and first true leaves than on the stems. ALT II produced higher infection on the cotyledons. The reaction of leaves and stems was very similar for the isolate ALT II (Table.4).

Table 4. Pathogenicity of two strains of *A. linicola* (ALT I; ALT II to plants in GS 13-15 of 16 cultivars of linseed

Cultivar Strain	Disease Score (1-9 score) Stems I/II	Cotyledons I/II	Leaves I/II	Mean I/II
1	3.5/4.8	2.3/6.8	2.8/7.0	2.83/6.17
2	2.0/6.0	3.0/8.8	4.0/4.5	3.00/6.42
3	2.0/4.5	2.0/4.5	2.8/4.0	2.25/4.33
4	4.0/3.8	5.0/8.0	6.0/6.3	5.00/6.00
5	2.5/6.3	3.5/4.3	3.5/4.0	3.17/4.83
6	6.0/8.8	3.3/9.0	5.8/7.0	5.00/8.17
7	5.5/8.0	8.3/8.0	5.3/7.3	6.25/7.83
8	4.8/7.5	5.8/6.0	3.8/4.8	4.67/5.92
9	1.5/3.8	5.0/5.8	6.8/7.3	4.42/6.42
10	2.5/5.3	7.5/7.5	6.3/7.3	5.42/7.17
11	1.0/4.8	5.3/6.5	3.3/6.8	3.17/6.58
12	1.0/4.0	2.8/4.0	3.0/4.3	2.25/4.17
13	2.5/3.5	2.5/3.8	2.0/3.8	2.33/3.92
14	6.3/7.8	5.0/6.8	5.5/7.0	5.58/6.83
15	2.0/5.5	4.0/6.5	4.5/5.5	3.50/6.50
16*	-	-	-	-
Mean	3.1/5.6	4.3/6.9	4.3/5.6	3.92/6.08
LSD (p=0.05%)	0.42	0.32	0.21	0.97

1=Liflora 2=Ariane 3=Tadorna 4=Kreola 5=Gießen 464/76 6=Gießen 600/74 7=Gießen 704/74 8=Gießen 1270/73 9=Linda 10=Antares 11=Atalante 12= Norlin 13=McGregor 14=Kiszombori 15=Szegedi 43 16=Szegedi 62
* = lowest germination rate

There are only a few differences in the estimation of cultivarreaction between the cotyledon-, leaf and stem assessment. The ranking correlation for the single organs have demonstrated a correlation coefficient with high significance (Table 5).

Table 5. Ranking correlation for the single organs leaves, cotyledons, stems and whole plants on 16 Cultivars of Linseed

	Leaves	Cotyledons	Stems	Mean
Leaves	1.0000	.6678**	.4437**	.8198**
Cotyledons	.6678**	1.0000	.4764**	.8727**
Stems	.4437**	.4764**	1.0000	.7889**
Mean	.8198**	.8727**	.7889**	1.0000

* significant at p=0.01 ; ** significant at p=0.001
* = Mean of all variants

Data from these experiments indicate that the infection level is significantly influenced by the growth stage of the plants.

At both seedling and young plant growth stages the cultivars showed variability in their susceptibility to the strains, although none showed an absolute resistance to the pathogen. The effect on the subsequent growth and yield of the plants inoculated at these early growth stages was not determined. Furthermore, it was not possible to determine whether similar results would be expressed in inoculation and screening of mature plants. The results show that screening a particular cultivar at a single growth stage produces consistantly similar scores regardless of the plant part examined.

4. References

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Session 3

IOBC-Joint Oilseed Rape Experiment 1990/91

RESPONSE TO FUNGICIDES OF SIX CULTIVARS OF WINTER OILSEED RAPE IN 1990/1991

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Summary

Grain yields were greater in plots of double-low winter oilseed rape sprayed with fungicides in autumn, spring and summer than in unsprayed plots but the size of the yield response differed between cultivars. Glucosinolate concentration in seed was generally smaller in sprayed than in unsprayed plots. The incidence of the two most common pathogens on leaves in May, *Pyrenopeziza brassicae* (light leaf spot) and *Phoma lingam* (cause of stem canker, teleomorph *Leptosphaeria maculans*) was decreased by spray treatments, but the incidence of *Peronospora parasitica* (downy mildew) was increased. *P. brassicae* and *P. lingam* were the principal pathogens on stems in June and *Alternaria brassicae* (dark pod spot) and *P. brassicae* were the principal pathogens on pods in July. The incidence of these pathogens on stems and pods was decreased by spray treatments.

1. Introduction

There has been concern that the replacement of single-low (low erucic acid) cultivars of winter oilseed rape by double-low (low erucic acid, low glucosinolate) cultivars may result in an increase in the incidence and severity of diseases, because glucosinolates can decrease growth of oilseed rape pathogens *in vitro* (Doughty *et al.*, 1991). However, in experiments at Rothamsted, double-low cultivars were not more or less susceptible to diseases than single-low cultivars, although fungicide treatments increased yields of double-low cultivars more than those of single-low cultivars (Rawlinson *et al.*, 1989; Rawlinson & Williams, 1991). Furthermore, ADAS national surveys of oilseed rape diseases in England and Wales from 1986 to 1991 provided no evidence that the change from single-low to double-low cultivars had increased the severity of diseases (Fitt & Hardwick, 1992). However, many of the crops sampled had been sprayed with fungicides and there were large differences in disease incidence associated with differences in weather between seasons. This paper presents the UK results from the first year of an IOBC experiment using fungicide treatments to investigate the effects of diseases on growth and yield of several double-low cultivars of winter oilseed rape in France, Germany and the UK.

2. Materials and Methods

Six cultivars of winter oilseed rape were grown at Rothamsted: Capricorn, Cobra, Envol, Falcon, Libravo and Samourai. The experiment consisted of four blocks, each with two replicates of each cultivar, one with and one without fungicide treatment. Fungicide-treated plots received autumn and spring spray applications of prochloraz + carbendazim (Sportak Alpha) at 1.851 in 200 l/ha (applied at rosette and green bud

growth stages respectively) and a post flowering spray of iprodione (Rovral Flo) at 0.5 kg in 200 l/ha. Plots from two blocks were sampled, the others being for yield only. Plots were sown on 4 September 1990 at a rate of 120 seeds/m^2; desiccated on 7 August 1991 and combine harvested on 13 August 1991.

Destructive samples for disease assessment were taken on five occasions between November and July, with two more in-field assessments, on terminal racemes only, prior to harvest, and one post-harvest assessment on the stubble. Before stem extension, samples consisted of 10 plants per plot, taken diagonally across the plot. After that five plants were taken from each side, at least 2 rows into the plot. Plant samples were kept in polythene bags at a temperature of 4°C for 7 to 10 days before disease assessment. Disease incidence on leaves was recorded for all pathogens and for light leaf spot and Phoma leaf spot disease severity was recorded on a 0.1-3.0 scale (where 0.1 indicates a trace of the leaf area affected, 1.0 = trace-10%, 2.0 = 10-50% and 3.0 = >50%, Rawlinson, Muthyalu & Cayley, 1984). Later disease assessments were made on the stems and pods. Growth stages, numbers of leaves and pigeon damage were also recorded.

Results

3.1 Yield and seed glucosinolate concentration.

Grain yields were greater in plots sprayed with fungicides in autumn, winter and summer than in unsprayed plots for all six double-low winter oilseed rape cultivars (Table 1). However, the size of the yield response to fungicide was greatest for cv. Cobra and cv. Samourai, which yielded less than cvs Capricorn, Envol, Falcon and Libravo in the absence of fungicides. The yield response was smallest for cv. Falcon and cv. Libravo. The glucosinolate concentrations in seed from plots treated with fungicides were generally smaller than those in seed from untreated plots, except for cv. Falcon.

Table 1. Seed yield and seed glucosinolate contents of six double-low cultivars of winter oilseed rape in plots with or without fungicide treatments, 1990/1991.

Cultivar	Yield (t/ha)		Glucosinolates(μmol/g)[1]	
	Untreated	Fungicide treated	Untreated	Fungicide treated
Capricorn	2.5	3.0	15.1	14.9
Cobra	1.8	2.8	15.2	13.0
Envol	2.2	2.6	13.4	9.9
Falcon	2.6	2.8	10.9	11.8
Libravo	2.6	2.9	16.4	13.9
Samourai	1.8	2.8	12.6	11.9
SED (33 df)	0.21		-	

[1] Grain from replicates mixed before assessment so no SEDs calculated

3.2 Disease incidence.

The two most common pathogens on leaves were *Pyrenopeziza brassicae* (cause of light leaf spot, anomorph *Cylindrosporium concentricum*) and *Phoma lingam* (cause of stem canker, teleomorph *Leptosphaeria maculans*). On 7 May 1991 the % leaves infected by *P. brassicae* in untreated plots ranged from 86 to 47% and the % leaves infected by *P. lingam* from 37 to 19% (Table 2). The incidence of *P. brassicae* was greatest on cv. Capricorn whilst that of *P. lingam* was smallest and there were differences between cultivars in the incidence of both pathogens. Fungicide treatments greatly decreased the incidence of both pathogens on leaves but generally increased the incidence of *Peronospora parasitica* (downy mildew) from 1 - 7% to 3 - 23%. *Alternaria brassicae* (dark leaf spot) and *Botrytis cinerea* (grey mould) were also present on leaves at a low incidence on 7 May.

Table 2. Incidence of diseases on leaves (% infected) of six double-low cultivars of winter oilseed rape in plots with or without fungicide treatments, sampled on 7 May 1991 (GS 3,7).

		% leaves infected				
Cultivar	Fungicide	Alt.[1]	Bot.	Per.	Pho.	Pyr.
Capricorn	-	0	0	1.1	19.1	86.2
	+	1.4	2.8	12.0	13.8	35.0
Cobra	-	2.6	0.6	1.4	36.9	52.7
	+	0.5	0	3.2	20.8	16.1
Envol	-	0	0.8	0.7	34.9	47.1
	+	1.2	1.2	4.3	20.2	12.5
Falcon	-	0.6	1.1	3.3	27.9	65.7
	+	1.1	0.6	9.2	13.9	15.1
Libravo	-	3.3	2.9	6.5	22.1	68.3
	+	0	1.0	23.1	14.2	7.7
Samourai	-	6.3	1.4	1.4	29.1	80.1
	+	0	0	5.6	24.9	19.2
SED (11df)		2.6	10.4	7.50	6.06	15.2

[1] Alt., *Alternaria* spp.; Bot., *Botrytis cinerea*; Per., *Peronospora parasitica*; Pho., *Phoma lingam*; Pyr., *Pyrenopeziza brassicae*.

The two commonest pathogens on stems were *P. lingam* and *P. brassicae* and by the end of the season almost 100% of stems were infected by both pathogens for most cultivars (Table 3). However, on 13 June, differences between cultivars were apparent in untreated plots with a greater incidence of *P. lingam* on cvs Cobra and Envol than on cv. Capricorn and a greater incidence of *P. brassicae* on cvs Capricorn, Libravo and Samourai than on cvs Cobra or Falcon. Spray treatments consistently decreased the incidence of diseases on stems and the severity of diseases on stems was generally low in all plots. A little stem rot (*Sclerotinia sclerotiorum*) was also observed.

Table 3. Incidence of diseases on stems (% infected) of six double-low cultivars of winter oilseed rape in plots with or without fungicide treatments, sampled on 13 June 1991 (GS 6,1).

Cultivar	% stems infected			
	Phoma		*Pyrenopeziza*	
	Untreated	Fungicide treated	Untreated	Fungicide treated
Capricorn	15	15	100	70
Cobra	45	25	50	20
Envol	42	25	89	35
Falcon	35	15	50	5
Libravo	25	10	100	35
Samourai	25	55	95	80
SED (11 df)	12.0		15.5	

Alternaria brassicae (dark pod spot) and *P. brassicae* were the commonest pathogens on pods with up to 90% of plants with symptoms on some pods on 5 July (Table 4). *B. cinerea* was also present on pods at a low incidence. Spray treatments generally decreased the proportion of plants with pod infections but the severity of such infections was generally low in all plots. Pigeon damage was severe with up to 100% plants and up to 60% of leaves affected on most plots by the middle of March. The application of fungicide may have restricted further damage on treated plots, but damage on most untreated plots continued for some time.

Table 4. Proportion of plants (% infected) with diseases on pods of six double-low cultivars of winter oilseed rape in plots with or without fungicide treatments, sampled on 5 July 1991 (GS 6,3)

Cultivar	% plants with infected pods			
	Alternaria		*Pyrenopeziza*	
	Untreated	Fungicide treated	Untreated	Fungicide treated
Capricorn	85	25	80	75
Cobra	55	20	60	30
Envol	60	25	40	15
Falcon	70	10	5	35
Libravo	70	20	80	25
Samourai	73	20	89	35
SED (11 df)	26.1		14.3	

4. Discussion

In these experiments it was not possible to relate the differences in yield response to fungicides between cultivars to differences in disease severity, since the severity of diseases was generally slight. The yield responses were greatest for cvs Samourai and Cobra and least for cv. Libravo. Whilst cvs Samourai and Cobra are classified as more susceptible to stem canker and light leaf spot than cv. Libravo in the Natural Institute of Agricultural Botany recommended list (Anon., 1991), such differences were not clearly apparent in this experiment. Some of the response to fungicides in all plots may have been attributable to the decrease in pigeon damage but this could not account for the differences between cultivars. Whilst it is possible that some of the cultivars were more tolerant to the diseases than others, as was suggested to explain differences in fungicide response between single-low and double-low cultivars, it is also possible that some of the effects of fungicides were not associated with control of pathogens (Rawlinson *et al.*, 1989).

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EFFECTS OF FUNGICIDE TREATMENTS IN DIFFERENT VARIETIES OF WINTER RAPE

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Summary

In a field trial with different fungicide treatments and different varieties of winter rape plant diseases were scored and yields were measured. The most important disease was stem canker (Phoma lingam). Leaf disease assessments showed no differences between the varieties except the most susceptible one, which showed a higher degree of plants with leaf symptoms. Application of fungicides in autumn and spring or spring reduced leaf area affected. The scoring of the root neck disease in July showed differences between the varieties. There was no correlation between leaf infection and root neck disease. Fungicide treatment did not reduce of root neck disease in moderately susceptible varieties but did reduce canker in highly susceptible varieties. Fungicide treatment increased yields, in highly susceptible cultivars more than in those with lower susceptibility. Application of fungicides was not profitable except on the most susceptible variety with spring treatment. On all other cultivars, fungicide application was not cost effective.

1. Introduction

Stem canker (Phoma lingam (Tode ex Fr.) Desm., teleomorph: Leptosphaeria maculans (Desm.) Ces. et de Not.) is one of the most important diseases in winter rape in Germany. In regions with a high intensity of oilseed rape production like Schleswig-Holstein 75 % of the rape area is treated with fungicides because of P. lingam (Krostitz, 1991). Results of fungicide treatments on P. lingam are variable, some reports show control (Schramm, 1989, Paul et al, 1991), others showed no effect (Ahlers, 1988, Ahlers, 1990). Differing reports of the effects on yields have also been obtained: small effects on yield were reported by Ahlers (1990) but yield increases were observed by Hornig (1988) and Schramm (1989). Reasons for the variation of the results may due to differences in disease severity, climatic conditions or susceptibility of the cultivars used.

The aim of this study was to establish the effects of different fungicide programmes on stem canker and yield in a range of cultivars with differing disease susceptibility.

2. Material and Methods

The site of the field trial was Friedrichsthal, Schleswig-Holstein. It was part of the IOBC joint experiment with INRA, France, Rothamsted, United Kingdom and University of Paderborn, Germany. Sowing date was the 25 August 1990. Cultivars with

different susceptibility were used: Lirajet (2), Liberator (3), Falcon (4), Envol, Ceres (5) and Samourai (Classification of susceptibility against stem canker after "Beschreibende Liste des Bundessortenamtes"; 1 = not susceptible, 9 = extremely susceptible).

Fungicide treatments were:

1. untreated
2. spring treatment (14.04.91)
3. autumn and spring treatment (01.11.90, 14.04.91)
4. autumn, spring and flowering treatment (01.11.90, 14.04.91, 19.05.91)

For autumn and spring treatment Sportak (prochloraz, 1,2 l/ha) was used, for flowering treatment Ronilan (vinclozolin, 1,5 l/ha). Seed rate was 3,5 kg/ha. Date of harvesting was 13.08.91. Plot size was 28 m² with harvested area 21,6 m². Four replications were used.

Disease assessment was made at different dates during the vegetation period. Scored were P. lingam, Cylindrosporium concentricum, Verticillium dahliae, Botrytis cinera and Sclerotinia sclerotiorum.

Assessed were the incidence and severness of leaf infection. Root neck disease was scored in the end of March (EC 31) and July (EC 85).

3. Results

Major disease was P. lingam. C. concentricum was also present with a higher degree of infection of about 30% plants with symptoms, but had no recognizable effect on yield.

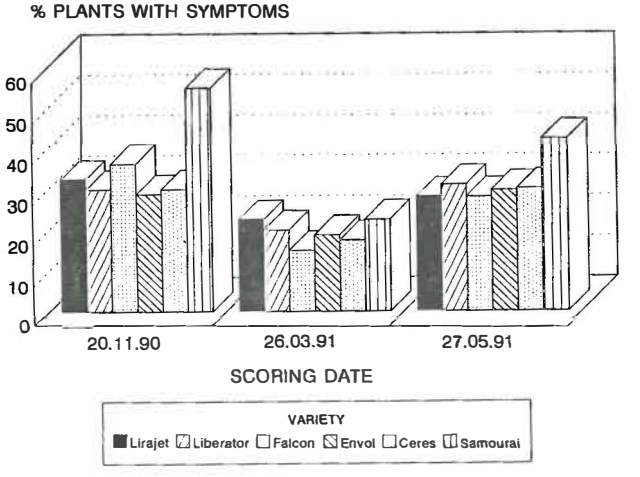


Fig. 1: Incidence of P. lingam in different varieties of winter rape

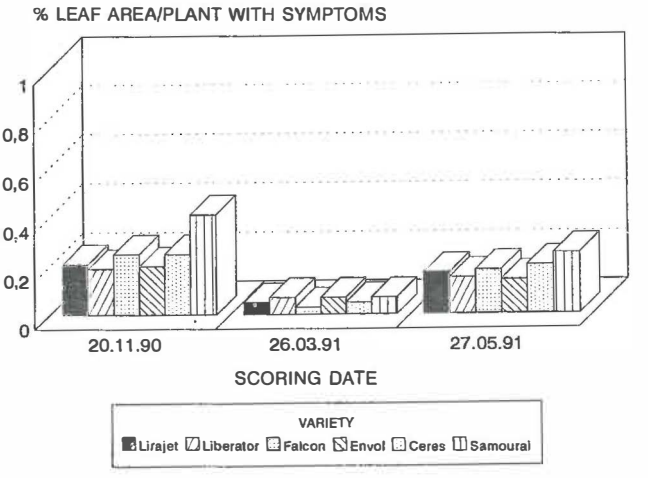


Fig. 2: Severity of leaf infection of P. lingam in different varieties of winter rape

Infestation of P. lingam on the leaves showed no significant difference in incidence and severity (Fig. 1 & 2) between the varieties Lirajet, Liberator, Falcon, Envol and Ceres at the scoring dates 20.11.90, 26.03.91 and 27.05.91. Significantly higher levels of infection were found in Samourai which had 62% plants affected on 20.11.90 whilst Lirajet had 28% plants with symptoms. Scoring of the root neck disease at 26.03.91 showed only small differences between cultivars (Fig. 3).

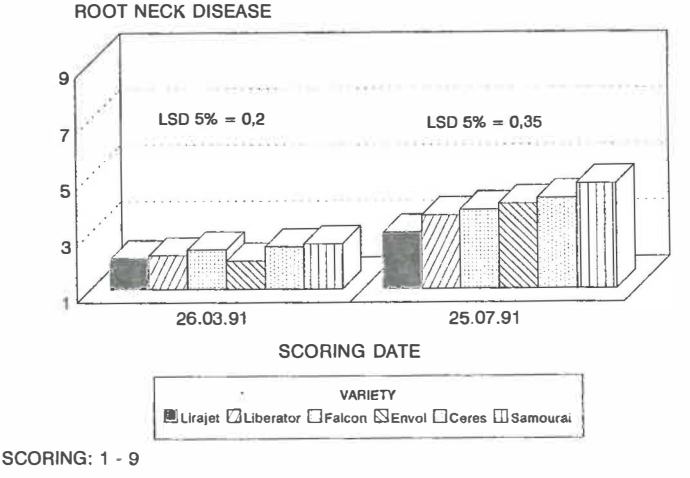


Fig. 3: Severity of root neck disease in different varieties of winter rape

The incidence of root neck disease increased until 25.07.91, than there was a significant difference between the varieties. Lirajet had the lowest incidence of root neck disease (mean severity 3.0) and Samourai was the worst affected with a mean severity of 4.7 (Scoring after Krüger, 1982). The differences in susceptibility between the cultivars correspond with the official classification. No correlation could be found between the leaf infection and root neck disease in July. For example there was a similar or lower degree of leaf symptoms estimated in Ceres and Lirajet (Fig. 1 & 2). The difference between Ceres (4.2) and Lirajet (3.0) was also significant (Fig. 3).

Fungicide treatments reduced leaf infection. The effects of autumn application were still apperent in early spring (26.03.91, Fig. 4). On average the autumn application reduced the incidence of plants with symptoms from 19.4% to 12.5%. All cultivars showed a decrease in plants with symptoms, the most susceptible cultivar Samourai showed the greatest reduction from 22.5% to 11.3%.

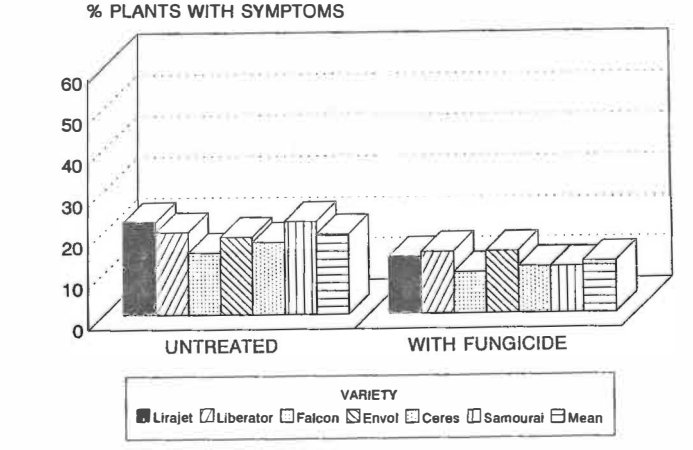


Fig. 4: Influence of fungicide application in autumn on incidence of P. lingam in different varieties of winter rape

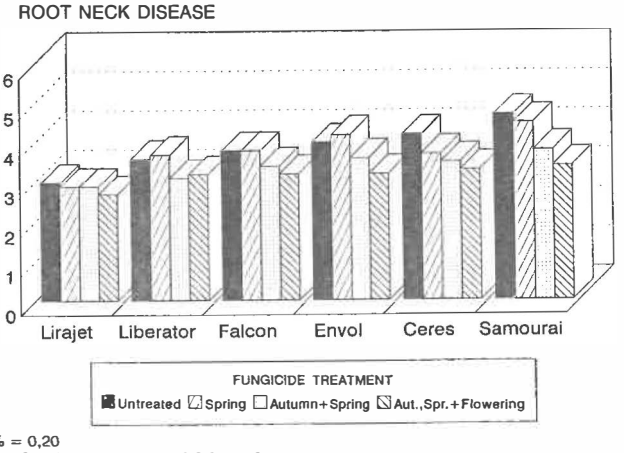
The assessment in May also figured out an effect of fungicide application (Table 1). Spring, autumn + spring and autumn + spring + flowering treatment reduced the frequency of plants with symptoms from 31.5% in "untreated" to 23.7% respectively 20.5% or 20.7%. There were no significant differences between different fungicide treatments. Reductions in the incidence of leaf symptoms differed between cultivars, the greatest effect was noted in Samourai.

Table 1. Frequency of plants with symptoms of P. lingam in winter rape with different fungicide intensity; Friedrichsthal 1990/91, date 27.05.1991

Variety	**% Plants with symptoms**			
	Fungicide treatment			
	Untreated	Spring	Autumn + spring	Autumn + spring + flowering
Lirajet	28.0	23.0	20.4	21.8
Liberator	31.0	20.2	19.8	18.8
Falcon	28.0	22.3	18.6	20.1
Envol	29.6	22.2	19.4	18.7
Ceres	30.0	24.8	21.8	20.8
Samourai	42.3	27.7	23.0	24.0
Mean	31.5	23.7	20.5	20.7

LSD = 6.9 %

The effects of fungicide application on the severity of root neck disease differed between the cultivars and the intensity of the treatment (Fig. 5).



LSD 5% = 0,20
SCORING DATE 25.07.91; SCORING 1 - 9

Fig. 5: Influence of fungicide treatments on stem canker in different varieties of winter rape

Smaller effects were recorded in moderately resistant cultivars than in the susceptible ones. Reductions in Lirajet for example was from 3.0 in the untreated to 2.7 in the variant with the highest intensity of fungicide application. In Samourai the reduction was from 4.7 to 3.4. The effect of spring treatment alone was in the most varieties small or there was no influence. Autumn and spring treatments led to clear reductions in the severity of root neck disease except in Lirajet. There was a further decrease of canker severity by the flowering application except in Liberator.

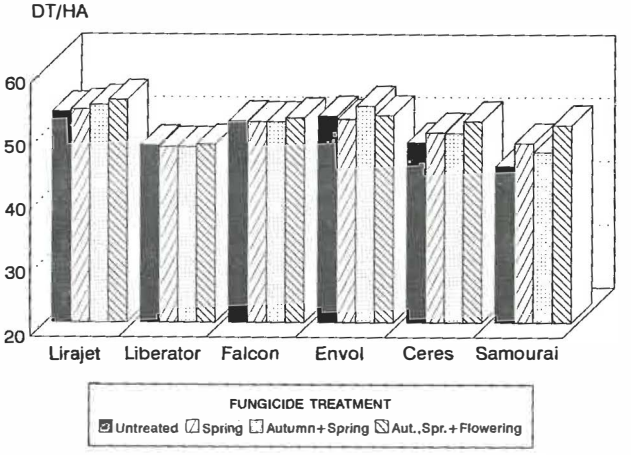
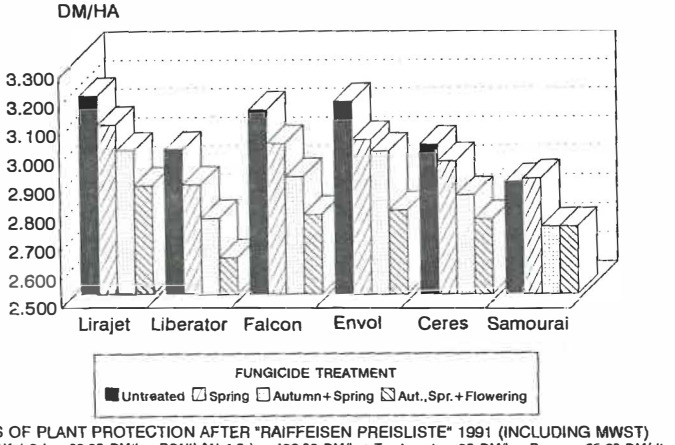


Fig. 6: Effect of fungicide treatment on yield in different varieties of winter rape

The susceptibility of the cultivar influenced yield (Fig. 6). No effect was noticed on Lirajet, Liberator, Falcon and Envol whereas in Ceres there was an increase in yield from 48.4 dt/ha in the untreated to 51.8 dt/ha in the variant with three fungicide applications. Samourai showed a stronger yield response to fungicide treatment in autumn and spring and flowering, giving a response of 6.5 dt/ha over untreated yield of 44.7 dt/ha.



COSTS OF PLANT PROTECTION AFTER "RAIFFEISEN PREISLISTE" 1991 (INCLUDING MWST)
SPORTAK 1,2 l = 89,95 DM/ha; RONILAN 1,5 l = 126,03 DM/ha; Treatment = 25 DM/ha; Rape = 35,60 DM/dt
Subsidy/ha = 1293 DM/ha

Fig. 7: Influence of fungicide treatment on benefits in different varieties of winter rape

Considering the conditions of the new market regulation for oilseed crops, the profits decreased through fungicide treatment in all cultivars except Samourai (Fig. 7). This reduction increased with the intensity of fungicide use. In Lirajet for example the decrease was more than 300 DM/ha with autumn and spring and flowering application. In Samourai, spring application led to a small profit, the other treatments reduced net benefits by about 150 DM/ha.

4. Discussion

The results indicate that it is not possible to differentiate between the susceptibility of cultivars by leaf symptoms. This confirms results of Renard & Brun (1979), Wittern (1984), Schramm (1989) and Paul et al (1991). After results of Brunin (1970) and Brunin & Lacoste (1970) it could be assumed that the tolerance of cultivars to P. lingam depends on the ability of the fungus to penetrate and to expand in the stem of rape. This differs between cultivars and explains why there is no correlation between the incidence or the severity of plants with symptoms and the root neck disease caused by P. lingam in different varieties.

Differences in the susceptibility of cultivars to stem canker are most apparent just before harvesting rape at EC 85 as shown by Krüger (1982) and Wittern (1984). Results of the field trial confirm the classification of the Bundessortenamt (1991).

Fungicide treatments influenced the development of P. lingam. The incidence and severity of plants with symptoms were reduced by autumn + spring applications. Schramm (1989) and Paul et al (1991) showed that fungicide treatments reduced root neck disease. This was also confirmed in this field trial. The reduction of root neck disease by autumn application showed the importance of autumn infection of P. lingam as well as the possibility of controlling severe stem canker on highly susceptible cultivars.

The limited effect of fungicide treatments on root neck disease in moderately resistant varieties corresponds with the results of Paul et al (1991). This supports the view that there is less need for fungicide treatments in varieties with moderate resistance.

The reduction of stem canker by flowering application supports results of Steinbach (1990), who also showed that late infections of P. lingam can increase root neck disease and decrease the yield.

