IOBC / WPRS

Working Group "Integrated Control in Oilseed Crops"

OILB / SROP

Groupe de Travail "Lutte Intégrée en Cultures d'Oléagineux"

Proceedings of the meeting

Compte-rendu de la réunion

Zürich-Reckenholz (Switzerland)
24-25 February 1994

Edited by
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IOBC wprs Bulletin
Bulletin OILB srop **Vol. 18 (4) 1995**

The IOBC/WPRS Bulletin is published by the International Organization for Biological and Integrated Control of Noxious Animals and Plants, West Palaearctic Regional Section (IOBC/WPRS)

Le Bulletin OILB/SROP est publié par l'Organisation Internationale de Lutte Biologique et Intégrée contre les Animaux et les Plantes Nuisibles, section Régionale Ouest Paléarctique (OILB/SROP)

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ISBN 92-9067-072-X

Preface

The seventh meeting of the working group on integrated control in oilseed crops was held at the Swiss Federal Research Station for Agronomy in Zürich-Reckenholz, Switzerland, 24 - 25 February 1994.

At the meeting further results of the collaboration on 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.

Results of the Joint IOBC Oilseed Rape Field Experiment which started in autumn 1990 with different countries participating were presented and discussed.
Results of another joint project which started in spring 1990 were presented and discussed: monitoring and potential use of parasitoids against oilseed rape pests.

Further results of research in linseed, the second oilseed crop, were given.

Two new subjects were discussed at the meeting:

1. Seed pathology in oilseed crops.
2. Gene technology in oilseed crops- significance, economics and environment.

On 21 and 22 October, 1993, a subgroup-meeting took place at the National Institute of Agricultural Botany Cambridge (UK), where both provisional results and further work in IOBC joint oilseed crops experiments and EC proposals were discussed.

V. H. Paul
convenor.

Contents

Monitoring Diseases - Biology of Pathogens

OCCURRENCE OF CANKER (*LEPTOSPHAERIA MACULANS*) IN WINTER OILSEED RAPE IN EASTERN ENGLAND 1977 - 1993

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Summary

Severe attacks of canker (*Leptosphaeria maculans*) were first detected in winter oilseed rape in 1977 and 1978 in eastern England on the susceptible cultivars such as Primor. The disease has been confirmed each year since 1977 but it caused little premature ripening during the period 1979 - 1992. Crops sown in autumn 1992 showed a high incidence of phoma leaf spot from October to May and canker developed subsequently to affect 75% plants prior to harvest. It caused a low incidence of plant death during the winter and spring and some premature ripening in late June and early July. There appeared to be little effect of cultivar resistance on canker incidence and severity in monitored crops. Few crops received fungicide sprays for canker control in 1992-1993 compared with the late 1980's and this may have contributed to the increase in canker. The incidence of canker during the period 1977-1993 was positively correlated with rainfall, particularly during the periods August, September and January.

1. Introduction

Canker, caused by *Leptosphaeria maculans* (teleomorph of *Phoma lingam)*, first caused problems in winter oilseed rape in the UK in 1977 (Evans and Gladders, 1981), when susceptible cultivars such as Primor were widely grown (Gladders, 1988). Severe canker was also recorded in 1978 but a dry autumn in 1978 and the introduction of the resistant cultivar Jet Neuf reduced its severity subsequnetly (Gladders, 1988; Gladders and Musa, 1979). ADAS has monitored diseases in winter oilseed rape crops in southern and eastern England since autumn 1976 (Evans and Gladders, 1981) and in all regions of England and Wales since 1986 (Hardwick *et al.*, 1989). This paper draws together records on canker from eastern England since 1977 and examines observations made during a resurgence of the disease in 1993. The

importance of rainfall in the development of canker epidemics is discussed in relation to strategies which might be used for control of canker.

2. Methods

Crop monitoring was carried out in commercial crops using samples 50 plants (1977 only) or 25 plants per field collected in late February to early April, at the early stem extension stage (GS 2,0-3,3 Sylvester-Bradley, 1985) and again in July during pod ripening (GS 6,3-6,5) from 30-40 crops per year in eastern England. Data for 1978 was derived from only 9 sites which were monitored more frequently using samples of 100 plants per assessment.

The incidence and severity of all diseases was recorded at each stage as described by Hardwick *et al.*(1989). The incidence and severity of stem canker and stem lesions were recorded using a 0-4 index: 0 - no infection; 1 - slight infection,< 50% stem circumference affected; 2 - moderate infection, >50% circumference affected; 3 - stem completely girdled and/or weakened and 4 - plant dead. A canker lesion was defined as one associated with the basal leaf scars from the over-wintering rosette leaves, whilst stem lesions were those occurring higher up the stem, on either main or lateral stems. The total incidence of phoma lesions on stems for each crop was determined from the presence or absence of canker and/or phoma lesions on stems of individual plants. For some years data on either total phoma incidence on stems or canker incidence was not available and estimated values have been used. Canker incidence was used as the estimate of total phoma incidence on stems in 1979 and 1986, and total stem phoma incidence was used as the estimate for canker incidence in 1987-1990.

In 1993, disease assessments were also made using the methods described above for disease surveys, in samples taken at approximately monthly intervals from untreated plots of winter oilseed rape cv. Envol (40 plants per sample) or cv. Apache (60 plants per sample) in crops grown on clay loam soil at ADAS Boxworth near Cambridge. The crop cv. Apache was a fifth successive oilseed rape crop sown on 2 September 1992 and harvested on 26 July 1993; cv. Envol was sown on 3 September after a previous crop of winter wheat and harvested on 20 July 1993. The incidence and severity of phoma leaf spot, and the incidence of canker and stem lesions is shown for for each crop (Fig. 3). In 1993, monitoring of commercial crops was on 36 crops in eastern England which were visited in the autumn (November, GS 1,5-1,9), spring,

(March,GS2,0-3,3) and summer (July,GS6,3-6,5) and disease data was examined in relation to cultivar resistance ratings for canker (Anon, 1993).

Preliminary correlation and regression analyses were done with disease data from crops monitored during the period 1977-1993, using records of the incidence of leaf spotting the spring, canker in July and total phoma incidence on stems in July and total monthly rainfall at the ADAS Boxworth Research Centre which is central to the area used for the disease survey. The period from July (prior to sowing) to June each year was considered for canker and total stem phoma models. However, as phoma leaf spot samples were taken from late February onwards, only the period from July to February (inclusive) has been included in leaf spot models. Stepwise regression using forward selection and backwards elimination procedures (MINITAB Release 7, Minitab Inc.) was used to identify significant relationships between disease incidence and mean total monthly rainfall. The probabilities of significant ($P<0.05$) regression models and their coefficients of determination (r^2) (adjusted for degrees of freedom) were calculated.

3. Results

The incidences of phoma leaf spotting at early stem extension and of total phoma stem infections for the period 1977-1993 are shown in Fig. 1. Canker incidence is shown in relation to mean total rainfall for August, September and January (Fig. 2). The highest incidence of canker and phoma stem infections occurred in 1977, 1978 and 1993. Premature ripening was seen commonly in these years. Phoma leaf spot was most common in 1993. Samples were also collected in the autumn (November/early December) from 1989 onwards and these showed a mean incidence of 10.1%, 24.0%, 21.1% and 27.2% plants affected in 1989-1992, respectively.

Mean disease incidence and severity data for 1993 are shown in Table 1.There were small differences in the incidence and severity of leaf spot, canker or stem phoma between cultivars with different resistance ratings for canker. There was no correlation for individual crops between incidence of leaf spot in the autumn and the incidence of leaf spotting in the spring or canker incidence in July in 1993. In addition, there were no correlations between leaf spot, canker or total stem phoma incidence between successive years during the period 1977-1993.

During the course of these observations there have been major changes in the range of cultivars grown. Primor was introduced in 1975 and this was superceded by the more canker resistant cultivar Jet Neuf from 1979 until 1984 when Bienvenu

became the most widely grown cultivar. Double low (i.e. cultivars producing seed with a low erucic acid and low glucosinolate content) cultivars, which included cv. Ariana were first monitored in 1988. Most recently, cvs Libravo and Falcon have been replaced by cvs Envol and Apache, which predominated in 1993.

Table 1. Incidence and severity of phoma leaf spot, canker and phoma stem lesions on different cultivars of winter oilseed rape in eastern England in 1992/93

Main Cultivars	No. of crops	Canker resistance rating (1-9)	Phoma leaf spot				Canker		Stem lesions	
			Autumn		Spring		July		July	
			% Plants	% Leaf area	% Plants	% Leaf area	% Plants	Index	% Plants	Index
Envol/Falcon	10	5	28	0.04	66	0.78	72	1.19	42	0.57
Apache/Libravo	12	6	18	0.03	68	0.77	69	1.10	50	0.58
Capricorn	5	7	29	0.08	81	1.11	76	1.19	42	0.50
All	40	-	27.2	0.05	71.8	0.86	74.9	1.25	45.8	0.55
S.E. of Mean			3.38	0.008	4.19	0.151	3.94	0.087	3.17	0.040

The development of phoma in winter oilseed rape in 1992/93 is illustrated in Fig. 3. The incidence of leaf spotting was high; (76% plants affected on cv. Apache when the first sample was examined on 16 October and 100% plants affected during the period 30 January (GS1,16) to 29 March (GS 3,3). The severity of leaf spotting was also higher in this period with the maximum severity (7.6% leaf area affected) occurring in the samples taken on 29 March. A low incidence of canker was detected from 29 October onwards and occasionally plants died following severe infection of the hypocotyl. The incidence of canker and phoma stem lesions increased rapidly between early June and early July when canker affected 87% of plants (15% plants ripened prematurely and a further 7% had severe canker). The crop cv. Envol grew more slowly and plants remained smaller than those of cv. Apache during the winter. Leaf infection of cv. Envol increased from early November until 21 January and then the incidence remained high until early April. Leaf infection was most severe in samples taken in January. Occasional canker lesions were seen during the winter but symptoms developed rapidly from May (GS4,9) onwards to affect 97.5% plants (55%

moderate lesions, 5% severe lesions) by 28 June. Stem lesions developed during June to affect 70% of plants. A late assessment on 12 July showed that only 39% of stems were still green and other stems had started to desiccate.

Preliminary examination of meteorological data suggested that high rainfall in August or September preceded seasons with a high incidence of canker. A number of significant models for both canker and total stem phoma incidence and mean monthly rainfall were identified and these incorporated mean total rainfall for one, two, three and four months (Table 2). The most appropriate models included mean rainfall for three or four months. Only one significant model was identified for phoma leaf spot and rainfall (Table 2).

Table 2. Significant regression models for the incidence of canker, phoma infection on stems prior to harvest and phoma leaf spot in the spring and monthly rainfall.

y	b	a					r^2	P
		Jan	Nov	Aug	Sept	Jul		
% Plants with canker	-14.7	0.616	0.519				36.8	0.016
	0.8			0.373	0.392		32.1	0.026
	-27.6	0.614		0.393	0.391		57.3	0.003
	-25.5	0.635	0.470	0.243			44.9	0.013
	-16.9	0.627		0.383	0.407	-0.260	65.1	0.002
	-29.9	0.620	0.132	0.365	0.332		54.7	0.008
		Sept	May	Aug	Jan			
% Stems with phoma	26.6	0.407					22.4	0.032
	9.8	0.375	0.367				36.0	0.017
	8.7	0.481		0.290			30.7	0.030
	- 8.6	0.451	0.371	0.295			46.5	0.011
	-23.6	0.454	0.322	0.306	0.374		52.0	0.011
		Feb	Nov					
% Plants with phoma leaf spot	22.2	-0.350	0.335				28	0.039

Regression equations are in the form $y = b + a_1 x_1 + ...a_n x_n$
(x = mean monthly rainfall)

4. Discussion

Canker has remained at low to moderate incidence during the period 1979-1992 in England and only occasional crops of susceptible cultivars were severely affected. However, in 1993, premature ripening was seen in many parts of England (ADAS,

unpublished data) and it is clear that the disease is still capable of causing yield loss in susceptible or moderately resistant cultivars. Survey results failed to show major differences between cultivars with different resistance ratings (Table 1), but the sample size was small. The use of fungicide treatments on winter oilseed rape has changed considerably since 1991 when the UK experienced widespread attacks of Sclerotinia (Gladders, Davies and Hardwick, 1993) and EC support changed to an area payment (Gladders, Hardwick and Sansford, 1993). Fungicides such as prochloraz may have provided some control of canker (Evans *et al.*, 1984) prior to 1991 when many crops received fungicide sprays during the winter (Hardwick *et al.*, 1989). In 1992 and 1993, most fungicides were applied during flowering for Sclerotinia control (ADAS, unpublished data) which would have been too late to achieve control of canker (Gladders,1988). This change in fungicide use may have contributed to the increase in canker. New fungicides such as flusilazole and tebuconazole have recently become available for disease control in oilseed rape in the UK, but until crops which are likely to suffer significant yield losses can be identified, many farmers will be reluctant to apply fungicides during the autumn and winter.

Data from eastern England suggests that early warning of severe canker might be given on the basis of monthly rainfall at critical periods (Table 2). The models identified from regression analyses are promising because they appear to link closely with our current understanding of the development of phoma in oilseed rape. High rainfall in August should promote rapid saprophytic colonisation of the stubble by *L. maculans* and early maturation of ascospores (Alabouvette and Brunin,1970; Gladders and Musa, 1980; Rempal and Hall,1993). The negative effect of July rainfall on canker incidence is more difficult to explain though very early maturation of ascospores may not produce disease if they are released prior to crop emergence. September rainfall is likely to favour ascospore maturation, ascospore release and early crop infection (Brunin and Lacoste,1970). Rainfall in November and January coincide with critical periods for the peak of leaf symptoms in the autumn and the initiation of the spring leaf spot epidemic, respectively (Gladders and Musa, 1979; 1980).

The selection of May rainfall in the models for total stem phoma incidence (Table 2) but not in models for canker is of particular interest. Stem phoma lesions develop later than canker, as in 1993 (Fig. 3) and are thought to develop during the period from stem extension to the end of flowering whilst infected leaves are still present. May, therefore, is the last significant opportunity for stem infection to occur before leaf abscission.This late phase of disease development is distinct from canker development which occurs earlier (Gladders and Musa,1980).

Only one model for phoma leaf spot and rainfall was identified (Table 2) and this included a positive effect of November rainfall but a negative effect of February rainfall. The latter is rather surprising as February is often a period when leaf spotting increases (Fig.3). The correlation between leaf spot incidence and canker in survey crops was poor, probably because there are relatively large changes in the incidence of leaf spotting in the spring. Assessments at early stem extension will give an incomplete indication of peak incidence of leaf spotting in the crop.

The models for canker in particular appear to have practical value in predicting years with a high incidence of canker. The models considered have a maximum of 4 (monthly) variables and the inclusion of more variables only slightly improved the r^2 values. Sprays for canker control are normally applied in November and late February/March (Evans *et al.*,1984) and early warnings of canker risk and appropriate fungicide treatment could be applied in the autumn based on July, August and September rainfall. Crop monitoring would also be needed to substantiate that leaf symptoms had developed and to assess local rather than the overall regional risk identified by these models. Further adjustment to advice for the spring spray could be made in the light of January rainfall totals. High rainfall during August could also be used to reinforce advice to plough in rape stubbles prior to the emergence of new crops.

These models should also be validated using disease survey data from other parts of England and Wales to establish if regional differences are important. Data from eastern England also needs to be examined in relation to local rainfall records to establish if more appropriate models can be developed. The approach may also be of value in developing predictive models for other diseases of oilseed rape.

The return of widespread attacks of canker raises many questions about the economics of using fungicides to control the disease. It is clear that there is little information on disease-yield loss relationships for canker in currently grown cultivars. There is also a need to investigate both timing and rates of application of fungicides for control of canker to ensure that treatments give a high degree of control under high disease pressure.In 1992/93, our experiments with fungicides in the crops illustrated in Fig. 3 showed that single sprays of prochloraz + carbendazim were effective for canker control on cv. Apache but an experimental treatment using prochloraz + iprodione + thiophanate methyl on cv. Envol gave more than 75% control of canker and a 15% yield response when applied during the period November to February. Two sprays of

Fig.1 Incidence of phoma leaf spot and stem infection in eastern England 1977-93

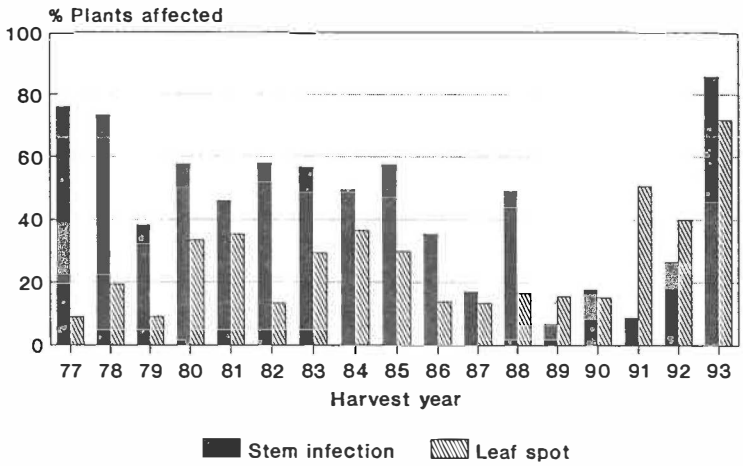


Fig.2 Canker incidence in relation to total rainfall in August,September and January

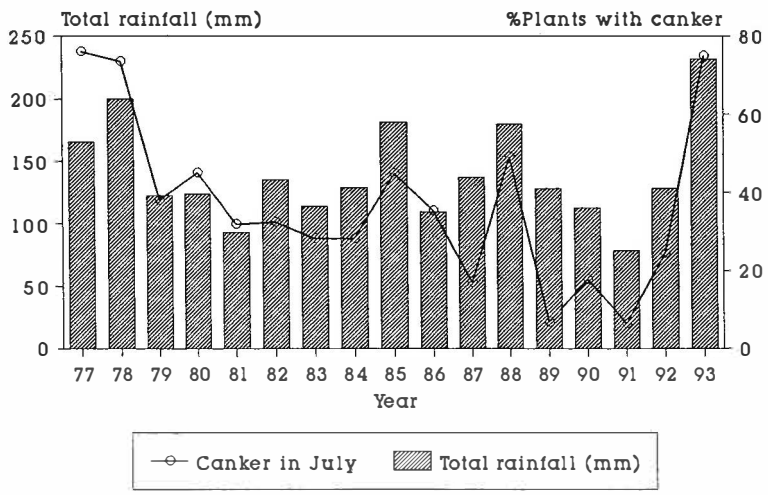
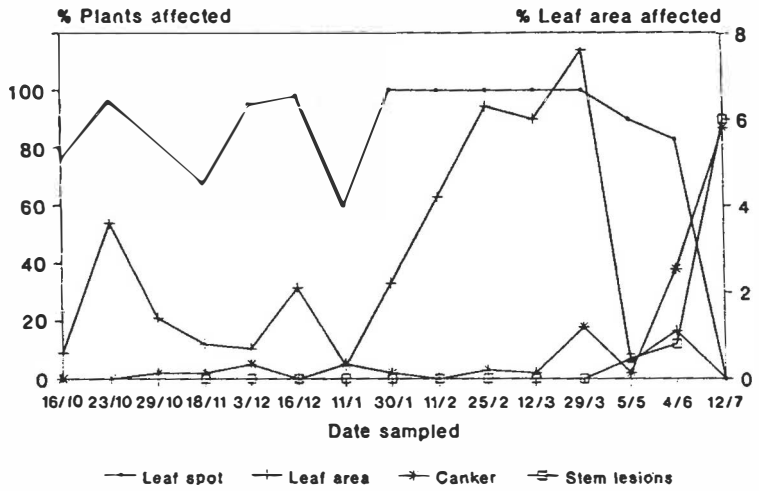
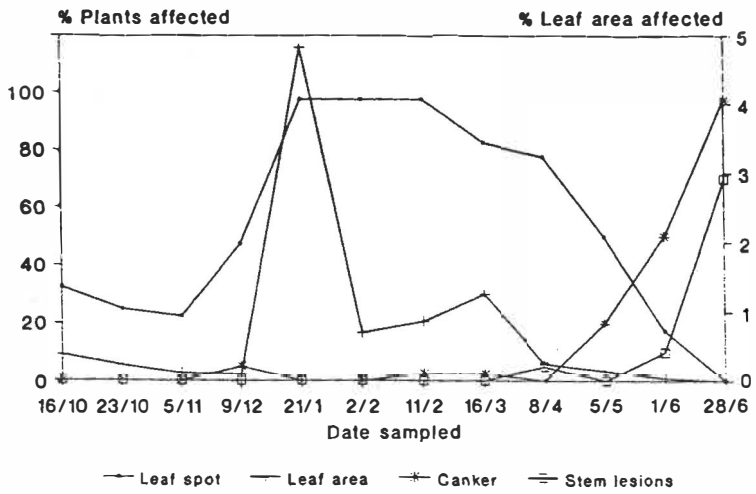


Fig.3 Development of phoma leaf spot, canker and phoma stem lesions in two crops of winter oilseed rape at ADAS Boxworth in 1992-93

a) cv.Apache



b) cv.Envol



prochloraz, at full rate, provided good control of canker at Rothamsted and yield response was related to canker control (Church and Fitt,this volume). Practical and profitable fungicide treatments now need to be developed for farmers, especially since significant yield effects were demonstrated in 1993.

Acknowledgements

Funding of this investigation by the Ministry of Agriculture, Fisheries and Food is gratefully acknowledged.

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PREDICTING EARLY DEVELOPMENT OF LIGHT LEAF SPOT (*PYRENOPEZIZA BRASSICAE*) ON WINTER OILSEED RAPE

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Summary

On oilseed rape (cv. Cobra) inoculated with spore suspensions of *Pyrenopeziza brassicae*, the number of light leaf spot lesions produced was greater at 15°C than at 5,10 or 20°C. The lengths of the incubation period (time from inoculation to production of 50% of the lesions) and the latent period (time to production of the first conidia) decreased linearly with increasing temperature from 5 to 15°C. At 12 or 18°C lesions developed with continuous leaf wetness periods of 16 to 48h but not with periods $\leq$13h. In oilseed rape crops at Rothamsted light leaf spot lesions developed on exposed, inoculated, glasshouse-grown plants only after mid-October 1990 and after mid-September 1991, when recorded wetness duration was $\geq$17h. The length of the latent period on these plants was inversely proportional to the mean air temperature after inoculation, which ranged from 5 to 15°C. Accumulated temperatures calculated for the latent period ranged from 170 to 250 day-degrees. At Bristol the development of light leaf spot was studied in detail in 1989/90 on oilseed rape crops growing on plots inoculated with infected debris. Infection periods with wetness duration $\geq$17h were recorded on 19-21 and 28-30 October and lesions had developed by 23 November, giving estimated accumulated temperatures during the latent period of 338 or 252 day-degrees, respectively.

1. Introduction

Epidemics of light leaf spot, caused by *Pyrenopeziza brassicae*, are most damaging to winter-sown crops of oilseed rape (Hardwick *et al.*,1991) when infection occurs early in the autumn (Rawlinson & Cayley,1984; Jeffery *et al.*,1989). Furthermore, when disease is present in the autumn, fungicide programmes which include autumn applications give greater decreases in light leaf spot incidence later in the season and greater increases in yield than do programmes which include only treatments in spring or summer (Figueroa *et al.*,1994a). Thus, to predict the need for, and benefits of the use of fungicides to control light leaf spot, it is important to study factors affecting the development of the disease in the autumn. Methods for detection of inoculum early in the season include the use of spore samplers or

bait plants to collect air-borne or splash-borne spores and incubation of plants sampled from the crop to detect the presence of latent disease (Figueroa *et al.*,1993). Given the presence of inoculum, light leaf spot epidemics will develop only when weather conditions are suitable for infection and lesion development to occur. This paper describes experiments at Rothamsted to establish the criteria for infection of winter oilseed rape by *P.brassicae* and for the development of light leaf spot lesions in relation to data from field experiments at Bristol to study the early development of light leaf spot epidemics.

2. Materials and Methods

2.1 Controlled environment experiments,Rothamsted

Two similar experiments investigated the effects of temperature and one experiment investigated the effects of leaf wetness duration on light leaf spot lesion development. For all three experiments oilseed rape, cv. Cobra, grown in soil-less compost in 12.5cm diameter pots for 4-5 weeks, was inoculated by spraying with spore suspensions of *P.brassicae* (2 x 10^6 spores /ml). In the experiments that investigated the effects of temperature, plants were kept at 100% r.h. for 2 days after inoculation, then grown at 5,10,15 or 20°C. Two leaves per plant on each of four replicate plants were assessed by counting new lesions which were traced onto acetate sheets at 2-day intervals until all lesions had appeared. The time from inoculation until the first acervuli bearing new conidia appeared (latent period) was recorded. The time from inoculation to the appearance of 50% of the lesions (incubation period) was also estimated. Data presented are mean values for the two experiments. In the experiment that investigated the effects of leaf wetness duration, treatments were 0,6,8,11,13,16,20,24 or 48h of leaf wetness after inoculation at 12 or 18°C. Three leaves per plant on three plants per replicate (i.e. nine leaves per replicate with three replicates) were assessed 9 days after inoculation and subsequently at 4-day intervals until all lesions had appeared.

2.2 Field experiments, Rothamsted

Oilseed rape plants (cv. Cobra) grown in the glasshouse for 4-5 weeks were inoculated with suspensions of conidia of *P.brassicae* (2 x 10^6 spores/ml). Groups of 12 plants were placed in oilseed rape crops immediately after inoculation, twice weekly from 31 August 1990 to 1 March 1991 and weekly from 20 September 1991 to 14 February 1992. These plants were assessed for the presence of light leaf spot every 1-3 days for 6 weeks. The time from inoculation to the appearance of acervuli and the maximum severity of light leaf spot on each plant (% area affected) were recorded. Rainfall, leaf wetness duration above and within the crop and dry and wet bulb temperatures were recorded hourly with meteorological instruments connected to a 21X Campbell data logger.