The field trial was carried out under the conditions of medium infestation of P. lingam. The results of the yield assessment indicate that then there is no requirement to use fungicides against stem canker in moderately resistant cultivars. Highly susceptible cultivars showed a stronger increase of yields by fungicide treatments, but the calculation of the profits of fungicide application under the conditions of the new market regulation shows that even treatments on highly susceptible varieties may be not cost effective.

Acknowledgements

Many thanks to Mr. J. Krostitz and the staff of the Amt für Land- und Wasserwirtschaft, Lübeck who assisted in the field trial.

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REACTION OF CULTIVARS AND EFFECT OF FUNGICIDES ON WINTER OILSEED RAPE DISEASES IN 1990/91

First results from Germany, site Soest/Westfalen in 1990/91

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Summary

This is a report on the first results of a Europeanjoint experiment to optimize the cultivation of oilseed rape in Germany (site Soest/Westfalen; Germany). Europe´s most important rape cultivars at present were consideredwith regard to disease susceptibility and their yield response to fungicide treatments.

Five disease scorings were carried out in 1990/91 in different growth stages (EC 22-24, 33-39, 62-64, 75-79, 81-85) on the double low cultivars: Ceres, Lictor, Liberator, Falcon, Envol, Libravo, Darmor, Samourai, Capricorn, and Wotan.

The incidence of the pathogens *Cylindrosporium concentricum*, *Phoma lingam*, *Botrytis cinerea*, and *Sclerotinia sclerotiorum* were considered in each case. A correlation between leaf attack of *Phoma lingam* in autumn or spring, the infection of the root neck by the pathogen in spring and later in the growing period, and its effect on the yield could not be found.

The cultivars differed in suscepibility to the individual pathogens and varied in their reaction to the fungicide treatments in autumn, spring, and flowering. The economically best results were obtained with healthy cultivars like Libravo and Liberator (no fungicide treatment, ''extensive'') and the highest with susceptible cultivars like Ceres, Falcon, Samourai and Lictor after fungicide treatment.

1. Introduction

When looking at the yield development of winter oilseedrape since 1960 it is obvious that the yield increase is relatively low in comparison to competing commercial crops. (Pahl,H. & Steinhauser,H., 1991).

Considering the changing agricultural policy in the EC it is

essential to optimize production in order to ensure an economically interesting rape cultivation in future. That means among other things to reduce the pesticide application to a minimum and if possible to do without.

While approximate values exist or are worked out for weed- and insect pest control respectively and are used in practical farming for the first time, there are almost no helpful guidelines for optimizing the application of fungicides up to now. The profitability of this treatment is frequently made doubtful.

Referring to the application of fungicides in winter oilseed rape in Germany, it is not yet clear what influence the application time has on the development of infection of different diseases and the yield. There are results from the intensive rape cultivated areas in Schleswig - Holstein, that due to several fungicide treatments production losses could be avoided. Furthermore clear effects on the *Phoma* and *Sclerotinia* infection could be reached by extended applications of fungicides like autumn and early spring applications. However, these results hane not yet been verified (HORNIG,H.,1990). Further on SCHRAMM & HOFFMANN (1988) observed in their trial a high correlation between latent autumn infection of *Phoma* and a yield-relevant infection severity during the next year until harvest. They concluded that an application of fungicides in autumn is economically justifiable.

Three years´trials in North Rhein-Westphalia showed on the other hand, that most fungicide treatments were not economical when the *Phoma* root neck and stem-canker incidence was of a moderate intensity of infection (PAUL et al., 1991).

Within the scope of an international working group in which Germany, France, England, Denmark, Ireland, and Switzerland participated, a several years´trial program was built up. Its goal was to set up a comparison of the optimal application of fungicides in winter oilseed rape on a European base with regard to the different site conditions.

In the growing season 1990/91 the joint experiment started in which Great Britain participated. in the first instance new double low cultivars which play an important role in the EC were studied with regard to their resistance to different pathogens and their response to fungicide treatments as well as yield. The goal was to offer more information on a profitable cropping of healthy cultivars together with a minimum of pest control to the interested farmer to keep an economic rape cultivation in the Ec under the future circumstances.

2. Material and Methods

The winter rape field experiment was set up in a randomized block design with small plots (30 m²) and four replications.

Table 2: IOBC Joint Oilseed Rape Experiment 1990/91, factors, treatments, products, amount of application.

Factor	Product	a.i. g/ha	Amount appl. l/ha	Growth stage
F0	no treatment			
F1	Versian (260 g/l Iprodion)	780	3	EC 62-64 3. spray
F2	Sportak alpha (300g/l Prochloraz 80 g/l Carbendazim)	450 Prochloraz	1,5	EC 39 1. spray
	+ Custos (450g/l Carbendazim)	170 Carbendazim	0,11	
	Verisan (260g/l Iprodion)	520	2	EC 62-64 3. spray
F3	Folicur (250g/l Tebuconazol)	187,5	0,75	EC 39 1. spray
	Sportak alpha (300g/l Prochloraz 80g/l Carbendazim)	225 Prochloraz	0,75	EC 51 2. spray
	+ Custos (450g/l Carbendazim)	85 Carbendazim	0,055	
	Versian (260g/l Iprodion)	390	1,05	EC 62-64 3. spray

Participants: Biologische Bundesanstalt Braunschweig,/ V. Garbe, FRG.
Rothamsted Experimental Station/ B. Fitt, UK.
Universität-GH-Paderborn/ V.H. Paul, FRG.

60 seeds/m² of the following cultivars were sowed:
Wotan Libravo Liberator Falcon Ceres
Capricorn Samourai Darmor Envol Lictor

Each plot was divided into three subplots. Two of the latter being used for sampling and one as harvesting plot.
In spring, at the beginning of the vegetation period, nitrogen was applied twice in the form of AHL. Altogether 180 kg N/ha.
Table 2 shows the application of fungicides at EC 39,51 and 62-64.

The assessment of the diseases was carried out by single scoring at EC 22-24, 33-37, 62-64, 75-79 and 81-83. 10 plants per plot were assessed.

Plant samples were stored at 5-8°C for 5 days. the last scoring before harvest was carried out in three cv.s (Libravo, Ceres, Samourai) in the course of which only the infection with *Phoma* was determined.

In addition to the disease incidence the leaf attack was evaluated according to KRÜGER (1991) and the stem attack according to a scale from NEWMAN (1984).

The results were calculated at the Rothampsted Experimental Station in Great Britain.

3. Results

During the vegetation period 1990/91 five disease scorings were carried out. In each case the incidence of the individual diseases was registered.

First scoring (EC 22-24)

During the scoring in November 1990 at EC 22-24 the *Phoma* root and stalk infection as well as *Cylindrosporium concentricum* was assessed (Table 3).

The infection rate of *P. lingam* in the different cultivars varied from 28.8% to 53.8% infested plants. A higher incidence was found in the cv. Wotan, Libravo, Falcon, Ceres and Lector, a slighter incidence on the cv. Liberator, Capricorn, Darmor, Envol. The cv. Samourai showed a medium incidence.

The incidence of *C. concentricum* in the different cultivars ranged from 23.1% to 43.1%. Epecially the cv. Wotan and Samourai. In all other cultivars an incidence of 30% was assessed.

The variations in cultivars with regard to above mentioned pathogens could be analysed statistically (Table 3).

Second scoring (EC 33-39)

The next scoring took place after winter (April 1990) at EC 33-39. Infection with *P. lingam*, *C. concentricum* und *B. cinerea* were

Table 3: Incidence of *Phoma lingam*, *Cylindrosporium concentricum* and *Psylliodes chrysocephala* on 10 oilseed rape cultivars grown at the site Neuengeseke/Westfalen (Germany) without fungicides in 1990/91 (Disease assessment in EC 22-24)

Cultivar	Incidence (%) of infected plants		
	P. lingam	C. concentricum	P. chrysocephala
Wotan	48,8	23,1	13,1
Libravo	53,1	37,5	11,9
Liberator	33,1	27,5	8,8
Falcon	50	32,5	15
Ceres	50	29,4	10
Cpricorn	28,8	27,5	8,1
Samourai	44,4	24,4	6,9
Darmor	35,6	43,1	13,1
Envol	38	29,4	10
Lictor	53,8	28,8	3,8
LSD 5%	4,3	3,5	2,3

Table 4: Incidence of *Phoma lingam*, *Cylindrosporium concentricum* and *Botrytis cinerea* on 10 oilseed rape cultivars grown at the site Neuengeseke/Westfalen (Germany) without fungicides in 1990/91 (Disease assessment in EC 33-39)

Cultivar	Incidence (%) of infected plants		
	P. lingam	C. concentricum	B. cinerea
Wotan	36,3	56,9	6,9
Libravo	36,3	61,3	6,9
Liberator	32,7	54,3	6,7
Falcon	33,1	63,1	5,6
Ceres	33,1	57,5	7,5
Cpricorn	46,9	73,1	8,8
Samourai	41,9	60,6	6,9
Darmor	43,1	67,5	11,9
Envol	40	51,9	4,4
Lictor	33,8	59,4	15,4
LSD 5%	4	4,6	2,1

assessed (Table 4).

The *Phoma* root infection ranged from 32.7% to 46.9% plants and thus showed a slight increase in comparison to the values obtained in autumn. The cv. Capricorn showed an especially severe incidence. A slighter incidence was assessed in the cv. Darmor, Samourai and Envol. In other cultivars an incidence value from 32.7% to 36.3% was assessed. When comparing these results with the results obtained before winter there is no correspondance to the slightly infected cultivars in autumn and spring.

In the spring scoring the infection with *Cylindrosporium* varied from 51.9% to 73.1%, thus increased slightly. An especially severe incidence could be assessed in the cv. Capricorn and Darmor. The cv. Wotan, Liberator Ceres and Envol showed a slighter infection. Moderate infection values could be assessed in the cv. Libravo, Falcon, Samourai and Lictor. As well as with *P.lingam* there was no correspondance to the infection values in autumn and spring.

A infection with grey mould of up to 15.4% could also be scored. In most cultivars there was a range of incidence from 4.4% to 8.8%. The higher infection in the cv. Darmor (11.9%) and Lector (14.5%) was striking (Table 4).

Third scoring (EC 62-64)

The scoring during flowering (EC62-64) in May 1991 assessed the infection with *C.concentricum*, *P.lingam* and *B.cinerea.* At this stage fungicides had been applied at EC 35 and 51 (Table .1, Table 5).

Just a slight infection with *P.lingam* could be found and run up to 3.3% at the most in the untreated control (Envol and Lector).

The cv. Falcon, Ceres, Darmor and Lictor showed low infection values of 1.7%. Libravo, Liberato, Capricorn and Samourai were not infected at all.

A comparison to the infection values of the spring scoring, the cv. Libravo, Falcon, Samourai and Envol showed a statistically significant decrease in infection when compared to the factor with only one fungicidal treatment.

In comparispon to the untreated control the cv. Liberator and Lictor showed no significant reduction of infection. In the case of Lictor there was a significant increase in infection of 100%.

In the untreated control incidence of *B. cinerea* was 25% infected plants at the most. This value was reduced by various fungicide applications up to no infection.The high infection of the cv. Darmor (25%) as well as the slight infection of the cv. Liberator (3.3%) was striking. A correlation to the results of the spring scoring was found. Due to a very low incidence a statistical analysis of these results was not possible (Table 5).

Fourth Scoring (EC 75-79)

At EC 75-79 in June 1991 infections with *P. lingam*, *C. concentricum* and *S. sclerotiorum* were scored (Table 6a, 6b, 6c). At

Table 5: Incidence of *Phoma lingam, Cylindrosporium concentricum*, and *Botrytis cinerea* in dependence on different fungicide treatments on 10 oilseed rape cultivars grown at the site Neuengeseke/Westfalen (Germany) during 1990/91 (disease assessment EC 62-64).

Cultivar	Incidence (%) of infected plants								
	Untreated control			Fungicide treaments					
				1x in EC 39			1x in EC 39 and 1x in 51		
	P. lingam	C. concentricum	B. clnerea	P. lingam	C. concentricum	B. cinerea	P. lingam	C. concentricum	B. cinerea
Wotan	3,3	38,3	10	0	33,3	0	0	27,6	3,3
Libravo	0	21,7	6,7	0	20	0	0	3,3	10
Liberator	0	20	3,3	3,3	10	6,7	0	13,3	3,3
Falcon	1,7	53,3	10	0	30	3,3	0	20	0
Ceres	1,7	56,7	11,7	10	23,3	6,7	0	23,3	0
Capricorn	0	56,7	13,3	0	10	0	0	30	6,7
Samourai	0	55	25	0	50	0	0	23,3	6,7
Darmor	1,7	41,7	18,3	0	13,3	0	3,3	13,3	0
Envol	3,3	23,3	15	3,3	30	3,3	0	10	3,3
Lictor	1,7	28,3	8,3	3,3	20	6,7	3,3	40	0
LSD 5%		9			9			9	

this time the infection with *P. lingam* had again slightly increased and showed a maximum value of 7.5% infected plants in the cv.s Falcon and Envol. The cv. Libravo showed no infection. In all other cultivars an incidence of 2.5% or 5% could be assessed.
Looking at the factor ''fungicide application in full flowering'' the cv. Wotan, Damor, Envol and Lictor showed no infection. On the other hand the cv. Samourai (15%) and Falcon (10%) showed considerably higher infection rates, in the case of Samourai these were significant. The cv. Libravo also showed a significant increase in infection, when looking at the above mentioned factor.

When compared to the untreated control, the factor with two fungicide applications (EC 39 and 64) showed no significant changes in infection with *P. lingam*. In the case of the factor with fungicidal treatment at EC 39, 51 and 64 there could only be assessed a significant reduction in infections for the cv. Ceres and Lictor. Libravo, Capricorn and Darmor however, showed a significantly higher disease incidence in comparison to the control.

The infection with *C. concentricum* was reduced strongly in this scoring and ranged from 7.5% to 32.5%. The infection in the cv. Capricorn was strikingly high, and very slight in the case of cv. Falcon and Envol. These observations show no correlation with the results of the preceeding scorings.
On the other hand the factor ''treatment in full flowering'' showed a higher infection. Only the cv. Liberator, Capricorn and Envol responded positively to the fungicide applications and a significant reduction in infection could be assessed. Apart from the cv. Lictor, which had no variation in the infection rate, all other cultivars showed no significant increase in infection. The factor with two fungicides applications in EC 39 and 64 however revealed drastic reductions in infection. In comparison to the untreated control, significantly lower incidence rates could be assessed for all other cultivars, except for Envol. In the cv. Wotan, Liberator, Falcon, Ceres and Lictor no infection could be observed. An incidence of 2.5% was assessed in the cv. Libravo and Darmor. The latter do not vary significantly from the cultivars with no incidence.

The experimental factor with three fungicide applications showed an even higher reduction in infection than the one with two fungicide treatments. An only slight infection could be assessed in the cv. Capricorn, Samourai and Envol, whereby the infection in the cv. Envol did not vary significantly from the susceptible cultivars.

In the scoring in the untreated control the *Sclerotinia* infection reaches a maximum rate of 10% infected plants in the case of the cv. Capricorn. Falcon showed an incidence of 7.5%. All other cultivars showed no infections or reached incidence rates of 2.5%. Throughout all treatments the infection could not be prevented. The results have not been analysed statistically as the infection level was very low (Table. 6a, 6b, 6c).

Table 6 a: Incidence of *Phoma lingam*, *Cylindrosporium concentricum*, and *Sclerotinia sclerotiorum* in dependence on different fungicide treatments on 10 oilseed rape cultivars grown at the site Neunegeseke/Westfalen (Germany) during 1990/91 (dieseas assessment EC 75-79).

Cultivar	Untreated control			Incidence (%) of infected plants Fungicide treaments 1x in EC 64		
	P. lingam	C. concentricum	S. sclerotiorum	P. lingam	C. concentricum	S. sclerotiorum
Wotan	2,5	12,5	0	0	17,5	0
Libravo	0	17,5	2,5	5	27,5	0
Liberator	5	17,5	2,5	5	10	0
Falcon	7,5	7,5	7,5	10	22,5	0
Ceres	5	17,5	2,5	2,5	25	0
Capricorn	2,5	32,5	10	2,5	37,5	0
Samourai	5	22,5	0	15	30	2,5
Darmor	2,5	15	0	0	32,5	0
Envol	7,5	7,5	2,5	0	20	0
Lictor	5	17,5	0	0	17,5	0
LSD 5%	3,5	4,5		3,5	4,5	

Table 6 b: Incidence of *Phoma lingam*, *Cylindrosporium concentricum*, and *Sclerotinia sclerotiorum* in dependence on different fungicide treatments on 10 oilseed rape cultivars grown at the site Neunegeseke/Westfalen (Germany) during 1990/91 (dieseas assessment EC 75-79).

Cultivar	Untreated control			Incidence (%) of infected plants Fungicide treaments 1x in EC 39 and 1x in 64		
	P. lingam	C. concentricum	S. sclerotiorum	P. lingam	C. concentricum	S. sclerotiorum
Wotan	2,5	12,5	0	2,5	0	0
Libravo	0	17,5	2,5	2,5	2,5	0
Liberator	5	17,5	2,5	5	0	0
Falcon	7,5	7,5	7,5	2,5	0	0
Ceres	5	17,5	2,5	2,5	0	0
Capricorn	2,5	32,5	10	0	7,5	0
Samourai	5	22,5	0	5	7,5	2,5
Darmor	2,5	15	0	2,5	2,5	0
Envol	7,5	7,5	2,5	0	7,5	0
Lictor	5	17,5	0	7,5	0	0
LSD 5%	3,5	4,5		3,5	4,5	

Table 6 c: Incidence of *Phoma lingam*, *Cylindrosporium concentricum*, and *Sclerotinia sclerotiorum* in dependence on different fungicide treatments on 10 oilseed rape cultivars grown at the site Neunegeseke/Westfalen (Germany) during 1990/91 (dieseas assessment EC 75-79).

Cultivar	Untreated control			Incidence (%) of infected plants Fungicide treaments 1x in EC 39 ,1x in EC 51 and in EC 64		
	P. lingam	C. concentricum	S. sclerotiorum	P. lingam	C. concentricum	S. sclerotiorum
Wotan	2,5	12,5	0	5	0	0
Libravo	0	17,5	2,5	7,5	0	0
Liberator	5	17,5	2,5	5	0	0
Falcon	7,5	7,5	7,5	7,5	0	0
Ceres	5	17,5	2,5	0	0	0
Capricorn	2,5	32,5	10	7,5	5	0
Samourai	5	22,5	0	2,5	7,5	0
Darmor	2,5	15	0	10	0	0
Envol	7,5	7,5	2,5	10	2,5	0
Lictor	5	17,5	0	0	0	0
LSD 5%	3,5	4,5		3,5	4,5	

Table 8: Seed yield response (t/ha, 91 % dry matter) to untreated and fungicide treated oilseed rape cultivars grown at the site Neuengeseke/Westfalen (Germany) during 1990/91.

Cultivar	Untreated control	Fungicide treatments			
		1x in EC 64	1x in EC 29 and 1x in EC 64	1x in EC 39 and 1x in EC 51 and 1x in EC 64	Mean
Wotan	3,67	3,69	3,99	4,06	3,86
Libravo	3,7	3,45	3,61	3,78	3,63
Liberator	3,51	3,32	3,82	3,74	3,6
Falcon	3,79	3,92	4,16	4,29	4,04
Ceres	3,68	3,84	4,2	4,06	3,95
Capricorn	3,54	3,97	4,08	4,34	3,98
Samourai	3,09	3,48	3,77	3,66	3,5
Darmor	3,64	3,79	4,15	4,1	3,92
Envol	3,6	3,72	4,18	3,9	3,85
Lictor	3,24	3,62	3,54	3,85	3,56
Mean	3,55	3,68	3,95	3,98	3,79

LSD 5% cultivar: 0.158
LSD 5% variation: 0.100
LSD 5% cultivar x variation: 0.136

Table 7: Incidence of Phoma lingam on 3 oilseed rape cultivars grown at the site Neuengeseke/Westfalen (Germany) with and without fungicide treatments during 1990/91 (disease assessment EC 81-83).

Cultivar	Untreated control	Incidence (%) of infected plants		
		Fungicide treatments		
		1x in EC 64	1x in EC 39 and 1x in EC 64	1x in EC 39 1x in EC 51 1x in EC 64
Libravo	36,7	26,3	50	36,7
Ceres	23,3	30	27	30,3
Samourai	53,3	60	43,3	53,3
LSD 5%	7,7			

Fifth Scoring (EC 81-85)

In the final scoring at EC 81-85 the *Phoma* infection in the cv. Libravo, Ceres and Samourai was assessed (Table 7).
The infection rates of the untreated control reached 23.3% infected plants in Ceres, 36.7% in Libravo and 53.3% in Samourai.

The cv. Ceres did not demonstrate any significant change in incidence.

The cv. Libravo, however, showed a significant reduction in infection due to the ''fungicide treatment in full flowering''. On the other hand a significant increase in diseases incidence could be observed at EC 39 and 64 due to the application of fungicides (Table 7).

Yields

The highest yield was obtained in the cv. Falcon with 37.9 dt/ha, lower yields with 30.9 and 32.4 dt/ha in the cv. Samourai and Lictor respectively. In all other cultivars 35-37 dt/ha could be obtained in the untreated control (Table 8).

In most cultivars a yield increase could be observed when the applications of fungicides had been increased.

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Session 4

Monitoring Pests - Biology of Insect Pests

MONITORING OF BRASSICA POD MIDGE (*Dasineura brassicae*)

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Abstract

In Denmark winter oilseed rape is a major crop, with brassica pod midge (*Dasineura brassicae*) as one of the most important pests. Treatments are, generally, too frequent and, therefore, the Research Centre for Plant Protection has initiated a project to study whether it is possible, on the basis of soil samples taken in autumn, to develop a reliable forecast on the occurrence of brassica pod midge the following year. Emergence traps and wind traps were also used in the investigation.

The results showed that at the low occurrences of brassica pod midge found in this study it is difficult, on the basis of soil samples taken in autumn in the rape field the preceding year, to establish a clear relationship with the occurrence in a nearby oilseed rape field the following year.

Furthermore, it is discussed whether it is possible, on the basis of infested pods the preceding year, to make a forecast which, with a reasonable degree of reliability, can predict the need for control.

1. Introduction

In 1991, the area grown with winter oilseed rape in Denmark was 200,000 ha and with spring oilseed rape 75,000 ha. The indications are, however, that with the new EC subsidy schemes the distribution will, in future, be 125,000 ha and 100,000 ha, respectively. The most serious pests are brassica pod midge (*Dasineura brassicae*), cabbage seed weevil (*Ceutorrhynchus assimilis*) and blossom beetle (*Meligethes aeneus*). On an average this area is treated 2-3 times against these pests, half of the treatments are against brassica pod midge alone. In Denmark, brassica pod midge produces 3 generations of which the two first have the greatest economic importance. Usually, the first generation emerges at the end of May, with variations depending on temperatures.

In recent years, brassica pod midge occurrences have decreased somewhat in Denmark, probably due to a reduction in the area grown with spring rape. Thus, since 1986 the area has diminished from 209,000 ha to 75,000 ha whereas the winter rape has increased from 17,000 ha to 200,000 ha in the same period. Since third generation of brassica pod midge propagates in spring rape, the decreasing population seems to be due to lack of propagation sites in spring rape. This is also a well-known phenomenon in Sweden where brassica pod midge is only causing minor problems in areas where winter and spring rape are not grown side by side (Nilsson, 1975).

The lower brassica pod midge occurrence has not resulted in a corresponding reduction in the control frequency. The reason for this is primarily that the pest is so small that it is not easily detected. Therefore, a routine treatment is often carried out at the emergence of the first generation.

It has been difficult for the advisory service to improve recommendations because there exist no satisfactory monitoring methods which can form the basis of reliable forecasts and warnings.

Therefore, in autumn 1990 we initiated a project at the Research Centre for Plant Protection to study whether, on the basis of soil samples taken in autumn and spring, it was possible to make reliable forecasts on the occurrence of brassica pod midge.

2. Materials and methods

The project contained three parts. Soil sampling to register brassica pod midge cocoons, emergence trap sampling to monitor migration from fields previously grown with rape and wind trap sampling to monitor migration into existing rape field.

2.1 Soil Samples

At 4 experimental stations (Rønhave, Jyndevad, Askov and Roskilde) soil samples were taken in November 1990 and examined for brassica pod midge. The samples were taken in fields where winter rape had been grown in 1990. In each field 40 samples were taken (Ø=5.5 cm) in the depth of 10 cm. The samples were put, separately, into plastic bags and kept at < 5°C until they were examined about 4 weeks later. Brassica pod midge cocoons were washed out by flotation.

In April 1990, new soil samples were taken from the same fields.

Furthermore, soil samples were taken from another 30 fields. The 40 samples taken in each field were pooled and a sub-sample of 1 kg was taken.

2.2 Emergence traps

Emergence traps were placed in the fields investigated to register the number of migrating midges and the time of migration of the first generation. An emergence trap consists of an inverted black plastic bucket (Ø=25 cm, height 25 cm). A small hole is made in the bottom of the bucket and covered by a transparent plastic jar. The adult brassica pod midges will seek light and enter this jar after hatching. At the 4 experimental stations 10 emergence traps were placed in each of the fields investigated. 2 traps were situated in the remaining fields. The emergence traps were put out at the end of May and removed about 4 weeks later. The traps were emptied once a week.

2.3 Wind traps

On the edge of winter rape fields lying max. 500 m from one of the fields from which soil samples were taken, a wind trap was placed for the registration of migrating brassica pod midges. A wind trap consists of a strong, funnel-shaped wire frame - largest diameter 30 cm, smallest diameter 1.5 cm. The frame is covered with nylon and a collecting jar containing water and antifreeze is mounted over the small opening.

One wind trap was placed in each field and 10 traps were placed at each of the research stations. The traps were situated on the edge of the field, height 1.5 m, so that they could turn freely with the wind. They were put out at a total of 46 localities at the beginning of June and subsequently emptied weekly over 3 weeks.

3. Results

3.1. Soil samples

Results from the 4 experimental stations show that mortality is very high (table 1). All localities were ploughed before sampling so this does not explain the differences in mortality between 'Jyndevad' and the remaining localities.

Table 1. Occurrence of Brassica Pod midge in soil samples - research stations

Locality	Brassica pod midge/m²		Mortality in %
	Autumn-90	Spring-91	
Rønhave	680 (±200)	0.0 (±0)	100
Jyndevad	2440 (±200	1600 (±160)	34
Askov	2240 (±320)	360 (±80)	84
Roskilde	1760 (±240)	160 (±40)	91

Results from the remaining 30 fields shows that only in very few fields were many brassica pod midges found (table 2).

Table 2. Occurrence of Brassica pod midge in soil samples (remaining fields)

Brassica pod midge/m²	Number of fields	% fields
0	17	56
1-500	8	27
501-1000	2	7
101-2000	2	7
> 2000	1	3

3.2 Emergence traps

Migrating brassica pod midges were registered only at one locality, i.e. the experimental station 'Askov', where, on 14 June 1991, a total of 4 brassica pod midges were caught, distributed on 3 emergence traps. It is surprising that in fields with more than 500 midges per m² no migrating individuals were found.

Emergence traps were also placed at another 16 localities where no soil samples were taken. Here migrating brassica pod midges were found at 2 localities, 15 midges on 6 June 1991 and 1 midge on 11 June 1991, respectively.

3.3 Wind traps

Brassica pod midge was caught at 10 localities. Total catches were 35 midges or an average of 3.5 per wind trap. There was no relationship between catches in wind traps and catches in soil samples from nearby localities. The majority of the brassica pod midges found migrated in the period 11 - 18 June, a few were registered already on 3 June. No infestations by brassica pod midge were found in any of the fields investigated.

4. Discussion

To be able to make forecasts on the spring population of brassica pod midge on the basis of soil samples taken in autumn, it is necessary also to know the mortality. In the soil samples examined in this project the average mortality was 77% which is in accordance with the mortality of 75% found in a similar investigation (Axelsen 1992). The variation is great between years, however, and the question is whether a mortality of this order is of general validity or only typical of a winter with relatively high temperatures.

In this investigation, the emergence traps used to catch migrating brassica pod midge did not seem to work well. Assuming that the distribution of the brassica pod midge is fairly even within the small area from which soil samples were taken, about 25 brassica pod midges/m^2 would, in theory, give one individual in the emergence trap. In this investigation it was not possible to register densities of more than 500 midges/m^2 in the traps. The reason may be that the distribution of brassica pod midge is more clumped than what is immediately believed, which means that the low densities found in this investigation will only give a small probability of catching migrating brassica pod midges in 2 emergence traps.

With regard to using wind traps to determine time of migration into the field we found that the effort did not compare with the result at the low population densities of brassica pod midge found in this study. The uncertainty as to whether the first brassica pod midges are caught is too great.

The above reflections suggest that it may be possible to make a reliable forecasting model based on registrations of infested pods in winter rape fields of the previous year and registrations of day degrees in the course of the winter to determine the mortality. A warning could then be sent out based on knowledge about the temperature sum necessary for brassica pod midge development. Fig. 1 is an illustration of such a model.

A number of factors are important for how the population development progresses. Some of these factors have known sizes or relationships whereas others have been only vaguely elucidated. If the prerequisites shown in Table 3 are applied it is possible to make calculations predicting that an attack in winter rape with 20% infested pods will give an attack the following year with 48% infested pods. Investigations (Williams & Free 1979) have shown that the removal of up to 60% of the pods and buds did not give any significant yield loss. On the basis of this and other compensation investigations it is possible to forecast the order of the attack. It will be of great value to the environment if a reasonably reliable negative forecast could be given.

Table 3. Prerequisites applied in forecasting model

Winter mortality	80%
Number of eggs / midge	20
Number of destroyed pods / midge	3
Predation of larvae / adults	25
Diapause after 1st generation	10%
Diapause after 2nd generation	70%
Diapause after 3rd generation	100%

Of course, there are many uncertain factors in such a sequence of calculation and future investigations must determine the value of the individual factors and the more specific relationships.

5. Acknowledgement

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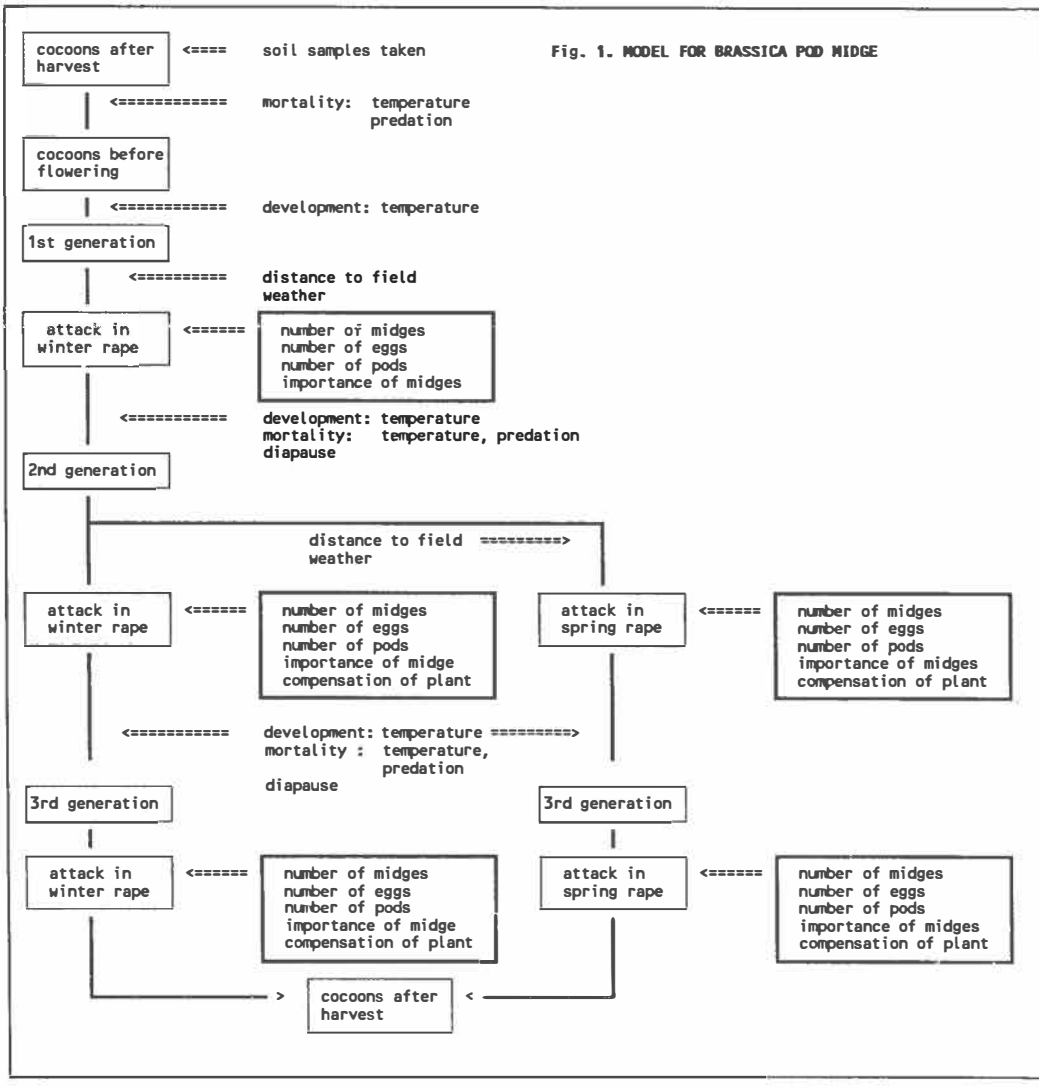

Fig. 1. MODEL FOR BRASSICA POD MIDGE

MONITORING OF PARASITOIDS OF THE CABBAGE SEED WEEVIL, CEUTORHYNCHUS ASSIMILIS DURING 1990 AND 1991 IN SWITZERLAND

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Abstract
In 1990 and 1991 ectoparastoids of the cabbage seed weevil, Ceutorhynchus assimilis Payk., were monitored in different regions of Switzerland. In 1990 the larval parasitism varied from 3-70% and in 1991 from 8-60%. Three species were found: Mesopolobus morys Wlk., Stenomalina muscarum L., and Trichomalus perfectus Wlk. The most abundant species was M morys.

1. Introduction

In connection with our trials to use turnip rape (Brassica rapa var. silvestris) as trap plants to control rape pests we began to monitor the parasitoids of rape pests. In 1989 we found ectoparasitoids of the cabbage seed weevil, Ceutorhynchus assimilis Payk. (Büchi & Roos-Humbel, 1991). At this time the species of the parasitoids found were unknown. In the literature there is a single hint in Günthart's publication (1949) about the parasitoids species of C. assimilis in Switzerland. Günthart (1949) mentioned two species: Trichomalus herbididus Walk. synonymous to Trichomalus fasciatus Thoms. and Xenocrepis pura Mayr. T. herbididus is synonymous to T. perfectus Wlk. and X. pura is probably synonymous to Mesopolobus morys Wlk. Laborius (1972) investigated from 1968 to 1970 the parasitoids of C. assimilis in nothern Germany and found in most cases the species Trichomalus perfectus. Therefore we believed that T. perfectus is also the most frequent species in Switzerland.

In 1990 and 1991 we monitored the rate of parasitism of C. assimilis larvae in different regions of Switzerland. Several adult parasitoids were determined by Dr. S. Vidal, Hamburg.

2. Methods

In 1990 we determined the rate of parasitism of C. assimilis larvae in the Rhine valley from Lake Constance to Chur (Büchi & Roos-Humbel, 1991). From several villages one to two rape fields were chosen and 200-300 infested pods were sampled. In the laboratory the pods were dissected and the larvae were monitored for parasitism.

In 1991 the rate of parasitism of C. assimilis larvae from different regions in Switzerland were monitored in the same way. In 1989 and 1991 we took out C. assimilis larvae together with its ectoparasitoid larvae and reared it to the adult stage. In 1989, 5 adult Pteromalids were sent to Dr. S. Vidal, Hamburg for determination and in 1991 a larger sample of 55 adult parasitoids from different regions were determined.

3. Results

a) Rates of parasitism

In 1990 the rate of parasitism was only monitored in the Rhine valley (Table 1).

Table 1: Rate of parasitism of C. assimilis larvae in the Rhine valley in 1990 (Büchi and Roos-Humbel, 1991)

Site	Date of sampling	Number of larvae of C. assimilis	Number of larvae of Pteromalidae	Rate of parasitism in %
Widnau	5.6.90	34	9	26.5
Kriessern	5.6.90	47	7	14.9
Altstätten	5.6.90	70	12	17.1
Saxerriet	5.6.90	73	19	26.0
Schaan	6.6.90	99	3	3.0
Balzers	6.6.90	68	5	7.3
Trübbach	6.6.90	31	18	61.3
Vilterser Au	11.6.90	82	33	40.2
Landquart	11.6.90	70	49	70.0
Zizers	11.6.90	62	29	46.8
Trimmis	13.6.90	60	40	66.7
Domat/Ems	13.6.90	33	19	57.6

In 1991 the monitoring of parasitism was extended to different regions of Switzerland. The results are listed in Table 2.

Table 2: Rate of parsitism of C. assimilis larvae in different regions in Switzerland in 1991

Site	Date of sampling	Number of larvae of C. assimilis	Number of larvae of Pteromalidae	Rate of parasitism in %
Zürich	9.7.91	50	25	50.0
Flaach I	25.6.91	187	70	37.4
Flaach II	25.6.91	53	15	28.3
Flaach III	25.6.91	51	29	56.9
Flaach IV	25.6.91	80	25	31.3
Buchberg I	25.6.91	58	23	48.3
Buchberg II	25.6.91	100	30	30.0
Buchberg III	25.6.91	50	13	26.0
Ermatingen	26.6.91	50	25	50.0
Langenthal	24.6.91	50	4	8.0
Lotzwil I	24.6.91	46	6	13.0
Lotzwil II	24.6.91	95	30	31.6
Madiswil I	24.6.91	46	8	17.4
Madiswil II	24.6.91	48	9	22.5
Huttwil I	24.6.91	39	3	7.7
Huttwil II	24.6.91	41	3	7.3
Bad Ragaz I	26.6.91	50	18	36.0
Bad Ragaz I	3.7.91	50	22	44.0
Bad Ragaz II	3.7.91	46	23	50.0
Maienfeld I	27.6.91	44	12	27.3
Maienfeld I	3.7.91	50	30	60.0
Maienfeld II	3.7.91	45	23	51.1
Landquart I	26.6.91	47	8	17.0
Landquart I	3.7.91	47	18	38.3
Landquart II	3.7.91	39	18	46.2
Trimmis I	27.6.91	43	8	18.6
Trimmis I	3.7.91	31	18	58.1
Trimmis II	3.7.91	38	12	31.6

In one sample of C. assimilis larvae from 25 June 1990 at Bad Ragaz we found also two endoparasitoids of an unknown species.

b) Distribution of parasitoid species

In 1989, 5 adult parasitoid species from the region of Huttwil were determined and 3 female of Stenomalina muscarum L. and 2 females of M. morys were found.

In 1991, 55 adults Pteromalidae were determined three species were found: S. muscarum, M. morys and T. perfectus (Table 3).

Table 3: **The occurence of three different species of ectoparasitoids of C. assimilis in 1991 in Switzerland**

	Number of parasitoids determinded		
	Mesopolobus morys	Trichomalus perfectus	Stenomalina muscarum
Buchberg	7	-	-
Flaach	6	-	-
Ermatingen	1	-	-
Madiswil	4	1	-
Zürich I	1	1	-
Zürich II	3	1	1
Bad Ragaz	9	1	2
Maienfeld	8	2	-
Landquart	6	-	-
Trimmis	1	-	-
	46	6	3

4. Discussion

Ectoparasitoids of C. assimilis larvae are known form several countries. Each country has a different species distribution. Von Rosen (1964) described three species occuring in Sweden: S. muscarum, M. morys and T. perfectus where the last one was the most important. Laborius (1972) almost exclusively found in Germany the species T. perfectus. Dmoch-Sulgostowska (1986) registered in Poland T. perfectus, S. muscarum and Habrocystus spp.

Günthart (1949) found in the northern part of Switzerland 7-9% of C. assimilis larvae parasitized with T. perfectus and X. pura syn. M. morys. From 1989 to 1991 we found also the two species and in addition S. muscarum. The rate of parasitism varied from 3% up to 70%. In many regions parasitoids are very abundant so that they could stabilize the population of C. assimilis. C. assimilis is not a serious pest in Switzerland because it is only dangerous as pioneer for the brassica pod midge, Dasineura brassicae Winn. Therefore C. assimilis should not be treated in Switzerland except in a few cases when the D. brassicae population is high.

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THE DAMAGE CAUSED BY SINGLE SPECIMENS OF THE SEED WEEVIL (*CEUTORRHYNCHUS ASSIMILIS* PAYK.) AND THE POLLEN BEETLE (*MELIGETHES AENEUS* F.).

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Abstract.

The problems "How many buds does an average pollen beetle damage per day and how many punctures does an average seed weevil make in the pods per day", were investigated by experiments in both field and laboratory. Small cages (net - sleeves in the field and plexi-glass tubes in the laboratory) were used to isolate single individuals. In the seed weevil experiments they were isolated on a raceme with flowers and at least 15 pods. In the pollen beetle experiment they were isolated on an inflorescence with at least 20 buds and no flowers.

The number of seed weevil feeding punctures and number of ovipositions in the laboratory were found to depend on temperature and time. An equation using these parameters as variables was fitted to the data. This equation was able to predict the results from the field experiments with good precision.

In the pollen beetle data there was a tendency towards a decrease in the number of damaged buds with time. A decrease in temperature also seemed to decrease the damage. The data were not consistent enough to fit into any eguation. Average number of damaged buds was 1.19 and 2.28 buds/day/beetle for males and females, respectively.

1. Introduction.

The pollen beetle (Meligethes aeneus F.) and the seed weevil (Ceutorrhynchus assimilis Payk.) are well known pests of rape crop in large parts of Europe, but the damage they cause seems difficult to quantify (Free et al., 1983; Lerin, 1987), i.e. economical damage thresholds are unprecise. This is due to both individual variance among rape plants and the fact that rape has a strong ability to compensate for pest damage (Axelsen and Nielsen, 1990). These two problems can be overcome by a computer model, which can simulate both growth of the rape crop and the pest damage. The model, that will be described in a later publication, requires detailed information on the damage caused by one single pest insect as a function of temperature and time. In this work the damage caused by one seed weevil and one pollen beetle was investigated in cages in both the laboratory and the field. Further the damage caused by more beetles together in one cage was investigated in the field.

2. Material and methods.

In the field the cages consisted of net sleeves hanging down from iron poles. In the bottom the cages were closed densely around the stem by rubber bands. The stems were protected by a piece of cotton wool. In the top the cages were closed by a dense tie. In the laboratory, cages consisted of plexi-glass tubes (20 cm. diameter, 50 cm. high). These tubes were placed on a bottom of two plexi glass plates. The two plates had a little hole in the middle to let the plant stem in. The top of the tubes were closed by fine mesh net. The tubes were placed on top of a small bucket with water to keep the plant material fresh. Plant material for the laboratory experiments were cuttings taken from the field less than 2 h before the experiments were started. Since the plants were taken from the field, they might have been visited by pollen beetles/seed weevils before. Therefore they were checked by the naked eye before use, and pods/buds with sign of pest damage were removed. In order to control the efficiency of this check, plants that had been checked, were investigated under 12 times magnification.

Beetles and weevils for both laboratory and field experiments were caught in the field shortly before the introduction. They were left in the cages for 1 - 4 days.

Laboratory experiments consisted of 10 replicates with one beetle per cage at each temperature (11, 14, 18, 21 and 24°C). 2 or 3 experiment were carried out at either temperature. In the field an experiment consisted of 10 replicates with different numbers of beetles in the cages. 1,2,3,and 5 per cage were used in the seed weevil experiments. 1,2,3,4 and 5 were used in the pollen beetle experiments.

When the experiments were stopped, the plants and the beetles/weevila were stored in a freezer until they were examined under 12 times magnification. Pods from the seed weevil experiments were examined for punctures. All pods with punctures were dissected to look for eggs. The buds from the pollen beetle experiments were examined for feeding damage and egg punctures. Buds with egg punctures were dissected to count the eggs.

The sex of all beetles/weevils used in the experiments was determined. The sex determination of the seed weevils was based on external characters (Hansen, 1965), while the pollen beetles were dissected.

The controls from the seed weevil experiments were 20 racemes taken on 17 June. The average number of punctures and eggs in the control pods was subtracted from the average values from each experiment. In the pollen beetle experiment controls were taken each time an experiment was started. The average values from the controls were subtracted from the experimental results from the same starting date.

Equations with 2 variables (temperature and days from start of the pod stage) were fitted to the number pods punctured by either sex and the number of eggs laid by seed weevils per 24 h. The equations that were fitted to the data were of the following type:

$$Holes/24hours = k_1 * temperature * \exp(-k_2 * D) \qquad (1)$$

where D is the number of days from the start of the pod stage; k_1 and k_2 are constants.

Field experiments were carried out at the field station at Ødum, 20 km north of Aarhus, Denmark. Temperature data were hourly measurements at 2 m hight taken at a meteorological station right next to the experimental field.

3. Results.

3.1. Seed weevils

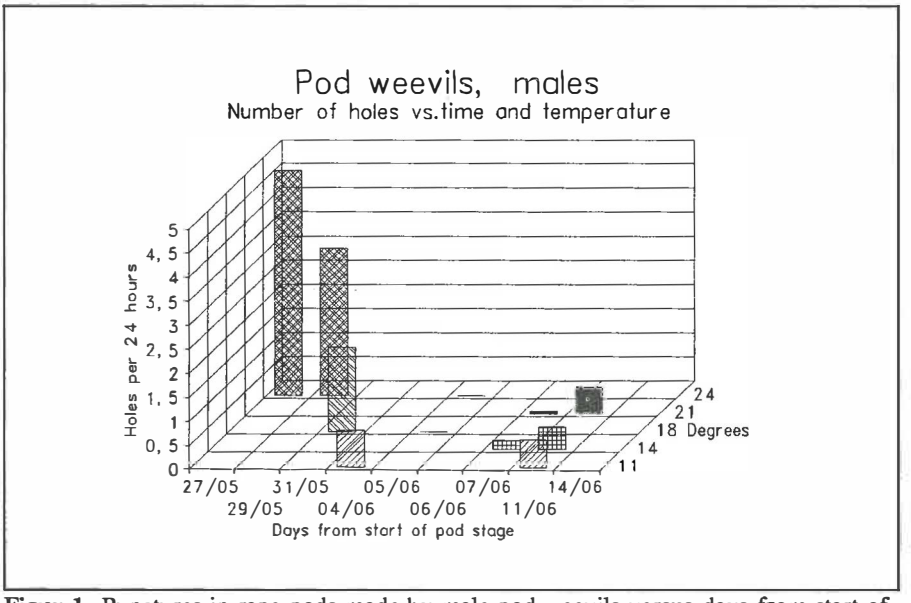
The number of punctures in the pods per day ranged from 0 to 11.1 in the laboratory experiments (fig 1 and 2). It is clear, that the number of days after start of the pod stage, is the most important variable, while the temperature is of secondary importance. Further the results show, that females make about 2.5 times as many punctures as males. Punctures made by females are only feeding punctures and do not include punctures made in connection with oviposition. The number of punctures produced by both sexes showed a good fit to the equation (1) (constants in table 1). The number of eggs laid per 24 h did not fit well to any equation. Average number of eggs laid per 24 h was 2,27 (S.E = 0.38, N = 34).

In the field experiments with 1 weevil per cage average oviposition per 24 h was 1.93 (S.E. = 0.31, N = 11).

Table 1. The constants and r-squared values obtained by fitting equation (1) to the observed number of punctures per 24 h for female and male seed weevils.

	k_1	k_2	r^2
Punctures per 24 hrs, ♂♂	0,246	0,224	0,940
Punctures per 24 hrs, ♀♀	0,943	0,222	0,828

The number of punctures from cages with one weevil per cage were compared with the values, that could be expected based on the equation found in the laboratory experiment. The average temperature from the experimental periode and the number of days after start of the pod stage were inserted in equation (1) to obtain an expected value. The observed and expected values are compared in fig. 3 and 4, and the coincidence is rather good, especially for the males.



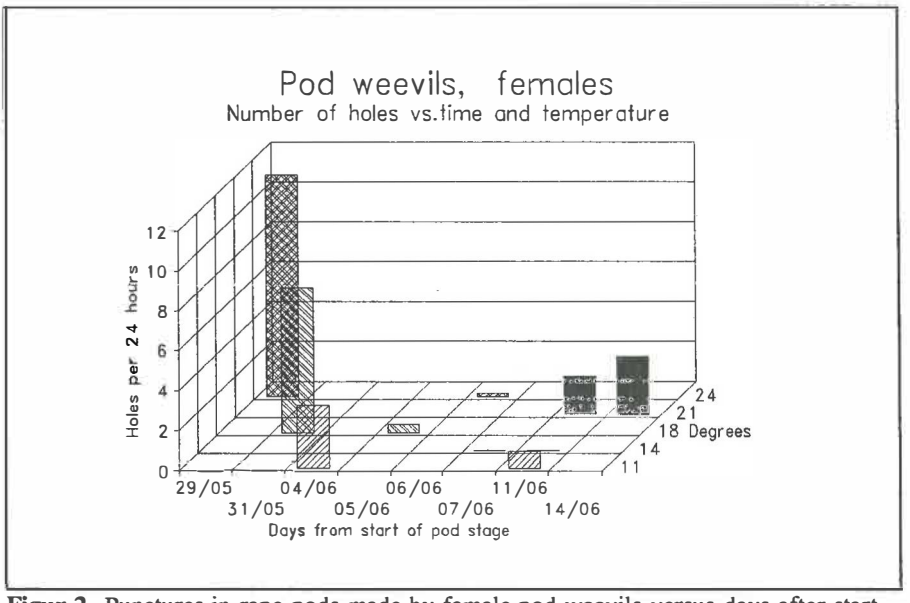
Figur 1. Punctures in rape pods made by male pod weevils versus days from start of pod stage and temperature in laboratory experiments. Note that the x-axis in not linear.

The field experiments with more than one weevil per cage, confirmed the decrease with the number of days from start of pod stage as the laboratory experiments. Further there is a strong tendency towards an increase in the number of punctures with the number of weevils in the cages (Fig. 5).

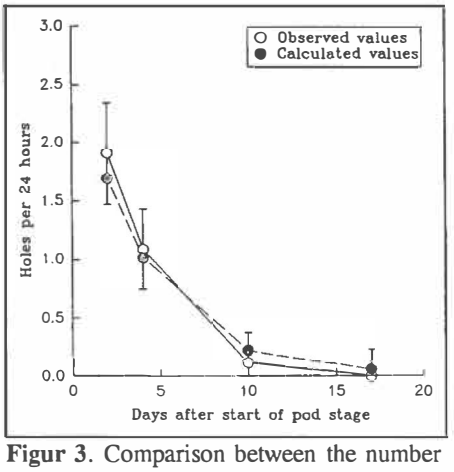
Equation (1) and the constants from table 1, were used to calculate how many punctures a population of seed weevils with a density of 1 weevil per plant can make in 14 days, if the sex ratio is 50/50. At average temperatures of 14°C and 18°C the results are 32 and 41 punctures per plant, respectively. The number of eggs in 14 days would reach about 16 per plant.

3.2. Pollen beetles

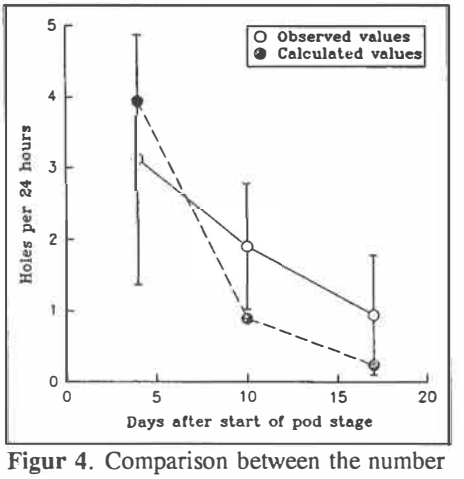
The number of buds damaged by one beetle per day in laboratory experiments ranged from 0 to 6.3, with a weak decreasing tendency with time and an increasing tendency with temperature (Fig. 6 and 7). These tendencies are not consistent enough to fit well into equation (1) like the seed weevil data. Several other equations (linear and exponential for both variables) were tried but did not improve the fit to data. The average number of buds damaged for males (all temperatures and dates) was 1.29 (S.E. = 0.28, N



Figur 2. Punctures in rape pods made by female pod weevils versus days after start of pod stage and temperature. Note that the x-axis is not linear.

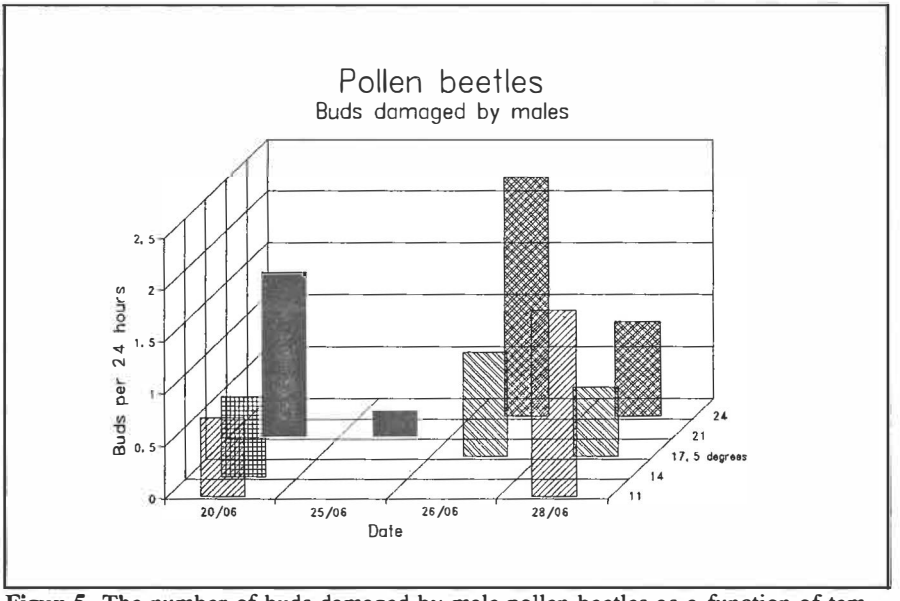


Figur 3. Comparison between the number of punctures made by male pod weevils in the field experiments and calculated values.

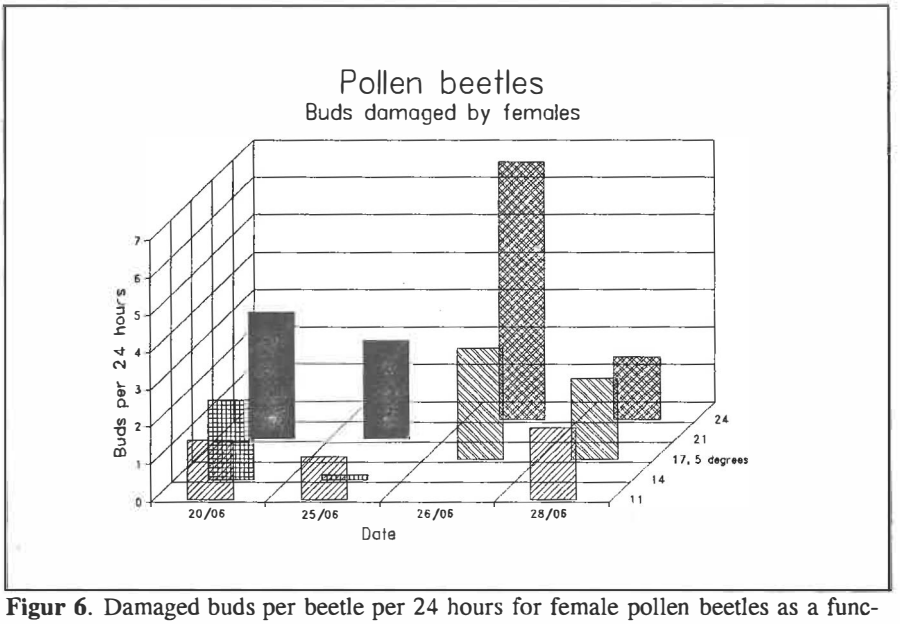


Figur 4. Comparison between the number of punctures made by female pod weevils in field experiments and calculated values.

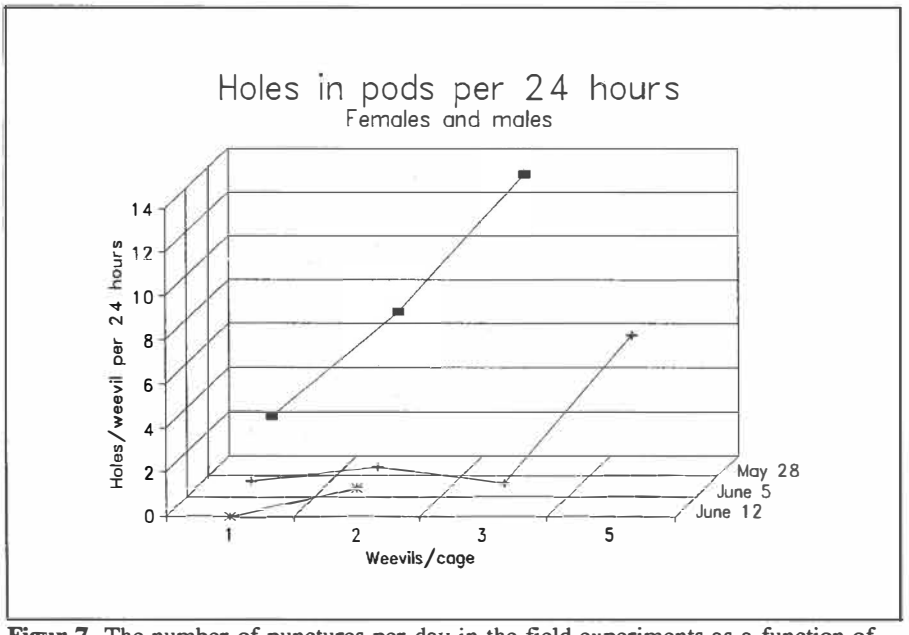
= 34) and for females 2.28 (S.E. = 0.27, N = 63). Most of the damaged buds were smaller ones, less than 1 mm.



Figur 5. The number of buds damaged by male pollen beetles as a function of temperature and time. Note that the x-axis iis not linear.



Figur 6. Damaged buds per beetle per 24 hours for female pollen beetles as a function of temperature and time. Note that x-axis is not linear.



Figur 7. The number of punctures per day in the field experiments as a function of date and number of weevils per cage.

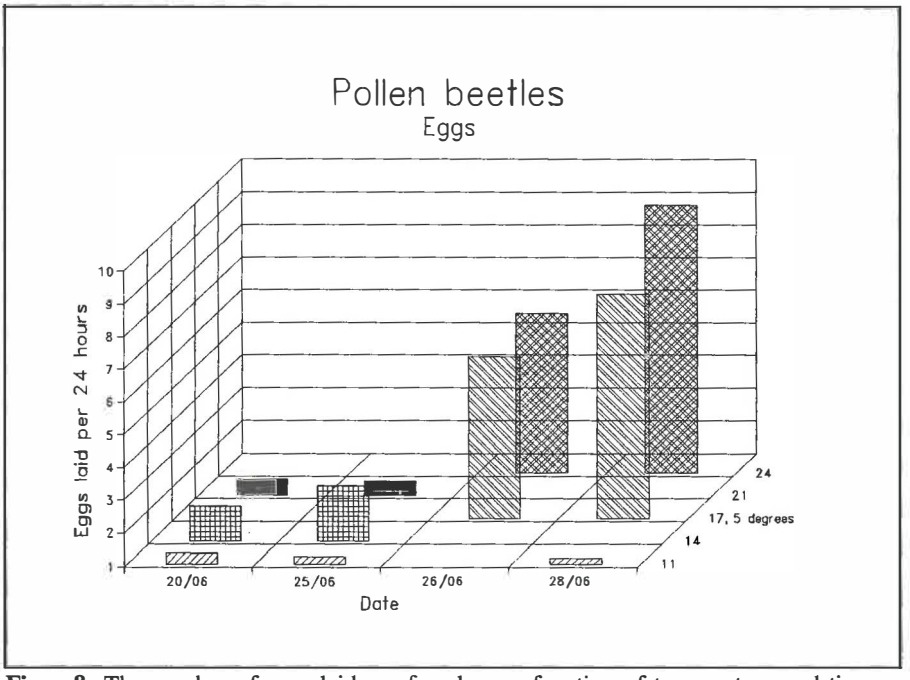
The number of eggs laid per female per 24 h showed an increase with time and a clear decrease with temperature (Fig. 8). At 11°C oviposition had almost ceased and on the first dates oviposition was also low at higher temperatures. The data did not fit well into neither equation (1), nor the other of the equations, that were tried. Average number of eggs per female per 24 h was 4.33 (S.E. = 0.58, N = 63).