2.3 Field experiment, Bristol

Three winter oilseed rape cultivars, Ariana, Darmor and Jet Neuf, were sown on 24 August 1989 in plots (area 5 x 5m) at a seed rate of 25kg/ha with a 15cm row spacing. These plots were inoculated immediately after sowing with oilseed rape stem debris infected

with light leaf spot from a commercial crop. At emergence (c. 7 days after sowing) 25 plants were marked and each leaf on these plants was assessed at c. 7-day intervals for light leaf spot infection. Maximum and minimum temperatures, rainfall and estimated rainfall duration were recorded hourly at a meteorological station 4km from the site. Accumulated temperatures above 0°C were calculated using the mean of the maximum plus minimum temperatures as the mean temperature.

3. Results

3.1 Controlled environment experiments, Rothamsted

The total number of light leaf spot lesions produced on $10cm^2$ areas of eight leaves increased with increasing temperature from 5 to 15°C but was less at 20 than at 15°C (Fig. 1). By contrast, the lengths of the incubation and latent periods decreased linearly, from 25 to 15 days and from 22 to 14 days respectively, as temperature increased from 5 to 15°C but were greater at 20 than at 15°C (Fig. 2).

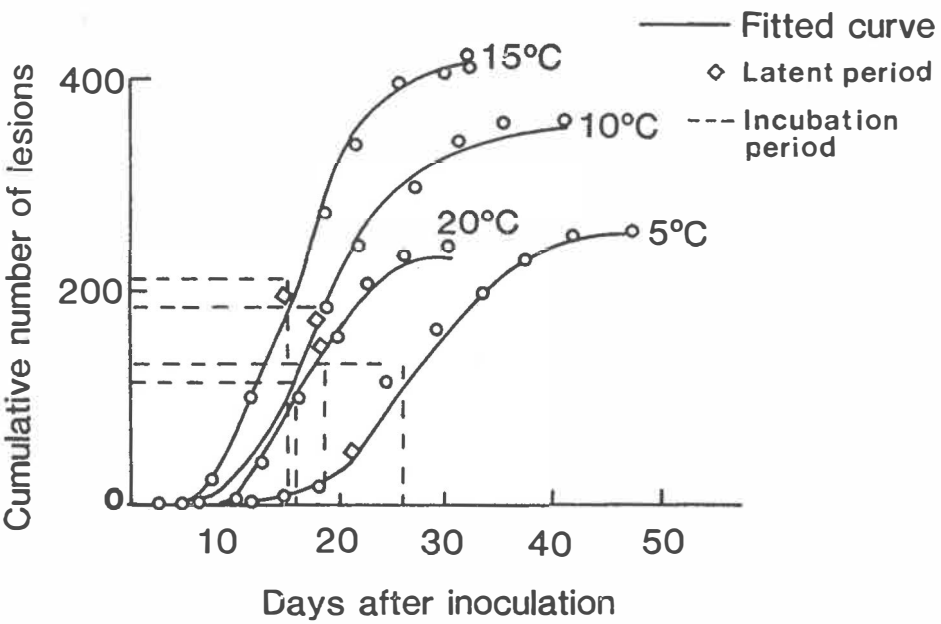

Fig.1. Cumulative numbers of light leaf spot lesions which developed on $10cm^2$ areas on 8 leaves of oilseed rape (cv. Cobra) after inoculation with conidia of *Pyrenopeziza brassicae* (2 x 10^6/ml) at 5, 10,15 or 20°C. The incubation period (time to 50% of the lesions) and latent period (time to the first acervuli) are also illustrated.

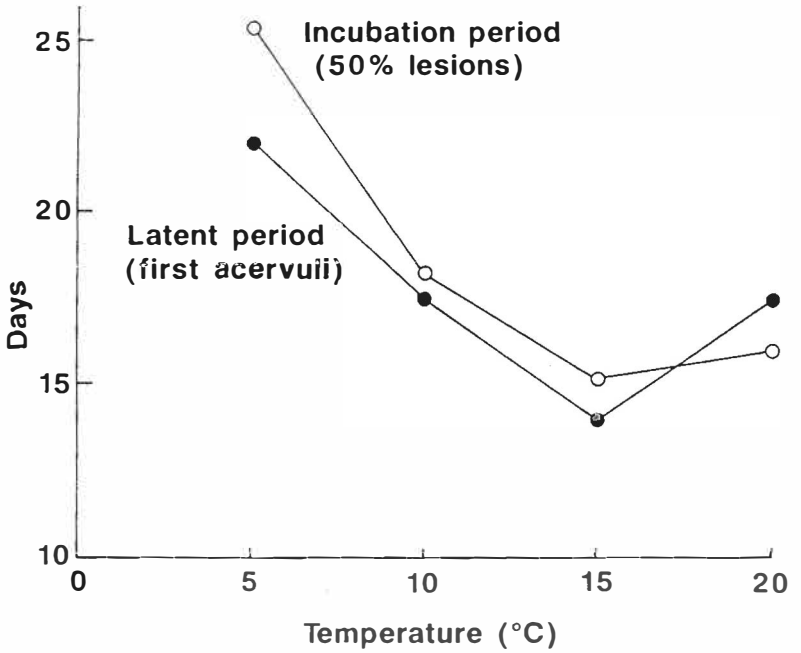

Fig.2. The lengths of the incubation period (time to 50% of the lesions) and latent period (time to first acervuli) in relation to temperature when light leaf spot lesions developed on oilseed rape (cv. Cobra) inoculated with conidia of *Pyrenopeziza brassicae* (2×10^6/ml).

At 12 or 18°C, light leaf spot lesions developed when leaf wetness duration was 16 to 48h but not when leaf wetness duration was ≤13h (Fig. 3). The total number of lesions produced was greater at 18°C than at 12°C and increased with increasing leaf wetness duration from 16 to 48h.

3.2 Field experiments, Rothamsted

Light leaf spot lesions always developed on inoculated oilseed rape plants placed in crops on dates from 19 October 1990 to 1 March 1991 (Figueroa *et al.*,1993) and from 22 September 1991 to 14 February 1992 (Figueroa, 1993). The severity of symptoms ranged from 1 to 20% leaf area affected in both seasons. Light leaf spot did not develop on plants exposed between 31 August and 16 October 1990 or on 20 September 1991, when recorded wetness duration was estimated to be ≤16h. The length of the latent period ranged from 16 to 40 days in 1990/91 and from 18 to 33 days in 1991/92. There was an inverse relationship between the length of the latent period and the mean temperature within the crop in the 8 days after inoculation and exposure (Fig. 4). Linear regressions of latent period on temperature, which was mostly in the range 5 to 15°C, accounted for 83% and 76% of the variance in 1990/91 and 1991/92, respectively. Accumulated temperatures above 0°C calculated for these latent periods ranged from 170 to 250 day-degrees.

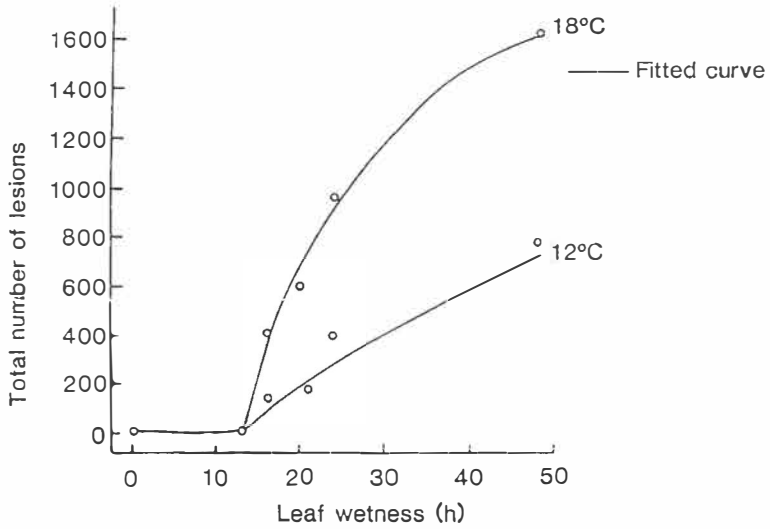

Fig.3. Total numbers of light leaf spot lesions which had developed on 9 whole leaves of oilseed rape (cv. Cobra) at 12 or 18°C after leaf wetness durations of 0,6,8,11,13,16,20,24 or 48h immediately after inoculation with conidia of *Pyrenopeziza brassicae* (2 x 10^6/ml).

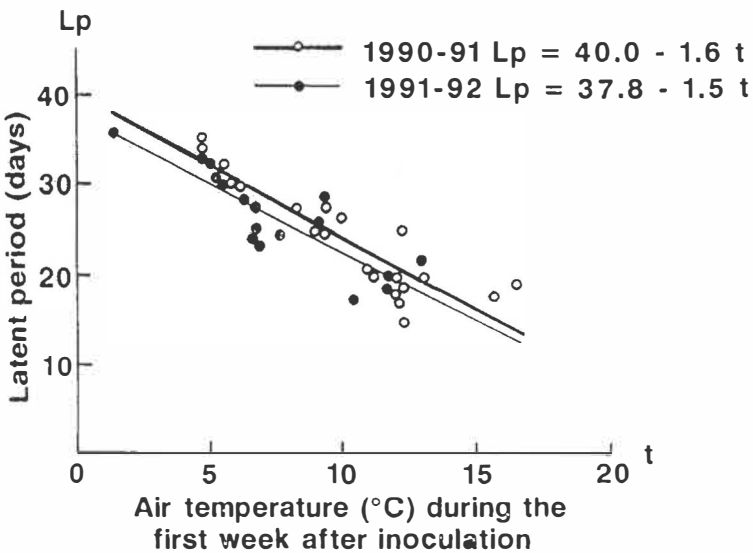

Fig.4. Regression of the length of the latent period (time to first acervuli) on mean air temperature in the 8 days following inoculation for glasshouse-grown oilseed rape (cv. Cobra) inoculated with *Pyrenopeziza brassicae* and exposed in oilseed rape crops at Rothamsted twice weekly from 31 August 1990 to 1 March 1991 and weekly from 20 September 1991 to 14 February 1992.

3.3 Field experiment ,Bristol

Periods with rainfall wetness duration of ≥ 17h, when infection could have occurred, were recorded at Bristol on 19-21, 26, 28, 29 October (56-58, 63, 65, 66 days after sowing) and 6 November (76 days after sowing) (Fig.5) . There were no symptoms on leaves of marked plants on 16 November but light leaf spot lesions were observed on leaves of cvs. Ariana, Darmor and Jet Neuf on 23 November (91 days after sowing). The estimated accumulated temperature during the latent period was therefore 338 or 252 day-degrees, corresponding to infection periods on 19-21 or 26-29 October, respectively. A further increase in light leaf spot incidence was observed on 22 December (120 days after sowing) on the younger leaves of all three cultivars. The accumulated temperature during the latent period from the wet period on 6 November was estimated to be 267 day-degrees.

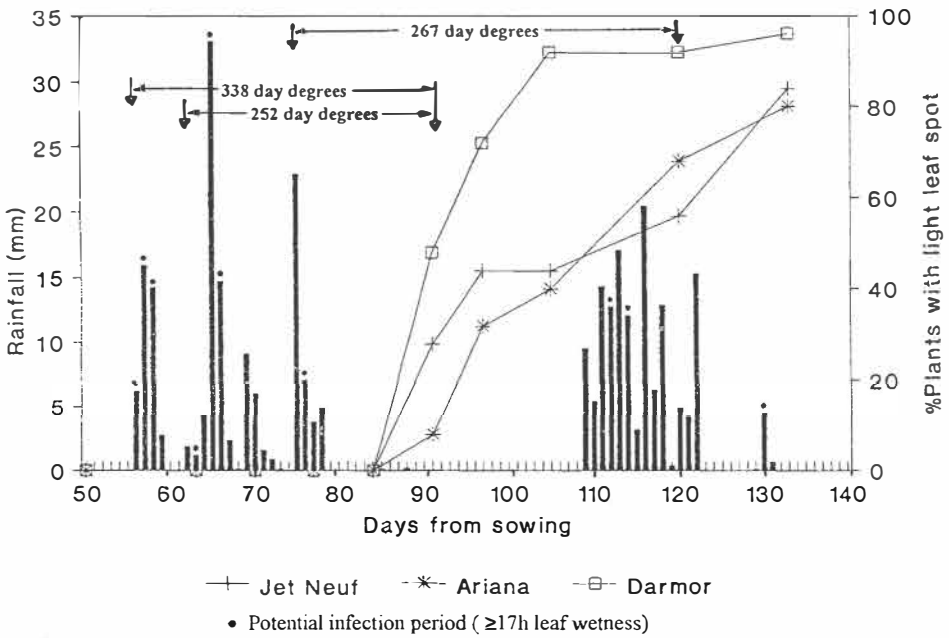

Fig.5. Development of light leaf spot on winter oilseed rape cvs. Ariana,Darmor and Jet Neuf (% plants affected) in 1989/90 at Bristol in relation to rainfall and occurrence of 'infection periods' with wetness duration >17h (●).

4. Discussion

These results suggest that it should be possible to predict the early development of light leaf spot in UK winter oilseed rape from meteorological information, given the presence of inoculum in the autumn. The observed development on three cultivars of winter oilseed rape at Bristol fitted reasonably well with that predicted by the criteria for infection and the length of the latent period developed in controlled environment and field experiments at Rothamsted. Nevertheless, there is a need for further testing and refining of these criteria to

determine whether the occurrence of severe light leaf spot epidemics later in the season, which appears to depend on the establishment of the disease early in the season (Rawlinson & Cayley, 1984; Jeffery *et al.*,1989; Figueroa *et al.*,1994a), can be predicted from such information.

The forecasting criterion of a 16h wetness period for infection may need to be modified because it was determined at only two temperatures (12 and 18°C) and such minimum wetness durations for infection are usually temperature-dependent. For example with *Puccinia arachidis* on groundnut, the minimum leaf wetness duration for infection increases as temperature decreases below or increases above the optimum for infection (Butler & Jadhav, 1991). The experimental results for *P.brassicae* on oilseed rape show only that a minimum wetness duration of >13h and <16h is required for infection at 12 or 18°C. It is possible that a slightly shorter minimum leaf wetness duration may be required at the optimum temperature of *c.*15°C (Figueroa *et al.*,1994b) and likely that a longer minimum wetness duration is required for infection at temperatures below 12°C, which commonly occur in the UK during the autumn and winter.

The accuracy of wetness criteria for determining 'infection periods' depends on the type and positioning of the sensors for measuring wetness. In the Rothamsted field experiments in 1990/91 and 1991/92, the artificial wetness sensor positioned at crop height suggested that a 16h wetness period occurred frequently after mid-October, and all plants exposed then developed symptoms. However, in the Bristol experiments the use of hourly rainfall wetness data suggested that a 16h wetness criterion was fulfilled less frequently there in 1989/90. There is thus a need for further work to determine what measurements are both practical and sufficient to predict when infection of winter oilseed rape by light leaf spot has occurred.

Controlled environment and field experiments at Rothamsted both suggest that the relationship between latent period and temperature is approximately linear over the range 5 to 15°C. Results at 20°C provide clear evidence that the temperature response of the latent period over a wider range has a typical curved shape, like that of other pathogens (Butler & Jadhav, 1991) and accumulated temperature could not be used if mean temperatures were above 15°C. Frequently mean temperatures during the autumn and winter in the UK are in the range 5 to 15°C, but it is not clear what is the effect on the latent period of mean temperatures below 5°C, which can also occur then. Whilst the estimated accumulated temperatures between infection and the appearance of lesions at Bristol were similar to those at Rothamsted, they were generally slightly greater. It is possible that the length of the latent period was different because the cultivars were different (Wilson, 1986) , although it was similar on the three cultivars used at Bristol and also on four cultivars used in controlled environment experiments at Rothamsted (Figueroa *et al.*,1994b).

To predict accurately the development of severe light leaf spot epidemics which decrease yields, and hence the need for application of control fungicides, from information about factors affecting disease development early in the season, there is scope for improving these infection and latent period criteria. For example, these experiments suggest that both the length of the leaf wetness duration above the minimum for infection and the temperature during the latent period affect the severity of light leaf spot lesions and hence the amount of inoculum produced to initiate further disease progress in the crop. Therefore, it may be appropriate to include a factor based on temperature and leaf wetness effects on disease

severity in a prediction scheme. Furthermore, any scheme needs to include both measurements of pathogen inoculum such as spore counts, assessments of visible disease or assessments of cryptic disease with diagnostic immunological kits (Figueroa *et al.*,1993) and meteorological factors determining infection and disease development to predict the development of severe light leaf spot epidemics.

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INVESTIGATIONS OF ISOLATE VARIABILITY OF *Pyrenopeziza brassicae* SUTTON & RAWLINSON (ANAMORPH: Cylindrosporium *concentricum* GREVILLE), THE PATHOGEN OF LIGHT LEAF SPOT ON OILSEED RAPE

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Summary

Isolates of *Pyrenopeziza brassicae* made from infected oilseed rape samples of different localities were investigated regarding their variability of biological properties and fungicide sensitivity.
The parameters mycelium growth, conidia production, length of conidia and germination rate were tested and differences, especially between strongly and weakly aggressive isolates could be observed. The parameters length of conidia and germination rate showed statistically significant correlations to the aggressiveness. Additionally the length of conidia correlated with the conidia production, germination and growth rate as well as the germination rate with the growth rate.
The examination of sensitivity to sublethal concentrations of the fungicides tebuconazole, iprodione, carbendazim, prochloraz and prochloraz+carbendazim revealed a high variation between isolates. Isolates with high as well as low sensitivity could be observed. There were no isolates which were highly sensitive to carbendazim. Some isolates appeared to be tolerant to tebuconazole. The implications of these results are discussed.

1. Introduction

Light leaf spot caused by *Pyrenopeziza brassicae* has been a disease with increasing importance in the German oilseed rape cultivation since the end of the eighties (Amelung & Daebeler, 1991; Paul et al., 1990) and some aspects of the biology of this fungus are not fully understood.

In some cases, fungicides are applied in order to control this disease. In some regions of Germany the use of fungicides is common to control other rape pathogens, especially *Phoma lingam*, *Sclerotinia sclerotiorum* and *Alternaria brassicae* (Ahlers, 1989; Paul, 1991). It is therefore possible that fungicides applied to oilseed rape crops have already influenced the sensitivity of *C.concentricum*.

Experiments with isolates of *C.concentricum* collected from different localities were made to investigate their

variability with regard to the biological parameters mycelium growth, conidia production, length of conidia, germination rate and fungicide sensitivity. Additionally the relationship of these biological properties to aggressiveness is investigated.

2. Materials and Methods

Single spore isolates of *C.concentricum* were made from infected rape samples of different localities in Germany and the UK in 1991-92. For the investigation of biological parameters nine isolates of different aggressiveness were used: Bans of ranking weak (TH4, SG3, BI5), moderate (BW5, BW3, NG1) and strong (BR5, BR6, HE3). The aggressiveness was determined before in trials with artificial infections of rape plants in a climate chamber. For the examination of sensitivity to fungicides, 68 single spore isolates were used.

All experiments were made on PDA (potato dextrose agar, pH6) with two replicates under controlled conditions of 15°C constant and darkness.

The diameter of the mycelium growth was measured on nine agar cultures per isolate after 7, 14, 21 and 28 days.

The production of conidia was determined on 28-day-old cultures, using three samples for each isolate. Demineralized water was given to the cultures on agar, the conidia were scraped off with a rubber spatula and the numbers of conidia was counted from the suspension by using a light microscope.

The length of conidia was also measured by a light microscope, three samples each isolate and 100 conidia each sample. The used cultures had grown 28 days under the above-mentioned conditions.

The germination rate of conidia was tested on water agar (12 g agar/l demin. water). One ml suspension with 10^6 conidia made from 28-day-old cultures was given on an agar culture and the germination rate was determined after 24, 48 and 72h. Three suspensions were tested per isolate.

To investigate the sensitivity to fungicides all single spore isolates were grown on PDA with supplement of sub-lethal concentrations of iprodione (Verisan), tebuconazole (Folicur), carbendazim (Custos), prochloraz (Sportak) and a combination of prochloraz and carbendazim (Sportak alpha). The growth of mycelium was measured on 6 cultures per isolate after a four week period. The effect of the fungicides were tested in advance in concentration experiments. The concentration which suppresses 50% of the growth (ED_{50}-value) was calculated by probit analysis and added for the sensitivity examination (Table 1).

Table 1: ED_{50}-values of fungicides

Fungicide	Active ingredient	(g/l)	ED_{50} (µg/ml)
Verisan	iprodione	260	2,8
Folicur	tebuconazole	250	0,018
Sportak	prochloraz	400	0,029
Custos	carbendazim	450	0,010
Sportak alpha	prochloraz	300	0,012
	+carbendazim	80	0,0032

3. Results

3.1 Growth of mycelium

The isolates showed different growth rates in culture (Fig.1). At all four measuring, the isolates HE3 and BW3 showed the highest mycelium growth, the isolates BW5 and BI5 the lowest. The other cultures showed medium growth.

3.2 Production of conidia

The conidia production of the isolates considered weakly aggressive was significant lower than those which were highly aggressive (Fig.2). The moderately aggressive isolates revealed different results. NG1 showed values similar to the highly aggressive isolates, BW3 was like the moderately aggressive isolates and BW5 similar to the weakly aggressive isolates.

3.3 Length of conidia

The longest conidie could be observed with the weakly aggressive isolates, whereas the highly aggressive isolates produced the shortest conidie (Fig.3). Like the highly aggressive isolates, the moderately aggressive isolates BW3 and NG1 formed short conidie. In contrast, isolate BW5 which was moderately aggressive produce conidie with the same length as the weakly aggressive isolates.

3.4 Germination rate

Distinct differences between the germination rates of weakly and strongly aggressive isolates were found at all four measuring (Fig.4). Medium aggressive isolates had both high (BW3) and low (BW5, NG1) rates of germination. The isolates with high germination rates reached this high values within the first 24h, the isolates with low rates as late as after 48h. In the last stage of experiment until 72h, there was only a small increase of the germination rate.

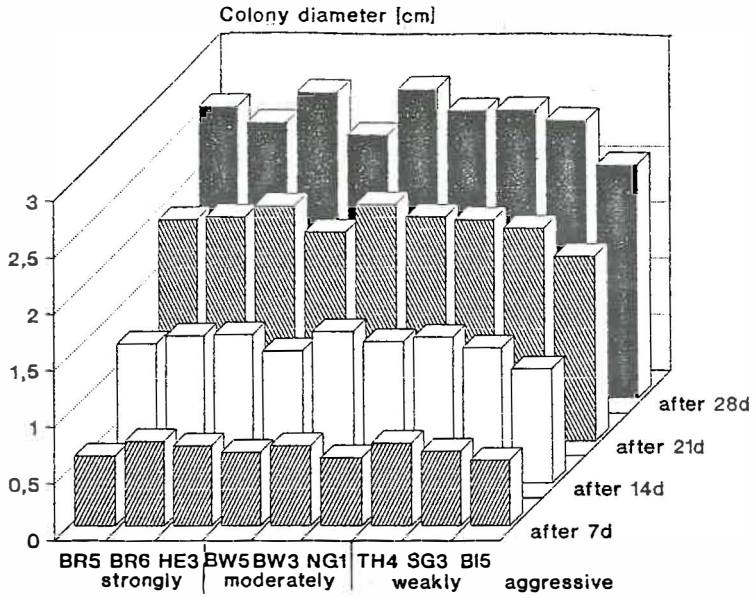

Fig.1: Mycelium growth of the nine single spore isolates after 7, 14, 21 and 28 days of growing (means of three experiments with nine replicates per experiment).

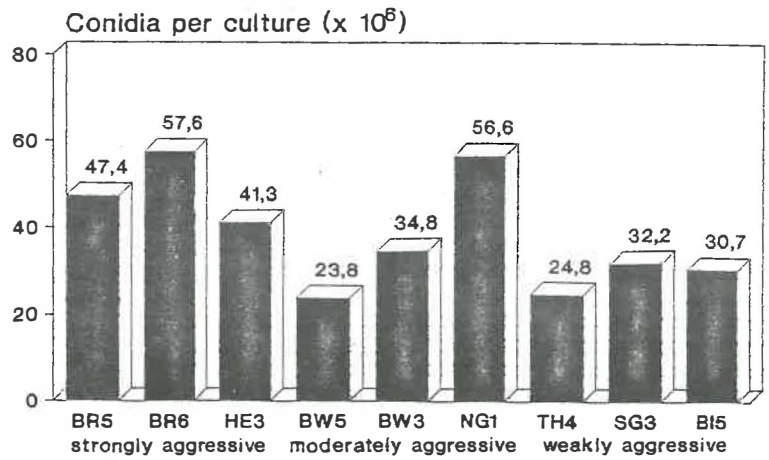

Fig.2: Conidia production from 28 day-old-cultures (means of three experiments with three relicates per experiment).

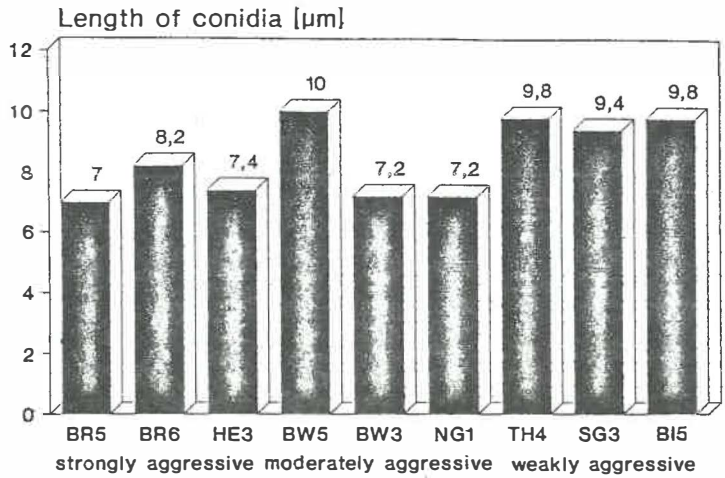

Fig.3: Length of conidia from 28-day-old cultures (means of three experiments with three replicates per experiment).