In the field experiments with 1 beetle per cage the average number of damaged pods per day was 1.63 (S.E. = 0.48, N = 14) for males and 4.57 (S.E. = 1.18, N = 23) for females. Average number of eggs per day was 3.2 (S.E. = 0.68, N = 23). The damage per day did not show any clear dependence on the number of beetles in the cage (not shown).

The average number of damaged buds per day was used to calculate the damage caused by a population of pollen beetles with a density of 1 beetle per plant and a 50/50 sex ratio. 15.5 and 31 buds should be damaged per plant in 5 and 10 days, respectively.

4. Discussion.

A striking result in this study is the difference in consistency between the seed weevil data and the pollen beetle data.



Figur 8. The number of eggs laid per female as a function of temperature and time. Note that the x-axis is not linear

The seed weevil data showed a good fit to equation (1), while the pollen beetle data did not fit either equation (1), nor any other equation. There may be a good reason for this difference. Both kinds of damage is due to the feeding of the insect, and therefore the extend of the damage must be correlated to the demand for enegy and nutrition. The amount of energy obtained from puncturing pods may be relatively constant, while the energy obtained from a bud is very dependent on the size of the bud. Thus, for a pollen beetle the daily energy demand may get satisfied by eating one large bud or by eating several smaller ones. If this is true, the variation in the damage caused by one pollen beetle will be considerably more random, than by one seed weevil.

Energy consideration can also explain the higher damage caused by females than by males, sice females need energy to produce eggs.

4.1. Seed weevil.

The seed weevil harms the rape crop in two ways. The larvae feed on the seeds and the feeding punctures of the adults opens the way for oviposition by the pod midge (Dasyneura brassicae Winn.). Further the exit holes of the larvae are also used for

oviposition by the pod midge. Therefore the pods, where the seed weevil oviposits will most likely get completely lost if pod midges are present. Further a large part of the pods with feeding punctures will get lost due to the pod midge. Therefore it is important whether the pods heal punctures during their growth. If they do not heal the potential damage due to seed weevils is large. In two weeks 1 weevil per plant makes 30 - 40 punctures, most often in different pods, and lays about 16 eggs per plant. With a large population of pod midges these pods will get lost. These calculation gives the important hypotheses, that the seed weevil population have to be very low to limit the damage by the pod midge considerably. This is supported by Axelsen (in prep), who was able to simulate the population development of the pod midge without taking the seed weevil population into consideration.

The figures from this calculation may even be too low, since the number of punctures per day per weevil seems to increase, when more weevils are together.

In cage experiments Free et al. (1983) correlated the number of pods infested by weevil larvae at harvest with the population of adult weevils. In their study 1 weevil per plant resulted in an infestation of about 30 larvae per plant. This suggests, that the results from the calculations made above are too low. The low figures are probably due to that the oviposition period of the seed weevil is longer than 14 days.

4.2. Pollen beetle

According to the calculations made in this paper a population of 1 pollen beetle per plant damages 31 buds over a 10 day period. The damage is expected to give a similar increase in the number of podless stalks per plant. This may not be true, because most damages pods are rather small and have almost no stalks by the time they get damaged. Hence, the number of podless stalks might not increase as much as expected. The extend of pollen beetle damage is often found by counting the podless stalks (Free an Williams, 1979; Tatchell, 1983). This may underestimate the number of buds actually damaged by the beetles. However, this error will most likely be countrebalanced (at least) by the fact, that podless stalks are the result of other factors than pollen beetle damage (Thachell, 1983).

The increase in number of ovipositions per day, is most likely due to that the oviposition had barely begun by the time of the first experiments. In Denmark the pollen beetles arrive to the spring rape fields one and two weeks before oviposition begins. Therefore a high number of oviposition could not be expected until the last experiments. Consequently, the average number of eggs per day is not a real estimate of the daily fecundity of a female pollen beetle.

The results from this study can not be used to calculate damage thresholds for the seed weevil and the pollen beetle,

since the compensation for the damage is not included. However, when these results are included in a computer model, that can simulate the compensation, calculations of economical damage thresholds can be made. The model is under development and will be described in a later publication.

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INFLUENCE OF THE GROWTH RATE OF OILSEED RAPE ON THE SPLITTING OF THE STEM AFTER AN ATTACK OF CEUTHORHYNCHUS NAPI GYLL.

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Summary

Ceuthorhynchus napi is one of the most common pest on oilseed rape in France. Most of the eggs are inserted in the stem pith in the first 2 cm below the buds on the main raceme. Their presence causes deformations of the stem during its growth and eventually a longitudinal split. In growth chamber experiments it was demonstrated that splitting occurs more frequently at 20°C than at 10°C on varieties Darmor and Bienvenu. The growth rate of the stem is the main cause of splitting. There is no relationship between the number of laying holes and the frequency of split stems.

1. Introduction

Ceuthorhynchus napi Gyll. has been a major pest of oilseed rape in France and other European countries (Switzerland, Czekoslovakia, Germany, Poland) since the forties (Jourdheuil, 1961). Yield losses have been studied by several authors and can vary depending on the infestation level (Dmoch & Lagowska, 1978; Ballanger, 1987a; Büchi, 1988). Strong correlations between yield losses and the number of eggs, the number of larvae or the percentage of attacked plants have been established, but regression coefficients are variable depending on location or agroclimatic conditions (Ballanger, 1987b). Part of the problem comes from the fact that at least two factors are suspected to be detrimental to the plant : larval feeding in the stem pith and egg laying which takes place in the 2 cm below the flower buds and may cause deformations and occasional longitudinal splitting. These splits are open doors to fungal diseases and water as the pith becomes hollow as a consequence of the perturbation caused by eggs. Many authors have described the changes caused to stem tissues (Günthart, 1949; Dosse, 1951; Deubert, 1952) and some have also tried to determine the origin of these changes (Deubert, 1955; Schmutterer, 1956; Kazda, 1958 in Jourdheuil, 1961; Le Pape & Bronner, 1987). It was thought at first that deformations and splitting were caused by the introduction of bacterias or chemical substances during egg laying. Le Pape and Bronner (1987) finally concluded that splitting was simply caused by the sheer presence of the egg and its exochorion which creates tensions in the growing stem and suggested that plant parameters were involved.

The simplest hypothesis was that the growth rate of the stem was the main cause of splitting, and a simple experiment to test it was devised.

2.Materials and methods

Plants of two cultivars, Bienvenu and Darmor were grown in 7l pots, each containing 4 plants. Twenty four pots were used for each cultivar. At the end of March these pots were caged with many weevils in a large insect proof tunnel covered with mesh. After 5 days the weevils were removed and the pots were transferred in two growth chambers regulated at 10 and 20°C with a photoperiod of 14h. For each temperature we had then 12 pots per cultivar half of which received 0.5g of "ammonitrate" granules. Egg laying holes were counted at the beginning of the experiment. The stem length was repeatedly measured on all plants as they were thoroughly examined to note deformations and splitting. After one month the plants held at 10°C were transferred at 20°C to hasten their growth. At the end of the experiment, plants were controlled to see whether eggs had actually been laid. All uninfested plants were eliminated from the results. The proportion of split stems for each lot were compared with CHI-square tests associated with Fisher's exact test because some expected frequencies were lower than five. Stem lengths were compared with an analysis of variance or t-tests.

3.Results and discussion

Nitrogen fertilization did have a negative effect on the lengthening of the stem at 20°C for Darmor : stems grew significantly slower with nitrogen, taking 14.4 cm in 12 days with nitrogen and 29.5 cm without ($F=10.23$, $prob<0.01$). All other differences were non-significant. For each cultivar and temperature the frequency of stem splitting was compared between plants with and without nitrogen fertilizer but no difference could be found, even at the 20 % level. So the results concerning splitting were pooled by temperature for further analysis.

Table 1 displays the results for cultivar Darmor and Bienvenu. It can be seen that stem splitting is more frequent at 20°C than at 10°C on Darmor. The same results were obtained with cultivar Bienvenu but frequencies are higher at both temperatures : this is attributed to the fact that growth rates were greater, particularly at 10°C, when stems reached a length of more than 20 cm.

The number of egg laying punctures were not significantly different between split and unsplit stems in each variety but Darmor was a little less infested than Bienvenu. *C. napi* is known to display preferences in the choice of plants for egg laying based on their growth stage (Jourdheuil, 1961). In the present case females had the choice between the two cultivars which were not exactly at the same growth stage. This was done on purpose to mimic what is happening in field conditions in a variety trial. In no choice conditions Darmor and Bienvenu are equally infested when compared at the same growth stage, i.e. the same stem length (Lerin unpublished).

These results confirm the hypothesis tested : the growth rate of the stems is the main factor inducing splitting after egg laying by *C. napi*. Splitting can occur with only one egg laid and is not correlated with the number of eggs. All splittings occurred in the first 12 days of the experiment, which justifies the use of the length of the stem at this time to explain the results. The plants tranferred from 10 to 20°C after a month did not display any further splitting indicating that it is the growth rate immediatly following egg laying that is important.

For cultivar Bienvenu, at 20°C, we had sufficient data to make three subgroups according to the initial stem length (Table 2). It can be seen that there is a

decrease in the frequency of split stems though the growth rates tended toward stabilization. This confirms the fact, which was empirically established through field observations, that rape plants become less susceptible to splitting when their stem reach a certain length. This length was thought to be 20 cm, but length can vary widely for the same growth stage depending on agroclimatic conditions (Ballanger, 1987) and is therefore not a good criterium. Cellulose, lignin or water content should be more reliable criteria as they are more related to stem 'strength'.

These results also show that comparing tolerance to splitting among cultivars cannot be done under field conditions : if one supposes that the observed frequencies of split stems on both varieties at 10°C (which is the average temperature for April in the region where the experiments were done), had been obtained in field conditions it could have been concluded that Darmor was less susceptible to splitting than Bienvenu; results at 20°c would have yielded a different conclusion as the frequencies on each cultivar are almost the same.

This experiment will have to be followed by others to complete the results with varying initial length at infestation time. It will also be necessary to conduct tests with fluctuating temperatures to have a more realistic approach to stem splitting.

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Table 1. Percentage of split stems (% split), initial height (height), growth in 12 days (growth), and number of egg laying holes (holes).

cultivar	temp.	number	%split	height(cm)	growth(cm)	holes
Darmor	20	26	42.3	11.2	16.3	4.8
Darmor	10	24	4.2	13.9	3.5	4.2
Bienvenu	20	46	67.4	31.5	31.2	6.2
Bienvenu	10	38	36.8	33.6	10.4	5.7

temp.= temperature in °C; number= total number of plants

Comparison of the frequencies of split stems on Darmor : X^2= 9.95, d.f.= 1, prob.=0.002

Comparison of the frequencies of split stems on Bienvenu : X^2= 7.81, d.f.= 1, prob.=0.005

Maximum value of t-test when comparing the number of egg laying holes on split and unsplit stems at each temperature for each cultivar : t=1.26, NS.

Table 2. Percentage of split stems among the subgroups selected according to initial height in Bienvenu at 20°C.

group	number	height	growth	% split
1	17	21.5	25.1	88.2
2	14	32.9	36.8	64.3
3	15	41.5	32.9	46.7

Comparison of frequencies of split stems : X^2= 6.35, d.f.=2, prob= 0.044 (Fisher's exact test, 2 tails).
number= total number of plants

INCIDENCE AND IMPORTANCE OF INSECTS ON LINSEED IN ENGLAND AND WALES

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Abstract

74 crops of linseed were monitored during 1988 and 1989 to gather information on the potential pests of linseed. Many of the insects reported in the literature as being common in linseed were either not found or were present in low numbers. However, others not listed as attacking the crop, eg capsid bugs, were easily found and caused notable damage to some fields. Pests which could increase in importance as the crop area expands include capsids (especially in crop headlands), thrips and flax flea beetles. Very few of the crops monitored showed more than slight damage from these pests.

1. Introduction

During the last ten years the area of linseed (Linum usitatissimum) grown in the United Kingdom (UK) has increased rapidly from less than 350 ha in 1980 to over 38000 ha in 1990 (Bastian, 1991), partly as a result of a steady market for the oil within the European Community and encouragement under the common agricultural policy to plant the crop. During this period work has been done to improve crop husbandry (Freer, 1991) and on some of the diseases affecting linseed (Rawlinson & Dover, 1986), but until recently little attention has been paid to potential pests of the crop.

The most extensive data on insects attacking linseed (flax) in the UK relate to the period of the Second World War when advisory entomologists surveying flax crops recorded the flax flea beetle Longitarsus parvulus, the large flax flea beetle Aphthona euphorbiae, the flax tortrix moth Cnephasia interjectana, wireworms, leatherjackets and slugs as the most important pests (in Ministry of Supply report - Insect Pests of Flax by I. Thomas and H.M. Edelston, 1944). Field thrips Thrips angusticeps were also recorded as an occasional pest of flax (Morison, 1943). By the beginning of the recent revival of interest in the crop this list had not changed substantially (Rawlinson & Dover 1986; Turner, 1987) and no pests were recognised as sufficiently damaging to warrant control measures.

In response to increasing interest in linseed within the agricultural industry, ADAS entomologists undertook in 1988 and 1989 a co-ordinated monitoring programme in England and Wales to gather the baseline data on potential pests and beneficial insects, which was required to develop current advisory policy.

2. Materials and Methods

A total of 34 crops with a combined area of 341 ha was monitored in 1988. In 1989 a combined area of 359 ha was monitored from 40 fields. In both years crops were sampled at three growth stages (Turner, 1987), first flower (GS7), full to late flower (GS8-9) and green capsule (GS10).

In 1988, at both GS7 and GS8-9, twenty plants from a transect across the field were beaten into a white tray and the numbers of thrips, flax tortrix moth caterpillars or other insects caught were recorded. The plants were then dug up and the numbers of stem miners, leaf miners, webbing and other insects or insect damage on the stems and leaves recorded. Other insects observed in the crop in significant numbers were also noted. At GS10, ten sweeps from a sweep net were taken in both the headland and centre of the field and the number of flax flea beetle and large flax flea beetle recorded. In addition twenty plants from a diagonal transect across the field were examined and the proportion of capsules infested with thrips was determined. Ten capsules from each of these plants were dissected and the number of seeds damaged by thrips was recorded.

In 1989, at both GS7 and GS8-9, beating samples were taken from twenty plants in a transect along the headland and a further twenty in a transect in the centre of the field. The numbers of capsids (Miridae), thrips or other insects caught were recorded. The plants were then dug up and similar records made to those in 1988. At GS10, ten sweep net samples were taken in the headland and centre of the crop and samples of capsules were examined for thrips attack, as in 1988, but in addition the proportion of capsules pierced by capsids was also determined.

3. Results

Capsids: Capsid bugs were first recognised as potentially damaging pests of linseed in the UK during the 1988 survey. They were observed in 52% of the crops monitored in 1988 but were only caught in beating counts in 18% of the fields. A mean of 0.02 capsids/beat was recorded from plants at GS8-9. During 1989, capsids were caught in beating counts in 20% of the linseed crops monitored at GS7 (with a mean of 0.01 per plant), rising to 35% at GS8-9 (0.02/plant). In both years the most common species recorded was the common green capsid Lygocoris pabulinus, but others found included Calocoris norvegicus and Lygus spp.

All observations in 1988 recorded capsid bugs as being restricted mainly to the headlands of the fields sampled. This was confirmed by the more detailed observations made in 1989 (Table 1) which showed that in all regions significantly more capsids were caught in beating counts taken in the headlands than in equivalent samples taken in the centre of the fields, at both GS7 and GS8-9.

Table 1. Mean numbers of capsids per plant in the headlands and centres of fields in 1989

	Growth Stage 7			Growth Stage 8-9		
	Headland	Centre	Total	Headland	Centre	Total
Mean	0.02	0.001	0.01	0.03	0.003	0.02
Range	0-0.25	0-0.05	0-0.025	0-0.20	0-0.05	0-0.20

Despite the generally low populations of capsids in linseed, significant numbers were found in two areas in 1988 and some crop damage was recorded. In some fields capsid feeding resulted in delayed and much reduced flowering, poor setting of flowers and loss of yield. In other crops capsids attacked the seed capsules, puncturing the bases of immature capsules and damaging or destroying the seeds within. Damage to one crop in SE England was sufficiently high to allow damage assessment samples to be taken and in this field feeding by the common green capsid L. pabulinus resulted in severe damage in the headlands but not in the centre of the field (Table 2), reflecting the distribution of these insects in the crops. In 1989 only 0.5% of the capsules examined had been damaged by capsids, and no individual fields were recorded as having high levels of damage caused by these insects.

Table 2. Capsid damage in the headland and centre of a linseed crop in SE England in 1988

	Total No. capsules/plant	% Damaged capsules	% Flower buds failing to form capsules
Headlands	4.2	14.3	23.8
Field	13.2	2.8	3.0

Thus although very few damaging infestations were recorded in 1988 or 1989, capsids may have the potential to cause yield loss in the headland areas of linseed crops.

Thrips: In both 1988 and 1989, thrips were found in most crops monitored at GS7 and GS8-9 and in about half the crops sampled at GS10 (Table 3). Numbers were generally low at the earlier growth stages and no damaging infestations were identified. At GS10 the number of capsules on which thrips were seen was variable but also generally low, with only 1.3% of the 6018 capsules examined in 1988 infested and 5.2% of the 10126 capsules in 1989. Samples of thrips taken from monitored sites were identified as Thrips angusticeps, Thrips vulgatissimus, Thrips tabaci, Limnothrips cerealium, Limnothrips denticornis, Aeolothrips intermedius, Frankliniella tenvicornis and Chirothrips manicatus. Of these only T.angusticeps is likely to breed in the developing capsules.

Table 3. Percentage crops infested with thrips and mean number of thrips per plant in 1988 and 1989

Year	% Crops with thrips			Mean No. thrips/beat	
	GS7	GS8-9	GS10	GS7 (Range)	GS8-9 (Range)
1988	78	72	46	1.0 (0-5.60)	0.82 (0-6.35)
1989	89	100	58	0.40 (0-2.65)	0.82 (0-3.7)

Table 4. Mean number of thrips per plant in the headlands and centres of fields in 1989

	Growth Stage 7			Growth Stage 8-9		
	Headland	Centre	Total	Headland	Centre	Total
Mean	0.41	0.36	0.40	0.83	0.80	0.82
Range	0-2.35	0-2.65	0-2.65	0-3.7	0-3.7	0-3.7

Observations made in 1988 indicated that the number of thrips per plant in the headlands of infested crops did not differ from the numbers found in the centres of the fields. More detailed sampling in 1989 showed that in all regions similar numbers of thrips occurred in both parts of the crop (Table 4). The mean number in headlands at GS7 was 0.41/plant compared with 0.36/plant in the centres, and by GS8-9 the numbers had risen to 0.83 and 0.80 thrips/plant respectively.

Thrips attack during the flowering period of linseed can affect seed setting (Franssen & Kerssen, 1962), although even in the absence of thrips incompletely formed seeds or barren seed sites are found in late formed or stressed capsules (Turner, 1987). The dissection of capsules in this study showed little damage of this type. In 1988 only 1.8% of the seeds examined were found to be damaged or incompletely formed with almost 85% of fields showing less than 5% seeds affected and 75% with less than 2% seeds damaged. However in a single field in Wales 18% of seeds were found to be affected, reflecting the higher average infestation level found in this field at GS10. In 1989, 0.7% of the seeds examined were found to be incompletely formed, with no fields showing more than 5% seeds affected and 84% with less than 2% damaged. No fields with notable levels of damage were recorded in 1989. Thus although thrips did not appear to be causing significant damage to linseed on a national scale, it is possible that localised damaging infestations may develop occasionally.

Flea beetles: In 1988 infestations of both L.parvulus and A.euphorbiae were at very low levels. A mean of only 0.3 A.euphorbiae per ten sweeps was found nationally in both the centre and headland areas of the field. No L.parvulus were found in the centre of the field, compared with 0.1 beetles per ten sweep samples in the headland.

Slightly higher infestations were recorded in 1989 when mean numbers caught in the ten sweeps taken in both the headland and centre of the field were 2.68 and 1.79 A.euphorbiae respectively and 17.27 and 7.48 L. parvulus.. However, most beetles were found in the eastern area of the country, which was the only region in which L.parvulus were readily found in all fields sampled and where mean numbers caught in ten sweep samples reached 104.6 in the headlands and 45.6 in the centres of the fields.

There were no significant differences in the numbers of either A. euphorbiae or L.parvulus caught in the headlands or centres of the fields in either 1988 or 1989. No significant damage attributable to flea beetles was observed in either areas of the field during the two years in which monitoring was undertaken.

Leaf miners: The widespread occurrence of leaf miners on linseed was recorded for the first time during this study. Infestations were at low levels in 1988 with 30% fields infested and a mean of 0.16 mines per plant at GS7, and only slightly higher numbers occurring at GS8-9 (59% crops infested, 0.39 mines/plant). Lower numbers were recorded in 1989 with 26% fields infested and a mean of 0.02 mines/plant at GS7 and 28% fields infested and 0.02 mines/plant at GS8-9. All specimens identified to species were the Agromyzid, Phytomyza horticola.

Flax tortrix moth: The results of this study support other observations (Turner, 1987) that flax tortrix moth Cnephasia interjectana occurs in very low numbers on linseed. Caterpillars of the moth were reported in only 5% of fields sampled in 1988 and 7% of fields in 1989. Damage was slight with few plants affected, and control measures were not required. Infested crops had the top leaves of occasional plants spun together with fine webs containing either a caterpillar or pupa.

Other insects: A large number of other insects including aphids, pollen beetles, leaf hoppers and various species of caterpillars were noted during the survey, but none approached levels that were likely to damage the crop directly. Beneficial insects such as honey bees and bumble bees were also attracted to the crops in large numbers.

4. Discussion

The monitoring of pests of the aerial parts of linseed plants has indicated that many of the insects reported in the literature as common in linseed in the UK were either not present, or were caught in very low numbers in the fields sampled. In addition some of the more common insects found were not listed in the literature, including capsid bugs which caused significant damage in some fields.

Work in continental Europe suggests that T.angusticeps and T.linarius are the most important species of thrips attacking linseed (Beaudoin, 1987; Czencz 1985). T.angusticeps was frequently caught during this study and was the only species recorded which is likely to breed in the developing capsules. It is a polyphagous species which will attack several arable crops and passes the winter as a brachypterous generation in the soil (Beaudoin, 1987; Bonnemaison & Bournier, 1964). Thus, depending on previous cropping, it is possible that UK linseed could be

damaged at the seedling stage as occurs in Hungary (Czencz, 1985) and the Netherlands (Franssen & Huisman, 1958). The subsequent macropterous generation, which this work concentrated on, feeds amongst the folded leaves of the growing points of linseed and can destroy the terminal bud causing distortion and branching. Seed setting may also be affected as damage to flower buds, ovaries and young seed bolls have been shown to result in a severe loss of seed (Franssen & Kerssen, 1962). Some damage of this type was observed in the crops monitored in this study but because of the low number of thrips present, no economic yield losses were incurred.

Capsids were first recognised as potentially damaging pests of linseed in the UK during the 1988 survey, although they had previously been recorded in Austrian crops (Cate, 1984) where they were found in large numbers from mid-May onwards. Capsids were caught during the flowering growth stage in most regions in 1988 and in all regions in 1989. Significant numbers were found in two areas in 1988 and the resulting damage caused to flowers and seed capsules was similar to that described in the Austrian study. No significant damage or yield loss specifically attributable to capsids was noted in the fields monitored in 1989.

The sampling in 1989 indicated that whereas capsids were unevenly distributed in the fields monitored, occurring mainly in the headlands, similar numbers of thrips occurred in both the headlands and centres of the fields. The capsid damage observed in 1988 was also largely confined to headlands.

The flea beetles A.euphorbiae and L.parvulus both colonise crops in May, attacking the emerging seedlings and young plants. Eggs are laid in the soil and the new generation emerges in mid-July, remaining in the field to feed until crop senescence. Serious infestations of these beetles have been reported in flax crops in France, Holland and Germany, but work in France suggests that the most serious damage occurs when young plants less than 7cm high are attacked (Beaudoin, 1989). Infestations in England and Wales were at low levels or absent in 1988, with slightly higher numbers being recorded in 1989. These beetles are common in hedgerows and despite these low infestations, if the area of linseed planted continues to expand or the crop is grown more intensively then flea beetles could become more damaging, particularly to establishing crops.

Previous studies have suggested that flax tortrix moth occurs in very low numbers in linseed, and causes only slight damage (Anonymous, 1982; Turner, 1987). Current work supports this view and showed that control measures are unlikely to be worthwhile. The widespread occurrence of small infestations of the leaf miner P.horticola was detected for the first time during this survey. However numbers of leaf miners were also too low to significantly reduce the yield of crops affected. Thus both these insects are unlikely to cause widespread damage to linseed crops at present.

If control measures are required for insect pests then careful choice of pesticides and application method is essential. Although linseed is largely self-pollinated, cross pollination is possible and the crop

produces small quantities of nectar. Observations made in this survey suggest that bees are attracted in large numbers and warrant serious consideration when deciding on pesticide usage.

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Session 5

Biological and Integrated Control of Pests

PREDATORS, MELIGETHES AND PHYLLOTRETA IN UNSPRAYED SPRING OILSEED RAPE

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Abstract

Pollen beetles, *Meligethes* spp., and flea beetles, *Phyllotreta* spp., were more abundant in *S. alba* than in *B. napus* before the beginning of July. Significantly more *Meligethes* spp. larvae were found in *B. napus* plant parts than in *S. alba*. The most abundant predators found in pitfall traps were two carabid spring breeders and spiders.

1. Introduction

In Sweden it is practically impossible to grow spring oilseed rape without insecticide input. This means that it is impossible for farmers using an organic approach to incorporate oilseed rape into their crop rotations. During the summer of 1991 populations of *Meligethes* spp., *Phyllotreta* spp. and *Ceutorhynchus assimilis* were monitored in a field on an organic farm. The field was planted with oilseed rape while two edges were planted with *Sinapis alba*. Pitfall traps were placed from the field edge into the middle of the crop. The occurrence of carabids, staphylinids, spiders and other predators was monitored. The goal was to see if generalist predators occur at a time when they may have an impact on insect pest populations. We also wanted to explore the possibility of using trap crops in organic farming.

2. Materials and Methods

On an organic farm near Uppsala, Sweden a field was sown with spring oilseed rape, *Brassica napus*. Two of the field edges (6m into the field), at right angles, were sown with *S. alba*. In the middle of the oilseed rape field eight 5m X 5m plots were measured. Four randomly selected plots were treated with mustard meal on 31 May 1991. The other

four plots were used as controls. Mustard meal has been tested as a herbicide and there have also been indications that cabbage fly infestations in cabbage have been lower where the mustard meal is spread on the ground (Jonasson 1989). We wanted to see if the mustard meal would attract or deter pests.

Pests and enemies were monitored in the following ways: 1) Counts of the pollen beetle, *Meligethes* spp., were made on 50 randomly selected plants in both *S. alba* and *B. napus*, weekly for seven weeks. 2) Yellow and blue sticky traps were placed in the two areas. These were changed about once a week for seven weeks. The number of pollen beetles, *Meligethes* spp., and pod weevils, *C. assimilis*, on each trap was counted. 3) Four pitfall traps were placed in *S. alba* and four in *B. napus*. The traps were emptied weekly over a period of 12 weeks. Species of potential predators and pests were identified and counted. 4) About three weeks after the maximum occurrence of *Meligethes* spp. in oilseed rape samples of buds and flowers from 10 plants were taken in the eight plots in *B. napus* and also form *S. alba*. The samples were frozen until the plant parts could be dissected and larvae and eggs counted. Random samples of 15 buds and 15 flowers were dissected from each plot and from *S. alba*. A further sample of 18 buds from *S. alba* and 20 buds from untreated *B. napus* were measured and dissected.

3. Results and Discussion

1) Counts of pollen beetles on plants are shown in Fig. 1. Until 8 July beetles were most abundant in *S. alba*. On 2 July *S. alba* was starting to flower (less than 50% of all buds flowering) while in *B. napus* buds on flower stalks were extending. The weather was also dry and warm for the first time that week after a cool and rainy early summer. *S. alba* develops faster that *B. napus* and buds suitable for oviposition may have occurred earlier in the mustard crop.

2) Occurrence of pollen beetles and pod weevils on sticky traps is shown in Table 1. About the same number of pollen beetles are found on both colors. The higher numbers found on the last date may be newly emerged beetles. Yellow traps obviously attract pod weevils. By 17 July pod development had begun in both crops.

Table 1. Number of pollen beetles and pod weevils on sticky traps of two different colors. Uppsala 1991.

Date	*Meligethes* spp. Blue	*Meligethes* spp. Yellow	*Ceutorhynchus assimilis* Blue	*Ceutorhynchus assimilis* Yellow
26 Jun	20	3	1	4
2 Jul	35	43	2	55
8 Jul	130	25	8	76
17 Jul	21	45	1	79
22 Jul	4	6	0	1
29 Jul	6	35	0	32
9 Aug	75	73	1	3
Total	291	230	13	250

3) Pitfall traps were the most relevant sampling system for flea beetles, *Phyllotreta* spp. Flea beetles move often on the ground and the passive sampling with pitfalls will give some measure of abundance. Counts of flea beetles per trap are shown in Fig. 2. In general, more were caught in *S. alba*. Mustard has been shown to have some resistance against flea beetles (Bodnaryk & Lamb 1991). One might hypothesize that greater catches are due too more movement in a less desirable crop. The end of the flea beetle oviposition period and overwintered generation usually occurs around the beginning to middle of July (Ekbom 1991) which is mirrored in the catches falling off after 15 July.