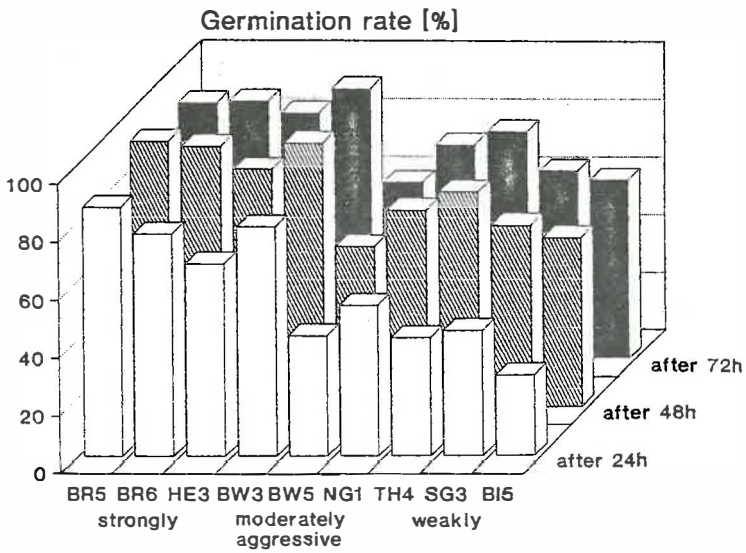

Fig.4: Germination rate of conidia after 24, 48 and 72h from 28-day-old cultures (means of three experiments with three replicates per experiment).

3.5 Correlations between the investigated parameters

The analysis of the correlations was made with Spearman's test for the ordinal scaled data (cf. aggressiveness) and Pearson's test for interval scaled data.

Table 2: Correlations of investigated parameters and aggressiveness (Pearson's and Spearman's test, two-tailed)

Parameter I	Parameter II	Correlation coefficient with $p<0,05$
Length of conidia	Conidia production	-0,73
Length of conidia	Germination after 24h	-0,83
Length of conidia	Germination after 48h	-0,75
Length of conidia	Germination after 72h	-0,77
Length of conidia	Growth after 21d	-0,71
Length of conidia	Growth after 28d	-0,71
Germination after 24h	Growth after 14d	0,70
Germination after 24h	Growth after 21d	0,74
Germination after 24h	Growth after 28d	0,69
Germination after 48h	Growth after 14d	0,74
Germination after 48h	Growth after 21d	0,73
Germination after 48h	Growth after 28d	0,70
Germination after 72h	Growth after 14d	0,80
Germination after 72h	Growth after 21d	0,80
Germination after 72h	Growth after 28d	0,76
Length of conidia	Aggressiveness	-0,78
Germination after 24h	Aggressiveness	0,92
Germination after 48h	Aggressiveness	0,76
Germination after 72h	Aggressiveness	0,67

As can be seen from Table 2, the length of conidia showed a negative correlation with the conidia production, germination rate and growth of mycelium, i.e. the longer the conidia, the lower the production of conidia, germination and growth rate. For the germination rate a positive correlation with growth could be observed.

There was a negative correlation of the conidia length with the aggressiveness and a positive correlation of the germination rate with the aggressiveness. The relation between the germination rate after 24h and the aggressiveness was very strongly developed.

3.6 Sensitivity to fungicides

The investigation of the sensitivity to fungicides showed significant differences between the isolates (Table 3). The highest range of growth rates could be noticed under the influence of Folicur (tebuconazole), the smallest under the influence of Custos (carbendazim). Sportak (prochloraz), Sportak alpha (prochloraz+carbendazim) and Verisan (iprodione) showed a similar range of variation.

Table 3: Growth of mycelium after 30 days of growing on PDA under effect of sub-lethal fungicide concentrations (ED_{50}-values, Table 1)

Fungicide	Range of growth rates in % of the control	Average growth rates in % of the control
Folicur	8,34 - 97,48	46,40
Verisan	5,98 - 73,71	24,04
Custos	35,13 - 87,43	62,44
Sportak	3,69 - 80,33	29,35
Sportak alpha	2,23 - 70,72	28,64

Highly sensitive isolates were found for all fungicides except Custos. Isolates with low sensitivity were observed for all fungicides. One isolate showed growth rates comparable to the untreated control under the influence of tebuconazole, indicating the tolerance of this isolate. Furthermore, there were several isolates with very low sensitivity to tebuconazole.
Results from German and British isolates were similar.

4. Discussion

The investigation of the biological parameters mostly showed considerable differences between the isolates, especially between strongly and weakly aggressive isolates. A clear relation of the investigated properties to the aggressiveness could be observed for the conidia production, the length of conidia and the germination rate, but statistically significant was only the negative correlation of conidia length with aggressiveness and the positive correlation of the germination rate with the aggressiveness, especially after 24h. Additionally a negative correlation of the conidia length with the conidia production, germination rate and growth of mycelium was found. A positive correlation of the germination rate with the growth exists.

The results described above could be misleading, if it is assumed that isolates which form few, long conidie are weakly aggressive only because the probability of infections for many pathogens is due to the inoculum density (Gäumann, 1951). The

probability of successful infection is higher in case of a high inoculum density than of a low. This factor can be excluded because in all experiments the inoculum density was adjusted to 10^6 conidia per ml.

Probably the speed of germination is of special importance for the success of infections and also for the degree of aggressiveness. Plants often try to resist the attack pathogens with defence mechanisms which are either already present in the plant or which are induced by the infection process (Heitefuß, 1987; Hoffmann et al., 1985; Isaac, 1992; Schlösser, 1983). The first described mechanism is independent of time because it is already fully developed in the plant. In contrast, the second mechanism is strongly influenced by time because the defence would only be activate by the attack of pathogens. The effectivity is dependent on the rapidity of penetration by the parasite and on the speed of the activation of defence mechanisms by the plant (Schlösser, 1983). There exist a lot of examples for the dependence on quality and quantity of these mechanisms by time (Mansfield, 1982; Beineke & Schlösser, 1990; Zeyen & Bushnell, 1979). This shows the importance of the rapidity of germination for the infection process, as conidia with fast germination are less influenced by defence mechanisms of the plant.

The variability of isolates could be also seen in Rawlinson et al. (1978). They found similar differences in growth rates and morphology in culture as described in this paper.

The investigation of fungicide sensitivity also showed a considerable variability of the isolates. Isolates with both high and low sensitivity could be observed under influence of the investigated fungicides. It was only under the effect of carbendazim that no highly sensitive isolates were found. One insensitive isolate and several isolates with very low sensitivity to tebuconazole were recorded.

The development of fungicide resistance is one of the main problems of disease control and since the introduction of systemic fungicides problems have occured from time to time (Dekker, 1987; Georgopoulos, 1982). Normally it is not possible to make forecasts for the field resulting by investigations in laboratories and greenhouses (Dekker, 1982a, 1987), but they can show a possibility or tendency in the behaviour of a pathogen under influence of fungicides. The risk to develop fungicide resistance when using carbendazim, a benzimidazole, is expected to be very high and could be observed for different pathogens (Dekker, 1982b; Georgopoulos, 1987) and *C.concentricum* shall possess the possibility of resistance development in the field (Ilott et al., 1987). Benzimidazoles are one-site-inhibitors, and resistance can be formed by one mutation (Georgopoulos, 1987).

Tebuconazole, an ergosterol biosynthesis inhibitor, belonging to the group of triazoles, is also an one-site-inhibitor. Resistance and decreased sensitivity could already be observed in the control of mildew fungi since the beginning of the eighties (Buchenauer, 1987; Scheinpflug & Kuck, 1987).

The fungicide experiments described in this paper show the high natural variability of the investigated isolates and also the possibility of problems with fungicide resistance which could occur if chemical control is used frequently. This especially applies to tebuconazole or triazole in general.

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POLLEN NECROSIS IN *Brassica* LEAVES

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Summary

Localized necrosis was observed under deposits of pollen grains on the leaves of *Brassica rapa*, *B. napus* and *B. juncea*. Eventually, a chlorotic zone developed around the necrotic lesions. The pollen necrosis is a new disease of Brassicas. Preliminary evidence indicated that pollen necrosis may be caused by a component of the pollen grains.

1. Introduction

The phylloplane is subject to a number of interactions among various factors, some of which are of plant origin. One such interaction takes place when the pollen grains are shed on the phylloplane. It has been shown in several different systems that the pollen grains serve as direct stimulants of fungal growth, thereby accentuating the severity of diseases caused by those fungi (Ogawa & English, 1960; Bachelder & Orton, 1963; Channon, 1965; Chou & Preece, 1968; Hartill, 1975; Castro & Matsumoto, 1990). The pollen grains may also serve as sources of nutrients for natural, resident microflora and inhibit the germination and subsequent infection of fungal pathogens (Fokkema, 1976; Skidmore, 1976). This paper describes the interactions that take place when pollen grains of *Brassica* species are shed on the phylloplane of these plants. A preliminary report on this work has been published (Tewari *et al.*, 1994).

2. Materials and Methods

Leaves of *Brassica rapa* L. and *B. napus* L. (spring-sown) were collected during the flowering stage from the fields in Alberta, Canada since 1984 and brought to the laboratory for microscopic examination. Leaves were also collected and examined from the greenhouse of

the Department of Agricultural, Food, and Nutritional Science, University of Alberta. Similar examinations of the leaves of *B. juncea* (L.) Czern. et Coss. collected from fields around Pantnagar, India in January, 1993, and of *B. napus* (fall-sown) from around Paderbam, Germany in May, 1993 were also carried out.

3. Results and Discussion

Both *B. rapa* and *B. napus* leaves had minute necrotic spots under deposits of pollen grains on the leaves. The necrotic areas extended only marginally beyond the leaf areas covered by the pollen grain deposits and with time, developed chlorotic areas surrounding them. These symptoms suggested a typical hypersensitive response caused by various agents on the leaves of plants. Similar necrotic lesions were also observed in areas of leaves on which anthers had fallen but they were not present under the filaments of anthers or petals. These observations indicated that the necrotic lesions were caused by the pollen grains only. These symptoms were not isolated occurrences as they were observed in the leaves from fields and greenhouse in Alberta, Canada every year since 1984.

Necrotic lesions similar to those described above were also observed in the leaves of *B. juncea* and *B. napus* collected from Pantnagar, India, and Paderborn, Germany, respectively.

Microscopic examination of the necrotic lesions did not reveal any microbe growing in and immediately around them. Preliminary work (data not presented here) was carried out to isolate microbes from the necrotic lesions and to inoculate them on the leaves of Brassicas. This work has so far not resulted in isolation of any microbe capable reproducing the localized necrotic symptoms, indicating that lesions are not of microbial origin. As mentioned earlier, pollen grains are known to stimulate several disease-causing agents including *Alternaria brassicicola* (Schw.) Wiltshire on cabbage (Channon, 1965). The mechanism of symptom development in pollen necrosis is not known at this time. However, it could be that a constituent of the pollen grains is perceived as an alien agent by the leaf cells which respond in a hypersensitive manner to it. The pollen grains contain many enzymes including the cell wall degrading enzymes and the possibility also exists that they may be responsible for the necrotic reaction. Severity of the pollen necrosis of Brassicas varies from time to time and from place to place and there is a need to study the factors affecting its incidence and severity.

Pollen necrosis appears to be a hitherto unreported disease of Brassicas. Its symptoms, however, resemble the initial symptoms of blackspot disease of crucifers caused by *Alternaria* species with which it may have been confused in the past. Pollen necrosis of Brassicas may also serve to predispose the plant to infection by pathogens, such as *Alternaria* species, *Sclerotinia sclerotiorum* (Lib.) d By., and some others.

4. Acknowledgements

This work was supported through grants from the Natural Sciences and Engineering Research Council of Canada (to J. P. T.). Field surveys in India and Germany were partly supported by the G. B. Pant University of Agriculture and Technology. Pantnagar, India, and the State Nordrhein-Westfalen, Germany, respectively.

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PRESENCE OF *ALTERNARIA LINICOLA* ON LINSEED SEED AND DEVELOPMENT OF THE DISEASE IN CENTRAL ITALY[1]

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Summary

Tests on linseed seed samples carried out in Italy from 1991 to 1993 showed the presence of *Alternaria linicola* in some seed lots imported from other countries, while those produced in Italy were pathogen-free. A comparison between different seed health methods showed that the freezing blotter method can be used as an alternative to the ISTA-suggested methods for detecting infected seeds. Sand and rolled blotter methods can be conveniently used to quantify the amount of seed-borne inoculum responsible for initiating the disease in the field.
The seeds from the most heavily infected seed sample were field sown in the spring of 1991 and 1992. During emergence the *A. linicola* caused seedling blight and symptoms were observed on the hypocotyls, cotyledons and youngest leaves. After flowering no symptoms were observed and the seeds produced were pathogen-free. Some Italian areas characterized by low and dry rainfall conditions after linseed flowering, are suitable for the production of high-quality, pathogen-free seeds.

1. Introduction

In Italy linseed (*Linum usitatissimum* L.) is grown in the southern regions, principally in Sicily and Apulia, where local ecotypes are employed. This crop annually reaches about 1,000 ha.
In Umbria (Central Italy) the Agronomy Institute of Perugia University has been experimenting with linseed as winter and spring crops. Before sowing linseed, a seed sample of each cultivar was tested for the presence of seed-transmitted pathogens. For detecting important pathogens such as *Alternaria linicola*, *Botrytis cinerea* and *Phoma exigua* var. *linicola*, the International Seed Testing Association (ISTA) suggests methods in three working sheets (Anselme and Champion, 1981; Malone, 1982a; 1982b). Infected seed samples were identified using these methods (Cappelli, 1993; Cappelli and Ciriciofolo, 1991; Cappelli *et al.*, 1993).
Became some seed lots were infected by *A. linicola*, all the seeds were treated with chemicals before sowing in the field (Mercer and McGimpsey, 1987; Mercer *et al.*, 1985; 1988; 1989; 1992). However seeds of the most infected cultivar were also sown in another field without seed treatment to observe disease development in the climatic conditions of Central Italy. Comparisons between ISTA suggested methods and other simple methods used in seed pathology (De Tempe and Binnerts, 1979; Neergaard, 1979) were also carried out.
This paper reports the principal data obtained from 1991 to 1993.

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[1]The work was supported by grant "MURST 60%" to Prof. C. Cappelli: "Alterazioni quali- quantitative prodotte da patogeni trasmissibili per seme".

2. Materials and methods

2.1 Seed testing methods

In each seed health test 400 non-disinfected or disinfected seeds with NaOCl (1% available chlorine for 5 min) were used as working sample. For routine testing the freezing blotter method (FBM) was used. For comparison between methods also those reported below and the seed sample with the highest percentage of infection by *A. linicola* (cv Bluechip) were used.

2.1.1 Agar plate - APM - (Anselme and Champion, 1981; De Tempe and Binnerts, 1979; Malone, 1982a; 1982b; Neergaard, 1979).

Seeds were incubated in Petri dishes (ø 90 mm) containing 2% agar and 1% malt extract in distilled water for 5-7 days at 20-22 °C.

2.1.2 Blotter - BM - (De Tempe and Binnerts, 1979; Malone, 1982a; 1982b; Neergaard, 1979).

Seeds were placed in Petri dishes (ø 90 mm) containing two sterile blotters soaked with sterile water, draining the water excess and incubating at 20±2 °C for 7 days under "near UV" (NUV) light with a 12 h light and dark cycle.

2.1.3 Freezing blotter - FBM - (Limonard, 1968).

Petri dishes containing seeds were incubated for 1 day at 18-22 °C, then at -20°C the second day and then for 5-6 days under NUV light with a 12 h light and dark cycle.

2.1.4 Rolled blotter - RBM - (De Tempe, 1963).

Seeds were placed between layers of filter papers (45x28 cm) soaked with sterile water. The papers were rolled and placed in an upright position in an incubator with a R.H. of 90-95% at 18-22 °C for 6 days. Non germinated seeds, normal and underdeveloped seedlings with and without symptoms were placed in moist chambers under NUV light with a 12 h light and dark cycle.

2.1.5 Sand - SM - (De Tempe and Binnerts, 1979; Neergaard, 1979).

Groups of 50 seeds were sown in plastic containers (25x30 cm) containing sterile sand at 18-22 °C with 14 h of day light. After 12-14 days all the seedlings were picked up and placed in moist chambers under NUV light with a 12 h light and dark cycle.

In each of the five methods after incubation seedlings symptoms and/or the features of the colonies were observed with a stereomicroscope and/or a compound microscope.

2.2 Field experiments.

Each year the seeds of different cultivars were sown at S. Apollinare (Perugia) a typical hill area of Central Italy. Before sowing in experimental plots (10.5 m^2/each) all the seeds were treated with a mixture of carbendazim + iprodione (880+440 g a.i./t). Untreated seeds of the most infected cultivar (Bluechip) were also sown in a field located near the Agricultural Faculty. The normal practices for linseed were used. During and after emergence the plants were checked for the presence of the disease. Plants with typical disease symptoms were collected from the field for the laboratory investigations (moist chambers, isolation in cultural media, etc.). In particular in the field sown with non-treated seeds of cv Bluechip after emergence and during the development of the first true leaves, 1,000 seedlings were examined. From 1991 to 1993 the seeds of each cultivar harvested were tested for the presence of seed-transmitted pathogens.

3. Results

In the first two years of the experiments *A. linicola* was isolated in some imported seed lots, while the following year (1993), when all the seed used was reproduced in Central and Southern Italy, they were pathogen-free (Table 1). The seeds reproduced in the experimental field from 1991 to 1993 were also pathogen-free (Table 1).
The comparison between methods shows that the percentages obtained with FBM, BM, APM, RBM were similar while that obtained with SM was lower (Table 2).
In the field where treated seeds were used the disease was observed during emergence on less than 2% of the emerged plants on the cv Bluechip, while in the field where untreated seeds of the same cultivar were sown 8.6% and 9.3% developed in 1991 and 1992. The fungus caused brown-red streaks on the hypocotyls, cotyledons and first true leaves.
After flowering no symptoms were observed on leaves, stems and capsules and the seeds produced were pathogen-free.

4. Discussion

In the past in different European countries the fungus caused severe disease and experiments on the seed health method to detect linseed pathogens were carried out (Anselme and Champion, 1981; Anselme *et al.*, 1965; De Tempe, 1963; Leduc, 1958; Malone, 1982a; 1982b; Malone and Muskett, 1964; Muskett, 1958; Muskett and Malone, 1941; Neergaard, 1945; 1962). The results of our experiments showed that since FBM is quick, cheap and easy, it can be used in routine testing as an alternative to the methods suggested by ISTA for *A. linicola.*

Comparison of data showed good correlation between FBM, BM, APM, RBM and SM which, better than other methods, simulates seed behaviour after sowing (Table 2). In particular the SM method, gave good indications on the seed-borne component of the inoculum for staring the disease (Table 3). Also RBM gave the same indications. It is less time and space consuming and permits the number of infected but ungerminated seed, that are less important from an epidemiological point of view, to be detected (Table 4).

The field observations suggest that the chemical treatment gave good results on the reduction of infection percentage of seedlings during their development. The disease however, due to the unfavorable climatic conditions, remained confined to the seedling phase in both treated and untreated seeds because during and after flowering no symptoms were observed on leaves, stems and capsules. The analysis of the seeds produced demonstrate that they were not infected by *A. linicola.*

In other countries, characterized by humid conditions the seeds can be easily infected (Fitt *et al.*, 1991a; 1991b). In particular, it has been reported that introducing infected debris into the linseed crop in July, the disease reached 20 m from the infection source after 2 months and was present on leaves, stems and capsules and the seeds became infected (Vloutoglou and Fitt, 1993).

For these reasons some areas of Central Italy, characterized by low and dry rainfall conditions after linseed flowering, are suitable for seed production, because after sowing infected seeds we obtained infected plants but high-quality, pathogen-free seeds.

5. Acknowlegement.

I tank Prof. E. Ciriciofolo of the "Istituto di Agronomia" of Agriculture Faculty, Perugia University for supplying seed samples and informations on linseed cultivation methods.

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Table 1. Percentage of seed infection by A.linicola in linseed seed samples.

Year	Number of Samples	Range (max-min)		Average	
		dS	ndS	dS	ndS
1991	39 (3)	25.5-0	29.0-0	0.7	0.8
1992	44 (3)	24.7-0	30.5-0	0.6	0.9
1993	44 (0)	0	0	0	0

Between brackets are reported the number of infected seed samples.
dS = disinfected seeds; ndS = non-disinfected seeds.

Table 2. Percentage of seed infection by A.linicola obtained with different methods (cv Bluechip).

Method	dS		ndS	
	% infection	K	% infection	K
FBM	24.7	2.4	30.5	2.1
BM	16.2	1.6	28.7	2.0
APM	18.7	1.8	24.7	1.7
RBM	23.2	2.2	34.5	2.4
SM	10.4		14.5	

K = ratio between the infection percentage of the method tested and that of the sand soil (SM).
dS = disinfected seeds; ndS = non-disinfected seeds.

See text for details of methods.

Table 3. Results obtained with the sand test (cv. Bluechip).

	Emerged seedlings	Normal seedlings	Underdeveloped seedlings without symptoms	Underdeveloped seedlings with symptoms	Infected seedlings %
dS	297	202 (1)	75 (14)	20 (16)	10.4
ndS	304	197 (3)	68 (15)	39 (26)	14.5

Between brackets are reported the number of the seedlings in which mycelium and conidia of A.linicola developed after deposing them in humid chamber.
dS = disinfected seed; ndS = non-disinfected seeds.

Table 4. Results obtained with the rolled blotter method (cv. Bluechip).

	Seedlings without symptoms	Ungerminated seeds	Underdeveloped seedlings without symptoms	Underdeveloped seedlings with symptoms	Infected seeds %
dS	284 (0)	55 (49)	28 (16)	33 (28)	23.2
ndS	217 (2)	87 (65)	52 (37)	44 (34)	34.5

Between brackets are reported the number of infected seeds or seedlings.

Disease Resistance and Integrated Control of Diseases

THE EFFECT OF SOWING DATE ON THE INCIDENCE OF BEET WESTERN YELLOWS VIRUS IN WINTER OILSEED RAPE IN ENGLAND AND WALES

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Summary

The incidence of beet western yellows luteovirus (BWYV) in crops of winter oilseed rape has been monitored in England and Wales in an annual survey begun in 1986. The incidence of BWYV reached a peak in 1990, with infection in 98% crops and 73% plants respectively. Levels of BWYV were correlated with the time of drilling, August sown crops were most at risk. Delaying drilling from August to September could reduce levels of BWYV without resort to insecticides and without adversely affecting yield.

1. Introduction

In a joint survey, ADAS and the Central Science Laboratory (CSL) have monitored the incidence of beet western yellows luteovirus (BWYV) in oilseed rape since 1986 (Hill *et al.*, 1989) and cauliflower mosaic caulimo virus (CaMV) and turnip mosaic potyvirus (TuMV) since 1992 (Hardwick, unpublished). Assessments for virus have formed part of a wider survey of oilseed rape diseases (Hardwick *et al.*, 1989). The widespread occurrence of BWYV in oilseed rape in the UK was first reported in 1985 (Smith & Hinckes). The virus is essentially symptomless in oilseed rape, although some reddening to the margins of leaves in the autumn has been associated with infected plants, as has chlorotic mottling at other times of the season. There are no reports of distortion or stunting of plants caused by BWYV, as has been recorded with CaMV and TuMV (Walsh & Tomlinson, 1985). Control of BWYV is difficult as the aphid vectors are active long after the rape crop has emerged and early applications of insecticide have ceased to be effective, but yield losses due to BWYV are not thought to be high (Hill *et al.*, 1989, Walsh *et al.*, 1989).

2. Methods

Details of the survey sampling procedures were as described by Hill *et al.* (1989). Twenty five plants were sampled from between 105 and 128 crops in England and Wales in the spring of each year from 1986 to 1993. The number of crops sampled was in proportion to the area of rape grown in each county. The oldest non-senescent leaf from each of 10 of the 25 plants was tested for the presence of BWYV by indirect enzyme-linked immunosorbent assay (ELISA) using gamma globulin, monoclonal antibody and anti-rat conjugate supplied by Dr D A Govier (Institute of Arable Crops Research, Rothamsted), CSL and Sigma Chemical Co. Ltd, respectively. Details of sowing date were obtained from a questionnaire sent to the cooperating farmers.

3. Results

The number of crops tested for virus in each year ranged between 105 and 128 (Table 1).

Table 1. Numbers of crops tested per Ministry of Agriculture, Fisheries and Food (MAFF) Region

Region	Year							
	1986	1987	1988	1989	1990	1991	1992	1993
Northern	23	22	20	19	26	19	26	26
Midlands and Western	12	17	19	20	22	19	20	20
Eastern	42	51	46	54	49	50	49	54
South Eastern	13	10	13	7	13	16	17	20
South Western	12	10	5	9	8	9	8	6
Wales	3	2	8	3	2	2	2	2
England & Wales	105	112	111	112	120	115	122	128

The number of crops infected with BWYV rose steadily from 1987 to a peak of 98% crops infected in 1990 and then declined to 42% crops in 1993 (Table 2). The percentage crops infected with virus in each region fluctuated from year to year but, in general, smaller proportions of crops were infected in the Eastern and South Eastern Regions compared with the rest of England and Wales.

Table 2. Crops infected with BWYV in the spring in each MAFF Region (%)

Region	Year							
	1986	1987	1988	1989	1990	1991	1992	1993
Northern	56	41	35	89	100	100	42	31
Midlands and Western	83	41	42	90	100	100	65	40
Eastern	62	25	33	61	96	86	51	41
South Eastern	62	17	69	86	100	75	18	50
South Western	42	70	100	100	100	89	100	67
Wales	33	100	38	33	100	100	100	100
England & Wales	60	30	43	75	98	90	59	42

The highest levels of virus were recorded in 1990 when, on average, 73% plants were infected (Table 3). The highest levels of virus were recorded in the Midlands and Western Region with 86% plants infected. Virus levels, however, varied for each region, no region was consistently worse than any of the others, although the South Western Region tended to have the most years with the highest percentage of plants infected (three out of eight years) compared with the Northern Region (two out of eight years) followed by Midlands and Western and South Eastern Regions and Wales (one out of eight years).