Only a few predators were numerous in the pitfalls. The patterns of occurrence for *Bembidion* spp., *Pterostichus cupreus* and spiders are presented in Figs. 3, 4 & 5. The two carabids occur early in the season and may be eating flea beetles. Larval overwintering carabids (e.g. *Pterostichus melanarius*, *Trechus* spp.) which occur in their adult stage later in the season were very sparse. Spiders increase in abundance later in the season. This may be due to increasing crop cover and a better microclimate for the spiders. Pollen beetle larvae dropping to the ground for pupation could potentially be prey for these spiders. Almost no coccinellids were caught in the pitfalls and very few were seen on the plants.

4) No difference in plant emergence was found when the plots treated with mustard meal were compared to the control plots. There is therefore no evidence of any effect on flea beetles.

Mean number of larvae found in the two treatments in *B. napus* and in *S. alba* are shown in Table 2. There is no statistical difference between the mustard meal treatment and the control for either buds ($t=1.44$, $df=118$, $p>0.05$) or

flowers (t=1.16, df=118, p>0.1). There is, however, a statistically significant difference between the mean number of larvae found in *S. alba* plant parts and the mean number found in the two *B. napus* treatments. (Buds: S.a. vs control, t=4.48, df=73, p<0.001; S.a. vs mustard meal, t=4.08, df=73, p<0.001; Flowers: S.a. vs control, t=4.96, df=73, p<0.001; S.a. vs mustard meal, t=5.06, df=73, p<0.001).

Table 2. Mean number of larvae found in buds and flowers of *S. alba* and *B. napus*. Samples taken 26 July 1991.

Treatment	N	Buds	N	Flowers
S. alba	15	0.13	15	0.47
B. napus, control	60	2.42	60	3.42
B. napus, meal	60	1.93	60	2.98

In Table 3 results from measurements of buds and dissections for eggs and larvae are shown. Again there is a statistically significant difference in the number of larvae found in buds from the two crops. The number of eggs per bud and size of bud is greater in *B. napus*, but not statistically.

Table 3. Mean length of buds, mean number of eggs and larvae of pollen beetles. Samples taken 26 July 1992. Standard error in parentheses.

Treatment	N	length(mm)	larvae	eggs
S. alba	18	4.08 (0.12)	0.17 (0.09)	0.61 (0.18)
B. napus	20	4.33 (0.19)	1.7 (0.42)	1.2 (0.34)
t test		t=1.06	t=3.37	t=1.49
P		0.30	0.001	0.15

Bud sizes are well over the 2 mm threshold for oviposition shown by Nilsson (1988). More larvae than eggs were found in the buds and flowers. The mean number of larvae per *B. napus* bud in this study was about the same as the number of eggs per bud with eggs in Nilsson (1988). However, a higher number of larvae were found in the flowers

than in the buds. This could be due to larvae moving about or it could reflect more intensive oviposition at an earlier date.

4. Concluding remarks

Unfortunately the pest pressure exerted by pollen beetles in unsprayed oilseed rape seems to be too great to be overcome by trap crops or predators. In a more conventional setting, however, there may be a positive effect of trap cropping. If the field edges had been sprayed when most pollen beetles were still in *S. alba* perhaps fewer pollen beetles would have moved into the oilseed rape crop. It is interesting that *Meligethes* spp. was found first in *S. alba* and seemed to prefer that crop for a period of at least 2 weeks but did not utilize *S. alba* for oviposition to the same extent as *B. napus*. One might speculate that glucosinolate levels in *S. alba* are higher than in commercial rape varieties and potential negative effects on the insects are also greater in *S. alba*.

5. Acknowledgments

We thank Kjell Sjelin for letting us use his field. We also thank Swedish National Board of Agriculture for financial support.

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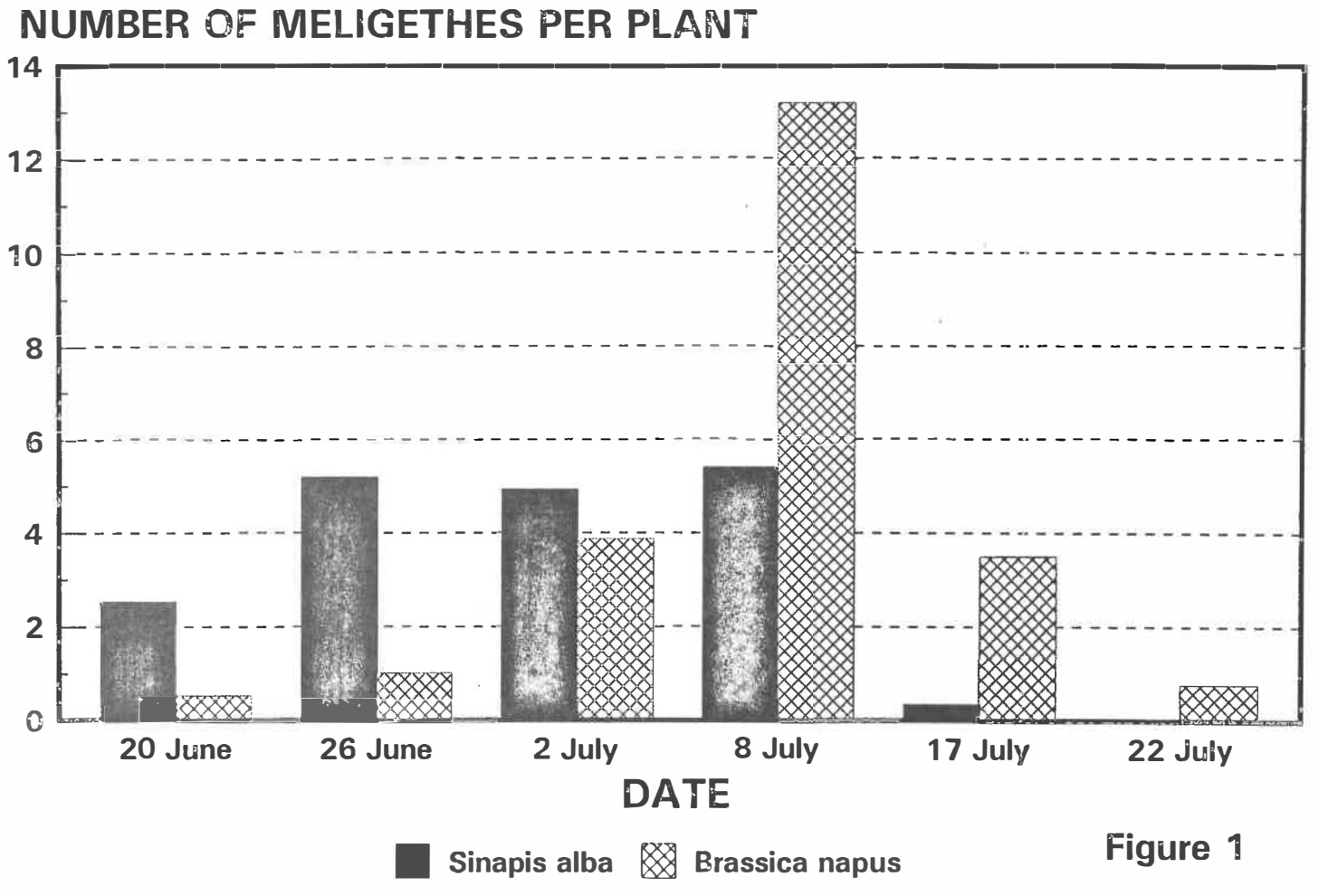
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8
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4
2
0
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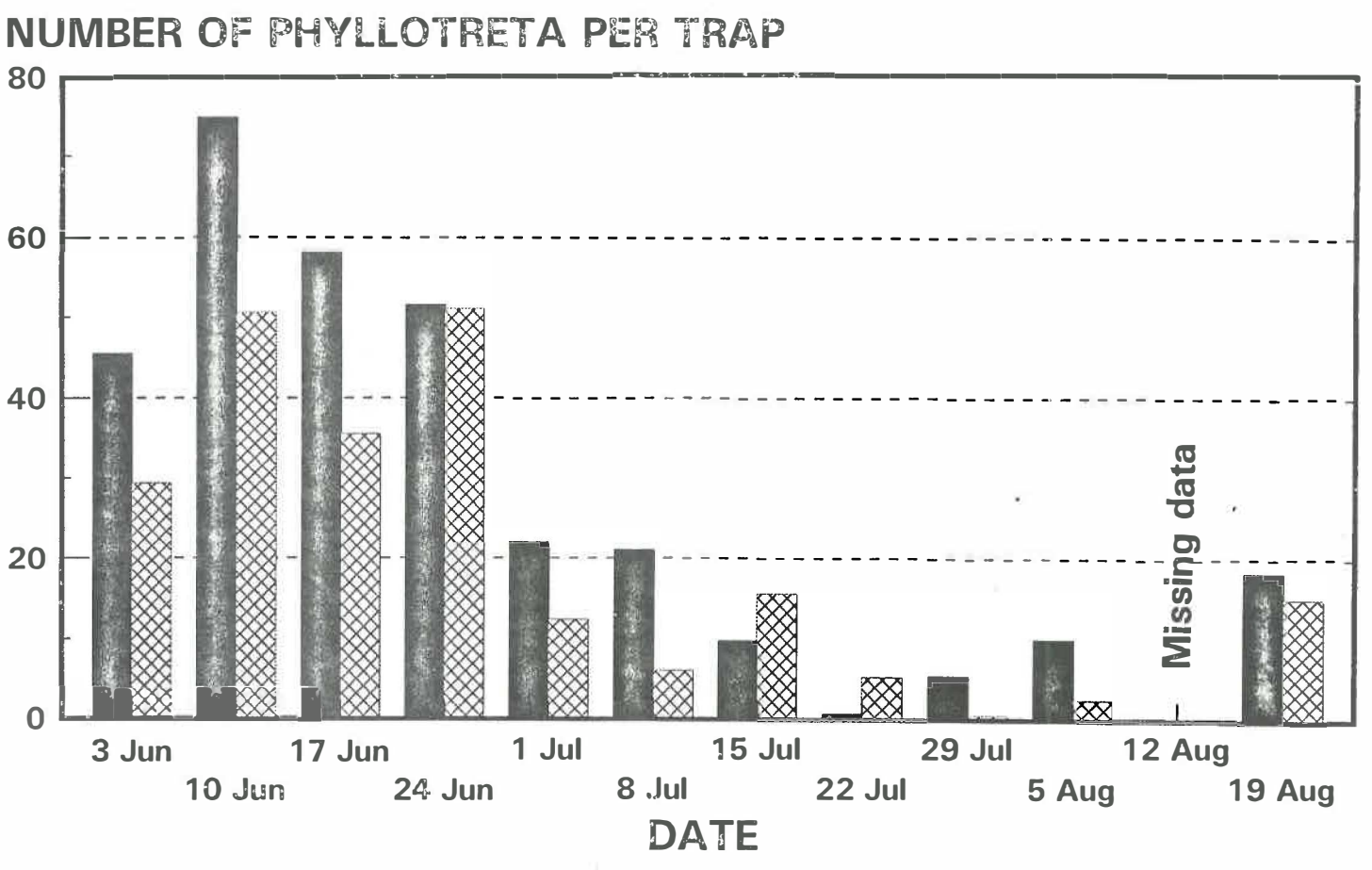
26 June
2 July
8 July
17 July
22 July
DATE
Sinapis alba
Brassica napus

Figure 1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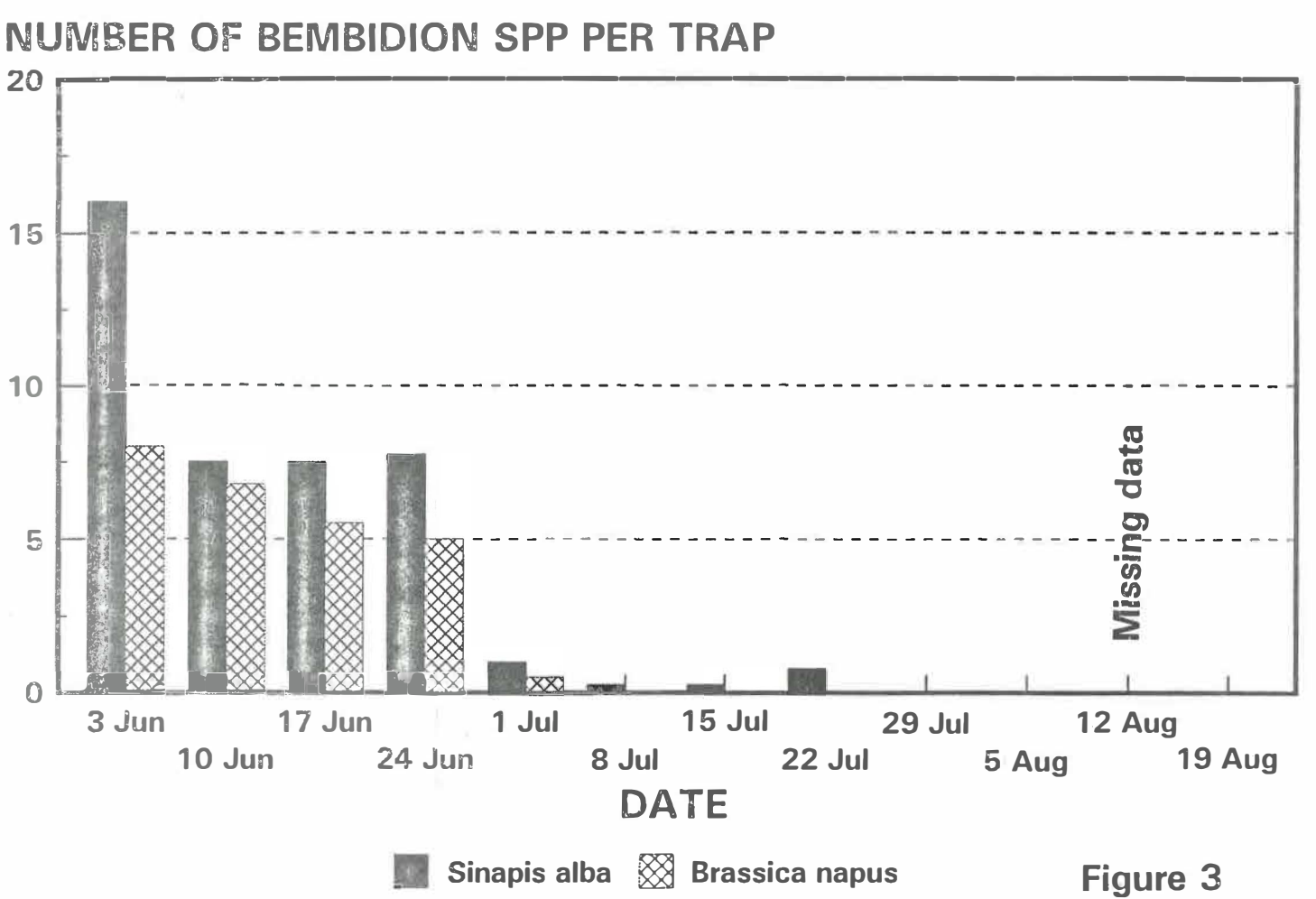
DATE
Sinapis alba
Brassica napus

Figure 2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5 Aug
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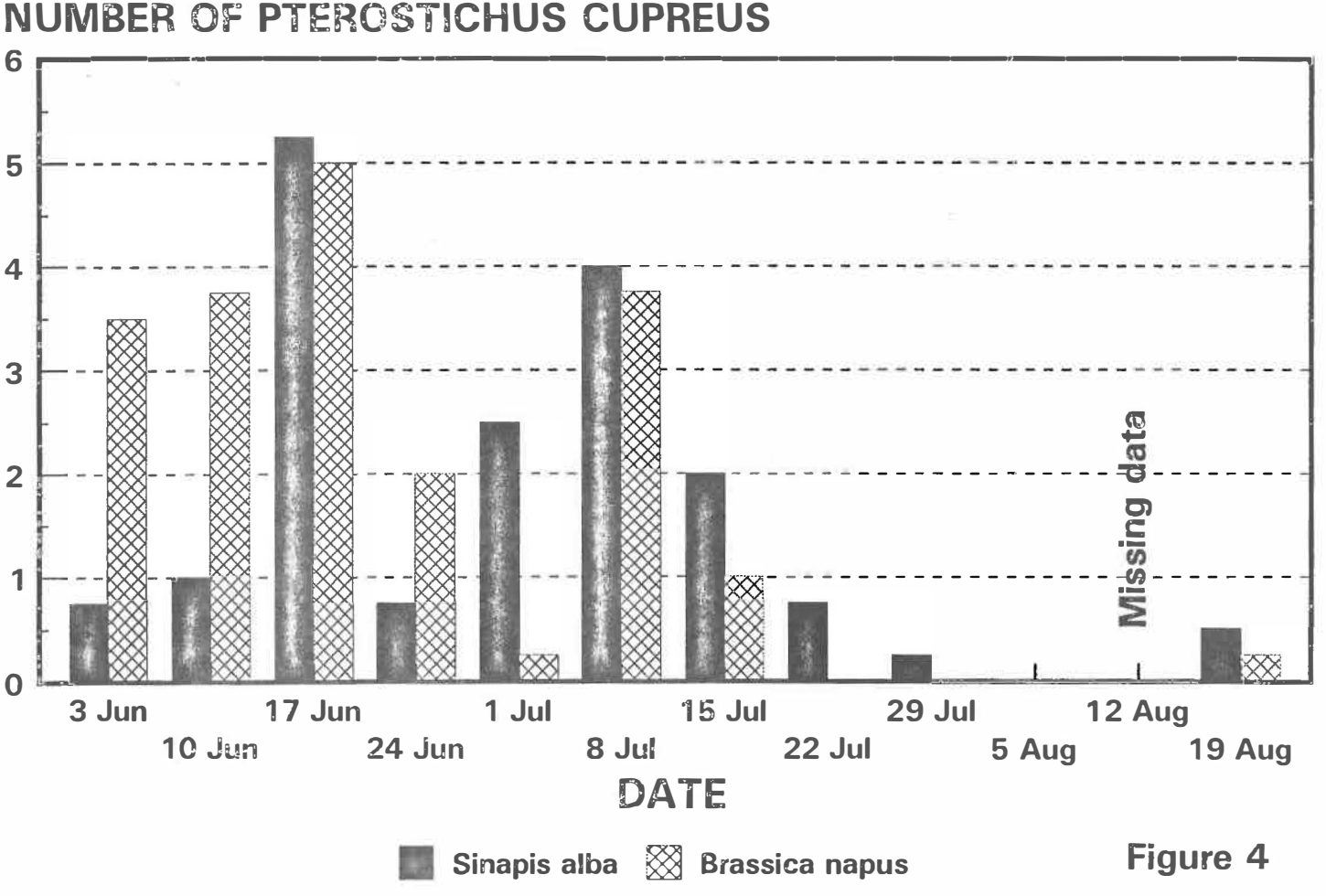
19 Aug
DATE
Sinapis alba
Brassica napus

Figure 3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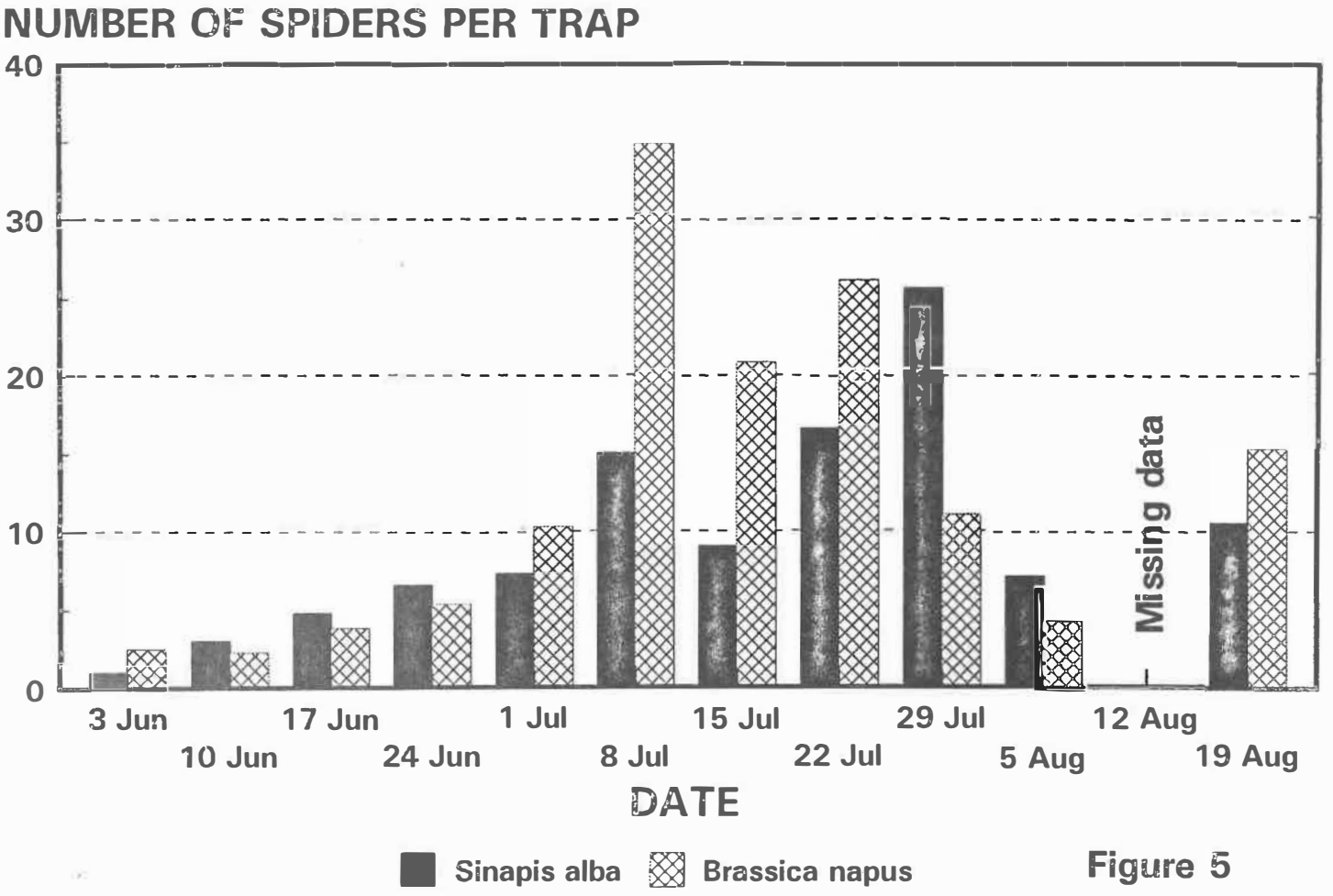
12 Aug
19 Aug
DATE
Sinapis alba
Brassica napus

Figure 4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10 Jun
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1 Jul
8 Jul
15 Jul
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29 Jul
5 Aug
12 Aug
19 Aug
DATE
Sinapis alba
Brassica napus

Figure 5

RECENT INCIDENCE AND COST EFFECTIVE CONTROL OF PESTS OF OILSEED RAPE IN ENGLAND AND WALES

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Abstract

Although widely distributed, infestations of cabbage stem flea beetle (Psylliodes chrysocephala) were low from 1989 to 1991. Autumn infestations of beet western yellows virus (BWYV) aphid vectors have declined slightly since 1989 but BWYV infection has remained high. Numbers of pollen beetles (Meligethes spp.) have remained high since 1986, but infestations of seed weevil (Ceutorhynchus assimilis) have fluctuated over the last 10 years. Despite low or variable pest levels, the area of rape treated with an insecticide in 1990 was more than double that of 1988. With the prospect of lower returns for oilseed rape with the introduction of a new Commission support scheme, economic thresholds for insect pest control need to be re-assessed.

1. Introduction

In the UK, winter oilseed rape continues to occupy the largest arable area after wheat and barley. There was an increase in the area grown from 347,000 ha in 1988 to 390,000 ha in 1990 (Anon 1991), increasing still further to a provisional forecast of 445,000 ha in 1991. The profitability of oilseed rape up to 1991 has resulted in an increased insecticide usage and the area treated with insecticide in 1990 was double that recorded in 1988 (Davis, Garthwaite & Thomas, 1991).

ADAS and MAFF CSL Entomologists have continued to monitor winter oilseed rape crops regularly to record the spread of establishment pests in the autumn and the importance of pests attacking buds, flowers and pods in spring and early summer (Cooper & Lane, 1991). Current research is aimed at improving effective control methods and investigating the biology of the major pests of oilseed rape in the UK together with the development of economic thresholds to reduce unnecessary spraying of crops.

A new Commission support scheme for the major oilseeds will take effect from 1 July 1992. Support will take the form of a direct per hectare payment to farmers, the rapeseed then being sold on the market at world price (1991, £130/t). Return to the farmer will be maintained by the area payment but the benefit from pesticide inputs will be significantly offset by the reduction in price per tonne of rapeseed. As a consequence, economic thresholds for insect pest control need to be re-assessed.

2. Pesticide usage

A comparison of insecticide usage survey data for 1988 and 1990 shows that the area of oilseed rape treated with an insecticide more than doubled in 1990 despite only a slight increase in the area of crop grown (Table 1).

This was accounted for largely by the increased use of pyrethroid insecticides for the control of establishment and flower/pod pests.

Table 1. Insecticide usage on oilseed rape in England and Wales in 1988 and 1990

Group	1988 ha (000)	1988 t	1990 ha (000)	1990 t
Organochlorine	22.0	11.4	19.2	8.4
Organophosphate	58.1	34.8	70.7	29.1
Carbamate	1.4	0.3	6.1	0.8
Pyrethroid	166.4	3.9	448.5	8.2
Total	256.1	50.5	546.2	46.5
Area Grown	347		390	

Whilst the oilseed rape crop has remained profitable to grow, insecticide usage, especially of the relatively cheaper pyrethroids, has increased. This is in spite of pest levels being below the treatment threshold in many areas. With the imposition of the new support system for oilseed rape, it is unlikely that this level of insecticide usage can be sustained.

3. Survey of autumn/winter pests

A. CABBAGE STEM FLEA BEETLE

The most important autumn/winter pest is the cabbage stem flea beetle (Psylliodes chrysocephala) (Cooper & Lane, 1991). The pest now occurs in most areas of England and Wales where rape is widely grown, its distribution being similar to that reported by Lane & Cooper, 1989. The incidence of cabbage stem flea beetle in unsprayed crops during the autumn and early winter has been monitored over the last three seasons. Mean levels of infestation of larvae assessed from 25 plants per crop, are shown in Table 2.

Table 2. Incidence of cabbage stem flea beetle larvae on unsprayed crops 1989/90 - 1991/92

	No. fields	Mean no. larvae/plant (range)	Fields with > 5 larvae/plant
1989/90	100	1.5 (0-34.2)	6
1990/91	111	0.18 (0-2.6)	0
1991/92	106	0.24 (0-5.8)	1

Although the data set from the 1991/92 survey is incomplete, the results show that overall, infestations of cabbage stem flea beetle larvae have been low over the period 1989/90 to 1991/92; very few fields exceeding the autumn/early winter treatment threshold of 5 larvae/plant.

B. APHIDS AND BEET WESTERN YELLOWS VIRUS

In some autumns, aphids can be potentially damaging pests of oilseed rape. Large numbers of cabbage aphid (Brevicoryne brassicae) or peach-potato aphid (Myzus persicae) can reduce crop vigour. However, they may be of greater importance as vectors of beet western yellows virus (BWYV). ADAS surveys since 1986 (Hill, Lane & Hardwick, 1989) have confirmed the widespread occurrence of BWYV in winter rape. Its significance in the crop is not certain, although insecticide trials have shown that yield responses to aphid vector control can be obtained (Walsh et al.,1989).

As part of the survey to assess incidence of cabbage stem flea beetle, plants were examined for aphids and infestation levels of M. persicae and B. brassicae recorded as shown in Table 3.

Table 3. Incidence of M. persicae and B. brassicae on unsprayed crops 1989/90 - 1991/92

	No. fields	% crops infested	
		M. persicae (>1 per plant)	B. brassicae (>1 per plant)
1989/90	100	50 (40)	40 (20)
1990/91	111	27 (2)	22 (1)
1991/92	106	28 (2)	8 (0)

Since the autumn of 1989, fewer crops have been infested with aphids and infestation levels much reduced.

As part of the ADAS/CSL national pest and disease survey of oilseed rape, crops are sampled each spring and assessed for beet western yellows virus (BWYV) infection. The oldest non-senescent leaf is taken from each of 10 plants per crop and tested for the presence of BWYV using ELISA (Hill, 1984). Incidence and distribution of virus infection over the period 1987-1991 is shown in Table 4.

Table 4. Incidence and distribution of beet western yellows virus 1987-1991

ADAS Region	% virus infection 1987	1988	1989	1990	1991
Northern	7	4	49	81	64
Midlands & Western	9	14	25	86	45
Eastern	4	8	29	66	52
South East	12	16	27	65	35
South West	25	46	44	78	46
Wales	45	30	13	65	55
% crops infested	36	44	75	98	90
mean % infection	12	17	33	74	49

The results clearly show that since 1987 when sampling commenced, the incidence of BWYV has increased. By spring of 1990, almost every crop sampled was infected, a reflection of the aphid infestation levels in the previous autumn.

Despite the uncertainty over the effects of BWYV on oilseed rape, many UK farmers perceive the virus to be a limiting factor. This has resulted in the widespread use of pyrethroid insecticides in the autumn to control both aphids and cabbage stem flea beetle. Prophylactic applications of insecticides to control aphids are not recommended. However, it is recognised that where a pyrethroid insecticide is applied in early autumn to control flea beetle, this will give incidental control of aphids and so reduce virus infection levels. On-going work by ADAS/CSL Entomologists is attempting to quantify further the damaging effects of cabbage stem flea beetle and BWYV and their interactions.