Table 3. Plants infected with BWYV in the spring (%)

Region	Year							
	1986	1987	1988	1989	1990	1991	1992	1993
Northern	12	9	5	51	78	75	12	6
Midlands and Western	23	12	12	29	86	44	40	16
Eastern	16	4	10	27	66	43	18	10
South Eastern	28	6	15	27	62	34	32	15
South Western	11	25	46	44	78	47	80	28
Wales	6	45	21	13	65	55	70	15
England & Wales	16	4	12	32	73	50	27	12

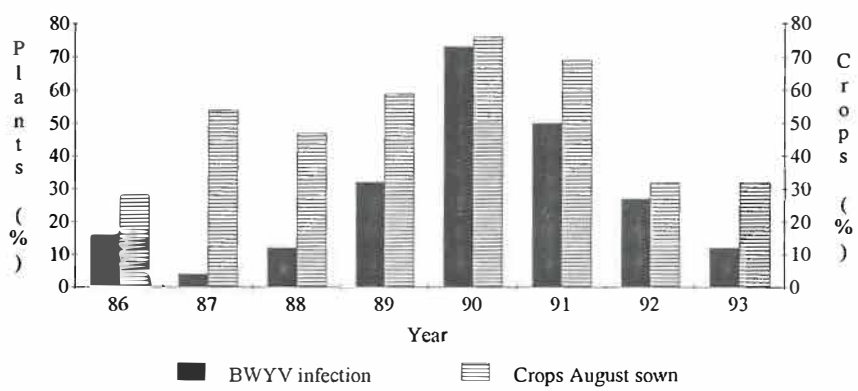
Generally, more than two thirds of crops were sown between 20 August and 7 September. In the years 1990 and 1991 this proportion exceeded 80% (Table 4).

Table 4. Sowing dates of crops (%)

Date	Year							
	1986	1987	1988	1989	1990	1991	1992	1993
Before 20 August	1	11	6	9	7	7	3	5
20-31 August	27	43	41	50	69	62	29	27
1-7 September	36	31	27	26	17	22	39	41
8-14 September	19	8	16	9	5	5	15	17
After 14 September	17	7	10	6	2	5	14	10

The percentage of crops drilled in August varied from year to year and reached a peak in 1990. This coincided with the highest percentage of plants infected with BWYV (Fig. 1). The percentage of plants infected with BWYV in each year correlated well with the percentage of crops drilled in August ($P = 0.038$).

Figure 1. Plants infected with BWYV (%) and crops sown in August (%)



4. Discussion

The levels of BWYV in winter oilseed rape have shown marked changes from year to year since 1986. The changes in levels would appear to have been influenced by sowing date; the greater the proportion of crops sown in August the higher the levels of virus. In any one year the western and northern parts of England tended to have a higher level of BWYV than the eastern and south eastern parts. It is not surprising that levels of virus should be higher in the milder western parts of England, but the level of infection in the north is surprising. However, spraying for cabbage stem flea beetle is more common in the east than in the north, which might provide some control of aphids and therefore virus, and may account for the differences. BWYV is virtually symptomless in winter oilseed rape and while control of BWYV can be achieved by the application of insecticides, only about 20% of crops give a significant yield response to control (Hill *et al.*, 1989). Walsh *et al.* (1989) also reported that good control of BWYV could be achieved by early applications of insecticides, but they did not record differences in seed yield between infected and uninfected plants. However, the results reported here indicate that control of the disease, without the use of insecticides, would appear to be available by delaying sowing into the first week of September. Work by Mendham *et al.* (1981) has shown that such delayed sowing does not unduly penalise yield.

Acknowledgements

We wish to thank ADAS colleagues who collected the samples and the Ministry of Agriculture, Fisheries and Food who provided funding for the survey.

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INVESTIGATIONS ON NATURAL DISEASE RESISTANCE OF 6 OILSEED RAPE CULTIVARS FOR MINIMIZING APPLICATION OF FUNGICIDE IN INTEGRATED PRODUCTION FROM 1992/93

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Summary

In an IOBC experiment in 1992/93, six different cultivars were grown for investigation of their natural disease resistance. Three different seed-rates were used.For disease control two different fungicide treatments were applicated. Assessment of the pathogens *Phoma lingam, Peronospora parasitca, Alternaria brassicae, Botrytis cinerea and Cylindrosporium concentricum* was done at EC 22, 62 and 75. Yield, thousand seed weight, glucosinolates, protein and oil-content were measured on harvested seed.
The major pathogen at any assessment was *Phoma lingam*. The incidence of other diseases was much lower. Lirajet and Liberator were the cultivars with the highest yield. Fungicide treatment had an effect on disease incidence and increased yield but was ,in general,not profitable. The different seed-rates had no effect on yield but thousand seed weight, glucosinolates and protein content decreased as seed-rates increased.

1. Introduction

Considering the competitive market situation for winter oilseed rape it is economically important to optimize rape production. For profitable cropping, costs must be minimized and the production techniques must be improved.

In an experiment arranged through the International Organization for Biological and Integrated Control of Noxious Animals and Plants, Working Group "Integrated Control in Oilseed Crops" 1992/93, six double-low cultivars, with different resistance to the major diseases occuring in rape production were grown. In this experiment, the effect of reducing

the number and rate of fungicide application was investigated. No fungicide was applied in autumn.

In addition to the selection of cultivars and the different fungicide treatments, yield-response and disease development were examined in relation to different seed-rates as well.

2. Material and Methods

In the IOBC-winter oilseed rape experiment six different cultivars were grown: Lirajet, Liberator, Maxol, Falcon, Envol and Samourai. Three seed-rates of 2 kg/ha, 4 kg/ha and 6 kg/ha were used. For disease control two different treatments were conducted (Table 1). For the first spray in spring (EC 51) the amount of fungicide was reduced by using rape-oil. It improves plant wetness and lowers the costs for the treatment. The second spray at flowering (EC 62-64) was done following the conventional recommendation for this growth stage.

Table 1. IOBC winter oilseed rape experiment 1992/93, treatments and products.

Factor	Product	Rate of product applied (l/ha)	Growth stage
F0	no treatment		
F1	Folicur (250 g/l tebuconazole)	0,75	EC 51 1. spray
	+ rape oil	1	
F2	Folicur (250 g/l tebuconazole)	0,75	EC 51 1. spray
	+ rape oil	1	
	Verisan (260 g/l iprodione)	3	EC 62-64 2. spray

The experiment was arranged as a randomized block design with small plots of 30 m^2 and four replications. Each plot was divided into two subplots for disease assessment and a centre subplot for harvesting. Sowing date was 10 September 1992 and harvest was on 22 July 1993.

Disease assessment was carried out at EC 22, 62 and 75 by scoring 10 plants per plot. Leaf attack was evaluated according to KRUGER (1991) and stem attack according to Newman (1984). Pathogens scored were *Alternaria brassicae, Botrytis cinerea, Cylindrosporium concentricum, Peronospora parasitica* and *Phoma lingam.*

The results were analysed at Rothamsted Experimental Station in Great Britain using GENSTAT.

3. Results

3.1 First assessment (EC 22)

At the first sampling (24. - 26.11.1992) plant development varied from an average of 4,91 leaves per plant for cv. Maxol to 5,86 leaves per plant for cv. Samourai (Table 2). Highest number of leaves per plant were obtained for the lowest seed-rate with a consistently lower number at the higher seed-rates (Table 3).

At this growth stage *Phoma lingam, Peronospora parasitica* and *Alternaria brassicae* could be assessed. *Phoma lingam* was the major pathogen. The highest infection level for this pathogen showed the cv. Lirajet followed by cvs Falcon, Samourai, Liberator and Envol on a medium level (Table 2). The lowest incidence with *Phoma lingam* was found on cv. Maxol. The incidence of *Peronospora parasitica* was greatest on cv. Falcon No significant differences could be found for *Alternaria.*

3.2 Second assessment (EC 62)

At the second disease assessment (26. - 28.4.1993) infection with *Alternaria brassicae, Botrytis cinerea, Peronospora parasitca* and *Phoma lingam* were noted (Table 4). For *Alternaria,* the cultivar with the highest incidence of infected plants was cv. Falcon. The other cultivars showed symptoms on a much lower level.- Few differences were apparent for *Botrytis* except on cv. Envol which showed a particularly low incidence of leaf infection. The highest degree of infection with *Peronospora* was recorded for cvs Falcon and Liberator and the lowest for cvs Envol and Samourai whilst the latter cultivars were the most susceptible for *Phoma.*

The first fungicide treatment at EC 51 gave a significant reduction in the incidence of *Alternaria* and *Phoma* (Table 5).
Seed-rate affected the incidence of infection, which increased for *Peronospora* in plots with a denser stand but decreased for *Phoma* (Table 6).

3.3 Third scoring (EC 75)

At the third sampling (25.5 -2.6.1993) cvs Falcon and Samourai reached the highest degree of infection for *Alternaria* with 35 % and for *Botrytis* with 19 % and 23 % respectively (Table 7).The most susceptible cultivar for *Peronospora* was cv. Falcon continuously and the slightest infection was recorded for cv. Maxol. At the second assessment *Phoma* infection was greatest in cv. Samourai followed by cvs Liberator and Envol. The cultivar Maxol showed the slightest infection rate as at the previous assessment (Table 2, 4).

The untreated plots showed the highest incidence of *Alternaria* and *Botrytis* whilst *Peronospora* was on the lowest level in comparison to the treated plots (Table 8). The second fungicide application reduced the incidence of *Alternaria* but had no effect on *Botytis*. The incidence of *Phoma* (leaves and stem canker) was less severe at a seed-rate of 2 kg/ha than for the higher rates (Table 9).

Table 2. Growth stage and incidence of *Peronospora parasitica* and *Phoma lingam* on 6 oilseed rape cultivars grown at the site Hüttinghausen/Westfalen (Germany) in 1992/93 (disease assessment EC 22)

Cultivar	No. of leaves per plant	Incidence (%) of infected plants	
		Peronospora	*Phoma*
Lirajet	5,41	10,00	77,22
Liberator	5,15	7,22	45,00
Maxol	4,91	6,67	28,33
Falcon	4,99	36,67	62,22
Envol	5,47	8,33	43,89
Samourai	5,86	14,44	52,22
LSD 5%	0,16	8,30	10,01

Table 3. Growth stage and incidence of *Peronospora parasitica* and *Phoma lingam* at 3 different seed-rates of oilseed rape at the site Hüttinghausen/Westfalen (Germany) in 1992/93 (disease assessment EC 22)

Seed-rate	No. of leaves per plant	Incidence (%) of infected plants	
		Peronospora	*Phoma*
2 kg/ha	5,41	9,17	55,00
4 kg/ha	5,38	18,06	52,22
6 kg/ha	5,11	14,44	47,22
LSD 5%	0,19	6,28	n.s.

n.s.= Not significant (P=0,05)

Table 4. Incidence of *Alternaria brassicae, Botrytis cinerea, Peronospora parasitica* and *Phoma lingam* on 6 oilseed rape cultivars grown at the site Hüttinghausen/Westfalen (Germany) in 1992/93 (disease assessment EC 62)

Cultivar	Incidence (%) of infected plants			
	Alternaria	*Botrytis*	*Peronospora*	*Phoma*
Lirajet	24,72	20,00	29,44	49,72
Liberator	18,33	18,89	48,61	40,00
Maxol	20,28	15,56	27,22	34,44
Falcon	35,56	20,00	54,44	34,44
Envol	17,78	8,61	11,39	57,50
Samourai	22,50	19,17	11,94	69,72
LSD 5%	7,12	6,00	7,23	6,90

Table 5. Incidence of *Alternaria brassicae, Botrytis cinerea, Peronospora parasitica* and *Phoma lingam* in dependence of different fungicide treatments in oilseed rape at the site Hüttinghausen/Westfalen (Germany) in 1992/93 (disease assessment EC 62)

Fungicide	Incidence (%) of infected plants			
	Alternaria	*Botrytis*	*Peronospora*	*Phoma*
F0	34,44	13,33	30,14	63,89
F1/ F2	17,57	18,89	30,69	39,51
LSD 5%	16,09	n.s.	n.s.	18,60

n.s.= Not significant (P=0,05)

Table 6. Incidence of *Alternaria brassicae, Botrytis cinerea, Peronospora parasitica* and *Phoma lingam* at 3 different seed-rates of oilseed rape at the site Hüttinghausen/ Westfalen (Germany) in 1992/93 (disease assessment EC 62)

Seed-rate	Incidence (%) of infected plants			
	Alternaria	*Botrytis*	*Peronospora*	*Phoma*
2 kg/ha	19,31	15,42	19,31	58,33
4 kg/ha	24,86	16,67	30,28	51,11
6 kg/ha	25,42	19,03	41,94	33,47
LSD 5%	n.s.	n.s.	7,97	7,40

n.s.= Not significant (P=0,05)

Table 7. Incidence of *Alternaria brassicae*, *Botrytis cinerea*, *Peronospora parasitica* and *Phoma lingam* on 6 oilseed rape cultivars grown at the site Hüttinghausen/Westfalen (Germany) in 1992/93 (disease assessment EC 75)

Fungicide	Incidence (%) of infected plants				Canker (%)
	Alternaria	*Botrytis*	*Peronospora*	*Phoma*	*Phoma*
Lirajet	25,00	15,00	51,39	78,61	71,94
Liberator	24,72	8,33	25,83	84,17	80,00
Maxol	24,17	9,17	11,11	69,44	66,39
Falcon	35,28	19,17	68,61	75,56	72,50
Envol	15,56	13,89	22,78	78,89	75,00
Samourai	35,83	23,61	43,33	87,22	82,78
LSD 5%	7,08	5,74	8,27	6,42	7,61

Table 8. Incidence of *Alternaria brassicae*, *Botrytis cinerea*, *Peronospora parasitica* and *Phoma lingam* in different fungicide treatments in oilseed rape at the site Hüttinghausen/Westfalen (Germany) in 1992/93 (disease assessment EC 75)

Fungicide	Incidence (%) of infected plants				Canker (%)
	Alternaria	*Botrytis*	*Peronospora*	*Phoma*	*Phoma*
F0	57,50	25,42	26,11	74,72	64,44
F1	15,97	8,61	37,92	82,78	80,83
F2	6,81	10,56	47,50	79,44	79,03
LSD 5%	7,38	12,80	5,90	n.s.	n.s.

n.s. = Not significant ($\underline{P}$=0,05)

Table 9. Incidence of *Alternaria brassicae, Botrytis cinerea, Peronospora parasitica* and *Phoma lingam* at 3 different seed-rates of oilseed rape at the site Hüttinghausen/ Westfalen (Germany) in 1992/93 (disease assessment EC 75)

Seed-rate	Incidence (%) of infected plants				Canker (%)
	Alternaria	*Botrytis*	*Peronospora*	*Phoma*	*Phoma*
2 kg/ha	25,28	12,78	38,75	70,14	62,78
4 kg/ha	25,69	16,39	36,94	80,69	77,08
6 kg/ha	29,31	15,42	35,83	86,11	84,44
LSD 5%	n.s.	n.s.	n.s.	7,30	7,44

n.s.= Not significant (P=0,05)

3.4 Yield, thousand seed weight and concentration of glucosinolates, protein and oil in seed

Yield was highest for cvs Lirajet and Liberator which gave 4,10 t/ha and 3,95 t/ha respectively, whereas cvs Maxol and Samourai produced the lowest yields (Table 10). The highest thousand seed weight and concentration of glucosinolates was obtained for cv. Liberator and the lowest for cv. Falcon. Protein concentration varied between 22,08% for cv. Samourai and 20,98 % for cv. Lirajet, oil concentration between 42,98 % for cv. Envol and 41,30 % for cv. Maxol.
Both fungicide treatments had a positive effect on yield, thousand seed weight, concentration of glucosinolates and oil (Table 11). Only the protein concentration decreased in the fungicide treated plots.

The seed-rate had no significant effect on yield response (Table 12). Thousand seed weight, concentration of glucosinolates and protein were generally smaller and for oil higher in plots with a medium or high seed-rate.

Tabel 10. Yield, thousand seed weight and concentration of glucosinolates, protein and oil in seed of 6 oilseed rape cultivars grown at the site Hüttinghausen/ Westfalen (Germany) in 1992/93

Cultivar	Yield (t/ha)	Thousand seed weight (g)	Glucosinolate content (µmol/g)	Protein (%)	Oil-content (%)
Lirajet	4,10	4,67	14,66	20,98	41,85
Liberator	3,95	4,78	15,62	21,38	41,99
Maxol	3,49	4,76	13,42	21,32	41,30
Falcon	3,74	4,32	10,20	21,33	42,10
Envol	3,83	4,54	13,36	21,51	42,98
Samourai	3,44	4,43	12,10	22,08	41,55
LSD 5%	0,18	0,09	0,43	0,21	0,20

Tabel 11. Yield, thousand seed weight and concentration of glucosinolates, protein and oil in seed in different fungicide treatments in oilseed rape at the site Hüttinghausen/ Westfalen (Germany) in 1992/93

Fungicide	Yield (t/ha)	Thousand seed weight (g)	Glucosinolate content (µmol/g)	Protein (%)	Oil-content (%)
F0	3,59	4,51	12,87	21,53	41,82
F1	3,82	4,61	13,30	21,45	42,00
F2	3,86	4,62	13,51	21,32	42,06
LSD 5%	0,13	0,07	0,31	0,15	0,14

Tabel 12. Yield, thousand seed weight and concentration of glucosinolates, protein and oil in seed at three different seed-rates of oilseed rape at the site Hüttinghausen/ Westfalen (Germany) in 1992/93

Seed-rate	Yield (t/ha)	Thousand seed weight (g)	Glucosinolate content (µmol/g)	Protein (%)	Oil-content (%)
2 kg/ha	3,72	4,66	13,61	21,65	41,82
4 kg/ha	3,81	4,60	13,19	21,31	42,10
6 kg/ha	3,75	4,49	12,88	21,34	41,96
LSD 5%	n.s.	0,07	0,31	0,15	0,14

n.s.= Not significant (P=0,05)

4. Discussion

In this experiment *Phoma lingam* was the major pathogen at all assessment dates. The infection level of this pathogen in later growth stages e.g. EC 81 was not determined. *Peronospora parasitica, Alternaria brassicae and Botrytis cinerea* were noted at a much lower level. *Cylindrosporium concentricum* was also scored but incidence and severity of this pathogen was too low. At all scoring dates the cv. Maxol was the least susceptible variety to *Phoma lingam* and almost nearly the least susceptible to *Peronospora parasitica*. But the yield of this cultivar was comparatively low. In contrast, cv. Falcon showed the highest number of infected plants at all dates for *Peronosopora parasitica* but yield was moderate. The highest yield was obtained for cvs Lirajet and Liberator which showed a medium or high infection rate for all diseases.

Only the first fungicide treatment reduced the attack of *Alternaria brassicae* and *Phoma lingam* significantly. The second spray only had a slight effect on *Alternaria brassicae* but resulted in an increase for *Peronospora parasitica*. This effect was reflected in the yield response, only the first spray gave a significant increase in yield. But this increase in yield did not enable treatment costs to be recovered. Benefits were reduced by about 19 DM/ ha for F1 and 151 DM/ ha for F2.

(Costs for plant protection incl. MWST. for Folicur 0,75 l = 51,65 DM; Telmion 1 l = 11,06 DM; Verisan 3 l = 119,19 DM; treatment = 25,00 DM; rape = 30,00 DM/ dt). This demonstrates that under the current economic pressures fungicide treatments may not be worthwhile even though an increase in yield and a decrease in disease incidence was obtained. There may also be the possibility of reducing seed rates as no yield response were found as seed rates increases from 2-4-6 kg/ha. Higher seed-rates significantly reduced thousand seed weight, glucosinolate content and protein content.

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STUDIES ON THE OPTIMUM TIMING TO CONTROL RAPESEED BLACKLEG CAUSED BY *LEPTOSPHAERIA MACULANS* WITH FUNGICIDES.

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Summary

Studies on the chemical control of blackleg caused by *Leptosphaeria maculans* on rapeseed were carried out under field conditions. A triazole granule treatment at sowing and foliar sprays in autumn reduced canker symptoms on basal stems. However there was a major difficulty in applying foliar sprays when necessary. Ascospore trapping seemed to be a promising predictor if when to initiate the chemical control.

1. Introduction

Over the last five years, the collar necrosis caused by *Leptosphaeria maculans* has developed on winter rapeseed. Genetic control remains the best way to control the disease, but presently available cultivars do not always have a good level of resistance.

Another possibility could be chemical control, and a number of such studies have been carried out. The aim is to protect rapeseed plants when they are particularly sensitive, i.e. during the early stages of their development (Brunin, 1970). Most often, this period coincides with the release of ascospores of *L. maculans*.

Seed-treatments appeared to have no effect on collar necrosis. However, micro-granules of fungicide applied at sowing and foliar fungicide applications can be effective when applied at the right time (Penaud, 1993). Experiments carried out in 1992 and in 1993 tried to confirm the efficacy of these treatments and define a biological indicator to start foliar sprays.

2. Material and methods

In both 1991/92 and 1992/93, experiments were carried out in open fields with infested rape residues on two sites, Saint-Pathus (77) and Saint-Florent (18), following methods described by Penaud (1993). In each experiment, cv. Samourai was used.

The experimental design was a split plot with four replications. The main plots consisted of the rate of the microgranule fungicide treatment. Foliar sprays were applied at different stages.

Used fungicides were 1) a triazole-based microgranule coded FG 325 at sowing, and 2) Punch CS 0,8 l/ha (flusilazole 250 g/l + carbendazim 125 g/l) as foliar sprays. In 1992, two rates of microgranules were studied : 7,5 and 12 kg/ha. In 1993, only the rate of 7,5 kg/ha was used in our experiments.

The presence of inoculum was monitored by using a Burkard 7-day volumetric spore trap.

In 1991/92, we applied 4 treatments in the growing period : V0 untreated control, V1 first trapped ascospores or at the latest stage B1, V2 same treatment as for V1 repeated a fortnight later, and V3 first leaf spots or at the latest, stage B6.

In 1992/93, we compared 5 modes of treatments applied in the vegetation period : V0 untreated control, V1 well-established release of ascospores, V2 same method as for V1 but repeated a fortnight later, V3 fungicidal protection since the cotyledon stage until B2, and V4 fungicidal treatment since the cotyledon stage until early winter (late in November).

Disease assessments were made on 5 x 1 linear meter row on each plot. In autumn, leaf infection was expressed as percentage of plants with at least one leaf spot. The day after harvest, stem canker was evaluated using the scale : 1 = healthy plant; 2 = limited lesions ; 3 = lesion less than half the circumference of the tap root; 4 = lesion more than half the circumference of the tap root. The collar resists stem bending; 5 = lesion more than half the circumference of the tap root. The collar does not resist stem bending; 6 = plant lodged when observed. For each replication, an index called G2 was calculated using the formula : G2 = (n2 + 3*n3 + 5*n4 + 7*n5 + 9*n6) / N, n2 meaning the number of plants in th 2nd category and N the total number of plants.

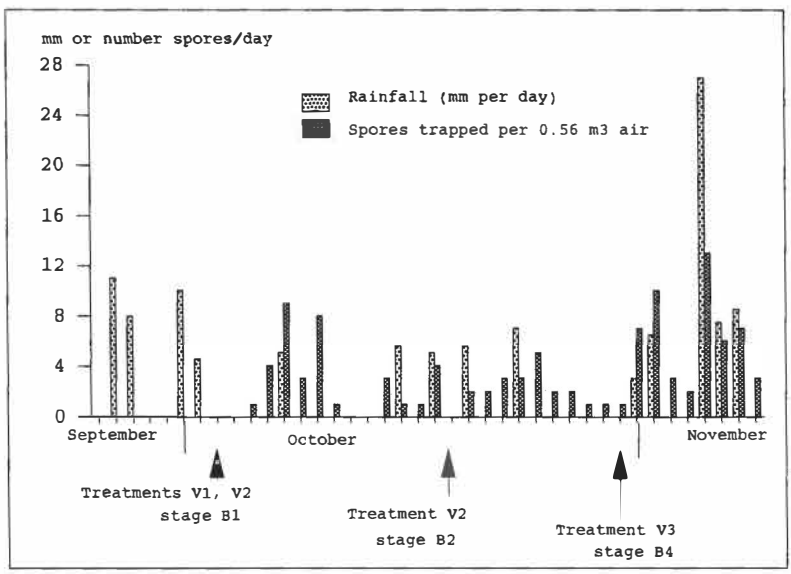
The field trial in Saint-Florent was harvested on 6 July 1993 to determine yield.

3. Results

3.1. Experiments at the CBA in Saint-Pathus, in 1991/92

Foliar sprays were applied in October, at the time of ascospore release (Fig.1).

Figure 1. *L. maculans* ascospore release in Saint-Pathus in autumn 1991.



In autumn, there was a very strong interaction between the treatment applied at sowing and the post emergence treatment. The most significant results are those from 15/11/1991. Foliar infection amounted to 30% on the untreated control and thus was reduced by half after a microgranule treatment, or by one spray treatment. The best protection was obtained with the high rate of microgranules and a two spray treatment, which came just before and after the first release of ascospores (MG12 + V2).

At harvest, both the microgranule treatments and sprays applied at V2 and V3 reduced the severity of collar canker significantly. The treatment applied at the first ascospore release was not different from the untreated control.

Table 1. Importance of leaf infection following treatments at sowing and/or in the period of vegetation

Treatments	leaf infection (%)	
	24/10/91	15/11/91
MG0 + V0	13.7 a	30.3 a
MG7.5 + V0	2.5 c	14.8 b
MG0 + V1	0.4 c	15 b
MG0 + V3	5.4 b	12.1 b
MG7.5 + V2	0.2 c	6.9 bc
MG12 + V3	0.2 c	7.1 bc
MG0 + V2	0.8 c	6.4 bc
MG7.5 + V1	0.2 c	6.2 bc
MG12 + V1	0.4 c	6 bc
MG7.5 + V3	0.8 c	5.7 bc
MG12 + V0	0.2 c	5.6 bc
MG12 + V2	0 c	2.9 c

Treatments means followed by the same letter do not differ significantly (p=0.05)

Table 2. Importance of stem canker level following treatments at sowing and/or in the vegetation period.