4. Surveys of flower/pod pests

The annual surveys previously reported by Cooper & Lane (1990), have continued in order to gain further information on the incidence of pollen beetles (*Meligethes* spp.) and cabbage seed weevil (*Ceutorhynchus assimilis*). Each year a minimum of 50 unsprayed crops, forming a representative sample from the main rape growing areas is monitored during the flowering period. Pollen beetles and seed weevils are beaten onto a white tray from the main flowering racemes of 20-25 plants and numbers per plant recorded. Mean counts from samples taken at full flowering of the crop each year are shown in Table 5.

Table 5. Incidence of pollen beetle and seed weevil on unsprayed crops during flowering 1982-1991

	No. fields	Mean no. beetles /plant	Mean no. weevils /plant	% fields with 1 or more weevils	No. fields with 2 or more weevils
1982	70	0.55	0.27	6	-
1983	76	0.65	0.48	12	-
1984	74	0.44	0.35	8	-
1985	65	0.74	0.65	26	-
1986	63	0.75	0.34	5	-
1987	52	4.61	0.31	10	-
1988	92	3.27	0.26	4	-
1989	76	5.87	0.58	16	-
1990	68	4.72	0.70	9	2
1991	81	4.54	0.48	11	1

The incidence of pollen beetle increased substantially in 1987 and has since remained high. However, in these monitored crops the current ADAS threshold of 15 or more beetles per plant at green/yellow bud, applicable at this susceptible stage, was not reached by that time. Occasionally, in a few crops, numbers exceeded this value, at the peak of beetle activity during full flowering. The increased incidence of pollen beetle has stimulated new damage assessment work on winter oilseed rape which is currently on-going.

Numbers of seed weevil have fluctuated over the last 10 years reaching a peak in 1990 with a mean of 0.70 weevils per plant (Table 5). In 1991 only 11% of crops monitored were above the treatment threshold of one weevil per plant. If the threshold is set higher at 2 weevils per plant then only 3 crops out of a total of 149 monitored in 1990 and 1991, would have required insecticide treatment.

The current threshold of one weevil per plant during flowering, can sometimes prove unreliable (Cooper & Lane, 1990), especially in Northern England. This may be due to the extended flowering period in this area or the cooler weather conditions usually prevailing at the time of flowering. Work is continuing to develop correction factors which can be applied to weevil counts made under sub-optimal conditions and so improve the reliability of the threshold.

5. New price support system for oilseed rape: A re-assessment of economic thresholds for pests of oilseed rape

The thresholds currently in use for the major oilseed rape pests and revised thresholds post harvest 1992 are shown in Table 6. Calculations have been based on a lower return of £130/t (1991 World price) and an average UK yield of 3 t/ha for winter rape and 2.2 t/ha for spring rape.

Table 6. Thresholds currently in use for major oilseed rape pests and adjusted post-harvest 1992

Pest	Time/growth stage	Threshold-Mean no/plant Current	Revised
Cabbage stem flea beetle larvae	October-December	5	5
	Crop backward/thin	3	3
Aphids	September-October	Spray if easily found	
Pollen beetle	Winter rape; green/yellow bud	15	15
	Winter rape; backward/poorly growing	5	5
	Spring rape; green/yellow bud	3	3
Seed weevil alone	Winter rape; during flowering	1	2
Seed weevil plus fungicide tank-mix	" "	0.5	1
Seed weevil plus pod midge	" "	0.5	1
Seed weevil alone	Spring rape before flowering	1	2

Autumn pest control is still likely to be cost effective in most situations, despite lower returns. The cost of a pyrethroid plus application being relatively inexpensive at £8/ha.

For pollen beetle control, cost of treatment with a pyrethroid is £20/ha for winter rape (including application and wheeling damage) and £18/ha for spring rape. Advice is unchanged. Most winter crops will not need treatment. For spring rape it is cost-effective to spray once at 3 or more beetles per plant but not at lower infestation levels. A repeat spray

for pollen beetle before flowering will only be cost-effective if incidental control of seed weevil and stem weevil is achieved.

For seed weevil/pod midge control on winter rape, cost of treatment with a pyrethroid at flowering is £25/ha and for triazophos (post-flowering), £34/ha. For seed weevil control only, it will be cost effective to spray only when weevils exceed 2 per plant and more profitable to use a pyrethroid. Results from recent surveys, however, would suggest that very few crops would require spraying at this threshold (Table 5). Where pod midge is a significant problem in the area, it then becomes cost effective to spray at 1 weevil per plant. Similarly when tank mixing with fungicide and apportioning costs of application and crop damage, it becomes cost effective to spray at 1 weevil per plant, but only with a pyrethroid.

For seed weevil control on spring rape, losses are assumed to be similar to those recorded for winter rape. Consequently it is unlikely to be cost effective to spray for seed weevil unless populations exceed 2 weevils per plant.

6. Prospects

ADAS/CSL surveys have indicated that populations of oilseed rape pests vary greatly from season to season. This demands close crop monitoring and use of treatment thresholds where appropriate, to prevent the overuse of insecticide which is expensive and could be environmentally detrimental. On-going work evaluating the importance of autumn pests, pollen beetle and seed weevil, has an important role in minimising the unnecessary use of pesticides.

Recent pesticide usage surveys have demonstrated that whilst oilseed rape has attracted profitable returns, farmers have been less inclined to cut-back on insecticide inputs. However, with the prospect of lower returns for oilseed rape, some current inputs will cost more than the benefit accruing. It is likely, therefore, that the current level of insecticide usage on oilseed rape, especially for flower/pod pest control will not be maintained.

It is also possible that there could be a major shift to cropping of spring-sown oilseed rape because it has lower input requirements than winter rape. This could stimulate the need to investigate the incidence and importance of pests of spring rape in the UK which have not been researched for almost 20 years.

7. Acknowledgements

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STUDIES OF THE OVIPOSITION DETERRING PHEROMONE OF THE CABBAGE SEED WEEVIL (*CEUTORHYNCHUS ASSIMILIS* PAYK.): BEHAVIOURAL BIOASSAYS AND OVIPOSITION BY WEEVILS WINTERED IN THE LABORATORY.

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Abstract

A simple choice bioassay was used to confirm that, after ovipositing in a pod of oilseed rape, the seed weevil deposits an oviposition deterring pheromone (ODP) by brushing her abdomen on the pod and that the deterrent effect lasts 1-2 h. Observations have suggested that the ODP is perceived by contact chemoreception rather than olfaction and accordingly the bioassay has been modified. The new bioassay protocol is described and its advantages discussed. It gives additional information about the behaviour of individual weevils, it provides a check on weevil responsiveness during experiments and it further reduces the importance of positional bias. The survival rate of weevils in winter and summer conditions in the laboratory was good. In the spring, fewer laboratory overwintered weevils than field-collected weevils oviposited and the numbers that did so increased more gradually.

1. Introduction

After ovipositing into a pod of oilseed rape (*Brassica napus* L.), the cabbage seed weevil (*Ceutorhynchus assimilis* Payk.) brushes the tip of her abdomen from side to side against the pod as she walks up and down it. Kozlowski *et al.*, (1983) described oviposition behaviour in detail and obtained experimental evidence that untouched pods were preferred for egg-laying to pods recently used for oviposition. They attributed this preference to the presence of an oviposition deterrent which they showed was chemical in nature and associated not with oviposition itself, nor with weevil faeces or pod sap but with abdomen brushing (Kozlowski *et al.*, 1983; Kozlowski, 1991). They suggested that the chemical was an oviposition deterring pheromone (ODP) produced by female weevils.

The seed weevil is an important pest of oilseed rape and its ODP clearly has potential for use in its control. We have therefore started a multidisciplinary study to isolate and chemically identify the pheromone and test it in integrated management of this pest. Ferguson and Williams (1989, 1991) divided the sequence of seed weevil activities making up oviposition behaviour into its component parts and tested each individually for deterrent effect. We confirmed the finding of Kozlowski & Dmoch (1985) that the deterrent was associated only with abdomen brushing and that its effect was short lived, lasting 1-2 h only. Although other females respond to it, the primary function of the deterrent may be to prevent an individual from repeatedly ovipositing in

the same pod (Ferguson & Williams, 1991; Kozlowski, 1991). For this reason, Kozlowski (1991) argued that it was more correctly called a marker than a pheromone.

In their tests, Kozlowski *et al.* (1983) sometimes presented weevils with single pods (counting the number of pod visits before egg-laying occurred) and at other times with a choice of four pods (two treatments; counting the number of ovipositions in each pod). The choice tests more closely resembled the natural situation. Furthermore, ODPs are not absolute deterrents but behavioural modifiers (Sakai *et al.*, 1986; Klijnstra & Bruggemann, 1988) and therefore the response of an individual to ODP will depend partly upon the strength of its drive to oviposit. Choice tests measure relative responses and so are less affected by inter-individual differences in drive or in sensory sensitivity to ODP. We developed a simple bioassay in which two pods with different treatments were presented to a weevil and the site of first oviposition was recorded (Ferguson & Williams, 1991). Our results supported the conclusion that the ODP is of low volatility and probably perceived by contact chemoreception (Kozlowski, 1984; Ferguson & Williams, 1991). If this is so, then in a true choice test individual weevils must have the opportunity to examine both pods closely. In the present paper we describe modifications to our bioassay to allow this and to give more information about individual weevils. The method also provides a check on individual responsiveness and further reduces the importance of positional bias.

In the field *C. assimilis* overwinter as adults in soil or litter (Dmoch 1965). Ni *et al.* (1990) overwintered *C. assimilis* in the laboratory. Weevils had completed diapause after 16 weeks and after a period of feeding on rape racemes, the ovaries of most females were fully developed. They did not test oviposition behaviour. The ability to overwinter weevils in the laboratory and bring them early to sexual maturity and readiness to oviposit could extend the season for studying ODP. Here we compare the oviposition performance of weevils wintered in natural or laboratory conditions in 1989/90.

2. Materials and Methods

Seed weevils were collected from a crop of winter oilseed rape and maintained on cut oilseed rape racemes in nylon mesh bags in the laboratory. In each test (both old and new bioassay protocols) two size-matched oilseed rape pods (13-16 mm long) attached to 50-80 mm bare lengths of stem (stripped of other pods, flowers or leaves) were selected. These were presented in a Y or T-configuration (with stems positioned contiguous to one another) supported in a water-saturated porous block ('Oasis'). Each pod received a different treatment immediately before the start of a test when a female weevil was introduced to the base of one stem. In the original bioassay protocol, the criterion for completion of a test was that a single oviposition had occurred. If no eggs were laid within 30 min the test was abandoned. A record was made of which pod the weevil examined first and whether it rejected one pod before ovipositing in the other. Experiments consisted of 20 tests. In the revised protocol there were three criteria for completion of a test: that the weevil should have examined each pod at least twice; that this occurred within 60 min (ODP activity persists 1-2 h); and that oviposition occurred at least once within 30 min (indicating that the weevil is able and ready to oviposit). For each pod a record was made of whether the weevil accepted or rejected it for oviposition during the first two visits. The small number of tests in which a weevil oviposited twice

in the same pod were discarded and results were analysed as a contingency table (classified by treatment and response) using generalised linear models. Full details of experiments and treatments tested using the original protocol, of the test apparatus and insect maintenance techniques are given elsewhere (Ferguson & Williams, 1991). We present here the results of one additional experiment using the revised protocol to test the deterrent effect of pod exudate when spread over the pod surface.

In late June 1989, winter rape plants infested with seed weevil larvae were collected from the field and placed over trays of moist potting compost (peat:sand 1:1 by volume) in a controlled environment room (day/night: 18°C/10°C; 70% RH/50% RH; 16 h day). Mature larvae emerged from the pods, dropped into the compost, pupated and adult weevils emerged by the end of July. These were maintained on flowering racemes of oilseed rape in the same conditions for three weeks. Temperature was then reduced to 15°C/10°C day/night and day-length to 14 h for a further two weeks. On 31 August weevils were transferred to plastic trays (140 x 200 x 50 mm tall; 135 weevils per tray) containing a litre of moist potting compost and covered with nylon mesh. Trays were kept at 10°C with a 12 h day for three days and thereafter at 5°C in the dark; the compost was kept damp. Most weevils were removed from the trays in early May 1990 and placed on cut racemes of rape maintained in 'summer conditions' at 16°C/9°C day/night with a 16 h day. Weevils were collected from the field in late April 1990 and maintained in the same way. All weevils were kept in groups of mixed sex. Field and laboratory-overwintered weevils were regularly tested for their ability to oviposit when placed in cages with two oilseed rape pods (13-18 mm long) for 24 h at 18°C.

3. Results and Discussion

Summaries of the results obtained using the original bioassay protocol are presented in Tables 1 & 2. The ODP was active for 1-2 h and deterrence was associated only with abdomen brushing. Tests of the significance of deterrence relied upon the number of tests in which oviposition occurred in test or control pods. Some useful information was also obtained concerning pod rejection for oviposition, e.g. weevils did not oviposit significantly less in pods brushed 2 h previously than in controls but they rejected the brushed pods for oviposition on 33% of explorations whereas controls were always accepted, so indicating some persistence of the deterrent. However, weevils examined both pods presented in only seven out of 20 tests at the most; in 87% of all tests only one pod was examined. This proportion is high because in most tests neither pod had an oviposition deterrent and weevils usually oviposited into the first pod they visited, terminating the test. In experiments where one pod had a deterrent, both pods were more often visited (Tables 1 & 2). Replication of tests and measures to reduce the effect of positional bias (e.g. alternation of the position of test and control pods and of the stem onto which the weevil was initially placed) ensured that both test and control pods were encountered first approximately equally. Therefore, conclusions drawn concerning the relative response of populations of weevils to the treatments were valid. However, information about the responses of individual weevils to both treatments would provide valuable supporting data.

Table 1. Effect of delay between pod brushing and testing on oviposition deterrence.

Delay between pod brushing and testing	Significant oviposition deterrence? ($P < 0.05$, exact binomial test, $n = 20$)	% pod explorations resulting in rejection		No tests out of 20 in which both pods were examined
		Test	Control	
None	YES	69	0	7
1 hour	YES	44	0	5
2 hours	no	33	0	3
24 hours	no	0	6	0

Table 2. Analysis of the role of individual components of egg-laying behaviour in conferring oviposition deterrence.

Component of behaviour tested	Significant oviposition deterrence? ($P < 0.05$, exact binomial test, $n = 20$)	% pod explorations resulting in rejection		No tests out of 20 in which both pods were examined
		Test	Control	
pod brushing	YES	100	6	6
presence of egg in pod	no	13	7	2
pod puncture (for oviposition)	no	0	0	0
pod puncture (for feeding)	no	0	9	1
pod puncture (with pin)	no	0	22	2
♀ weevil walked on pod	no	0	9	1

The results of an experiment using the revised test protocol are presented in Table 3. We have already demonstrated that plant volatiles and exudate released from a puncture in a pod has no deterrent effect (Ferguson & Williams, 1991). However, the tip of the abdomen can become wet with pod exudate during oviposition; in *Dacus oleae* an oviposition deterrent effect is associated with the smearing of olive exudate over the surface of the fruit (Cirio, 1971). Here we have confirmed Kozlowski's (1991) conclusion that pod exudate has no deterrent effect for *C. assimilis* even when smeared over the pod surface. There was no significant difference in the number of tests in which each treatment received the first oviposition and the new protocol now shows that the rate of rejection of both treatments was low (Table 3). A mean of 80 ± 14% of all pods were accepted and only 20 ± 7% were rejected on their first examination by weevils (estimated means and standard errors; n = 20). Furthermore, experimental treatment did not significantly influence the relative proportions of pod acceptance and rejection in either first or second pod examinations, supporting the conclusion that neither treatment deters oviposition. Such additional data is especially valuable where differences between treatments are small. The revised bioassay is currently in use for the identification of pheromone activity in chemical extracts, where sensitivity is particularly important.

Table 3. Effect of pod exudate on oviposition deterrence; tested using the modified bioassay.

Treatment of pod	No. tests (out of 20) in which weevil oviposited first in each pod	No. tests in which weevil rejected pod	
		on first examination	on first two examinations
Wiped with cut end of another pod	11	5	1
Untreated	9	3	1
P (exact binomial test)	0.82		

The new protocol allowed weevils to visit each pod twice. Sometimes a weevil which had oviposited into a pod and brushed it on its first visit was not deterred from repeating the behaviour on its second visit. Such behaviour was more common from mid July onward when weevils were aged; they may have had impaired functioning of their ODP sensory organs or of their pheromone glands, or perhaps had a stronger drive to oviposit and correspondingly were less responsive to ODP. They were therefore eliminated from experiments. This 'quality control' of weevils during tests had not been possible before. Positional bias was small: in 200 tests (Tables 1, 2 & 3) oviposition occurred first in the left-hand pod 82 times, and in the right-hand pod 118 times; on 54% of occasions weevils oviposited in the pod attached to the stem onto which they had been

placed at first. Experimental design was balanced to minimise the effect of position but when using the revised protocol weevils always explored both pods; therefore the additional data was probably even less influenced by bias.

Eighty percent of 675 weevils survived overwintering in the laboratory (243 days at 5°C). After they had been moved to racemes of rape in 'summer conditions', the mortality rate of another group of 116 overwintered weevils (206 days at 5°C) was 6% per week for the first 12 days. The latter compares favourably with 4% mortality per week over the first 16 days in the laboratory for 1180 weevils collected from the field on 25 April 1990 and with 10-27% mortality per week over 14 days reported by Ni *et al.* (1990) who transferred laboratory-overwintered weevils into temperatures ranging from 10-25°C.

The oviposition performance of laboratory-overwintered weevils was markedly poorer than that of field-collected individuals. In comparison to weevils collected from a crop of winter rape on 25 April 1990, the proportion of overwintered weevils (moved to 'summer conditions' on 4 May) that oviposited was smaller and increased more gradually (Fig. 1). When first tested, neither group of weevils oviposited but the proportion of field-collected weevils that did so increased rapidly to 80% by 15 May. Seed weevils need to feed for about three weeks on cruciferous plants before mature ovarioles are present in their ovaries (Williams & Free, 1978; Free & Williams, 1978, 1979; Ni *et al.*, 1990). Weevils collected from the field on 25 April may already have been feeding for some days whereas those overwintered in the laboratory did not feed until 4 May. However, even by early June only half as many laboratory-overwintered weevils oviposited as did field-collected weevils (Fig. 1). Although those individuals which did oviposit laid similar numbers of eggs in both groups (Fig. 2), seven out of the 40 laboratory-overwintered weevils tested in June deposited a total of 15 eggs on the surface of pods rather than inside them. On 15 June ten weevils from another laboratory-overwintered group (moved to 'summer conditions' on 28 March) were tested. Seven out of ten weevils laid a total of 23 eggs but 14 of these were left on the surface of pods.

All weevils survived well in the laboratory and the diet and other 'summer conditions' provided in the laboratory were adequate for oviposition to develop in field-collected weevils. Temperature, photoperiod and time are implicated in the control of diapause in other weevils (McGiffen & Meyer, 1986; Stevenson & Boivin, 1990). In our conditions, cues for the induction or completion of reproductive diapause may have been incorrect or absent for laboratory-overwintered weevils: there was no diurnal light cycle during winter; weevils were cooled in abrupt stages in autumn and warmed rapidly in spring; they had no opportunity to fly towards hosts or mates in spring. Ni *et al.* (1990) worked with a North American (Idaho) population of *C. assimilis* but maintained weevils over winter in the laboratory (4°C) with a 12 h photoperiod. When weevils were moved to 'summer conditions' similar to those used here (rape racemes, 15°C, 15 h day) the ovaries of 84% of them became fully developed within three weeks (oviposition behaviour was not tested). Lack of a diurnal light cycle could have impaired the control of diapause in the present study. Although their mortality was low, the reproductive tracts of our laboratory-overwintered weevils may have been affected by disease (ovaries were not examined); this might explain egg deposition on the outside surface of pods. In view of the good survival of weevils we are optimistic that further studies of overwintering in this weevil will facilitate our work on its ODP.

Fig. 1.

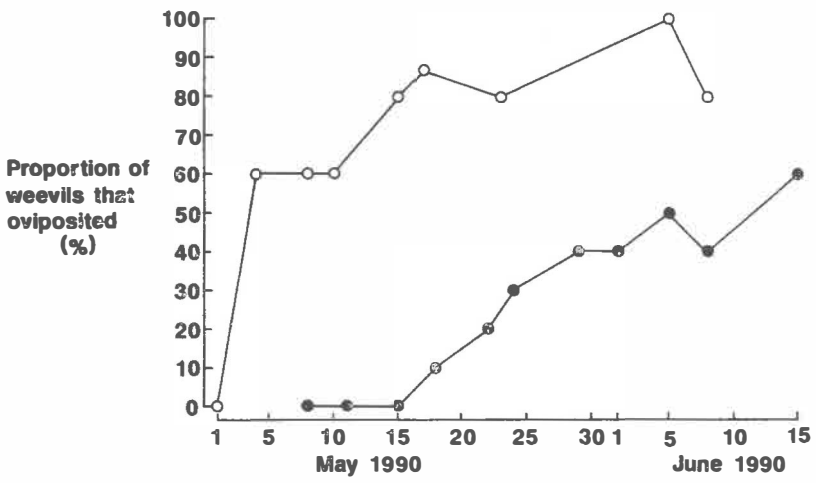
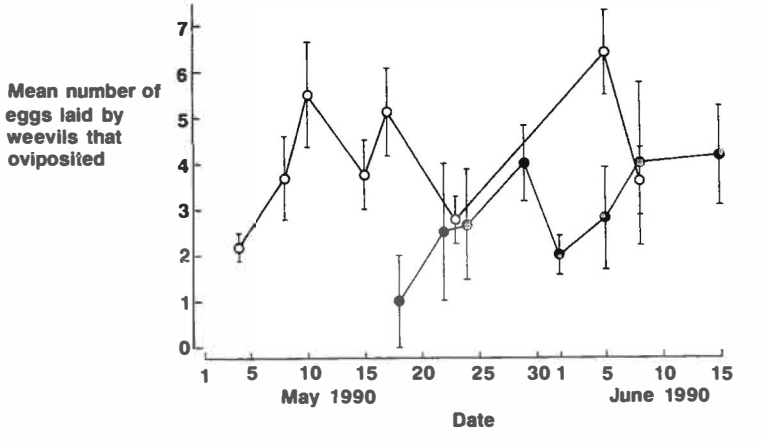


Fig. 2.



Key : ○ weevils overwintered in field ; collected 25 April
● weevils overwintered in laboratory ; emerged 4 May
Bar = 2 x standard error

Oviposition by field and laboratory-overwintered seed weevils in overnight tests:

Fig. 1 : the proportions of weevils that oviposited
Fig. 2 : the numbers of eggs laid by those weevils that oviposited

(n = 10 weevils except on 15 May when n = 5 for field-overwintered and 8 for laboratory-overwintered weevils and on 5 June when n = 5 for field-overwintered weevils)

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HOST PLANT FACTORS AFFECTING THE FEEDING OF CABBAGE STEM FLEA BEETLES (*Psylliodes chrysocephala* L.) ON OILSEED RAPE

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Abstract

Bioassays testing the acceptability of leaves (from cruciferous and non-cruciferous plants) to adult cabbage stem flea beetles and stems and leaves of these plants to larvae of the insect, showed that only plants that contained glucosinolates were eaten. Solvent extracts of plants, that contained glucosinolates but were not eaten, deterred feeding on oilseed rape when applied to it, indicating the presence of feeding inhibitors. Rape extract and glucosinolates stimulated feeding on agar when mixed with it.. No correlation was found between feeding on different cultivars of rape and their seed glucosinolate rating.

1. Introduction

Psylliodes chrysocephala L., the cabbage stem flea beetle, is an important pest of oilseed rape (*Brassica napus* L.) in the U.K. (Alford *et al.*, 1991). The adults feed on the leaves, and the larvae in the stem and leaf petioles but the host plant range of this beetle has not been thoroughly investigated. Previous studies on host plant selection of other crucifer feeding Chrysomelidae, e.g. *Phyllotreta* and *Phaedon* spp. has shown that their feeding seems to be confined to plants that contain glucosinolates, secondary plant compounds characteristic of the family Brassicaceae (Feeny *et al.*, 1970; Nielsen, 1989). We report here some studies to determine the role of host plant factors in feeding behaviour of the cabbage stem flea beetle.

2. Materials and Methods

Experimental procedures are only summarised here, some techniques are described more fully in Bartlet & Williams (1991) and Rawlinson & Williams (1991).

Adult feeding tests

(a) Leaf disc test

A disc (20 mm diameter) was cut from the leaf of the test plant and from the leaf of oilseed rape cv. Ariana (control), with a cork borer and pinned onto damp filter paper within a Perspex box. Ten beetles, previously starved for 24 h, were allowed to feed on the discs for 48 h, after which the area consumed from each disc was assessed using a

Joyce-Loebl 'Magiscan' image analyser. Each test was replicated five times. The feeding preference (f.p.) was calculated from

$$\text{feeding preference} = \frac{\text{area of test disc eaten}}{\text{area of (test \& control) disc eaten}} \times 100$$

Tests of the effects of plant extracts were made after dipping one oilseed rape disc in the test extract and another (control) into 50% aqueous ethanol, and allowing them to dry. A test and control disc were placed in a Perspex box and tested for feeding preference of the beetle as above.

(b) Agar tests

Agar (2%) was used as a feeding substrate; test chemicals were stirred into the agar solution during preparation after it had cooled to below 70°C. In dual choice tests, Petri dishes (90 mm diameter), partitioned with plastic into two halves, were prepared to contain agar alone in one half and agar with test chemical in the other half (depth 10 mm). Insects had free access to both sides of the partition. In multiple choice tests, cylinders (20 mm diameter, 3 mm deep) were cut from dishes containing agar or agar with test chemical using a cork borer and allocated to random positions around the edge of a Petri dish (90 mm diameter) lined with damp filter paper.

In both types of test ten beetles, starved for three days, were allowed to feed in each dish for three days after which the bite marks in the agar were counted. Seven to ten replicates of each test were made.

Preparation of leaf extracts

Water, chloroform or methanol extracts were made of plants that contained glucosinolates but were not eaten. The water and chloroform extracts were prepared by stirring lyophilized leaves (5 g) with solvent (200 ml) for 2 h, filtering the mixture and either freeze drying the filtrate or concentrating it to dryness in a rotary evaporator. The methanol extract was prepared by stirring the leaf material remaining after chloroform extraction in methanol (200 ml) for a further 2 h, followed by filtration and concentration. Before testing, each extract was made up in a 50% aqueous ethanol solution (20 ml) into which the oilseed rape discs were dipped. After drying, the discs were presented as before. Control rape discs were dipped into ethanol before testing.

Larval entry tests

A newly hatched larva was placed onto a piece (10 mm) of the stem or petiole of the test plant, contained in a Petri dish, and entry was recorded if, after 24 h, it had burrowed into the tissue. Twenty replicates were used for each plant type.

Pest incidence on and feeding damage to different cultivars of oilseed rape

(a) Field trials

Two field experiments, in 1987-88 and 1988-89 recorded beetle incidence on and damage to different cultivars of oilseed rape arranged in 2 randomised blocks of a 6 x 2 x 2 factorial trial. Full details, including all basal treatments and agronomy are given elsewhere (Rothamsted Experimental Station Yields of Field Experiments, 1988, 1989). Damage to cotyledons and first leaves was assessed in September and larvae were counted in March.

(b) Laboratory tests

In January 1989, leaves from the field cultivars trial were cut for a leaf disc bioassay in the laboratory. A disc (20 mm diameter) from a double-low cultivar was compared with one cut from the single-low cultivar Bienvenu, and presented as described above. Five double-low cultivars were tested and there were five replicates per test.

For a second bioassay, seeds from five cultivars, differing widely in seed glucosinolate rating, were grown to the cotyledon stage in the glasshouse. Discs (12 mm diameter) were then cut from the cotyledons of each of the five cultivars and presented in a multiple choice bioassay, pinned in random order in a circular arrangement close to the perimeter of a moist filter paper disc (90 mm diameter). There were 27 replicates of each test.

3. Results and conclusions

The feeding of cabbage stem flea beetle was confined to plants containing glucosinolates. They fed on most of the Brassicaceae (Table 1), crucifers that contain glucosinolates, as well as *Reseda alba* (Resedaceae) and *Tropaeolum majus* (Tropaeolaceae), non-crucifers that contain glucosinolates (Table 2). Adults and larvae preferred a similar range of plants. When glucosinolates were added to agar, they all stimulated beetles to feed on the agar, and some did so more than others (Tables 3 & 4). We conclude that as in other crucifer specialists, glucosinolates are feeding stimulants for cabbage stem flea beetles.

However, not all glucosinolate-containing plants were accepted as food. *Crambe maritima* and *Plantago major* were rejected by both adults and larvae while *Capsella bursa-pastoris, Hesperis matronalis, Iberis amara, Erysimum linofolium, Cheiranthus cheiri* and *Lunaria annua* and *Cleome spinosa* were fed on only minimally. At least one, or in the case of *C. spinosa*, the combined mixture of all three solvent extracts of the plants reduced feeding on oilseed rape when applied to it (Table 5), and we conclude that they contained feeding inhibitors which counteracted the glucosinolates.

In the field, early feeding damage to the cotyledons (9 September) of the single-low cultivar Bienvenu and the double-low cultivars was similar (Table 6). Tapidor was damaged most and significantly more than Cobra, Capricorn and Libravo. A week later, damage to the cotyledons of Bienvenu was significantly greater than to those of Capricorn

only. Tapidor remained the most damaged, significantly more than all other cultivars except Bienvenu. Bienvenu, Cobra and Tapidor had significantly more feeding damage to their first leaves than Capricorn and Libravo. Larval infestation on insecticide-free plots, was low in 1987-88 and very high in 1988-89 and in both years differed with cultivar (Table 6). In 1987-88, all five double-low cultivars were more infested than Bienvenu, but the differences were significant only for Corvette and Cobra. In 1988-89, all five double low cultivars except Capricorn were more infested than Bienvenu, but the difference was significant only for Cobra, and Cobra was more infested than Tapidor and Capricorn. The four cultivars tested in both years ranked in the same order each year except that in 1989 Capricorn was relatively less infested than in 1988.

Table 1. *P. chrysocephala* adult feeding and larval penetration of Brassicaceae. (0, no feeding; *, f.p. 1-9; **, f.p. 10-50; ***, f.p. > 50; +, 1-10; + +, 11-20)

	Adult feeding	Larval entry
Brassica napus L.	-	+ +
Brassica oleracea L.	**/***	+/+ +
Brassica rapa L.	**/***	+ +
Brassica nigra L.	***	+ +
Eruca vesicaria L.	***	+ +
Nasturtium officinale R.Br.	***	+
Sinapis alba L.	**	+ +
Sinapis arvensis L.	**	+ +
Raphanus sativus L.	**	+ +
Isatis tinctoria L.	**	+ +
Matthiola incaua (L.) R.Br.	**	+ +
Alliaria petiolata Bieb.	*	+ +
Lepidium sativum L.	-	+ +
Capsella bursa-pastoris L.	*	+
Hesperis matronalis L.	*	+
Iberis amara L.	0	+
Erysimum linofolium (Pers.) Guy	-	+
Cheiranthus cheiri L.	0	+
Lunaria annua L.	0	+
Crambe maritima L.	0	0

Table 2. *P. chrysocephala* adult feeding and larval penetration of non-crucifers. (o, no feeding; *, f.p. 1-9; **, f.p. 10-50; +, 1-10; + +, 11-20)

	Adult feeding	Larval entry
Solanum tuberosum L. (Solanaceae)	*	+
Helianthus annuus L. (Compositae)	0	+
Pisum sativum L. (Papilionaceae)	0	0
Papaver rhoeas L. (Papaveraceae)	0	0
Linum usitatissimum L. (Linaceae)	-	0
Tropaeolum majus L. (Tropaeolaceae)	**	+
Cleome spinosa Jacq (Capparidaceae)	0	+
Reseda alba L. (Resedaceae)	-	+ +
Plantago major L. (Plantaginaceae)	0	0

Table 3. Effect of addition of rape extract or glucosinolate to agar on *P. chrysocephala* feeding in single choice tests

	Mean number of bite marks	
Test material	Agar + test material	Agar control
Rape extract	600*	10
Gluconapin	95*	34
Glucotropaeolin	87*	6
Gluconasturtiin	66*	5
Glucobrassicin	170*	6
Sinigrin	28	4

*significantly ($p < 0.05$) more than control

Table 4. Comparison of effect of different glucosinolates on *P. chrysocephala* feeding, in a multi-choice test

	Mean number of bite marks
Agar	36*
Agar + gluconapin	79
Agar + glucotropaeolin	76
Agar + gluconasturtiin	48†
Agar + glucobrassicin	81
Agar + sinigrin	120‡

*significantly ($p < 0.05$) less than all other treatments;
†significantly ($p < 0.05$) less than other glucosinolates;
‡significantly ($p < 0.05$) more than other treatments

Table 5. Inhibition of feeding by adult *P. chrysocephala* on oilseed rape leaf discs by solvent extracts of different plant species (+, significant inhibition; 0 no inhibition; - not tested)

	Chloroform	Methanol	Water
Brassica napus	0	0	0
Crambe maritima	0	0	+
Hesperis matronalis	0	0	+
Iberis amara	+	+	-
Erysimum linifolium	+	+	-
Cheiranthus cheiri	0	+	-
Lunaria annua	0	+	-
Capsella bursa-pastoris	0	0	+
Plantago major	0	+	-
Cleome spinosa	0	0	0

Table 6. Cabbage stem flea beetle incidence on and damage to oilseed rape cultivars in field trials and laboratory tests.

Cultivar	NIAB seed GS rating (1, high; 6 low)	Pest damage & incidence in field				Feeding damage in laboratory Disc bioassays	
		Damage scores (88-89)		No. of larvae per plant			
		Cotyledons	First leaves	87-88	88-89	Leaves (f.p.)	Cotyledons
Jet Neuf	1	-	-	-	-	-	14
Mikado	2	-	-	-	-	-	13
Bienvenu	3	116	154	0.04	16.8	-	7
Ariana	5	106	148	0.10	21.2	47.9	-
Tapidor		123	155	-	18.5	38.6	-
Capricorn		99	126	0.27	12.7	36.9	-
Libravo	5	101	130	-	20.8	53.3	-
Cobra	5	104	157	0.34	30.0	62.0	6
Corvette		-	-	0.60	-	-	-
Cosmic		-	-	0.25	-	-	-
Topaz	6	-	-	-	-	-	13
S.E.D.		7.4	12.0	0.118	5.16		

The laboratory leaf disc bioassay using field collected leaves gave similar results to the field trial (Table 6). Cobra was eaten most, Capricorn the least. Two cultivars, Cobra and Libravo were fed on more than Bienvenu, while the other three, Ariana, Tapidor and Capricorn, were fed on less. However, in the multi-choice test with cotyledon discs, similar amounts of Cobra and Bienvenu were eaten, whereas greater and equivalent amounts of the low seed glucosinolate cultivar, Topaz were consumed to the high glucosinolate cultivars, Jet Neuf and Mikado. We conclude that pest incidence and feeding damage by cabbage stem flea beetle was not related to the seed glucosinolate concentrations of the cultivars tested, a finding that confirms our previous studies on this and other pests of oilseed rape (Milford *et al.*, 1989; Williams, 1989; Rawlinson & Williams, 1991).

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EFFECT OF CYROMAZINE INSECT GROWTH REGULATOR FOR CABBAGE ROOT FLY (*DELIA RADICUM*) CONTROL ON RAPE

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Abstract:

Cabbage root maggot invades cruciferous roots and causes damage to vegetable crops as well as to rape in Europe and America. There are difficulties with chemical control since organophosphates and carbamates are destroyed by soil microbial degradation, so other control methods are being investigated.

Cyromazine, a tramine insect growth regulator (IRG) was very active against developing *Delia radicum* in laboratory tests made with Trigard (PW 75) at different doses. Results showed that larvae and adults were more susceptible to IGR (BRUNEL and al., 1991). Also Trigard was tested on rape in semi artificial conditions in a greenhouse. Results are presented on the number of leaves, length and weight of plant and number of pupae developed after 40 days after treatement with 5 doses levels. Comment are made on experiments in natural conditions.

1 . INTRODUCTION

Cabbage root fly (*Delia radicum* (L.), Diptera, Anthomyiidae) is a pest of cruciferous crops. The larvae feed on the roots of vegetable crops such as cauliflower, turnip, radish, as well as on oilseed crops like rape. Most work on this pest has aimed to develop biological, ecological and control methods towards vegetables. More recently, *D. radicum* has caused losses to rape and has been studied as a pest of this crop. In France each year losses occur in one or more regions and insecticides are applied. It appears that the increase in rape area has facilitated the increase of *D. radicum*, explained by the presence of its host plant late in autumn and early in spring.

Although some studies have been made in biological and alternative control, results don't permit its use in practice. Chemical control by broadcast treatment has been the preferred method. Until recently use of organophosphates and carbamates have given satisfactactory control. However for some years failures have been observed in many areas on diptera or other underground insects (wireworm). This loss of efficacy is explained by soil micro-organisms destroying the chemical and reducing

the protection period. For a pest with a very long laying time in the crop from April to September it was necessary to think out control and to turn towards new solutions.

The use of an insect growth regulator (IGR) which behaves principally either as a hormonal moulting regulator or on chitin synthesis is a way which has been tried against various diptera (TREECE, 1962; ODE & MATTHYLE, 1964; HALL & FOEHSE, 1980). Among them, cyromazine (N - cyclopropyl - 1, 3, 5 - triazine - 2, 4, 6 - triamine) known under code name CGA72662, created by Ciba Geigy company, has shown promise on diptera like *Musca domestica*, *Lucilia cuprina*, *Liriomyza* more recently on *Delia antiqua* of same family than *D. radicum*. These results encouraged us to try the effect of cyromazine on different stages of *D. radicum* in the laboratory (BRUNEL & al, 1991). This product has been also tested on rape in the greenhouse, and results are given here.

2 . MATERIAL AND METHOD

a) Insect

The *D. radicum* strain used was reared in the laboratory for many years supplemented by individuals caught in the field. Adults were reared in a cubic cage (25 cm) of transparent PVC with lateral sides partially covered by wire netting. Milk powder and beer yeast in a petri dish and water were supplied. In the cage eggs were laid on a turnip slice on a petri dish which facilitated egg recovery.

b) Cyromazine

The commercial names of cyromazine are Trigard for control of minor pests in greenhouse crops, Larvadex against coprophagous diptera, or Vetrazin or Neoprix against insects giving cattle miasis. We used Trigard wettable powder 75 % a. i. This systemic chemical gets into leaves and roots. In laboratory test DL 50 was 1.2 - 2.5 % of trigard 0.266 g a. i. / l on larvae and adults (BRUNEL & al, 1991).

c) Trials

Three rape seed were sown in a 9 cm pot. When the plants had three leaves, they were infestated with three eggs per plant. 20 cm3 of chemical was put into each pot, while the control received the same quantity of distilled water. Five concentrations were tested, obtained with 0.266 g of Trigard per liter, dilutions were 20 %, 10 %, 5 %, 2.5 % and 1.2 % noted 20, 10, 5, 2.5, 1.2 and 0 for control. Each treatment consisted of 12 pots in one tray and four replicates.

d) criterion

40 and 50 days after treatment and infesation we recorded:
- the length of the two first leaves on four plants per tray
- the number of faded plants
- the number of leaves whith modified colour when 50 % of the leaves are red, yellow-red or yellow

- the weight of plant for four pots and twelve pots in each tray
- the number of pupae per pot after examination of root system.

3 . RESULTS

a) Length of two first leaves

Table 1 gives the mean lengths of leaves of four plants receiving different doses, 40 and 50 days after infestation. Analysis shows that there are no differences due to concentration. The attack of larvae had no significant effect on leaf length the development of which began before infestation.

b) Count of faded plant

Faded plants indicated that the root systems of the plants had been reduced by larvae to cause hydric stress phenomena. Number obtained are 5, 12, 5, 2 for concentration of 0, 1.2, 2.5 and 5 respectively, at high doses we have no faded plant. The choice of three eggs per plant was deliberately low since we did not want to kill the plants (BRUNEL & al., 1983). No faded plants were obtained at high doses signifying that Trigard is not phytotoxic to rape.

c) Number of plant with "red" leaves

Change in leaf colour is a well known symptom of plant weakening. It may be result of numerous causes but *D. radicum* infestation often is indicated in this manner. Table 2 gives results obtained from four replicates. The total number of leaves counted in each tray (36 plants) is variable, greater for three high doses, lower than control in two low doses. This is explained by the fact that insects can develop and weaken the plant at low doses compared to high doses. Examination of the percentage of red leaves tend towards lessen report since 50 % of leaves are red in control.

d) Plant weight

Before examination of pupae developed presence, result of larva activity can be seen by the measure of green matter weight made by cutting plants at the neck and weighed. We distinguish 12 plants put in the center of the tray and the totality. Table 3 indicate analysis of 12 plants, 36 plants and mean plant weight. In all cases differences are highly significant and agree. Weight is significantly higher at high doses 5, 10 and 20, and we have a greater protection of the plant by Trigard. But it is not possible to say that he have stimulant action on the plant growth since we had no controls without infestation.

e) Number of developped pupae

Table 4 gives the results of examination of soil and root systems. The number of eggs used does not permit the destruction of the plant. Also we should be have 50 % of pupae like assumption in regard to the number of

Table 1 - Mean length of two first leaves of rape after treatment of trigard at different doses.

	first date		second date	
Doses	First leaf	second leaf	first leaf	second leaf
00	9.43	13.12	8.93	12.43
1.2	9.62	13.12	9.31	11.68
2.5	9.68	12.56	9.62	11.68
5	10.43	12.68	10.50	12.68
10	9.87	13.00	11.37	13.87
20	12.68	12.93	11.00	13.12

Table 2 - Number of red leaves and total number of leaves in different doses of trigard in four replicates.

repl.	red/tot.	red/tot.	red/tot.	red/tot.	red/tot.	red/tot.
1	65/111	50/103	46/96	62/119	56/127	53/131
2	61/114	48/91	58/102	72/124	67/130	65/130
3	49/117	56/112	48/99	52/116	70/137	44/130
4	55/110	34/97	56/113	64/124	69/132	65/135
Total	230/452	188/403	208/413	250/483	262/526	227/526
o/o	50.88	46.65	50.36	51.75	49.98	43.15

Table 3 - Weight of rape plants treated with different doses of Trigard and infested by *D. radicum*

Doses	12 plants	36 plants	means
0	24.00	67.00	1.91
1.2	22.75	59.75	1.72
2.5	24.00	61.75	1.82
5	27.50	89.25	2.56
10	31.75	99.50	2.85
20	32.75	100.00	2.84
F (test)	6.11	13.22	12.04
S	.003	.0001	.0001
CV %	12.8	13.0	13.2

Table 4 - Number of pupae of *D. radicum* developed in 12 pots treated with Trigard at different doses.

Doses	Number of pupae on number of eggs	% pupae formed	$\sqrt{\ }$ %
00	224 / 432	51.85	46.07
1.2	222 / 432	51.38	45.80
2.5	210 / 432	48.61	44.21
5	66 / 432	15.27	21.80
10	14 / 432	3.24	8.55
20	9 / 432	2.08	6.45
Test F			53.35
Significant			***
CV %			17.9

eggs deposit per plant. The effect of cyromazine is all the more interesting because the plant is not destroyed while the insects were killed. In control and in two lower doses developed pupae proportion is equal and significantly higher than high doses. Doses of 10 and 20 prevent insect development beginning of attack observed in root system entail start of new young roots which favour plant growth.

4 . CONCLUSION

In this experiment, we confirm the potential of cyromazine as an insect growth regulator like chemical with insecticide action. Rape absorbs the product through its roots and insects are poisoned while feeding. Further experiments are necessary to confirm that this chemical has a stimulative action on the plant (control without infestation) and if foliar spray efficiency is maintained before field trials can commence.

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INVESTIGATIONS ON THE OCCURENCE OF PEST INSECTS IN OIL SEED RAPE AS A BASIS FOR THE DEVELOPMENT OF ACTION THRESHOLDS, CONCEPTS FOR PROGNOSIS AND STRATEGIES FOR THE REDUCTION OF THE INPUT OF INSECTICIDES.

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Abstract

This paper deals with autumn pest insects (e.g. *Psylliodes chrysocephala*) as well as spring pest insects (e.g. *Ceutorhynchus pallidactylus, C. napi, C. assimilis, Meligethes aeneus, Dasineura brassicae*) of oil seed rape. The aim is to develop pest management strategies with a reduced input of insecticides. Results from four growing seasons are presented.
For *P. chrysocephala* it is demonstrated that
- at different locations even in one region the main immigration peak occurs in a range of four weeks.
- the relation between yellow trap- and emergence-trap-samples is not constant, so that a correlation between numbers of beetles in yellow traps and the density in the field can not be assumed.
- one additional spraying of a pyrethroid not before mid October controls *P. chrysocephala* sufficiently, even if the immigration peak occurs one month earlier.
For *C. pallidactylus* and *C. napi* it has been recorded that
- they regularly show two immigration peaks 14-21 days apart.
- activity in the field increases 14 days after immigration.
- the second immigration peak coincides with the immigration of other pest insects like *M. aeneus* and sometimes *C. assimilis*.
Spraying of pyrethroids in the spring had long lasting effects on other summer pest insects, so that altogether one insecticide application in the spring at the second peak of *C. pallidactylus* or *C. napi* is most effective.
Finally, assessments of prognosis based on the density of larvae falling down from blossoms or pods and the emergence rate of their new generation are demonstrated.

1. Introduction

Many action thresholds used in Germany today have no actual scientific base including the recent status of cultivation technique, the actual varieties of the crop plant and the new economical conditions. Because of this matter the range of damage thresholds recommended by local plant protection services is very wide. The latest approaches to action thresholds for oil seed rape pest insects are given in Lauenstein (1992).

This lack of knowledge is the basis of our work with pest organisms in oilseed rape. The aim of these investigations - which started in 1989 - is to get under the influence of different input of insecticides as far as possible an exact correlation between

- the occurrence of the pest organism in yellow traps,
- their abundance and dispersal in the field,
- the attack of the plants by the pest organism,
- the damage caused by each species of pest organism,
- the yield.

From this basis the intention is

- to define the optimal time for a precise application of an insecticide,
- to develop strategies with a minimum of insecticide input,
- and finally, in the long term, to get in combination with abiotic factors a database for simulating and modelling the population dynamics to forecast the occurence of the pest insects.

2. Material and methods

The experiments started in 1989 and have been carried out at different locations near Braunschweig in the eastern part of Lower Saxony, Germany. In all years we had plots with carbosulfan- and isofenphos-treated rapeseed. Additionally we had plots with untreated (1989/90) or only with fungicides (Thiram) treated rapeseed (1990/91, 1991/92).

Due to actual developments and the occurence of the cabbage stem flea beetle (*Psylliodes chrysocephala*) the variations of treatments with insecticides changed slightly every year: In the season 1989/90 we had 1ha plots with one additional late application of a pyrethroid (deltamethrin 300 ml in 300 l H_2O/ha) in autumn (13.10.89) against *P. chrysocephala* and one in spring (2.4.90) against the cabbage stem weevil (*Ceutorhynchus pallidactylus*). In 1990/91 we added plots (>0,3 ha) with a second, "early" application (2.10.90) as well in the autumn as in the spring (21.03.91).

In 1991/92 due to the low numbers of immigrating *P. chrysocephala* we had to change our program in plots (ca. 0,3 ha) with only one "early" (14.10.91) or only one "late" (5.11.91) pyrethroid application, although the "early" application was relatively late too (it usually occurs in the first half of September). 1990/91 and 1991/92 at least 3 plots have been treated in the same way regarding spray applications of insecticides.

For collecting insects we used several different types of traps:

- Yellow traps (ICI-type; 33,5 cm x 26,0 cm = 814 cm^2) were used to monitor flight activity. In 1989/90 twelve yellow traps were set up in a distance of about 15 m to the field edges around the field in which the different plots were located. In 1990/91 and 1991/92 sixteen yellow traps were distributed regularly over the field (one each plot).

- Emergence traps (groundphotoeclectors; Smith 1933, Funke 1971) and the flooding method (3-4 replicates/plot and date; Desender & Segers 1985) were used to get information about the actual abundance of the different pest organisms in the field.

Emergence traps (0,25m^2 size) catch all arthropods which emerge from the soil covered by the trap and which are positively phototactic. They require a minimum of active movement by the pest insects which are hidden under clods in the upper layer of the soil. Their location is changed every week so that the photoeclector samples indicate the actual status of immigration of the pest organisms in a defined area. In later growth stages of the oil seed rape all plant parts higher than 50 cm are cut off and shaken out. At the end of the growing period of the oil seed rape the emergence traps register the hatching rate (ind./m ^{2}) of the new generation of all pest organisms which pupate in the soil or the lower parts of the crop plants.

The flooding method records the actual abundance in the field too, and it is suitable especially for *P. chrysocephala* in the autumn. In contrast to the emergence trap this method enables distinction between dead and live beetles in the field, so that it can be used especially to record the acute effects of spray applications or the insecticide dressings. For this method a metal frame (0,25 m ^{2}) is pushed into the soil and filled up with water (10-40 litres per sample depending on the kind of soil). Individuals of *P. chrysocephala* hidden under clods of soil emerge to the water surface where they are collected and checked whether they are dead or alive.

- Funnel traps of 0,25 m^2-size (one each plot) were used to detect the number of larvae of the pollen beetle (*Meligethes aeneus*), the cabbage seed weevil (*Ceutorhynchus assimilis*) and the Brassica pod midge (*Dasineura brassicae*) which fall from the blossoms or pods of the crop plants onto the soil for pupation. The funnel traps are installed in an early growth stage of the oil seed rape so that the crop plants are not destroyed, but are able to overgrow the funnel traps. In combination with the hatching rate of the new generation of the mentioned pest organism (registered by the emergence traps) the funnel trap allows calculation of the success of reproduction of each pest organism.

3. Results with discussion

Autumn pests (*P. chrysocephala*)

Phenological aspects. In 1989 the maximum immigration of *P. chrysocephala* was already registered on 12. September in the yellow traps whereas in the emergence traps and by the flooding method the maximum abundance was recorded at least two weeks later (Fig.1). Immediately after 12. September the plant protection services sent their warnings to the farmers who applied insecticides usually over the whole field. Regarding the fact, that dispersing of *P. chrysocephala* over the whole area of a field took two to three weeks there was obviously a rush to do a whole-field spraying at that time: spraying of the field edges would have been sufficient.

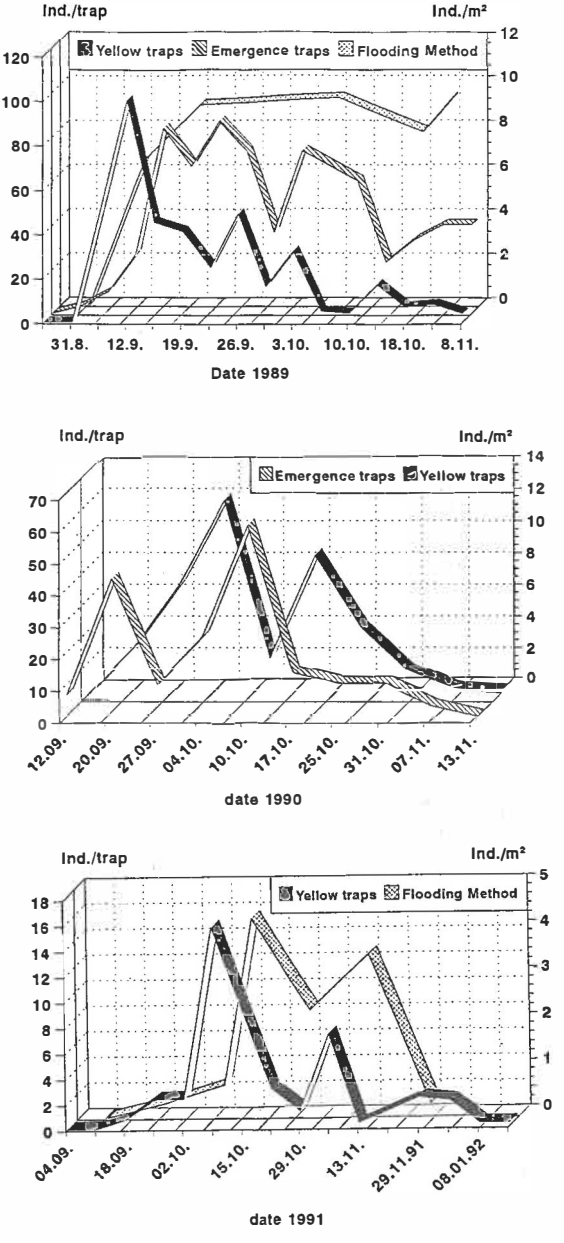


Fig. 1: Phenology of *P. chrysocephala* in 1989, 1990 and 1991: comparison of yellow traps (ind./trap), emergence traps (ind./m^2) and the flooding method (ind./m^2).

One reason for the time difference of the appearence of *P. chrysocephala* in yellow traps and the other methods was, that the yellow traps were situated as usual in current agricultural practice in a distance of about 15 metres from the field edges whereas the samples with the emergence traps and the flooding method were randomized over the whole area. Immigration of *P. chrysocephala* started at the southern and the northern field edges, so that the the yellow traps at the western and eastern field edges which were located right in the middle of the other yellow traps showed an increase of the numbers of *P. chysocephala* two weeks later (Fig. 2). That means, the yellow traps at the southern and northern edges registered mainly the beginning immigration of *P. chrysocephala* into the rape field whereas the distribution over the hole area of about 6 ha took another two to three weeks. As a consequence in 1990 the yellow traps were situated in the centre of each plot.

In 1989 we registered an emergence rate of the new generation of *P. chrysocephala* of about 420 ind./m^2, that means about 4,2 Mio. ind./ha. The plant protection services (Hoßfeld 1990) reported a large number of cabbage stem flea beetle during harvesting and expected a huge immigration in the autumn 1990, but this did not arrive.

Because of a long rain period in 1990 the immigration of *P. chrysocephala* began only at the beginning of October. By contrast in 1989 the emergence traps showed a maximum nearly two weeks before the maximum in the yellow traps. That indicates that *P. chrysocephala* seemed to immigrate in 1990 very slowly "on foot" because of the low temperatures and bad weather conditions (Fig. 1).

In 1989 we registered about 400 ind./yellow trap until the end of October, in 1990 a little less than 200 and nearly no beetles of the new generation hatched in July 1991 (tab. 4). According to this the immigration in the autumn of 1991 started very late (mid October) and the number of individuals decreased once more: on average only less than 50 ind./yellow trap were registered by mid November (Fig. 1). In contrast to 1990 the reason for this small amount was an extreme dryness over three weeks after drilling at the end of August, so that the germination of the rape began only at the beginning of October. Only on sandy soils where the seeds had a good contact to the surrounding soil the germination happened earlier and the development of the oil seed rape was quite normal.

So even in the same region it is obvious that the immigration maximum occurs in different locations at very different times beginning from mid September and ending at mid October (Fig. 3). That shows the difficulties for the plant protection services to give general recommendations for the exact time for spraying even in one region.

Correlation of yellow trap samples with the abundance in the field (recorded with emergence traps and the flooding method) and the number of larvae per plant

In spite of all scientifical doubts, there have been many attempts in Germany to derive action thresholds from yellow trap samples. These endeavours are based on the cognition that the yellow trap is the only method which possibly might have

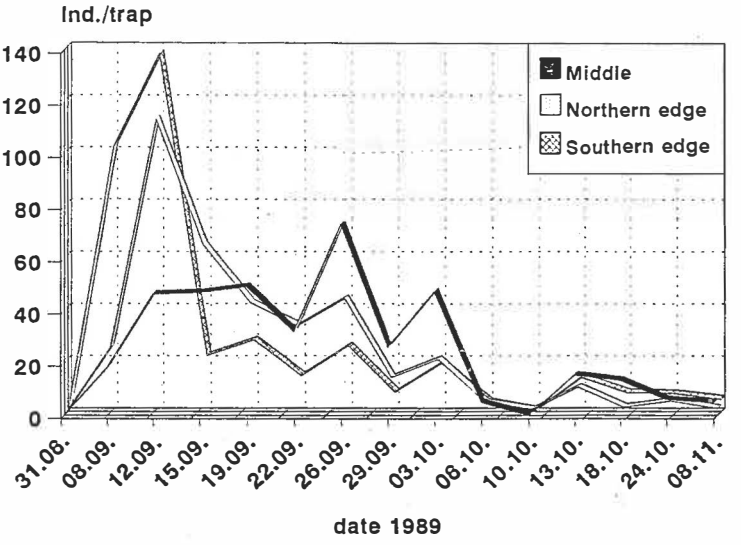


Fig. 2: Yellow trap samples (ind./trap) of *P. chrysocephala* and their dependence on the direction of immigration.

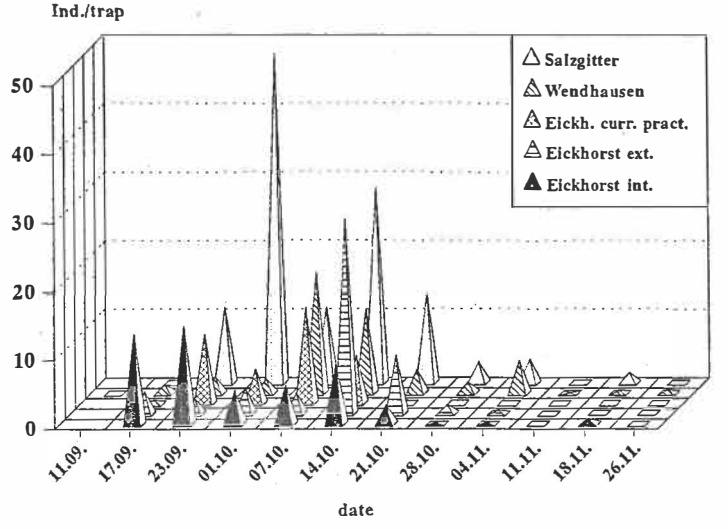


Fig. 3: Immigration of *P. chrysocephala* in 1991 (yellow-trap-samples): Comparison of different locations within a radius of 15 km (locations: Salzgitter-Nortenhof, Wendhausen, Eickhorst "current practice", Eickhorst "extensive management", Eickhorst "intensive management")

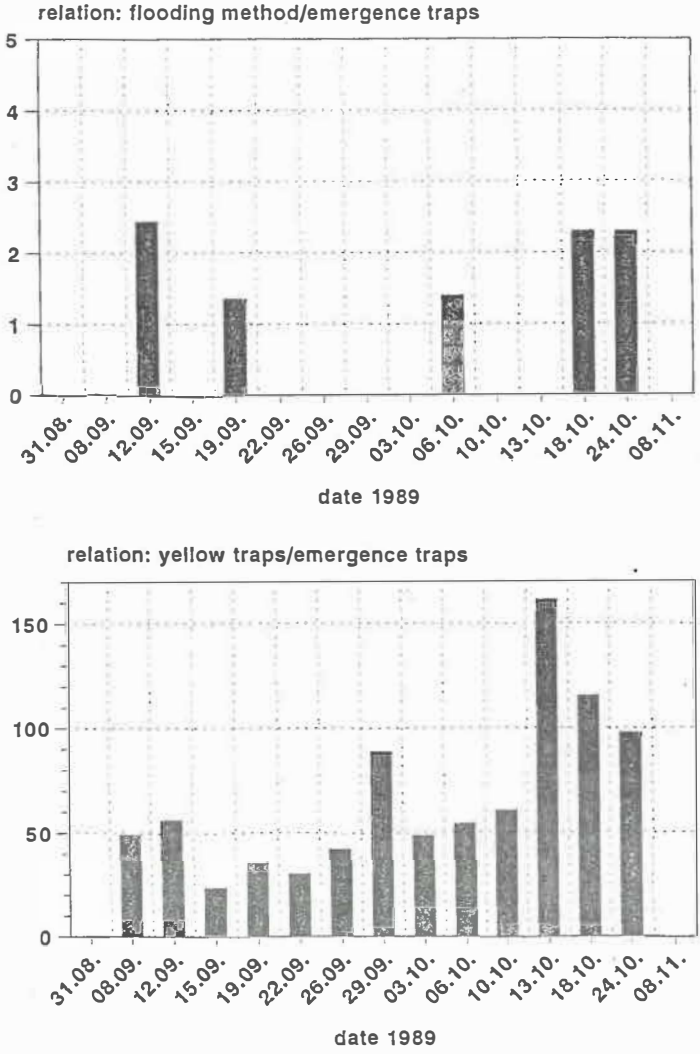


Fig. 4: *Psylliodes chrysocephala*: relations between samples with
a) yellow traps (ind./trap) and emergence traps (ind./m ^{2})
b) the flooding method (ind./m ^{2}) and emergence traps (ind./m ^{2})

a chance to become accepted by farmers and plant protection services. A special target for these approaches is the cabbage stem flea beetle (*P. chrysocephala*).