Treatments	canker severity G2
microgranules FG 325	
0	4.25 a
7.5 kg/ha	3.77 b
12 kg/ha	3.71 b
PUNCH CS foliar sprays	
V0=untreated control	4.28 a
V1	3.94 ab
V2	3.79 b
V3	3.64 b

Treatments means followed by the same letter do not differ significantly (p=0.05)

3.2. Experimentation in 1992-93

In Saint-Florent, the first ascospores were trapped a fortnight after rapeseed emergence, on 25 September 1992. Under these conditions, the microgranule showed an efficacy of about 60% in the control of leaf spots one month after sowing. Beyond this date, the product had no effect ; therefore, its persistence is limited. Foliar sprays brought about a reduction in leaf spots, the treatments applied just before trapping the first ascospores (V3, V4) being the most effective. For stem canker, continuous protection V4 (cotyledons → early winter) gave the best protection. The earliest applications V1 and V3 gave results which were no different to those of the untreated control, which suggests that infection leading to necrosis took place after the end of the fungicide remanence. These infections may have been due either to ascospores, or to pycnospores released in November. All the treatments lead to a significant yield increase of more than 2 q/ha and reached 6 q/ha for the best protection in autumn V4.

Table 3. Effects of treatments at sowing and/or in the vegetation period on foliar infections, root-collar necrosis and yield.

Treatment	% of plants with leaf spots			Canker severity	Yield
	7 Oct 92	2 Nov 92	16 Dec 92		
stage	B3	B6	B8	index G2	(GPS q/ha)
Sowing					
untreated	12 a	16 a	80 a	5.12 a	26.5 a
granules	5 a*	17 a	80 a	5.13 a	26.9 a
Vegetation					
V0	17 a	25 a	100	5.83 a	23.6 c
V1	12 a	17 b	100	5.68 ab	26.2 b
V2	11 a	18 b	100	5.09 b	26.7 b
V3	0.4 b	12 bc	100	5.69 ab	27.0 b
V4	0.9 b	10 c	0	3.32 c	30.0 a

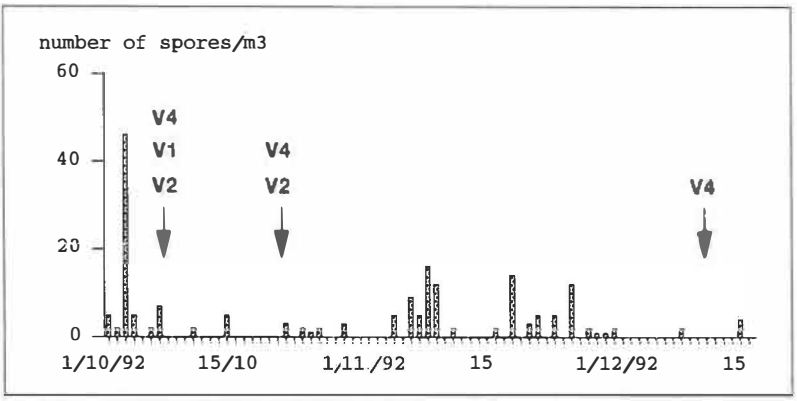
Treatments means followed by the same letter do not differ significantly (p=0.05)

In the experiment of Saint-Pathus, the treatment at sowing had no effect two and a half months after the application of microgranules. On the other hand, we recorded treatment efficacies in the vegetation period, in particular when the treatment V2 was applied at the time of a peak of ascopore emission and repeated a fortnight later (Fig. 2).

At harvest, the root collar necroses were significantly less serious after a microgranule treatment at sowing or after application of fungicide treatments well timed in relation to periods of ascospore release(V2, and to a lesser extent V1) or applied repeatedly in autumn (V4).

Also, a fungicide treatment in the spring could reduce the severity of necroses significantly. The addition treatment at sowing + treatment V4 + spring treatment led to a good protection (index G2 : 2,8), but however it did not lead to plants without *Phoma*.

Figure 2 . *L. maculans* ascospores release at Saint-Pathus in the autumn of 1992.



V1, V2, V4, fungicide applications of tested treatments
V3 applied on 25/9/92

Table 4. Effects of treatments at sowing, in the vegetation period in autumn, or in the spring on the leaf spots and the root-collar necrosis 1992/93.

Treatment	% of plants with leaf spots 25/11	Stem canker index G2
Sowing		
untreated	34.6 a	4.79 a
FG325	30.2 a	4.18 b
Vegetation		
V0	50.3 a	5.53 a
V1	43.7 a	4.64 bc
V2	12.5 b	4.17 c
V3	42.8 a	4.84 b
V4	12.8 b	3.26 d
Spring		
untreated	-	5.01 a
treated	-	3.97 b

Treatments means followed by the same letter do not differ significantly (p=0.05)

4. Discussion

The microgranule applied at sowing had a good efficacy in the case of early infection by *L. maculans*. However, its persistence for about one month cannot protect the young plants when they are particularly sensitive, between six and eight weeks after sowing. It would be necessary to have a formulation available which would free the active ingredient more slowly, as it seems to be the case when the product is formulated on fertilizer granules (Ballinger et al., 1988).

A programme seems necessary with foliar sprays.They showed a good efficacy when applied at the time of infection in autumn. Therefore, an indicator of infection seems to be necessary. The trapping of ascospores will give us information in real time on the ascospore release and will allow us to start a treatment before the fungus is deeply developed in the plant. Conversely, a diagnosis such as that developed by Schramm and Hoffmann (1988), which requires a sampling and reading ten days later, leads to underestimate of infection so that treatments are applied late. Fungicides have no pronounced curative effect towards *Phoma* and should be applied as protectants ideally.

As with previous observations, the percentage of plants with leaf spots in the autumn was not correlated with the severity of canker at harvest. Correlation coefficients for the instance of leaf spotting in the autumn with collar necrosis were found to be 0.44 (St Pathus, 1991/92), 0.44 (St Florent, 1992/93) and 0.64 (St Pathus, 1992/93) which were significant at 5% level. It is therefore confirmed that incidence of leaf spotting is a poor indicator of subsequent development of stem infection.

A systematic protection in autumn with at least three applications of fungicide lead to the best protection. Fungicide protection in the spring also contributed to the reduction in the severity of stem necrosis. These results indicate that the early contamination by ascospores in autumn are not the only origins of necroses. Later contaminations by ascospores and secondary contaminations by pycnidiospores at the time of extension growth could also bring about the development of necroses.

From an economic point of view, it would not be practical to think of applying several spray treatments to protect rapeseed against stem canker. However it would be interesting to have a healthy control available and thus establish the effects of *Phoma* on yield. The improvement of resistant cultivars seems to be the most economic short-term means to control *Phoma*.

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INCIDENCE AND EFFECTS OF DISEASES ON SEVEN WINTER OILSEED RAPE CULTIVARS IN 1991/92 AND 1992/93

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Summary

Seed yields were generally greater from plots sprayed with fungicides in autumn, spring and summer than from unsprayed plots but the sizes of yield responses differed between cultivars and were generally greater in 1992/93 than in 1991/92. Oil content differed between cultivars but was not affected by fungicide treatment. The incidence of light leaf spot (*Pyrenopeziza brassicae)* and Phoma leaf spot (*Phoma lingam*, cause of stem canker), on leaves in May 1992 and April 1993 was decreased by fungicides but that of downy mildew (*Peronospora parasitica*) was often increased. The incidence of stems with *P. brassicae* was greater in June 1992 than in June 1993, but the incidence of *Phoma* canker was greater in 1993 than in 1992; decreases in both in response to fungicides differed between cultivars and were related to yield responses. The incidence of *Alternaria* spp. and of *P. brassicae* on pods also differed between cultivars and was generally decreased by fungicide treatments.

1. Introduction

Diseases have consistently decreased yields of both single-low (low erucic acid) and double-low (low erucic acid, low glucosinolate) winter oilseed rape crops, in experiments when effects of diseases have been assessed by use of fungicides to control them (Rawlinson *et al.*, 1989; Leach *et al.*, 1994). However, the effects of diseases on crop growth and yield may differ between cultivars since both the incidence and severity of diseases and the effects of fungicides on seed yield differed between cultivars. Furthermore, ADAS national surveys of oilseed rape diseases in England and Wales for 1986 to 1991 have shown that different diseases are more damaging in different seasons and in different locations (Fitt & Hardwick, 1992). A series of IOBC experiments in France, Germany and the UK was started in 1990 to investigate the effects of diseases and consequently the need for use of fungicides on different cultivars in different locations and seasons. The results for the 1990/91 season have already been reported for Germany (Garbe, 1993; Paul & Beinecke, 1993) and the UK (Church & Fitt, 1993). This paper reports the results of experiments at Rothamsted, UK, using seven cultivars in 1991/92 and six cultivars in 1992/93 in plots with or without fungicide treatments in autumn, spring and summer.

2. Materials and Methods

Similar field experiments were done at the Rothamsted farm in 1991/92 and 1992/93, each with a range of double-low cultivars of winter oilseed rape in plots with or without fungicide treatments. Plots were 3 x 21m and were arranged in a randomised block design with four blocks.

2.1 1991/92 experiment

The cultivars Capricorn, Envol, Eurol, Falcon, Libravo, Samourai and Tapidor were all sown at 120 seeds/m^2 on 11 September 1991. Fungicide-treated plots received autumn and spring sprays of prochloraz (Sportak 45) at 0.5 kg a.i. in 200 l/ha water on 2 December 1991 and 1 April 1992, and a post-flowering spray of iprodione (Rovral Flo) at 0.5 kg a.i. in 200 l/ha on 4 June 1992. Sprays were applied by a tractor-mounted spray boom. Nitrogen was applied as Nitram fertilizer (35%N) on 20 February (77 kg/ha N) and 20 March (102 kg/ha N). Plots were desiccated on 15 July with diquat (Reglone) at 0.6 kg a.i. in 260 l/ha and combine harvested on 22 July. Seed yields were adjusted to 90% dry matter.

2.2 1992/93 experiment

The cultivars Capricorn, Envol, Falcon, Libravo, Rocket and Samourai were all sown at 120 seeds/m^2 on 26 August 1992. Fungicide treated plots received autumn and spring sprays of prochloraz (Sportak 45) at 0.5 kg a.i. in 200 l/ha on 8 December 1992 and 8 March 1993, and a post flowering spray of iprodione (Rovral Flo) at 0.5 kg a.i. in 200 l/ha on 18 May 1993. Nitrogen was applied as Nitram fertilizer (35%N) on 18 February (61 kg/ha N) and 23 March (129 kg/ha N). Plots were desiccated on 19 July with diquat (Reglone) at 3.0 l in 400 l/ha and combine harvested on 26 July. Seed yields were adjusted to 90% dry matter.

2.3 Assessments

Samples for disease assessment were taken from two blocks in autumn (November), winter (February), spring (April/May) and early summer (June). Ten plants per plot were sampled along a diagonal across each plot before stem extension and as five from each side, at least two rows into each plot, after stem extension. Plants were kept in polyethylene bags at 4°C for 10 to 14 days before disease assessment. The growth stage, the number of leaves and the number infected by each disease were recorded for each plant; the severity of light leaf spot and Phoma leaf spot was also recorded on a 0.1-3.0 scale (0.1, trace leaf area affected; 1.0, trace-10%; 2.0, 10-50%; 3.0, >50%; Rawlinson, Muthyalu & Cayley, 1984). Later in the season the presence of diseases on stems and pods was also recorded. In July, the severity of diseases was recorded by visual in-plot assessments, on six 1 m^2 areas per plot, using a NIAB key; mean estimated areas of stems and pods affected were multiplied by 33.3 to obtain a disease rating. There was also one post-harvest assessment on the stubble. Oil contents of harvested seed dried at 105°C for *c.* 16h were determined using low resolution nuclear magnetic resonance and oil yield at 90% dry matter was calculated. The relationship between the yield response and disease control was studied by linear regression of yield response on the decreases in the % plants with stems infected by light leaf spot or Phoma stem canker, respectively.

3. Results

3.1 Yield and oil content

Overall, seed yields were greater ($P < 0.001$) from plots sprayed with fungicides in autumn, spring and summer than from unsprayed plots in both seasons (Table 1). For cultivars which were grown in both seasons, both yields and yield responses to fungicides were greater in 1992/93 than in 1991/92. Cultivars Capricorn and Samourai gave good yield responses in both seasons, Envol and Libravo gave good responses in 1992/93 and Falcon did not respond greatly to fungicide treatments. Oil content differed slightly between cultivars but was not greatly affected by fungicide treatment or season.

Table 1. Seed yield and oil content (%) of double-low cultivars of winter oilseed rape in plots with or without fungicide treatments in 1991/92 and 1992/93.

Cultivar	Yield (t/ha)		Oil content (%)	
	None	Fungicide	None	Fungicide
1991/92				
Capricorn	3.90	4.33	49.2	48.9
Envol	3.69	3.73	50.1	50.1
Eurol	3.70	4.05	49.7	50.4
Falcon	3.70	3.49	48.3	49.5
Libravo	3.10	3.31	49.4	50.0
Samourai	3.67	4.03	49.6	50.0
Tapidor	3.82	4.26	50.4	50.0
SED (39 df)	0.199		0.48	
1992/93				
Capricorn	4.17	4.68	50.2	50.4
Envol	4.59	5.08	49.2	49.6
Falcon	4.08	4.27	48.0	48.2
Libravo	4.16	4.68	49.0	48.4
Rocket	3.87	3.99	49.0	49.7
Samourai	4.33	4.73	49.1	49.9
SED (33 df)	0.127		0.33	

3.2 Disease incidence

The incidence of leaves infected by light leaf spot(*Pyrenopeziza brassicae*, anamorph *Cylindrosporium concentricum*) in May 1992 (GS 4,5) was less in plots sprayed with fungicide (0-1.5% leaves infected) than in unsprayed plots (10-44%), as was the incidence of leaves infected by *Phoma lingam* (cause of stem canker, teleomorph *Leptosphaeria maculans*) (sprayed, 0-3%; unsprayed 6-18%) (Table 2). By contrast, fungicide sprays increased the incidence of downy mildew (*Peronospora parasitica*) from 4-25% to 16-39%. Similar effects were observed at GS 4,5 in 1993, except that the incidence of *Phoma* leaf spot was greater than in 1992 and the incidence of both light leaf spot and downy mildew was less. The incidence of pathogens differed between cultivars, with most *P. brassicae* on leaves of cv. Capricorn and most *P. lingam* on leaves of cv. Samourai in both years. *Alternaria* spp. and *Botrytis cinerea* were also observed on leaves at this stage in both years.

The two most common pathogens on stems of plants sampled in June (GS 6,2) were *P. lingam* (canker) and *P. brassicae* (light leaf spot) (Table 3). In unsprayed plots, the incidence of plants with canker ranged from 35% (cv. Capricorn) to 90% (cv. Tapidor) in 1992 and that of plants with light leaf spot ranged from 25% (cv. Falcon) to 90% (cv. Capricorn). In 1993, the incidence of light leaf spot on stems was less than in 1992 for all cultivars but the incidence and severity of canker were greater. Fungicide treatments substantially decreased the incidence of both pathogens on stems in both years with the greatest decreases in light leaf spot being on cultivars Capricorn and Samourai, and greater

Table 2. Incidence of diseases on leaves (% infected) of double-low cultivars of winter oilseed rape in plots with or without fungicide treatments, sampled on 6 May 1992 (GS 4,5) or 24 April 1993 (GS 4,5).

Cultivar	Fungicide	% leaves infected *Alt.*	*Bot.*	*Per.*	*Pho.*	*Pyr.*
1992						
Capricorn	-	2.1	7.9	20.4	9.4	44.2
	+	1.0	12.7	31.2	1.0	0.5
Envol	-	6.2	6.8	8.1	11.7	9.5
	+	2.9	7.3	27.6	3.0	0
Eurol	-	7.4	11.2	24.6	11.6	11.0
	+	3.9	11.2	19.3	1.5	0
Falcon	-	4.1	26.6	22.2	6.1	23.2
	+	0	30.5	38.6	2.6	0
Libravo	-	1.0	18.4	15.7	5.8	12.0
	+	0	10.5	27.6	1.0	1.5
Samourai	-	5.8	25.2	19.7	17.8	7.4
	+	2.0	21.5	25.6	1.3	0.7
Tapidor	-	4.5	9.3	4.2	14.6	18.0
	+	6.0	6.0	16.4	0	0.5
SED (13 df)		3.38	8.20	5.91	2.53	5.01
1993						
Capricorn	-	0.8	7.5	0.8	12.5	17.3
	+	0	5.4	6.0	8.5	0.4
Envol	-	0.5	1.1	1.2	15.7	4.7
	+	0.7	2.8	0.6	11.4	0.6
Falcon	-	1.8	9.9	3.7	6.7	14.0
	+	1.9	3.9	15.5	8.3	0
Libravo	-	3.4	4.3	4.7	14.8	1.7
	+	0	3.7	5.6	3.2	0
Rocket	-	1.9	7.4	8.6	12.7	2.4
	+	0.9	4.2	9.0	2.4	0.9
Samourai	-	1.7	8.1	4.7	16.2	4.0
	+	0.7	3.2	2.5	8.1	0.7
SED (11 df)		1.26	1.96	2.78	3.09	3.33

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

decreases in canker on Envol, Falcon and Libravo in 1993 than in 1992. The incidence of pathogens on pods in July (GS 6,6 - 6,7) was low in both 1992 and 1993; those observed most frequently were *Alternaria* spp. (dark pod spot), especially on cv. Falcon, and *P. brassicae*, especially on cv. Capricorn (Table 4). Fungicide treatments decreased the incidence of both these pathogens in both seasons. Regressions of yield response (Table 1) on decreases in the incidence of plants with stems infected by *P. lingam* or *P. brassicae* (Table 3) accounted for 56% and 79% of the variance, respectively (Fig. 1).

Table 3. Incidence of diseases on stems of plants (% infected) of double-low cultivars of winter oilseed rape in plots with or without fungicide treatments, sampled on 18 June 1992 (GS 6,2) or 4 June 1993 (GS 6,2).

Cultivar		% plants with stems infected			
		Phoma		*Pyrenopeziza*	
		None	Fungicide	None	Fungicide
1992	Capricorn	35	5	90	20
	Envol	47	35	41	35
	Eurol	50	30	55	25
	Falcon	30	25	25	43
	Libravo	35	10	40	20
	Samourai	60	26	65	16
	Tapidor	90	45	65	60
	SED (13 df)		14.9		18.1
1993	Capricorn	55	15	50	5
	Envol	75	30	10	0
	Falcon	95	55	0	0
	Libravo	95	50	15	5
	Rocket	95	80	0	5
	Samourai	95	35	55	0
	SED (11 df)		16.4		4.7

Table 4. Severity of diseases (disease rating) on pods of double-low cultivars of winter oilseed rape in plots with or without fungicide treatments, sampled on 9 July 1992 (GS 6,6) or 8 July 1993 (GS 6,7)

Cultivar		Disease rating on pods[1]			
		Alternaria		*Pyrenopeziza*	
		None	Fungicide	None	Fungicide
1992	Capricorn	0.6	0.6	5.0	1.4
	Envol	0.3	0	0	0
	Eurol	1.7	0.3	0.3	0
	Falcon	4.7	0.8	0.3	0
	Libravo	0.8	0	0.6	0
	Samourai	0	0.3	1.9	0.3
	Tapidor	0.8	0.6	1.7	0
	SED (13 df)		1.04		1.46
1993	Capricorn	2.8	1.4	7.2	0.3
	Envol	3.1	1.1	0.3	0
	Falcon	7.8	1.4	0.3	0
	Libravo	3.1	1.1	1.1	0.8
	Rocket	2.8	1.4	0	0
	Samourai	2.2	1.9	0.6	1.1
	SED (11 df)		2.48		[2]

[1] % area of pods affected, as assessed visually on 6 areas per plot, multiplied by 33.3

[2] Insufficient data to calculate an SED.

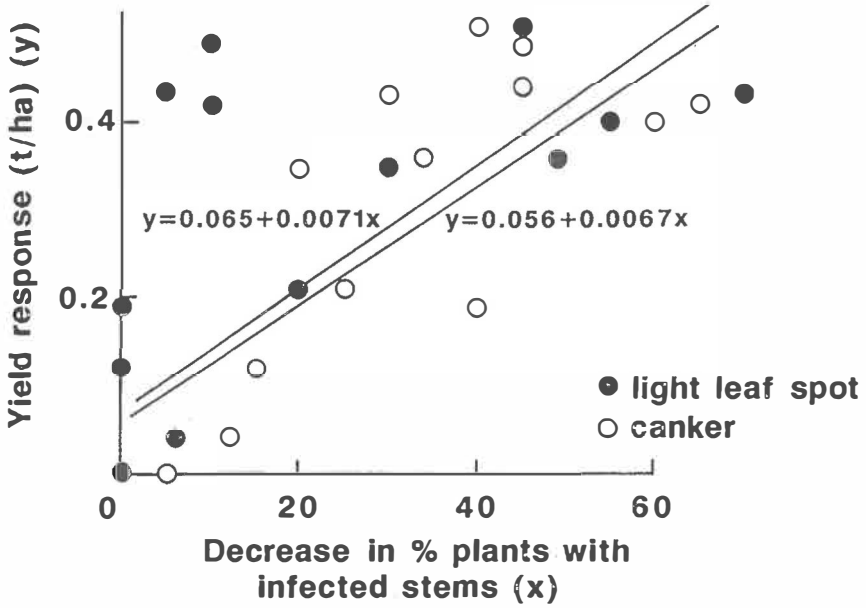

Fig. 1. Relationship between yield response (t/ha) to fungicide sprays (y) and the control of light leaf spot (●) or Phoma canker (○) on stems, assessed in June 1992 or 1993 (x, decrease in % plants with infected stems). Regression lines of the form $y = a+bx$ for light leaf spot, omitting points for plots with little disease ($a = 0.056$, $b = 0.0067$, $r^2 = 0.79$), and for Phoma canker ($a = 0.065$, $b = 0.0071$, $r^2 = 0.56$).

4. Discussion

These results demonstrate the effects of diseases caused by *P. lingam* and *P. brassicae* since there was a clear relationship between a decrease in the incidence of these pathogens on stems and an increase in yield. Thus, yield responses were greatest for those cultivars/seasons when fungicides decreased the incidence of canker and light leaf spot most, such as with cv. Capricorn in both seasons. Sometimes similar yield responses were obtained through control of stem canker alone, as with cvs. Envol and Libravo in 1993 and cv. Tapidor in 1992. When fungicide treatments decreased disease incidence little, as with stem canker on the susceptible cv. Rocket (Anon., 1992) in 1993 and with canker and light leaf spot on the more resistant cv. Falcon (Anon., 1993) in 1992, they increased yields little. It was interesting that more resistant cultivars, such as Falcon and Libravo, gave greater yield responses in 1993 than in 1992 when they developed less stem canker.

These results confirm that double-low cultivars of winter oilseed rape differ in their responsiveness to fungicides (Rawlinson *et al.*, 1989). However, in these experiments, cultivar differences in responsiveness can be explained in terms of differences in disease control by fungicides and it is not necessary to suggest phytotonic effects of fungicides as a

contributory cause. It may be possible to improve our understanding of the relationship between disease and yield response by expressing disease control in terms of decreases in disease severity rather than decreases in incidence. Nevertheless, these results suggest that it is important to know the responsiveness of the cultivar being grown, both in terms of disease control and of yield increase, when assessing whether or not to apply fungicide sprays for disease control.

Acknowledgement

We thank A.D. Todd for doing the statistical analyses of these data.

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EFFECTS OF DISEASES ON GROWTH AND YIELD OF FIVE CULTIVARS OF LINSEED, 1991-1993

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Summary

In 1991, 1992 and 1993 four linseed cultivars (cvs Antares, Barbara, McGregor and Norlin) and one breeding line (CD1747) generally produced greater seed and oil yields in plots treated with fungicides (2.39t seed/ha, 931kg oil/ha) than in untreated plots (2.16t seed/ha, 839kg oil/ha). Yields of all cultivars except Antares were greatest in 1993. Emergence was greater in 1992 than in 1991 for all cultivars, and was lowest in 1993 for cvs Antares, McGregor, Norlin and CD1747. All cultivars were tallest in 1991 and shortest in 1993. The proportions of the stem lengths with brown leaves at GS (growth stage) 10 were greatest in 1992 and least in 1993 and were sometimes decreased by fungicide treatments. Stem browning (*Verticillium dahliae*) scores were greatest in 1992 and least in 1993 on all cultivars. Numbers of capsules were greatest in 1993 and least in 1991 for most cultivars but were least for cv. Barbara in 1992. The proportions (%) of capsules with sporulating grey mould (*Botrytis cinerea*) at GS 10-11 were decreased by fungicide treatments in 1991 and 1992 and were very small in 1993. The proportions of capsules with sepals with brown lesions were greatest in 1992 and least in 1993, and were decreased by fungicide treatments.

1. Introduction

Different diseases can decrease seed and oil yields of linseed crops in the UK by affecting different stages in crop growth (Mercer *et al.*, 1991; Mercer, 1992). Seedling blights caused by seed-borne pathogens such as *Alternaria linicola*, which was common on seed samples from UK crops in 1987 and 1988 (Fitt *et al.*, 1991), can decrease emergence by 50% and yield by 30% (Mercer *et al.*, 1989). Foliar diseases appear to be most damaging in seasons when there are periods of wet weather between flowering and harvest. The use of fungicides in wet seasons decreased the leaf necrosis that is associated with *Alternaria* spp. and *Botrytis cinerea*, and greatly increased yields (Fitt & Ferguson, 1993). Grey mould (*B. cinerea*) can also cause losses through premature abscision of flower buds and senescing capsules. The development of stem browning, caused by the soil-borne pathogen *Verticillium dahliae*, can be widespread in maturing crops and probably causes yield losses in seasons when hot dry weather in August/September increases soil temperatures (Fitt *et al.*, 1992). Many of the experiments done in recent years to assess effects of diseases on linseed have used the widely grown cultivar Antares. This paper considers effects of diseases on growth and yield of four cultivars and one low linolenic acid breeding line in three seasons.

2. Materials and Methods

2.1 Experiments

Linseed cvs Antares, Barbara, McGregor and Norlin were sown at 600 seeds/m^2 on 10 April 1991 as a second linseed crop on the Rothamsted farm (soil type clay loam with flints). These cultivars and the low linolenic acid breeding line CD1747 were sown at 550 seeds/m^2 on 21 April 1992 (second linseed) and 700 seeds/m^2 on 20 April 1993 (first linseed). Plots (3x15m) with or without fungicide treatments were arranged in four randomized blocks. Prochloraz seed treatment (0.4g/kg seed) was applied to seed for fungicide plots in 1991 and 1992 and to seed for all plots in 1993.