1. Comparison of accumulated yellow trap samples with the results of methods like emergence traps and the flooding method which register the abundance of *P. chrysocephala* in the field.

One premise for an acceptable correlation between these methods is, that the relation between the samples of two methods is quite constant for a given time period and/or different localities. If this relation is quite constant, it is unimportant whether the sampling efficiency of one method is higher or lower than that of the other.

Fig. 4 shows for 1989 that the relation between yellow trap samples and the abundance in the field, registered with emergence traps indicates varies greatly. But if the samples of the emergence traps and the flooding method - which both register abundance - are compared, the relation is quite constant: The flooding method catches regularly about 2,5 times more *P. chrysocephala* than the emergence traps. That means finally, that it is not possible to use yellow trap samples to measure the abundance of *P. chrysocephala* in the field nor the attack of the plants by its larvae.

2. Correlation between the accumulated number of *P. chrysocephala* caught in yellow traps and the number of larvae per plant.

Older data from the region of Dresden (Schott 1961) showed a very good correlation between the number of larvae per plant and the number of beetles caught in yellow traps.
Especially Hoßfeld (1990) from Kappeln/Schleswig-Holstein, near the Danish border, carried out results which convinced him that a correlation between yellow trap samples and the number of larvae per plant exists. He compared the accumulated numbers of *P. chrysocephala* in a three week period of yellow trap samples with the number of larvae in plants of untreated plots in rape fields with current agricultural practice (Tab. 1a). Regarding the question of damage he characterizes 3-5 larvae/plant as the margin where yield losses of 0,15-0,20 t/ha are assumed. From an experience of several years he states that this margin will be crossed if more than 50 beetles (localities with low density of crop plants) or 75 beetles (localities with normal density of crop plants) are counted in a three week period.

Table 1 compares the results carried out by Hoßfeld (unpubl.) in Schleswig-Holstein and our results elaborated in the eastern region of Lower Saxony in the years 1989-1991.: For Schleswig-Holstein it is obviously recognizable that the number of larvae/plant crosses the critical margin (3 larvae/plant) regularly if more than 65 beetles are counted in the yellow traps over three weeks, so that the preliminary designated action threshold of 50 rsp. 75 beetles/trap seems to be quite reasonable. With reference to this preliminary action threshold in the eastern region of Lower Saxony 12 cases have been registered where this margin was crossed and two other cases where it was nearly reached. In 4 cases the margin was overstepped

Tab. 1: Comparison of the accumulated numbers of *P. chrysocephala* caught in yellow traps over 3 weeks and the number of larvae/plant in 1989–1991 at different locations in Schleswig-Holstein (a) and Lower Saxony (b).

a)

Locality	year	beetles/3 weeks and yellow trap	larvae/plant (untreated)	Locality	year	beetles/3 weeks and yellow trap	larvae/plant (untreated)
Lutzhöft	90	13	0,05	Lutzhöft	91	67	1,0
Steinberg	90	14	0,3	Kius	91	67	5,8
Kleinquern	90	14	0,6	Bienebek	89	72	4,1
Bienebek	90	15	0,6	Niesgrau	91	81	1,2
Fegetasch	90	20	0,65	Juhlschau	91	93	0,8
Kielsgaard	89	22	1,8	Faulück	89	97	4,4
Grüntal	90	23	4,75	Faulück	91	105	11,6
Handewitt	89	32	1,7	Fegetasch	89	106	15,1
Börsby	90	33	2,0	Sterup	91	112	9,15
Handewitt	90	39	0,7	Fegetasch	91	132	5,95
Schnarup	91	41	0,65	Juhlschau	90	149	9,9
Gintoft	91	55	1,2				

b)

Locality Year		Beetles/trap 6.-27.9.	Beetles/trap 27.9.-17.10.	Beetles/trap 17.10.-7.11.	Beetles/trap Total	Larvae/plant (Autumn)
Hemkenrode/II	90	2,5	25,8	0,75	28,8	0,38
Eickhorst/III	91	10,5	26	0	36,5	0,0
Wendhausen/VIII	91	1	28	8	42	0,0
Wendhausen/V	91	5	24	10	43	0,0
Wendhausen/XVI	91	1	7	23	49	0,0
Eickhorst/I	91	5,5	35,25	10,25	51	0,0
Eickhorst/II	91	27,25	19,5	4,0	51	0,0
Hemkenrode/I	90	13,25	45	2,25	60,5	0,24
Wendhausen/XV	91	3	30	17	61	0,0
Wendhausen/IX	90	7	48	39	97	0,0
Wendhausen/VI	90	59	23	32	118	0,08
Nortenhof	91	11	87,5	21	120	0,08
Wendhausen/I	90	26	59	30	125	0,1
Sickte	90	23,8	100	6,5	130	0,17
Wendhausen/XVII	90	2	78	62	158	0,48
Hötzum/I	89	302	73	19	394	0,8
Hötzum/III	89	282	103	10,5	396	3,5
Hötzum/II	89	192	170	28,5	397	4,3

in two consecutive 3 week periods, so that this field had to be sprayed twice, if one follows the action threshold (50 beetles/yellow trap x 3 weeks) seriously. But only in two of all the above mentioned cases the number of larvae exceeded the critical value of 3 larvae/plant.

Even if a very poor correlation between the number of beetles/trap and the number of larvae/plant can not be excluded the level where the critical number of larvae will be crossed in the eastern part of Lower Saxony seems to be very different to that in Schleswig-Holstein: with reference to the actual experience in Lower Saxony the number of beetles/yellow trap has to exceed at least 250 beetles/trap in one 3-week-period or 150 beetles/trap in two consecutive 3-week-periods before the critical value of 3 larvae/plant is crossed.

If the number of beetles is accumulated over the whole immigration period - to simplify the implementation of an action threshold - in the eastern part of Lower Saxony the number of beetles/trap must reach nearly 400 before one has to fear a critical attack by the larvae. Restrictively it has to be mentioned, that in the last 3 years of our investigations no critical attack by larvae has been observed except the one locality in 1989, so that we need some more data to confirm the above drafted thresholds. On the other hand it can be stated that under these circumstances an insecticide application against *P. chrysocephala* is necessary in only a few exceptional cases.

With regards to the apparently contradictory results from Schleswig-Holstein (Hoßfeld 1990) and the eastern part of Lower Saxony, perhaps great regional differences depending on differing local climatic conditions have to be accepted: Schleswig-Holstein is influenced by a more maritime climate with higher humidity and more rainfall whereas in the eastern region of Lower Saxony continental conditions predominate. These factors may influence egg production, the hatching rate or the success of young larvae attacking the crop which possibly results in a quite different damage to the crop even if the abundance of the cabbage stem flea beetle is similar.

Effects of different intensities of insecticide input on the number of larvae per plant and the yield

For 1989 it is clear (Table 2) that in the plot with isofenphos-dressed seed the percentage of larvae per plant was heavily reduced only by the seed dressing. Even an additional spraying of a pyrethroid (deltamethrin) did not result in further reduction of the number of larvae per plant. It is also obvious that in the plot with carbosulfan-dressed seed not the seed dressing but only the pyrethroid application on the 13 October - one month later than usually in current practice in that year - led to a reduction of the number of larvae per plant. The same result can be seen in the plot with the untreated seeds. The variations in the amount of larvae/plant caused by the different use of seed dressings and insecticides resulted also in clear effects on the yield (Table 2).

Tab. 2: Occurence of *Psylliodes chrysocephala* in 1989 under the influence of different seed dressings and additional pyrethroid applications (for the category "emergence of next generation" see remark in Table 4)

	Isofenphos + pyrethroid	Isofenphos	Carbosulfan + pyrethroid	Carbosulfan	untreated seed + pyrethroid	untreated seed
beetles per yellow trap (accum. -8.11.)	394	394	397	397	396	396
larvae/plant (autumn)	0,6	0,8	0,9	4,3	1,4	3,5
% of att. plants (autumn)	45,0	47,5	60,0	95,0	72,5	97,5
Emergence of next generation (Ind./sqm)	313	309	273	505	139	454
yield (t/ha)	5,14 (125%)	4,64 (113%)	4,72 (115%)	4,14 (100%)	4,38 (106%)	4,12 (100%)

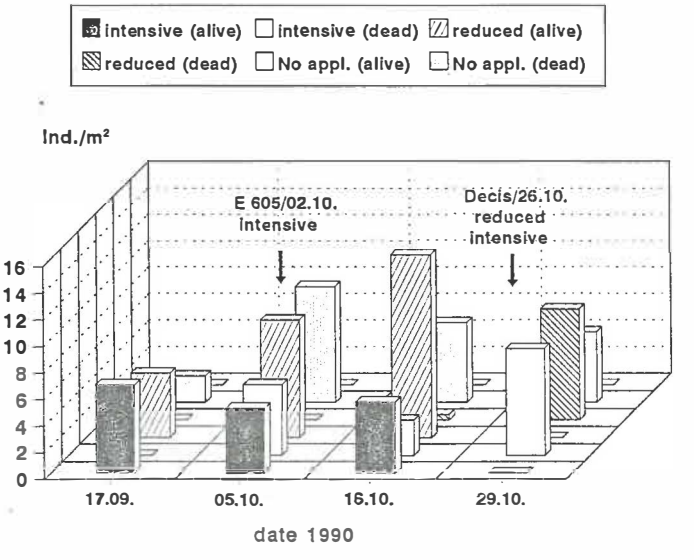


Fig. 5: Effects of different insecticide treatments detected by the flooding-method (further informations see text)

In 1990 and 1991 the seed dressings had no effect, because of the late immigration of *P. chrysocephala*. Also no remarkable numbers of larvae/plant could be registered so that the effects of different treatments could not be judged by this value. Fig. 5 shows that the acute effect of different treatments with insecticides on *P. chrysocephala* can be very easily recorded by using the flooding-method: the flooding is the only method recording abundance which enables dead and live beetles to be distinguished at once in the field (Fig. 5)

Spring pests (*C. pallidactylus, C. napi, C. assimilis, M. aeneus, D. brassicae*)

In the spring effects of two insecticidal applications (1990, 1991) were compared with plots with only one (1989, 1990, 1991), but very precise application.

One of the most abundant pest insect in the eastern region of Lower Saxony is the cabbage stem weevil (*C. pallidactylus*) which is the target of most of the insecticide applications in spring. For *C. pallidactylus* some regularities have been observed which might help to determine the optimum application time:
without exception, since 1989 *C. pallidactylus* showed two activity peaks in the yellow traps with an interval of two or three weeks between them.

In contrast to that the emergence traps showed a slow and continous increase in activity in the field, no clear second peak, a time-postponement of the maximum for about 14 days in comparison to the first peak in the yellow traps.

That means, the maximum activity in the field occurs at the earliest 14 days later than the first peak in the yellow traps and coincides nearly with the second peak in the yellow traps (Fig. 6). This phenomenon has been observed constantly for four years for *C. pallidactylus*. It has been also observed for the stem weevil (*C. napi*), but in this case the data base is too small for final conclusions (Fig. 7).

These results indicate obviously that flight activity which is connected with the immigration (registered by the yellow traps) and the activities which are connected with the copulation and the laying of eggs (registered by the emergence traps), occur with a time-postponement.

It is assumed that after its immigration *C. pallidactylus* passes through a phase of latency of about two weeks before it starts with mating activities and the egg laying procedure. This leads to the development of a strategy with reduced input of insecticides in spring: spraying of pyrethroids (deltamethrin) is reduced to only one application at the time 14-21 days after the first activity peak registered in the yellow traps for *C. pallidactylus*.

Additionally it had been observed that in most years the pollen beetle (*M. aeneus*) as well as the cabbage seed weevil (*C. assimilis*) have their maximum immigration into the field at the time of the second activity peak of *C. pallidactylus*. Therefore the possibility is set up to control also these pest organism with the one insecticide application 14-21 days after the first activity peak of *C. pallidactylus*. The effect of this delayed pyrethroid application on *C. pallidactylus* insect is shown in Fig. 8.

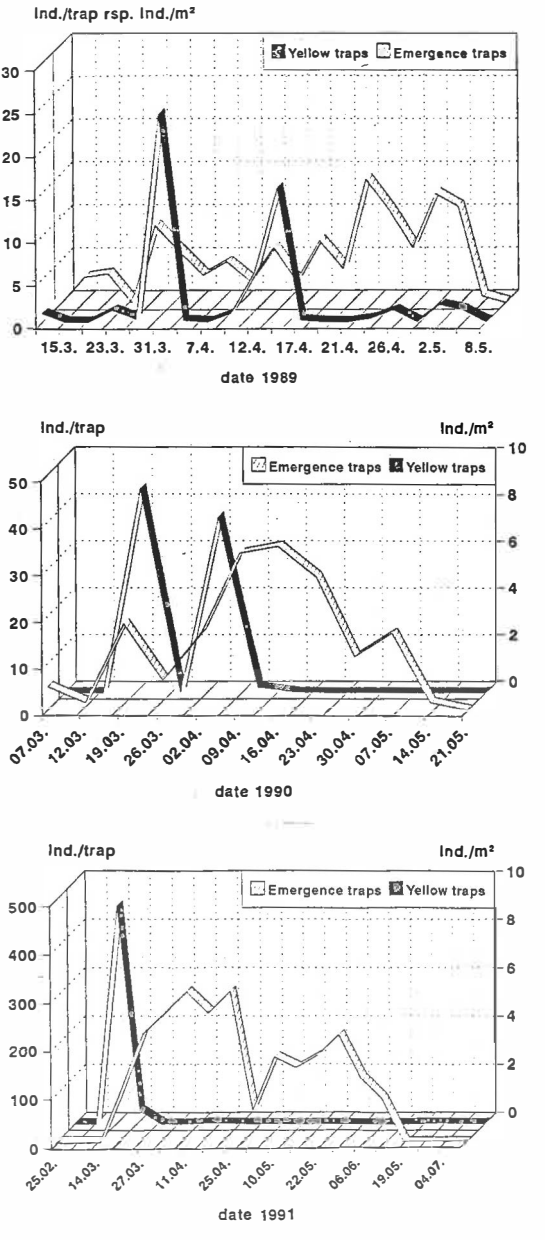


Fig. 6: Phenology of *C. pallidactylus* 1989, 1990 and 1991: comparison of samples with yellow traps (ind./trap) and emergence traps (ind./m ^{2})

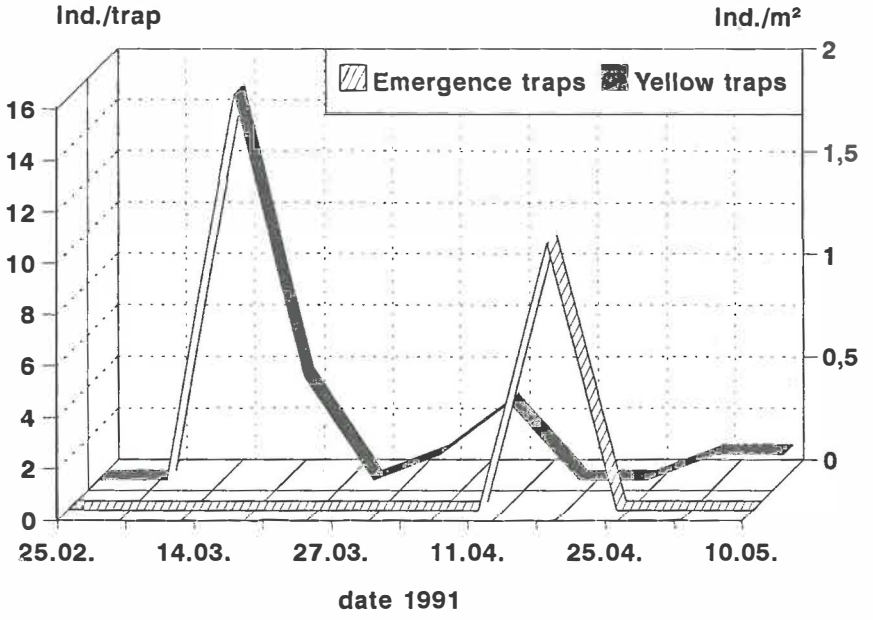


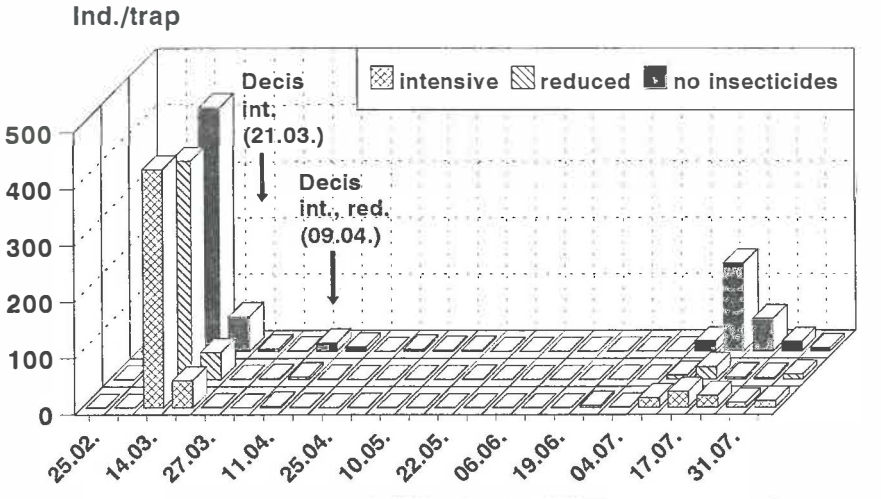
Fig. 7: Phenology of *Ceutorhynchus napi* in 1991: comparison of samples with yellow traps (ind./trap) and emergence traps (ind./m ^{2})

But independent of the question for the right moment of this delayed application in the spring effects on *M. aeneus, C. assimilis* and *D. brassicae* have been observed months later (Fig. 9a-c).

At present status of knowledge this phenomenon can not be explained clearly, but there are some hints from ICI (Petersen, pers. comm.) regarding aphids that pyrethroids may induce a long lasting repellent effect. This repellent effect might be also important for the above mentioned pest insects.

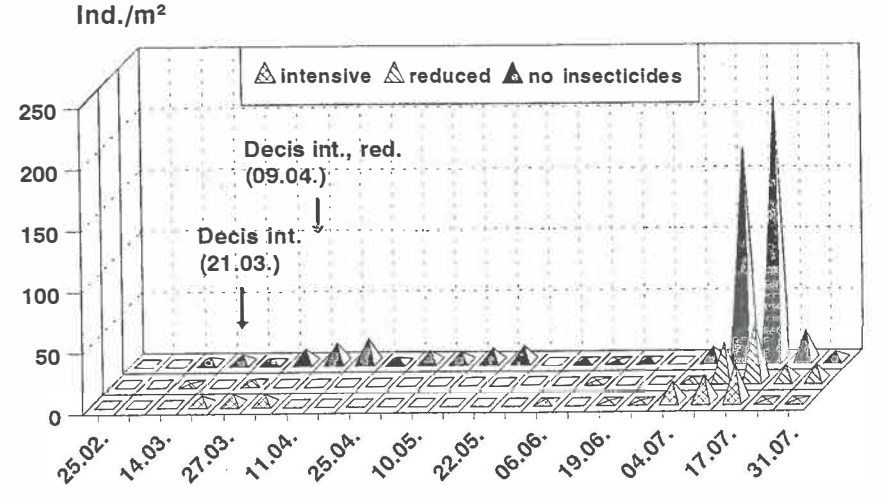
Effects of the different plant protection strategies on factors like larvae/plant, hatching of the new generation and the yield especially regarding *C. pallidactylus*.

The results of two years show decreases of all parameters with increasing intensity except the yield (Table 3): the yield is established nearly on the same level in the plots with the reduced input of insecticides as in the plots with intensive treatment.



no insecticides	0	0	432	62	5	1	15	8	0	4	2	2	0	0	0	0	0	0	0	18	156	58	17	6
reduced	0	0	387	48	1	2	5	1	0	0	0	0	1	0	0	0	0	0	0	7	22	4	3	9
intensive	0	0	422	48	1	0	3	1	0	1	0	0	0	0	0	0	0	4	1	17	28	21	9	12

date 1991



no insecticides	0	0	5	7	4	11	16	19	4	9	8	11	13	0	3	1	3	0	11	173	215	24	7
reduced	0	0	1	0	4	0	0	0	0	0	0	0	0	0	0	1	0	0	3	31	47	12	13
intensive	0	0	0	7	8	8	0	0	0	0	0	0	0	0	3	0	1	1	16	21	30	1	1

date 1991

Fig. 8: Effect of different intensities of insecticide application on *C. pallidactylus* (top: yellow traps (ind./trap); bottom: emergence traps (ind./m ^{2}))

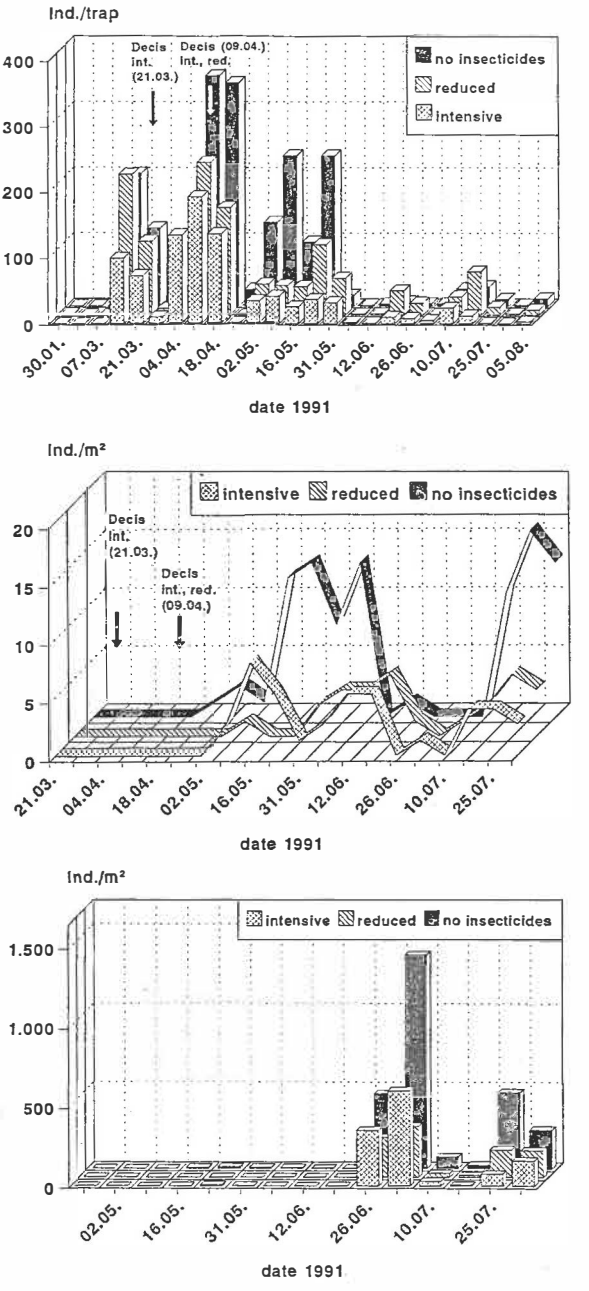


Fig. 9a–c: Long lasting effects of pyrethroid applications on *Meligethes aeneus* (a), *Ceutorhynchus assimilis* (b) and *Dasineura brassicae* (c), registered with yellow traps (ind./trap) or emergence traps (ind./m^2)

Tab. 3: *Ceutorhynchus pallidactylus* 1991: Effects of different numbers of insecticide applications on the number of beetles/yellow trap, percentage of attacked plants, the number of larvae/plant, the hatching of the new generation (emergence traps) and the yield. *

	Beetles/trap	Att. plants (%)	Larvae/plant	Beetles/sqm (emergence traps)	Yield (t/ha)
untreated	635	100,0	3,4	429	3,17
one application	558	84,6	1,3	105	3,63
two applications	546	63,2	0,43	72	3,49

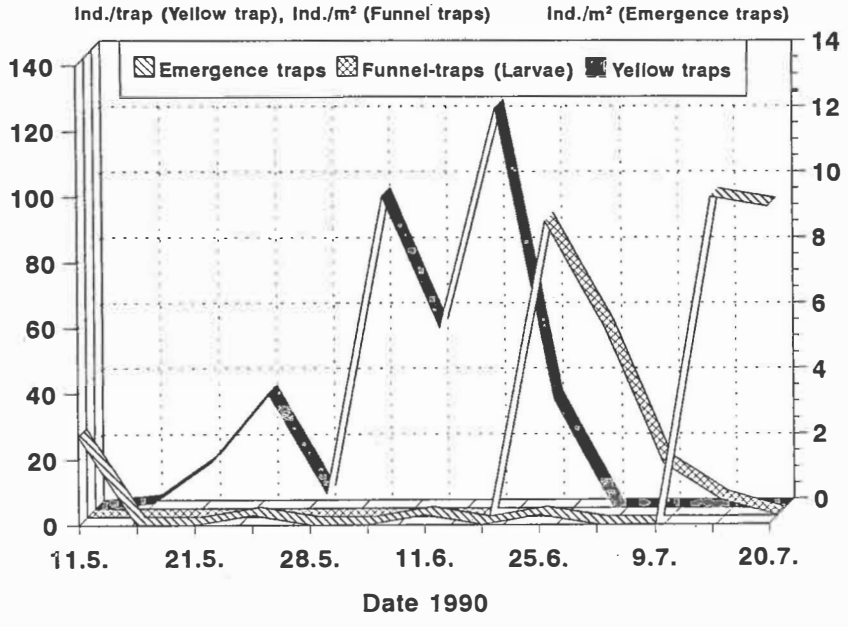


Fig. 10: Phenology of *Ceutorhynchus assimilis* in 1990 registered with yellow traps (immigration), funnel traps (larvae, falling down from pods to soil) and emergence traps (hatching of the new generation)

* Annotation: The number beetles/m^2 caught with emergence traps is obviously higher than it is to calculate from the number of larvae/plant basing on 60 plants/m^2. The reason is that the location of the emergence traps has been changed every week. Therefore not only the newly hatched beetles have been registered but also the beetles which were already located in the area covered by the emergence trap. So the emergence traps registered more beetles/m^2 than hatched in reality. But because this error is constant for all plots it is possible to compare different insecticide treatments

Tab. 4: Emergence (ind./m^2) of the new generation of pest organisms (exept *Brevicoryne brassicae*) registered with groundphotoeclectors in July, in relation to the numbers of insecticide applications and the yield (t/ha)

Species (Ind./sqm)	untreated 89/90	untreated 90/91	one applic. 89/90	one applic. 90/91	two applic. 90/91
Psyll. chrysoc.	423	0	241	0	0,43
Ceut. pallid.	477	429	316	105	72
Melig. aeneus	76	33,3	45	64,2	30,6
Ceut. assimilis	17	40	14	14,6	12
Dasyn. brassicae	465	2649	360	989	1222
Brevic. brassicae	515	248	278	178	121
Yield (t/ha)	4,30	3,02	4,75	3,63	4,70

At long term it is one aim of these investigations to get a data base for modelling a prognosis. For this with funnel traps the number of larvae of *M. aeneus, C. assimilis* and *D. brassicae* is recorded which fall down onto the soil from the blossoms and the pods to pupate in the soil. For the determination of the success of development of the new generation the emergence rate is registered by the groundphotoeclectors. As example for these mode of operation the results for *D. brassicae* are discussed in the text and these for *C. assimilis* are shown in Fig. 10.

Regarding *D. brassicae* in the untreated plots with the funnel traps about 7100 larvae/m^2 have been registered on average. The number of hatched midges however was higher in the untreated plots (465 ind./m^2) than in the plots treated with insecticides (360 ind./m^2). The success of hatching was established between 5,0% (treated plots) and 6,5% (untreated plots). From laboratory experiments we know that only about 10-20% of this new generation overlays to the next spring. In Germany nearly no summer rape is cultivated. For this reason *D. brassicae* is not able to build up another large (third) generation. So it is possible to estimate from the emergence of the second generation in July (registered with the groundphotoeclectors) the number of midges which will hatch in the next spring on last years oil seed rape fields.

Table 4 shows that the number of newly hatched imagines of *Dasineura brassicae* increased drastically between 1990 and 1991. Regarding these data and the above mentioned conclusions we have to expect a heavy attack by *Dasineura brassicae* in 1992, so that additional insecticide applications against this pest organism will be necessary.

Looking at the emergence of the new generation of the other pest insects (Table 4), the effect of an increasing number of insecticide applications results in most cases in a reduction of the emergence rate of all relevant pest organisms in oil seed rape, even if the insecticide application was conducted in a very great distance of time to the occurrence of the pest insect as it has been demonstrated above for *M. aeneus, C. assimilis* and *D. brassicae* (Fig.9a–c).

So especially in consideration to the new economical conditions for oilseed crops worked out by the European Community, it is assumed that the number of treatments with insecticides which are applied up to five times per growing season in some regions in Germany can be easily reduced to two treatments maximum: one late treatment at the end of the vegetation period (mid october at the earliest) and one in the spring shortly after the second peak of *C. pallidactylus* or *C. napi.* In exceptional cases – if the emergence of the second generation of *Dasineura brassicae* reaches high values and the winter is mild – an additional insecticide application against *Dasineura brassicae* can be necessary.

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