Spray treatments, applied by tractor-mounted spray boom, in 1991 were prochloraz (0.32 kg) as Sportak (emulsifiable concentrate, Schering AG) in 200 l/ha water on 2 July, iprodione (0.5 kg) as Rovral Flo (suspension concentrate, Rhone Poulenc) in 200 l/ha on 22 July and carbendazim (0.25 kg) + maneb (1.6 kg) as Delsene M (suspension concentrate, Du Pont) in 220 l/ha on 1 August. In 1992 treatments were iprodione (0.5 kg) in 200 l/ha on 24 June, prochloraz (0.41 kg) in 200 l/ha on 8 July and carbendazim (0.25 kg) + maneb (1.6 kg) in 200 l/ha on 23 July. In 1993 treatments were iprodione (0.5 kg) in 200 l/ha on 28 June, prochloraz (0.41 kg) + carbendazim (0.5 kg) as Sportak Alpha (suspension concentrate Schering AG) in 200 l/ha on 22 July and carbendazim (0.25 kg) + maneb (1.6 kg) in 200 l/ha on 4 August. Plots were desiccated with diquat (0.6 kg) as Reglone (suspension concentrate, ICI Agrochemicals) in 400 l/ha on 2 September 1991 and in 260 l/ha on 6 September 1993, and with glufosinate-ammonium (0.45 kg) as Challenge (soluble concentrate, Hoescht) in 400 l/ha on 5 September 1992 and combine harvested on 10 October 1991, 29 September 1992 and 23 October 1993, respectively.

2.2 Measurements

Emergence was assessed on several occasions in April/May by counting numbers of plants in six 0.5m row-lengths per plot. Samples of 10 or 12 plants per plot were taken regularly throughout the season for growth and disease assessments from the sampling areas. Measurements of crop growth such as height, number of capsules and growth stage (GS; Turner, 1987) were recorded and disease assessments such as the length of stem with necrotic leaves, the stem browning (*V.dahliae*) score on a 0-5 scale, and the numbers of capsules with sporulating grey mould (*B. cinerea*) and with sepals with brown lesions were made. Yields (t/ha) were calculated at 90% dry matter and % oil in seed dried at 105°C was measured by nuclear magnetic resonance to calculate the oil yield (kg/ha). Analyses of variance were done on these measurements to assess differences between cultivars and between fungicide treatments.

3. Results

3.1 Seed and oil yield

Seed and oil yields were greater in plots treated with fungicide than in untreated plots of the linseed cultivars Antares, Barbara, McGregor and Norlin in 1991, 1992 and 1993 and of the low linolenic acid breeding line CD1747 in 1992 and 1993, except for cv. Barbara in 1991 (Table 1). The greatest yield responses to fungicide treatments were for cv. McGregor in 1991 (0.46 t/ha) and cv. Barbara in 1993 (0.43 t/ha) and significant ($P < 0.05$) increases were also obtained on cvs Barbara and Norlin in 1992 and CD1747 in 1993. Yields of all cultivars except Antares were greatest in 1993; the yield of cv. Barbara was lowest in 1992 and those of other cultivars were lowest in 1991.

Table 1 : Seed yield (at 90% dry matter) and oil yield of four linseed cultivars and one breeding line in plots with or without fungicide treatments in 1991, 1992 and 1993.

Cultivar	1991		1992		1993	
Fungicide	-	+	-	+	-	+
			Seed yield (t/ha)			
Antares	2.22	2.43	2.41	2.55	2.03	2.16
Barbara	2.43	2.37	1.74	2.12	2.41	2.86
McGregor	1.67	2.13	2.31	2.42	2.71	2.80
Norlin	1.50	1.85	2.01	2.30	2.30	2.34
CD1747	*		2.15	2.32	2.38	2.75
SED (df)	0.179(21)		0.123(27)		0.157(27)	
			Oil yield (kg/ha)			
Antares	847	928	943	983	788	844
Barbara	943	901	678	831	933	1133
McGregor	615	817	899	953	1088	1126
Norlin	547	692	791	889	902	915
CD1747	*		831	907	942	1111
SED (df)	71.5(21)		48.3(27)		65.0(27)	

* not grown in 1991

3.2 Crop growth and disease incidence

Emergence was greater in 1992 than in 1991 for all cultivars and lowest in 1993 for cvs. Antares and Norlin, following severe flea beetle damage (Table 2). There was little effect of the fungicide seed treatment on emergence in either 1991 or 1992. All cultivars were tallest in 1991 and shortest in 1993 (Table 3). The proportions of the stems with brown leaves at GS10 were greatest in 1992 for all cultivars and generally least in 1991, and were decreased by fungicide treatments on some cultivars in 1991, 1992 and 1993. The stem browning (*V. dahliae*) scores at GS11 were greatest in 1992 and least in 1993. Stem browning scores were not greatly affected by fungicides in any season and did not differ greatly between cultivars in 1992 or 1993.

Table 2. Emergence of four linseed cultivars and one breeding line in plots sown with fungicide-treated or untreated seed in 1991 and 1992 and with treated seed in 1993.

Cultivar	% emergence 1991		1992		1993
Fungicide	-	+	-	+	
Antares	78.7	71.4	87.5	89.3	37.9
Barbara	73.3	70.0	90.9	92.8	77.2
McGregor	71.2	62.4	78.8	88.0	53.5
Norlin	67.9	61.0	82.7	78.0	46.3
CD 1747	*		80.5	91.5	71.7
SED (df)	7.10 (21)		3.49 (27)		3.5 (32)

* not grown in 1991

Table 3. Height, proportion (%) of stem with necrotic leaves and stem *Verticillium* score (0-5 scale) of four linseed cultivars and one breeding line in plots with or without fungicide treatments in 1991, 1992 and 1993.

Cultivar	1991		1992		1993	
Fungicide	-	+	-	+	-	+
	Height (cm) (GS 10-11)					
Antares	68.7	71.5	65.8	63.3	57.2	59.4
Barbara	67.5	72.5	66.5	63.7	55.0	55.2
McGregor	75.9	75.0	67.6	67.1	60.2	59.5
Norlin	82.5	78.9	70.7	70.2	68.7	69.4
CD 1747	*		57.4	57.5	51.4	51.9
SED (df)	1.73 (21)		1.37 (27)		1.58 (27)	
	% stem with necrotic leaves (GS 10-11)					
Antares	30.0	33.6	53.4	34.6	24.5	26.8
Barbara	32.0	32.8	70.0	51.6	49.5	51.7
McGregor	41.0	27.2	56.0	50.6	52.4	26.9
Norlin	39.6	33.4	72.6	46.0	63.2	49.1
CD 1747	*		58.4	51.0	47.3	30.7
SED (df)	5.28 (21)		8.06 (27)		4.92 (27)	
	Verticillium score (0-5 scale) (GS 11)					
Antares	0.67	1.17	2.72	1.98	0.38	0.40
Barbara	0.97	0.87	3.10	2.58	0.85	0.80
McGregor	2.13	1.60	2.80	3.10	0.60	0.25
Norlin	2.25	1.85	3.40	3.73	0.63	0.48
CD 1747	*		3.57	3.72	0.93	0.58
SED (df)	0.574 (21)		0.558 (27)		0.186 (27)	

*not grown in 1991

Numbers of capsules were greatest in 1993 and least in 1991 for most cultivars but were least for cv. Barbara in 1992, when many mature capsules on this cultivar abscised just before harvest (Table 4). Numbers of capsules at GS12 were not increased greatly by fungicide treatments. The proportions of capsules with sporulating grey mould (*Botrytis cinerea*) at GS10-11 were decreased by fungicide treatments on all cultivars in 1991 and 1992. No capsules with grey mould were observed on cvs Antares and McGregor in 1993 and the incidence of affected capsules was very low on other cultivars. The proportions of capsules with sepals with brown lesions at GS 10-11 were greatest in 1992 on all cultivars and were < 10% in 1993 on all cultivars except Barbara; the proportions of affected capsules were decreased by fungicide treatments in 1991 and, except on cv Norlin, in 1992.

Table 4. Total number of capsules, % capsules with *Botrytis* and % capsules with brown sepals of four linseed cultivars and one breeding line in plots with or without fungicide treatment in 1991, 1992 and 1993.

Cultivar	1991		1992		1993	
Fungicide	-	+	-	+	-	+
			Number of capsules (GS 12)			
Antares	10.0	12.5	11.5	11.7	22.3	21.9
Barbara	11.5	13.9	10.8	10.7	12.4	14.2
McGregor	14.4	16.0	16.7	18.3	22.4	23.8
Norlin	14.1	16.3	18.2	20.6	30.4	27.8
CD 1747	*		18.7	15.0	20.3	25.3
SED (df)	1.90 (21)		1.53 (27)		2.13 (27)	
			% capsules with sporulating *Botrytis* (GS 10-11)			
Antares	4.43	3.02	7.21	1.89	0	0
Barbara	6.51	4.80	3.88	2.50	0	0.26
McGregor	5.23	4.04	2.14	1.64	0	0
Norlin	5.51	4.65	8.30	4.20	0.64	0.97
CD 1747	*		3.23	3.27	0.58	0
SED (df)	2.23 (21)		2.67 (27)		0.525 (27)	
			% capsules with brown sepals (GS 10-11)			
Antares	21.6	18.7	63.6	45.5	8.7	5.7
Barbara	32.1	18.0	57.5	35.6	20.9	14.1
McGregor	30.1	15.9	51.7	37.4	1.9	0.5
Norlin	38.7	16.5	49.3	53.3	4.1	4.1
CD 1747	*		47.1	37.9	4.0	0.1
SED (df)	5.66 (21)		11.37 (27)		1.86 (27)	

* not grown in 1991

4. Discussion

These results provide further evidence that diseases can decrease yields of linseed crops in the UK in many seasons. The yield responses to fungicide treatments in these experiments were associated with decreases in leaf necrosis in 1991, 1992 and 1993 and with decreases in the proportion of capsules with grey mould and with sepals with brown lesions

in 1991 and 1992. *Botrytis cinerea* and *Alternaria* spp. are often isolated from such necrotic leaves or brown lesions on sepals. Thus, these results with four cultivars and one breeding line confirm those obtained with cv. Antares in 1988 (Fitt & Ferguson, 1993; Hardwick & Mercer, 1989), when yield responses to fungicides were associated with decreases in leaf and capsule diseases (*B. cinerea* and *Alternaria* spp.). Seasons with periods of wet weather between flowering (June/July) and harvest (September), which favour the development of these diseases, are more common in the UK than seasons such as 1989 and 1990, when hot, dry weather in these months does not favour them and yield responses to control of other diseases such as powdery mildew are smaller.

The small differences between cultivars in the proportion of stems with necrotic leaves, and the proportions of capsules with grey mould or with sepals with brown lesions may have been related to differences in maturity or flowering dates between cultivars. In National Institute of Agricultural Botany experiments (Beale, 1991), differences in the incidence of grey mould between cultivars were related to the earliness or lateness of flowering of the cultivars. These small cultivar differences do not provide evidence for physiological differences in resistance between cultivars, which would be unlikely against such necrotrophic pathogens. Infection by *B. cinerea* may, however, have caused the yield of cv. Barbara to be low in 1992 because *c.* 25% of its capsules abscised after maturation but before harvest in that year, largely associated with severe grey mould infection (Fitt & Harold, unpublished). There was some loss of capsules from all cultivars in both 1991 and 1992, when grey mould was observed on capsules, but loss of mature capsules did not occur in 1993 when the incidence of grey mould on capsules was very low. Grey mould has been observed to cause yield loss through causing loss of mature capsules in other linseed crops (Mercer *et al.*, 1991; Mercer, 1992). However, the magnitude of such losses is difficult to assess because the incidence of infected capsules on plants sampled may decrease as harvest approaches, as infected capsules have already been lost from plants.

There was no evidence that seed-borne pathogens decreased emergence in these experiments, although seed-borne pathogens such as *Alternaria linicola* can greatly decrease emergence and yield when the incidence of seed infection is great and conditions favour disease development (Mercer *et al.*, 1989). There was a cultivar-emergence interaction in 1993 when flea beetle damage greatly decreased emergence of cv. Antares (Table 2), so that it yielded less than other cultivars and less than Antares in 1992 and 1991. However, despite the decreased emergence and low plant population in 1993, other cultivars produced higher yields than in 1991 and 1992 because numbers of capsules were greater. Furthermore, the incidence of some diseases may have been lower in 1993 than previous seasons because the plant density was lower. It was not possible to assess whether the stem browning caused by *Verticillium dahliae* was causing yield losses in these experiments since this pathogen was not affected greatly by the fungicide treatments, as in 1990 experiments (Fitt *et al.*, 1992). However the incidence and severity of these symptoms was greater in the second linseed crops in 1991 and 1992 (Table 3) than in the first linseed in 1993, suggesting that commercial linseed crops should not be grown after linseed.

We thank P.E. Beaudoin, H. Davis, L. Ibrahim and M. Nelson for practical assistance and A. D. Todd for the statistical analyses on these data.

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METHOD FOR TESTING VARIETAL RESISTANCE OF LINSEED TO *PHOMA EXIGUA* VAR. *LINICOLA*

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Summary

Two screening tests for determination of resistance to *Phoma exigua* var. *linicola* in linseed were evaluated. Under standardized conditions, 18 linseed cultivars and lines were tested for resistance. For disease rating, a disease severity scale was developed. The infection index was calculated for each cultivar. An analysis of variance was performed on the infection index of the 18 cultivars in both tests. Both tests yielded differences in the susceptibility of the cultivars to *Phoma exigua* var. *linicola*. The screening test with pre-inoculated soil and additional inoculations after 7 and 12 days after emergence yielded the broadest differentiation of cultivar reaction to *Phoma exigua* var. *inicola*.

1. Introduction

The increase of linseed production in Germany has gone hand in hand with an increase in disease incidence of linseed-specific pathogens. The foot rot disease of linseed caused by the fungus *Phoma exigua* var. *linicola* is one of these pathogens. The disease causes serious losses in yield and quality of linseed (Fitt et al., 1991).

The most important strategy to control *Phoma exigua* var. *linicola* is resistance breeding (Paul et al., 1991). Our aim was to evaluate inoculation tests based on methods used by Cerceau (1992) for testing varietal resistance to *Phoma exigua* var. *linicola* under controlled conditions.

2. Material and Methods

2.1 Fungal cultures and inoculum

Inoculum was produced from a single spore culture of *P. exigua* var. *linicola* in a shaking culture (Czapek Dox Broth). After 20 days at room temperature in diffuse daylight inoculum was prepared by homogenizing filtered culture medium.

2.2. Inoculation and screening for suscepetibility

Thirty seeds of each linseed cultivar were sown in two replicate pots (15 cm diameter) containing 2,83 litres of soil substrate.

Inoculation A: The linseed cultivars were sown in inoculum-free soil substrate. The

first inoculation was 7 days after seedling emergence and the second was 12 days after emergence. The inoculation was made by spraying a spore-suspension (10^7 spores/ml) on the plants and the soil. The controls were treated with the liquid media from uninoculated flasks. The experiment was repeated 4 times.

Inoculation B: The linseed cultivars were sown in pre-inoculated soil substrate. The concentration of the pathogen in the soil was 8400 cfu/g soil. The controls were treated with the liquid media from uninoculated flasks. The experiments was repeated 4 times.

The experiments were conducted under controlled conditions in growth chamber (Table. 1).

Table 1. Environmental conditions for inoculation experiments under controlled conditions.

Temperature	day	23,0 °C
	night	20,0 °C
Humidity	day	55 % rel. humidity
	night	85 % rel. humidity
Light management	day/night	16/8 h
Light intensity	soil surface	8000-9000 lux
	30 cm above soil	10.000-12.000 lux

The cultivars were observed daily for symptoms. In the absence of a scoring scale for disease severity of *P. exigua* var. *linicola* we developed our own scale (Table 2.).

All inoculated plants including the controls were first assessed 8 days after the first inoculation (height of plants: 12-15 cm). The second and final assessment was made 11 days after the second inoculation. Altogether 100 plants were assessed per replicate of each cultivar.

Plant samples were taken for the isolation of the pathogen from diseased plant parts before and after inoculation, in order to confirm that the symptoms were due to the presence of *P. exigua* var. *linicola*.

The data was analysed by computing an infection index for each cultivar using the formula:

$$\text{Infection index} = \frac{1n_1 + 2n_2 + 3n_3 + 4n_4 + 5n_5 + 6n_6 + 7n_7 + 8n_8 + 9n_9}{N}$$

where:

N = Total number of plants

$n_1, n_2, \ldots, n_9$ = number of plants in each infection class

1, 2, ..., 9 = severity score

This data was then analysed by ANOVA.

Table 2. Scale for assessment of disease severity of *Phoma exigua* var. *linicola* on linseed.

Score	Symptoms
1	no symptoms
2	cotyledons necrotic spotting (> 50% area)
3	≥ 50% of cotyledon leaf area necrotic
4	cotyledons like in 3 true leaves necrotic (1 or 2 leaves)
5	≥ 75% of cotyledon leaf area necrotic ≥ 25% of true leaves necrotic
6	≥ 50% of true leaves necrotic
7	≥ 75% of true leaves necrotic
8	plant begins to wilt
9	plant wilted (dead)

3. Results

Significant differences in the infection indices were found between cultivars and between inoculation methods (Table 3.). The best differentiation of the linseed cultivars in their reaction to *P. exigua* var. *linicola* was obtianed with the inoculation method B (Table 3.).

No plants with infection by *P. exigua* var. *linicola* were observed in the controls.

Highly differentiated results were obtained with the pre-inoculation method (Table 3). Preliminary indications of low susceptibility in the cultivar Antares and the line DSV ST 1270 to *P. exigua* var. *linicola* were obtained. Rumania 1 and Rumania 2, Nusis, Szegedi 43 and DSV LU 1 were highly susceptible to *P. exigua* var. *linicola* (Table 3). In the inoculations no cultivar or line respectively were free from the pathogen (Table 3).

Table 3. Infection indices of linseed cultivars inoculated with *Phoma exigua* var. *linicola* with two inoculation methods. Assessment date: 23 days after seedling emergence. Method A: spraying spore suspension. Method B: pre-inoculated soil.

Cultivar	Method A Assessment *	Method B Assessment *
Nusis	1,0	6,1
Mikael	2,0	5,9
Kiszombori	5,6	6,0
McGregor	2,0	6,0
Kreola	2,0	4,7
DSV ST 1270	2,0	2,0
DSV LU 1	2,0	7,0
DSV LU 5	3,0	5,8
Gießen 704/74	2,0	5,9
DSV LU 7	4,0	5,0
Rumania 2	3,0	6,7
Antares	1,0	2,1
Linda	2,0	5,0
Szegedi 43	5,5	6,2
DSV LU 6	3,0	5,0
Rumania 1	3,0	6,1
Atalante	3,0	5,8
Szegedi 62	2,0	4,7
Mean	2,7	5,3
LSD 5%	0,015	0,015

* Infection index 1,0 = not diseased, ≥ 2,0 = diseased

4. Discussion

Two different screening tests for evaluating resistance of 18 linseed cultivars and lines to *P. exigua* var. *linicola* were tested under controlled environment conditions and a scale for assessment of disease severity of *P. exigua* var. *linicola* was developed.

The disease scale was convenient to use and had sufficient classes to provide for adeqaute resolution of differences in disease severity. However, this applies only to the inoculation experiments with the pathogen under the controlled environment conditions described in this paper.

Jouan and Sailly (1991) classified linseed cultivars in their sensitivity to *P. exigua* var. *linicola* by assessing the disease incidence after artificially inoculating a

field by spraying a spore suspension of the pathogen on the seedlings. The cultivars Linda and McGregor were classified resistant and moderately resistant, respectively. In our experiment Linda and McGregor could be rated moderately resistant after spraying a spore suspension 7 days after seedling emergence (Table 3.). Considering the natural variance in biological systems the results of this method support the results of Jouan and Sailly (1991). Correlations with field observations have yet to be demonstrated.

The results of cultivar sensitiveness to *P. exigua* var. *linicola* in pre-inoculated soil indicate higher disease severities than recorded in the spray inoculation. The inoculum density in the pre-inoculated soil was probably to high. Additionally the linseed plants did not demonstrate such a sturdy growth under controlled environment conditions as that observed in the field. It is common knowledge that the tissue of plants grown in a climate chamber is much softer (less fibre content) than from plants in the field in a comparative growth stage. The pathogen has better access to soft plant tissue and thus reaches higher disease severity under controlled conditions. This might have applied to the root tissue in the pre-inoculated soil.

We urgently need field inoculation experiments with *P. exigua* var. *linicola* in order to enhance our knowledge of this pathogen.

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Monitoring Pests - Biology of Insects

THE WINTER MORTALITY AND EMERGENCE TIME OF DASINEURA BRASSICAE IN DENMARK

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Abstract
The mortality of the pod midge (*Dasineura brassicae* Winn) was investigated during the winter and spring in an old spring oilseed rape field, which had had a strong pod midge attack in the summer. Cocoons were washed out from the soil samples and dissected. Mortality during winter and spring ranged between 25 and 63%.

Emergence was monitored the following spring in a barrowed part of the field and in part of the field with winter wheat. Emergence was much lower than expected in both parts of the field. This was due to a large percentage of the larvae in extended diapause. The average emergence time was about 1 week delayed in the wheat part relative to the barrow part.

1. Introduction

The pod midge (*Dasyneura brassicae* Winn.) is a well known pest of oilseed-rape in North-western Europe. In Denmark farmers usually spray at least once during bloom to control this pest, but legislation urges/requires farmers to reduce the use of pesticides in Danish agriculture. A reduced input of insecticides can be achieved only if unnecessarry applications are avoided. This is problematic, because it is hardly possible for a farmer to foresee whether a pesticide application pays off or not. Therefore there is a demand for establishing a prognoses/warning system, that should be concerned with forecasting the density of emerging pod midges and the time of emergence.

Forecasts of the time of emergence may be based on temperature measurements in the soil and knowledge about the thermal requirements of the midge (Axelsen, 1992a), and predictions of the emergence density can be based on soil samples taken during fall, winter or early spring. The latter requires some information on the mortality in the soil from sampling to emergence.

This paper deals with the mortality during winter and spring and the possibilities for making quantitative and qualitative predictions of emergence in spring.

2. Materials and methods

Winter mortality

The winter mortality was investigated by sampling *D. brassicae* in the soil from Janurary 1991 to May 1991 (first winter) and from September 1991 to July 1992 (second winter). Sampling was made by a 100 cm^2 core sampler and samples were taken down to a depth of at least 5 cm, which is sufficient to obtain more than 95% of the population (Sylvén, 1949). Samples were washed out according to the method described by Laboreus (1971) and the cocoons were dissected under a stereo microscope (12 x magnification) to examine whether the larvae/pupae were parasitized, dead, alive or the cocoons were empty.

During the first winter samples (15 each sampling date) were taken 5 km. north of Århus, Denmark, at a little area, which was not used for agricultural purposes. At this spot wninter rape had been growing in a dense stand for at least 3 consecutive years and there was a rather strong infestation by pod midges.
The sampling location during the 2. winter was the stubbles of a little (0.1 ha) spring rape field at Ødum Reasearch Station, 20 km. north of Århus. This field was situated right next to a much larger winter rape field (2 ha) and had been heavily attacked by pod midges. This year sampling was done at 4 sites in the field (10 samples per site each sampling date).

Sampling was made with 4-7 week intervals, shortest intervals in spring. The last sampling of the second winter (July 12) was taken in order to get information on the proportion of the population in extended diapause.

Emergence

After the second winter the emergence was monitored by 14 emergence traps (0.125 m^2). 50% of the field was left untouched after the oilseed rape was harvested and the rest was taken into normal crop rotation, i.e. ploughed and sown with winter barley. The emergence traps were split between the two parts of the field to get information about the effect of plouhing on the intensity and temporal distribution of emergence.

The observed emergence pattern was compared with predictions of emergence time based on summation of degree-days above 7.1 °C from 1. January. (50% emergence at 141 °D) (Axelsen, 1992a). The temporal emergence pattern was simulated by a little computer program that uses hourly temperatures from 10 cm depth as input and the number of emerging individuals as output. Ageing of the larvae/pupae in the soil and eventually emergence was simulated by a distributed delay procedure, which adds variance to the average emergence time.

Input-temperatures for the predictions were hourly measurements in the soil from an automatic weather station in Ødum, 100 m from the research field.
The soil was sandy clay.

3. Results

Field investigation

The densities of cocoons with living larvae (Fig. 1) are rather constant during fall and winter, but during spring densities decrease quickly. In 1991 the density decreases from 5570 per m^2 in early Marts to 2050 per m^2, i.e a mortality of 63 %. In 1992 densities in mid March ranged between 19080 and 25480 and decreased to between 8080 and 19680 in Mid May. Mortalities were 25.7, 58.6, 25,3 and 25,9 for site 1, 2, 3 and 4, respectively. (For site 1 the mortality is relative to the density 7. January, since the density from march seems to be under normal level; see fig 1.) The decrease from 15. May to 12. July is not only mortality since emergence takes place during this periode.

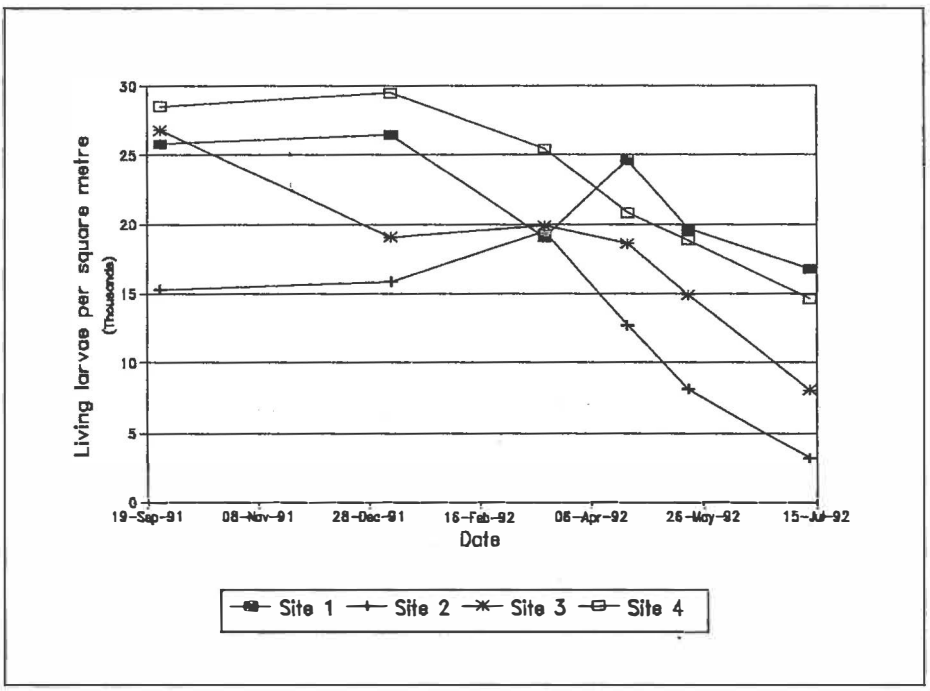

Figure 1. The densities of cocoons with living *D. brassicae* larvae or pupae during the winter 1991/92 at 4 sites from an old spring rape field. The field was left as a fallow field.

The total emergence was 458 pod midges per m^2 in the area between sample site 1 and 2. This figure is very low compared with the densities of living larvae at site 1 (19680) and 2 (8080) on May 15. If the total emergence is related to an average between site 1 and 2, only 3.3 % emerged. This low emergence was explained by the results from the soil samples from 12. July, which showed 16800 (85.4%), 3120 (38.5%), 8040 (54.0%) and 14600 (77.3%) larvae in extended diapause at site 1, 2, 3 and 4, respectively. (Relative to samples from 15. May). Average percentage in extended diapause was 69.2. Besides the diapausing larvae 114, 81, 67 and 85 dead pupae per m^2 were found at the 4 sites.

Emergence

Total emergence was 458 per m^2 from the fallow part and 446 per m^2 from the winter barley field. The temporal distrubution of the emergence in the 2 parts differed quite a lot from each other (Fig. 2). The emergence commenced 2 days earlier in the fallow part than in the winter barley and peaked 8 days later in winter barley and the midges kept emerging for much longer time. Emergence ended in early July in winter barley but in mid June in the fallow field.

The temporal distribution of emergence trap catches was compared with theoretically calculated catches. The calculated emergence curve misses the observed curve from the fallow field with about 2 days, but the curves are rather similar in shape (Fig. 3). On the contrary the calculated catches are very far from fitting the observed curve from the winter barley field (Fig. 4).

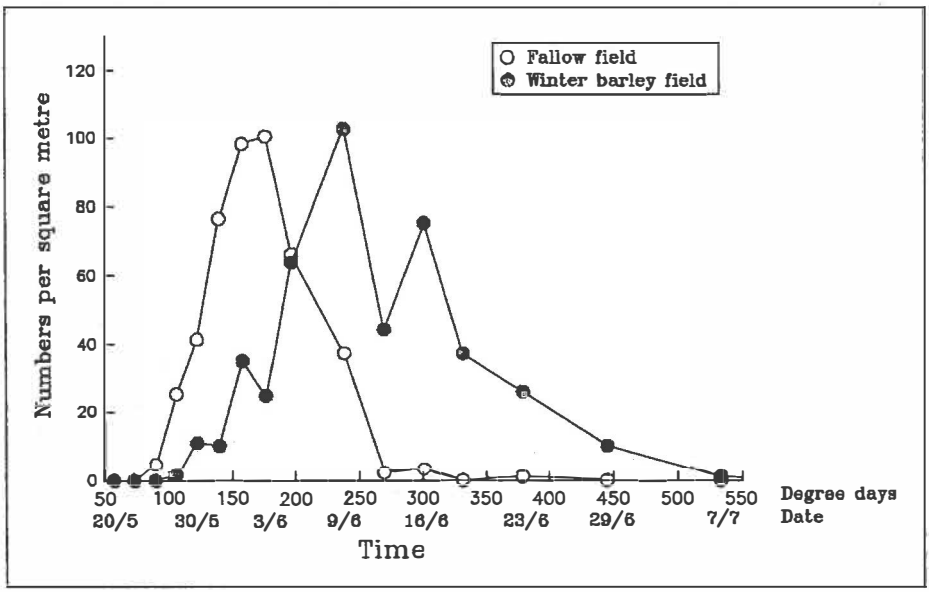

Figure 2. Emergence trap catches of *Dasineura brassicae* from fallow plot and winter barley plot in 1992.

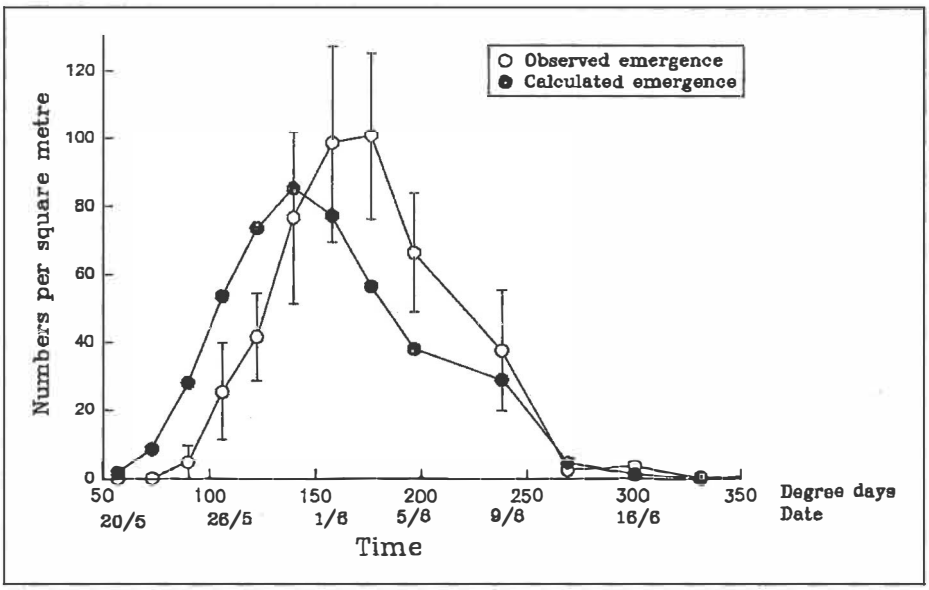

Figure 3. Comparison between observed and calculated catches in emergence traps in a fallow plot in 1992.

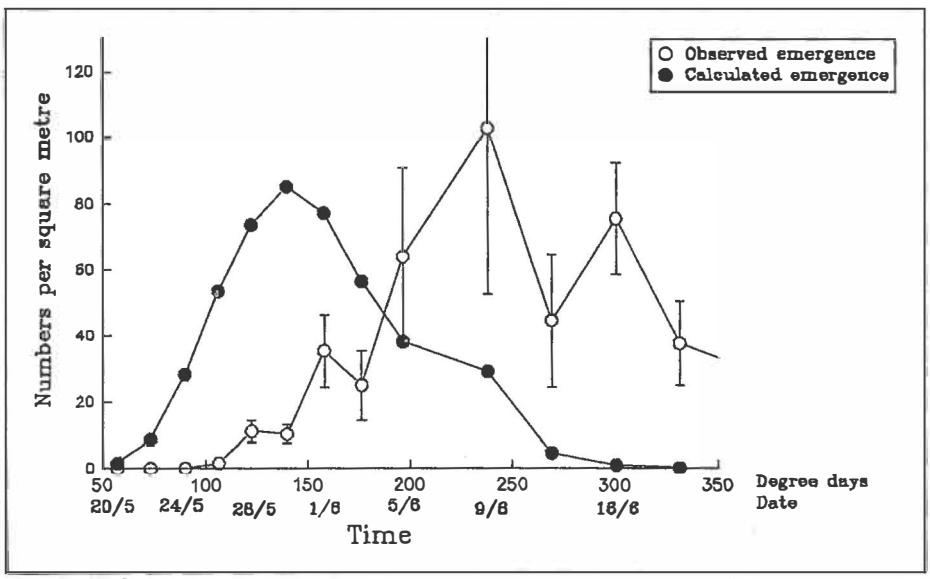

Figure 4. Comparison between emergence trap catches of *Dasineura brassicae* in winter barley and calculated emergence.

4. Discussion

Mortality

The mortalities in 1992 are low compared to 1991. The figures are also low compared to the "diapause mortality" (ranging between 67 and 86%) mentioned by made by Axelsen (1992b). It is not easy to explain the low mortality during the winter 1992. The densities were very high in all 4 sample sites this year, which makes one think of an inverse density dependent mortality. However, there is nothing in the results from 1992 (Fig. 1), suggesting inverse density dependence. Soil cultivation might destroy some of the cocoons and may be another reason? This is supported by comparing with Axelsen(1992b), who made the observations in a field that was part of a crop rotation system and consequently the field was ploughed. On the contrary the mortality in 1991 was rather high in an area, that was not at all used for agricultural purposes, but mortalities in this area is still lower than observed by Axelsen (1992b) in a ploughed field. This suggests ploughing to play a role for the winter mortality of the pod midge.

Emergence

Extended diapause is a well known phenomenon for the pod midge (Buhl, 1960, andre), but it is rare to see percentages as high as in this investigation. However, Axelsen(1992b) also mentions a high proportion of the larvae in extended diapause in 1989. A common feature for the springs 1989 and 1992 is extremley low rainfall. This strongly suggests that humidity is an important factor in the termination of diapause in *D. brassicae*, which is supported by Basedow (1977), who found the termination of diapause of the wheat blossom midge (*contarinia tritici*, Kirby) to be very dependent on humidity during a 6 weeks long humidity sensitive stage.

The predictions of emergence time based on temperature measurements in 10 cm depth, seemed to be rather good, when the barrow field is conserned. This is very likely because the input temperatures were measured under a shortly cut gras, which was comparable to the vegetation on the barrow field in spring. When emergence from the winter wheat field is concerned, predictions are rather poor.

This suggests that the temperature measurements can be used to predict emergence of the *D. brassicae*, but only as long as the temperatures in the field of emergence corresponds to the place where the temperature input is measured. The winter wheat was very dense and gave shade to the soil, which must have been cooler than the soil of the barrow field. The soil of this field was directly exposed to sunlight.

5. Conclusions

The results discussed above makes it very difficult to make precise predictions of emergence time based on temperature measurements in the soil, unless the temperatures can be measured within the soil of the old oilseed rape fields. Further is seems to be very hazerdous to make quantitative predictions of the *D. brassicae* infestation based on soil samples taken in late summer or autum. The mortality during winter seem to be rather variable and termination of diapause is another source of variation. A thorough understanding of the mechanisms behind these 2 factors is crucial, for reliable quantitative predictions of infestations.

6. Acknowledgements.
This work was supported by the Danish Veterinary and Agricultural Research Council.

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FLEA BEETLE (*Phyllotreta undulata*) FEEDING PREFERENCES

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Abstract

The feeding preferences of the flea beetle, *Phyllotreta undulata* Kutsch, were investigated for *Sinapis alba* L. and 5 cultivars of *Brassica napus* L. in the field and greenhouse in 1990. *S. alba* was the least preferred host plant while there was no significant difference in feeding levels on the 5 cultivars of *B. napus*. In 1992, choice tests for feeding preferences were carried out in the field and in the greenhouse. *B. napus*, *B. campestris*, *B. juncea*, *B. carinata*, *S. alba* and *Crambe abyssinica* were used. *C. abyssinica* had lowest damage levels in the field. In the greenhouse *S. alba* showed low levels of feeding damage, however, in the field *S. alba* was readily attacked. There was no difference between *Brassica* species.

1. Introduction

Flea beetles of the genus *Phyllotreta* are economically important pests of oilseed rape both in Europe and North America (Lamb, 1989). The most important species in Sweden, comprising over 90% of the species found in oilseed rape, is *Phyllotreta undulata* Kutsch (Ekbom, 1990). Studies on the impact of natural enemies on the flea beetles in Sweden have shown that biotic mortality factors are marginal. Population levels and pest activity of the species is much more dependent on abiotic factors such as weather (Ekbom, 1991). For this reason the potential of plant resistance as a control measure has become an important area of investigation (Palaniswamy and Lamb, 1992; Anderson et.al., 1992). The objective of this study was to determine if *P. undulata* shows feeding preferences for different cultivars of *Brassica napus* L. or different species of cruciferous plants in field and greenhouse trials.

2. Materials and Methods

1990 - Five cultivars of *B. napus* were used together with *Sinapis alba* L. in field, and greenhouse choice and no-choice tests. The cultivars were chosen to have different rates of growth, their emergence times are shown in Table 1. In the field the experiment was laid out as a complete randomized block with 4 blocks. Damage was assessed by counting holes and pits on 100 seedlings per variety which were removed from the field on two different dates. No-choice tests were done by exposing 4 cotyledons to 10 starved individuals of *P. undulata* for 24 hours (25 replicates for each cultivar and *S. alba*). Holes (completely eaten through the

leaf) and pits (surface damage) were counted under the microscope. Choice tests were done by exposing two cotyledons of *S. alba* (15 replicates) or Puma (14 replicates) together with two cotyledons of a *B. napus* cultivar. These were also exposed to 10 starved beetles for 24 hours. In both choice and no-choice tests seedlings were placed under a cylindrical cage (diameter 13 cm; height 30 cm) covered with netting. Many individual cotyledons in both field and greenhouse tests were completely undamaged. Therefore, we also noted the percentage of undamaged plants for each test.

Table 1. Cultivars, from Svalöf/Weibull AB, used in field and greenhouse trials 1990 and emergence times in the field.

Cultivar	Time to emergence
S. alba (Mustang)	3 days
Kunto	5 days
Puma (standard)	5 days
Granit	6 days
Korall	7 days
Global	8 days

1992 - Choice tests were carried out in the field and greenhouse using the following plant species: *B. napus* (cv. Paroll), *B. campestris* L. (cv. Agneta), *B. juncea* (L.) Czern., *B. carinata* Braun, *S. alba* (cv. Mustang) and *Crambe abyssinica* Hochst. In the field the experiment was laid out as a complete randomized block with 4 blocks. *B. carinata* did not grow successfully in the field and is therefore not included in that analysis. Damage was assessed as above, in addition the number of beetles was counted on 4 X 0.5 row meters per plot. In greenhouse choice tests all six species were present with six cotyledons of each species. The seedlings were transplanted to small vials containing soil and were arranged in a latin square design (Palaniswamy et. al., 1992). Seeds were germinated on moist filter paper and cotyledons of approximately equal size were chosen for each test. 10 trials were carried out, using 20 starved beetles for 24 hours per trial. Each trial was contained in a cage (42 cm X 38 cm X 78 cm). Holes (completely eaten through the leaf, deep damage) and pits (surface damage) were counted under the microscope.

In both years all beetles used in the greenhouses trials were field collected and starved for 24 hours before use. The temperature in the greenhouse was held at about 20° C varying at most 2 degrees above or below. The natural light in late May and early June, when the trials were done is about 20L:4D. Statistical analysis was accomplished using the GLM procedure in the SAS for PC package. Means were compared using a t-test (LSD) at $P<0.05$.

3. Results

Statistical tests on differences between cultivars and *S. alba* in 1990 revealed no statistically significant differences if total damage or only superficial damage was considered. However, when tested for number of holes (severe or deep damage) *S. alba* showed a significantly lower damage level, both in field and no-choice tests (Fig. 1a). The cultivar Korall showed slightly less damage than other *B. napus* varieties (Fig. 1a) in both field and

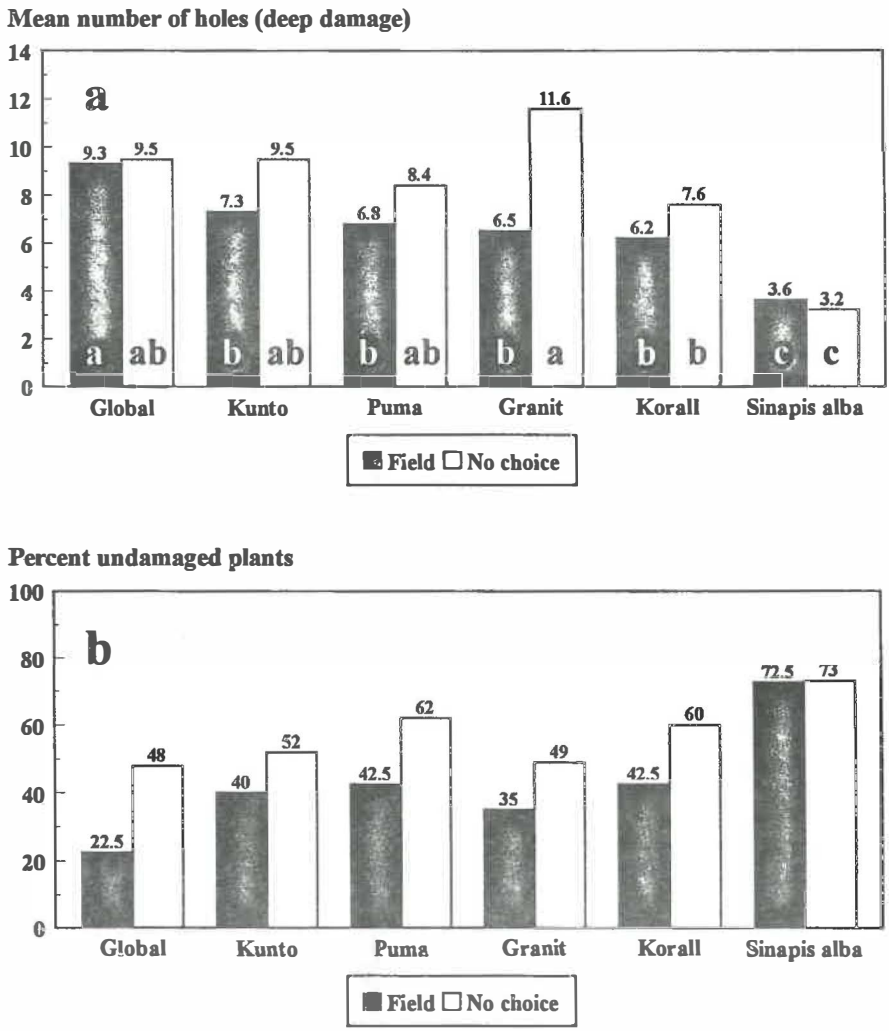

Fig. 1. Damage by ***Phyllotreta undulata***. Results from trials with ***Sinapis alba*** and different cultivars of ***Brassica napus***, 1990. a) Mean number of holes per cotelydon in field and no choice tests. Bars of the same color with the same letter are not significantly different. b) Percent undamaged plants in field and no choice tests.

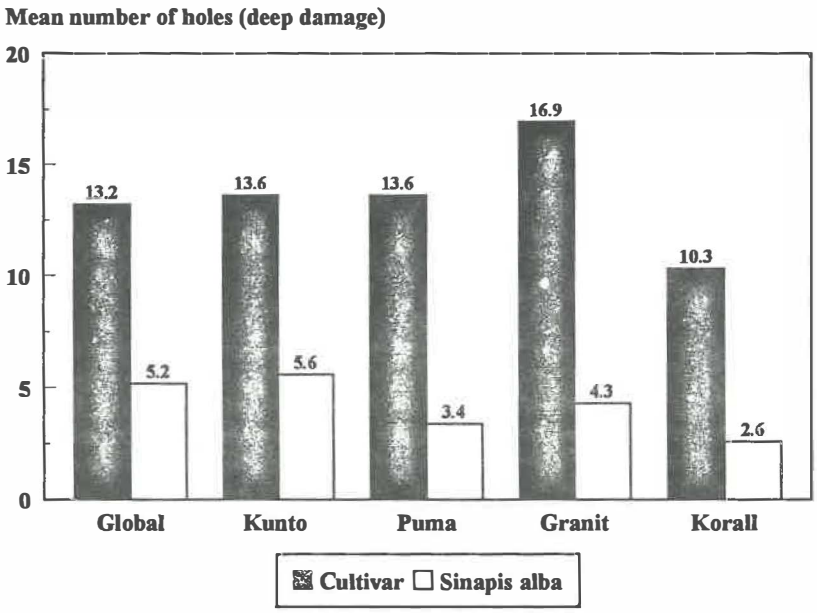

Fig. 2. Damage by ***Phyllotreta undulata***. Results from choice trials, 1990. Each cultivar of ***Brassica napus*** was compared to ***Sinapis alba***. All comparisons between cultivars and ***Sinapis alba*** were significantly different.

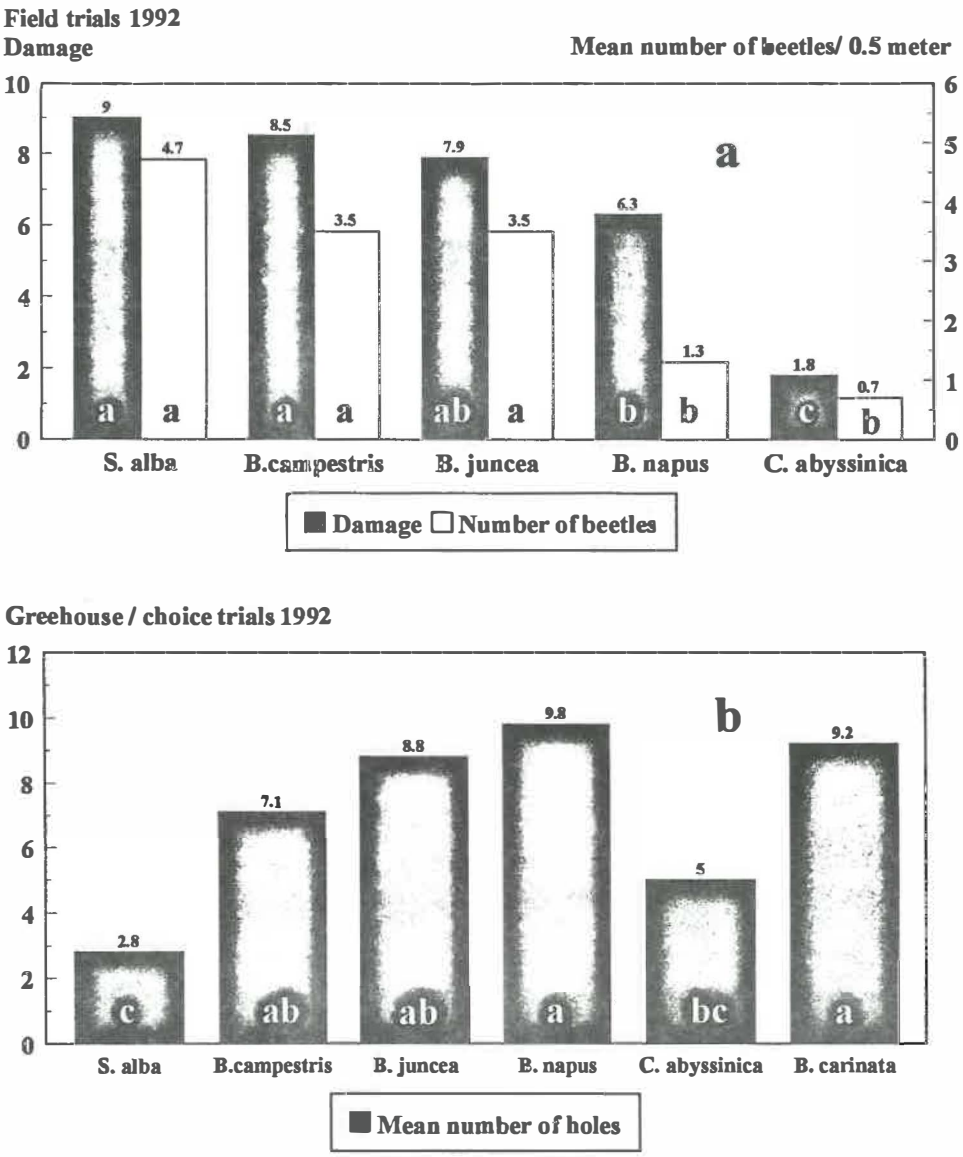

Fig. 3. Damage by ***Phyllotreta undulata***. Results from trials with different plant species, 1992. a) Damage measured as mean number of pits and holes per cotelydon. Bars of the same color with the same letter are not significantly different. b) Choice tests in the greenhouse. Bars with the same letters are not significantly different.

no-choice tests. The percentage of undamaged plants was highest for *S. alba* (Fig. 1b). In choice tests no differences were found when cultivars were compared to Puma, but all cultivars had significantly more damage than *S. alba* (Fig. 2).

Interestingly, in 1992, *S. alba* showed highest damage levels and the highest number of beetles in the field (Fig. 3a). Damage was assessed in the field without removing the seedlings, this meant that deep and surface damage could not be differentiated. *C. abyssinica* was the species which was clearly least attacked in the field (Fig. 3a). In choice tests *S. alba* showed the least amount of damage, but was not significantly different from *C. abyssinica* (Fig 3b).

4. Discussion

No outstanding differences between cultivars of *B. napus* were found in this study. This has also been shown to be the case for several cultivars tested in lab screening using the flea beetle *P. cruciferae* (Palaniswamy et. al., 1992). Field studies, in Sweden, showed no difference in flea beetle attack on 16 different populations of oilseed rape and hybrids (Åhman, 1993). Possible resistance mechanisms and their genetic basis will probably have to be found in plant species other than *B. napus*.

In a series of investigations using the flea beetles *P. cruciferae* and *P. striolata* it has been shown that *S. alba* is more resistant than other species within and between Brassicaceae genera (Lamb & Palaniswamy, 1990; Palaniswamy & Lamb 1992, Palaniswamy et. al., 1992). This is also true for *P. undulata*, which avoided *S. alba* in greenhouse preference tests. In a field situation part of *S. alba*'s resistance can be attributed to tolerance and rapid growth (Bodnaryk & Lamb, 1991). However, choice tests show that antixenosis is also a factor important for *S. alba* avoidance.

P. undulata displayed little interest in feeding on *C. abyssinica* either in the field or in the greenhouse. In all comparisons where damage could be differentiated *S. alba* had less damage than all *Brassica* species and cultivars. The difference between deep and superficial feeding was also shown to be important in field trials with *P. cruciferae*. Anderson et. al. (1992) found no consistent differences between *B. napus*, *B. campestris*, *S. alba* and *C. abyssinica* when using a measure of surface damage, if anything *C. abyssinica* and *S. alba* showed more superficial feeding. All of the species and cultivars tested will be visited by flea beetles in a field situation. However, *C. abyssinica* and *S. alba*, may be rejected after being 'tasted' by the beetles. The relative absence of severe feeding damage and the fact that many plants are left completely undamaged would indicate that, after beginning to feed, the beetles are not further stimulated for or deterred from continued feeding.

Three species of *Phyllotreta* have been shown to be rather general in their feeding preferences within groups of closely related Brassicaceae species. All three, however, do show some avoidance of both *C. abyssinica* and *S. alba*. Further studies should aim at identifying this 'resistance' in terms of either deterrents or absence of feeding stimuli.

Acknowledgements

I thank Carolyn Glynn for technical assistance in the 1990 studies. Cultivars and species of *Brassica* were obtained from Svalöf/Weibull AB, I thank them for their help. M.J. Weiss provided the Crambe seed. Financial support for the work in 1992 was provided by the Carl Trygger Foundation.

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ASSESSMENT OF YIELD LOSSES CAUSED BY INSECTS IN WINTER OILSEED RAPE, A CRITICAL REVIEW

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Abstract

Methods for studying yield losses caused by spring insects on autumn sown oilseed rape are reviewed and discussed. Some of the damage thresholds for the commonest pest are compared between countries. It is stressed that further work concerning the distribution of insect damage in the fields, interaction between pests and interactions with climatic conditions should be undertaken.

1. Introduction

France is one of the European countries in which oilseed rape has been grown for the longest time as there was already 40000 ha grown in 1920. Since 1963 the acreage has steadily increased, culminating at 828000 ha in 1988. Since the beginning less and less spring sown rape has been cultivated and *Brassica campestris* was dropped because of higher yields with autumn sown *Brassica napus* which also has the advantage of being self fertile eliminating pollination problems.

The permanence of a large acreage in oilseed rape seems to have led to a more diverse fauna than in countries which have a more recent history of growing rape (Bromand, 1990). Constant pests are *Psylliodes chrysocephala, Meligethes aeneus, Ceutorhynchus assimilis, Dasineura brassicae, Brevicoryne brassicae, Ceutorhynchus pallidactylus (quadridens)* and in the southern part of France (i.e. below Paris) *Ceutorhynchus napi* which is a major pest. Some other pests are locally abundant or are subject to outbreaks for some years before disappearing as *Ceutorhynchus picitarsis, Delia radicum*, and *Baris* species as *Baris coerulescens*.

The damage caused by most of these pests has been studied since the fifties by a few researchers mainly in France and in countries of eastern Europe (Germany, Poland, Czechoslovakia).

At the end of the sixties interest for the crop in northern Europe started a new round of investigations in England, Sweden, Denmark, ..., focusing on the interaction between damage and the plant capacity to compensate for it, which is quite developed in *Brassica* species.

2. Methods

Methods used for yield loss assessment range from open field trials with insecticide treatments to growth chamber studies with potted plants and simulated damage. All these experiments have inherent bias and drawbacks.

2.1 Field trials

It has been shown that some insecticides could act as a shot in the arm for some crops, even when pests are totally absent (Jones et al.,1986). Carbofuran showed such behaviour in a cage experiment with uninfested potted plants (Lerin, unpubl.; Ballanger, pers.com.). The lack of serious knowledge about a pest can also lead to misleading interpretations of the results of a field trial. For instance, two researchers used various insecticides and methods for applying them against *Baris* spp. and this was at the end of May when egg laying was completed and larvae, which live inside the roots of the plants, had already reached their second stage (out of four); the insecticides were pyrethroids without known systemic activity. Because the analysis of yield showed significant results they concluded that some of the products protected plants against the pest, though they made no control on larval population at harvest! In fact they did try to assess damage but through a criterion which is not directly related to the pest (the percentage of plants presenting dry stems at harvest). The main cause for this symptom is not the pest but fungal diseases such as *verticillium* and *phoma*. They may have protected their plants against some pests, but certainly not against the target pest. This is one of the main sources of bias in field experiments and it cannot be avoided except in the very rare circumstance of a crop attacked by a single pest. This assumption seems preposterous with oil-seed rape. Researchers would have to then apply their skills at monitoring, evaluating and controlling populations of other pests as well as the target pest.

Field trials are nevertheless required to validate controlled, i.e. mainly cage, glasshouse or growth chamber experiments.

2.2 Experiments in controlled conditions

Experiments in controlled conditions have been criticized by field researchers because the environment created is usually different from field conditions even in cages covered with mesh material. For instance temperature and relative humidity are not significantly modified but solar radiation can be reduced by 20 % (Hand & Keaster, 1967), and of course drops of rain are pulverized creating favourable conditions for the development of fungal diseases.

Nevertheless as far as *C. assimilis* and *M. aeneus* are concerned, cage experiments are necessary to assess losses caused by each pest because they usually invade fields at the same time. The same holds true for the 'seed weevil/pod midge' pair. The level of infestation can then be controlled but natural enemies cannot play their role : in the case of the pod weevil it has been shown that larvae parasitized by *Trichomalus perfectus* cause less damage than healthy ones (Dmoch, 1975).

Experiments of this type have yielded similar results in countries with fairly different climates (Free et al.,1983; Lerin, 1984). Furthermore these results have been later confirmed in field conditions which is the best answer to criticism and validates the method.

2.3 Simulated damage

Simulated damage is the most controversial method as it is often impossible to mimic insect damage or to reproduce the progressive aspect of an actual infestation. In some cases though, it enables the researcher to avoid the randomness linked with the behaviour of insects and to evaluate the plant capacity to compensate for damage (Williams and Free, 1979; Lerin, 1987). It can be also useful when there is a definite link between plant vigour and infestation by insects.

2.3 Plant variability

Plant variability in oil-seed rape is large and most of the pests display the unfortunate habit of choosing the biggest plants to feed or to lay on. Analysis of the grain production per plant, under an attack by *C. assimilis*, gives regularly surprising results as there is a positive correlation between plant production and the number of larvae per plant. Actually it is well known that production is highly correlated to the number of pods per plant ($r>0.8$), but the number of larvae is also correlated to the number of pods ($r>0.7$) (Lerin,1982).

It is almost impossible to obtain cages with plants that have a similar vigour in field conditions when caging occurs early to avoid natural contamination. The analysis of covariance is a very useful tool in this case once the best variable has been identified, i.e. a variable well correlated to production or yield, not modified by the action of the insect, and with a constant linear regression coefficient at all investigated infestation levels (Lerin, 1984). This method has been repeatedly used with a number of pests by the author with such variables as stem diameter, number of racemes or number of pods. It is also useful to reduce experimental designs to a manageable size.

3. Results and discussion for some common pests

The yield losses caused by *C. assimilis* (sometimes associated with *D. brassicae*), have been repeatedly assessed over the years because it is a major pest in Europe and because the damage caused by adults and larvae is quite clear cut. It is possible to actually count damaged seeds and larvae or exit holes, and yield losses have been linearly related to the ratio of the number of exit holes on the number of pods . From the publications on the subject it is obvious that even this late attack affecting the number of seeds is partly compensated for by the plant through an increase in the 1000 seed weight of undamaged seed and by a lowering of spontaneous abortion of the seeds. All references are in good agreement for thresholds, which vary from 0.5 weevil per plant to 1 depending on the risk of further damage by *D. brassicae*. Riedel (1989) introduced plant density and plant vigour in the decision rules and in her paper thresholds varied from 0.3 to 1 weevil per plant.

Direct control of *D. brassicae* is usually not possible because of its short life span and the length of the infestation flight and should be approached through control of the seed weevil. But it is still possible to kill larvae inside the pods at an early stage (before they split open) by using phosalone.

As a ubiquitous pest *M. aeneus* has also been extensively studied showing that the destruction of buds could ultimately lead to overcompensation and an increase in yield. In some cases plant vigour and nitrogen fertilization were included in decision rules leading to thresholds varying from 2 to 8 beetles per plant (Daebeler et al., 1982). This might explain why thresholds vary widely among countries, from 3 beetles per plant in France to 15 in England at the yellow bud stage, but the French threshold seems to take into account the ill-founded belief of growers that 'so many podless stalks on the main raceme MUST have an effect on yield!'.

In continental countries, Austria, France, Germany and Switzerland, where *C. napi* is one of the major pests, it has been thoroughly studied. Contrary to *C. assimilis* its deleterious effect comes more from the act of egg laying than from larval feeding. The presence of eggs in the upper part of the main stem at an early growth stage causes deformations which can ultimately lead to the splitting of the stem when it grows too quickly (Lerin, 1992). The stem also becomes hollow even when no larval development follows egg laying. The main effect of the pest is to disrupt sap flow among the different parts of the plant. Depending on agroclimatic conditions yield losses can be high (in the dry conditions of the southern part of France) or low when rain is more

regular (southwestern or central part) for the same level of attack, i.e. for the same number of eggs per stem (Ballanger, 1987). In the latter case plants can withstand as much as one or two eggs per plant without yield losses (Ballanger, 1987, Büchi, 1988). But climate can vary widely from year to year and for practical purposes there is no definite control threshold in France : spraying is required when the pest is known to be permanently present in high numbers and when it appears in the field before the stem has reached 20 cm in height, because after that stage stems are less likely to split. Spraying with pyrethroids at the beginning of the flight of infestation gives very good results thanks to the persistence of the products at low temperatures. As *C. napi* is the earliest of spring pests in France and appears before the others, its control is not likely to interfere with natural enemies controlling later pests as *C. assimilis* or *M. aeneus.*

In two other pests, larval development might have an impact on plant physiology depending on weather conditions : *D. radicum* and *B. coerulescens* which both attack the roots during spring in some areas, sometimes in large numbers. There is scant evidence that they have a constant damaging effect (Mc Donald and Sears, 1992). Studies on *B. coerulescens* are under way to test whether the variability in responses can be explained by an interaction between water stress and infestation. Anyhow the study of these pests is much more complicated because of their location in the plant and because no clear cut criterion for quantifying damage is available. In these conditions it is very difficult to determine a significant and constant correlation between infestation and yield losses.

4. Suggestions for future work

In spite of the large amount of data concerning yield losses in rape, even for the well known species (*C. assimilis, M. aeneus, C. napi*) studies shouldn't stop because a number of questions have not yet been answered. The spatial distribution of pests inside fields has not been sufficiently studied though some papers have been published (Free & Williams, 1979; Thioulouse et al., 1984; Büchi, 1989). It is now well known that most oil-seed rape pests at the beginning of infestation, and notably *Ceutorhynchus* species, concentrate on the border of the fields before invading the rest. This doesn't mean that damage will be restricted to the border, though it is sometimes true as in the case of the pod midge or with the seed weevil in the case of large fields of more than 80 ha (Edner and Daebeler, 1984).

In terms of spatial distribution an example of damage caused by *C. napi* in a field of 4 ha is given on the graph. Samples of 20 plants were taken every 20 m and the percentage of infested plants was estimated. From this result the number of larvae per plant was calculated using the relationship established by Mangin (1982) between the two variables, which had been thoroughly tested on several occasions. What is the significance of an overall mean (m=0.80) of less than one egg per plant (which used to be the threshold for insecticide control of the pest in our region) when a third of the field displays as much as 1.7 egg per plant, a contamination leading to real losses? Assuming that the samples gave a good image of the area around them, it was calculated that the overall loss was of about 4% instead of 0%. And it did not include losses expected on the very margin of the field : apart from the heterogeneity of the whole field there was also a border effect, infestation being high on the first 10 m and decreasing thereafter to reach the level of the corresponding sampling point.

The interaction between damage caused by several pests, each being under the threshold level, is also of interest. The author showed that the damage done by *M. aeneus* was not compensated for after an attack by *C. napi* (Lerin, 1988). Very few studies have explored this field except to show a link between insect attack and fungal diseases and the well known relationship between *C. assimilis* and *D. brassicae*.

The study of yield loss as an interaction between damage and agro-meteorological conditions was started mainly by the former East German school and should be carried on in other parts of Europe as it might enable growers to further improve the way they deal with insects.

5. Conclusion

The results above can be interpreted in a different way : yield loss assessment gets more and more complicated as the researcher goes from the tip of the plant downward to its root or as we deal with late pests involved with the last yield components (number of seed per pod or number of pods) or with early pests damaging the structure of the plant (stem weevils). The threshold for *C. assimilis* varies only by a factor of two or three but the threshold for *M. aeneus* by a factor of four or five. Defining a useful threshold for stem weevils is even more difficult because many events can occur during spring which can modify plant growth and yield. The same holds true for insects damaging the root whose status as real pests reducing yield is not even established, but which could, theoretically interfere with the translocation of metabolites during a hot dry spring.

The present author's belief is that insects which can modify the plant's ability to compensate should be more thoroughly controlled than late spring pests.

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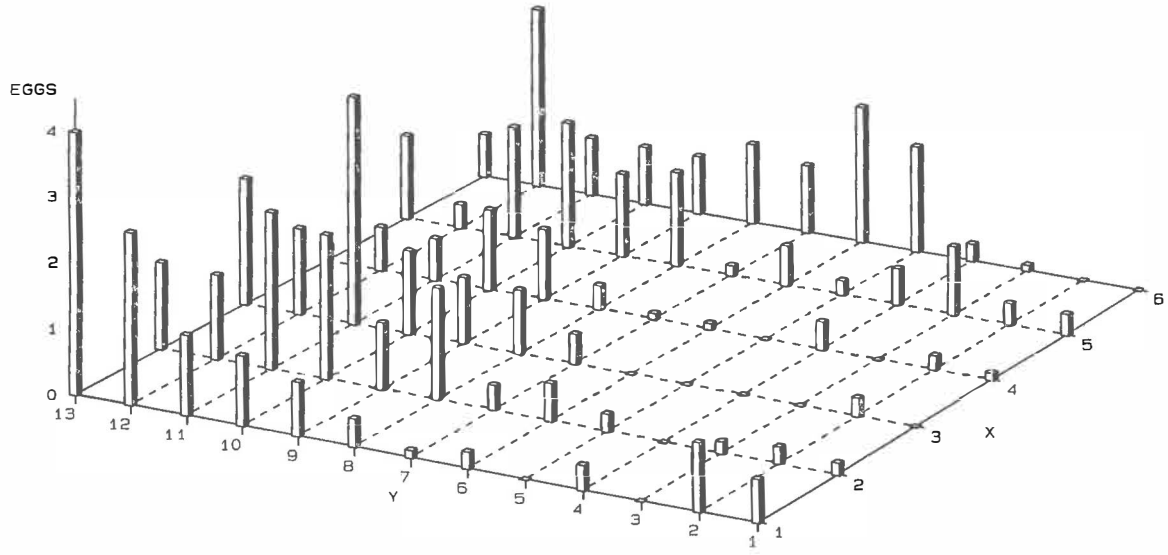
Spatial distribution of the number of eggs per plant

laid by the big stem weevil in a 4 ha field



COMBINATION OF TRAP PLANTS (*BRASSICA RAPA* VAR. *SILVESTRIS*) AND INSECTICIDE USE TO CONTROL RAPE PESTS

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Abstracts

From 1985-1993 a method with turnip rape as trap plants was tested in 71 field trials to control rape pests in rape fields with less insecticide. A mixture of turnip rape (*Brassica rapa*, var. *silvestris*) and winter rape (*Brassica napus* L.) was sown in a perimeter strip of 5 to 6 m in rape fields. The aim of the method is to concentrate the rape pests on turnip rape in the perimeter strip area and to control them on this limited area with an insecticide. The trials show that the method is not sufficient to control the stem weevil, *Ceutorhynchus napi* Gyll. Spraying the perimeter strip did not prevent a greater infestation in the inner part of the field.
However it was possible to concentrate during the first 7-10 days of immigration 28.4 - 80.3% of the pollen beetle (*Meligethes* sp.) population in the perimeter strip. The perimeter strip method probably contributes to an enhancement of parasitoids of rape pests.

1. Introduction

In Switzerland winter rape fields are treated 1 to 2 times on the average with insecticides. In order to reduce insecticide use we are looking for new or modified control methods. Günthart (1949) and Dosse (1951) reported that turnip rape (*Brassica rapa* var. *silvestris* or *Brassica campestris* var. *oleifera*) attracts some rape pests more than rape (*Brassica napus* L.).

Therefore, the idea was to use turnip rape as trap plants for pests in rape fields to reduce the damage to rape plants without the use of an insecticide. In the first trials we sowed rape fields with a mixture of 98% rape and 2% turnip rape seeds. These trials confirmed that the rape stem weevil (*Ceutorhynchus napi* Gyll.) and the pollen beetle (*Meligethes* sp.) preferred turnip rape to rape (Büchi et al., 1987 and Büchi, 1990). However, inclusion of only 2% turnip rape was not enough to attract sufficient numbers of rape pests to prevent damage to the rape plants.

Some rape pests (*Meligethes* sp., *Ceutorhynchus assimilis* and *Dasineura brassicae*) are more abundant in the border area than in the middle of the field (Free and Williams, 1979). Therefore, we tried to enhance this border effect with turnip rape, by sowing in a perimeter strip of 5-6 m width a mixture of 5% turnip rape and rape. During 1987-1993 the proportion of 5% turnip rape in the perimeter strip was enhanced from 5 - 15%.

2. Materials and Methods

From 1985-1993 in 71 rape fields turnip rape was tested as trap plant to control rape pests. In most cases turnip rape was sown in a perimeter strip of 5-6m width with 5-20% turnip rape. For the trials we used farmers fields which were ploughed, sown and harvested

by the farmers themselves. Weed control and fertilisation was as usual in practice. Turnip rape was sown and harvested with the rape. Although turnip rape ripens earlier than rape, it did not shed its seeds by rape harvest time.

To measure the concentration effect of the perimeter strip we used the following schema of trials. The perimeter strip with turnip rape was sown in only one half of the field. The other half of the field was without the perimeter strip (Fig. 1). The perimeter strip and the other half of the field were treated against the rape pests (either stem weevil or pollen beetle depending on the infestation level). At harvest the yields of the two halves of the fields were compared.

In the trials the following turnip rape varieties were used: Buko, Hanko (0), Rex (0), Titan (0) and the rape varieties: Bienvenu (0), Jet Neuf (0), Lingot (0), Arabella (00), Lirabon (00), Idol (00) and Eurol (00). Until now there are no (00) turnip rape varieties, but any turnip rape seed in the harvest does not enhance the glucosinolate content much.

The different trials for each rape pest are described below.

2.1 Flea beetle, *Psylliodes chrysocephala*

2.1.1 Distribution of the flea beetles in a field

In a field with a perimeter strip at 20 areas (Fig. 2) population of the flea beetle were estimated in the strip and in the inner part of the field using sweep net catches.

2.1.2 Larval infestation in turnip rape and rape

In 22 fields infestations of turnip rape and rape with larvae of the flea beetle were recorded. Samples of plants of each field were taken 1-2 times.

2.1.3. Seed dressing trial

In trials with randomized block design (plots 12.5 m^2) mixtures of 10% turnip rape and 90% rape were sown. The influence of seed dressing with the insecticide Oftanol (a.i. Isofenphos) on larval infestation was measured with all four combinations of turnip rape and rape with and without seed dressing.

2.2 Stem weevil, *Ceutorhynchus napi*

2.2.1. Larval infestation in turnip rape and rape

In 30 fields, infestations of turnip rape and rape with larvae and eggs of the stem weevil were recorded. In 5 fields 2 - 2.5% turnip rape were spread over the whole field, in 25 fields 5-20% turnip rape were sown in a perimeter strip.

2.2.2 Trials with yield recording

In 9 fields the perimeter strip and the other half of the field were treated against stem weevil according the scheme given in Fig. 1. From 20 areas in each field (Fig. 1) 10 plants were removed and larval infestation recorded.

In these fields the incidence of pollen beetle was either low or the whole field was treated against it. The abundance of the other rape pests was low and had no influence on yield.

2.2.3. Randomized block design trial

To check if the stem weevil has a preference for certain rape varieties we used randomized block design trials (plots of 12.5 m^2) with different rape varieties. Larval infestation with stem weevil larvae was recorded on one or two dates.

2.3 Pollen beetle (Blossom beetle), *Meligethes* sp.

2.3.1. Distribution of pollen beetle population in the field

To see how the pollen beetle spreads into the fields during its immigration, in six rape fields the pollen beetles on rape and turnip rape were counted on several dates.

Likewise the turnip rape and rape plants per m^2 within the perimeter strip and in the inner part of the field were counted. Based on these results the pollen beetle populations in the perimeter strip and in the inner part of the field were calculated for three fields. This gave us the proportion of the pollen beetle population in the perimeter strip and in the other part of the field on several dates.
To calculate which percentage of turnip rape is needed to concentrate at least 30% (for reason of the damage threshold) of the pollen beetle population of a rape field in the perimeter strip we used the following procedure. Based on the number of beetles on 30 to 60 plants in the perimeter strip and in the inner part of 6 rape fields we calculated the whole pollen beetle population of the field when the number of pollen beetles on turnip rape in 5 of 6 fields were highest (second countings in Table 3). Then we calculated the percentage of pollen beetle population in the perimeter strip, assuming 5, 10 and 15% turnip rape in the perimeter strip.

2.3.2. Trials with yield recording
In three rape fields the perimeter strip and the other half of the field were treated against the blossom beetle and at harvest the two halves of the field were compared (Fig. 1). Only those fields were selected where no other pests were present in such an amount that they could have an influence on yield.

3. Results

3.1. Flea beetle

Fig. 3. shows flea beetle larval infestation of 22 rape fields from 1985-1990. In all cases there were more larvae in turnip rape than in rape with on average 5.4 times more larvae on turnip rape than rape. We also found more feeding holes in the leaves of turnip rape than in those of rape (Büchi, 1990).

In one field trial with randomized block design infestation with flea beetle larvae in plants with and without seed dressing were recorded on three different dates. Table 1 shows the results. On 25 October, larval infestation on turnip rape was not recorded, because there were too few plants in the plots. There were more larvae on rape without seed dressing than with seed dressing. However, we are mainly interested in the last 2 lines of Table 1, because it represents the practical case. Rape with seed dressing and turnip rape either with or without seed dressing like it would be the case with the perimeter strip method. The results show that there is no statistically significant difference in larval infestation of rape in these two variants. That means that in the perimeter strip undressed turnip rape can be used.

In recent years flea beetle populations have been low in Switzerland. However, we observed that adult flea beetles were more often on turnip rape than on rape. In a field with more flea beetles than on average (20 times 20 sweeps with sweep net according Figure 2) in the perimeter strip area (85% rape, 15% turnip rape) we counted 37 flea beetles compared to only 16 flea beetles in the inner part of the field.

3.2. Stem weevil

Figure 4 gives the results of stem weevil infestations in 30 rape fields (1985-92). The number of larvae per plant varied considerably. In some fields there were more larvae in turnip rape than in rape. In other fields the contrary was observed.

In 2 field trials with a randomized block design we recorded the infestation of different rape varieties with eggs and larvae of the stem weevil (Fig. 5). The infestation rate was recorded twice. At the first date the early variety Bienvenu had more eggs

(statistically significant at Reckenholz) than the later flowering ones, but on the second date the contrary was true. In another trial in 1993 at Zollikofen on 21 April there were more eggs on the two moderately-early to late flowering varieties Arabella and Libravo than in the two early varieties Idol and Eurol (Fig. 6). That means that the stem weevil preferred Arabella and Libravo for egg laying in a short period before the 21 April.

In 9 of the 30 fields yield was measured. One half of the field was treated against the stem weevil, in the other part only the perimeter strip with turnip rape was treated. At harvest the yields of the two halves of the fields were compared. The results were given in Table 2. In 7 out of 9 cases the half with the perimeter strip had a lower yield than the other half of the field. In 4 out of 9 fields we found significantly (Kruskal-Wallis Test) more eggs and larvae in the plants checked in the untreated part of the field (No. 5-12 in Fig. 1) than in those of the treated part (No. 13-20 in Fig. 1).

3.3. Pollen beetle

The immigration of pollen beetle into rape fields with a perimeter strip of turnip rape was recorded in 6 experiments (Table 3). Immigration followed a distinct pattern: The first beetles are found almost exclusively on turnip rape (First count table 3). Several days later the number of beetles on rape increased (Second count table 3). In the third count the number of beetles on turnip rape decreased and the number of beetles on rape increased further, indicating beetle migration from turnip rape to rape. This migration occurred within both the perimeter strip as well as to the inner part of the field.

Based on the data from table 3 for three fields the pollen beetle population within the perimeter strip and in the inner part of the field were calculated. Figure 7 shows the results. In the first 7-10 days of immigration of the pollen beetle into the rape fields it was possible to concentrate 28 - 80% of the population in the perimeter strip.

Table 4 shows the calculated percentages of the pollen beetle population in the perimeter strip and in the inner part of the field assuming three ratios of 5, 10 and 15% turnip rape.

In 3 fields (1990-92) half of the field was treated with an insecticide whereas in the other half only the perimeter strip was treated; at harvest yields of the two halves were compared. The results are given in Table 5. In all cases the yield of the half with the perimeter strip was lower than that of the other half.

4. Discussion

4.1 Flea beetle

In recent years the flea beetle has not been a serious pest in nothern Switzerland. All rape seed crop is imported and treated with seed dressing. When flea beetles feed on the cotyledons they are killed by the insecticide (Derron and Goy, 1991). This method was sufficient to control the flea beetle. However, in the western part of Switzerland some insecticide resistance in flea beetles against Lindaram (a.i. Lindane) and partly against Oftanol (a.i. Isofenphos) and Mesurol (a.i. Mercaptodimethur) has been registered (Derron, 1985). Turnip rape clearly attracts flea beetles for post copulation feeding and egg laying (Figure 3) and is usually sown without seed dressing. Our results (Table 1) show, that in plots with 10% turnip rape without seed dressing larval infestation of rape plants was not statistically different than in plots with 10% turnip rape with seed dressing. From this observation we deduce that turnip rape should be used without seed dressing in order to lower the selection pressure on the flea beetles. In this way the perimeter strip method functions as a resistance management strategy to decrease the development of resistance in populations of flea beetles. We assume that also in future years seed dressing will be

sufficient to control flea beetles.

4.2. Stem weevil

In our trials to evaluate turnip rape as a trap plant (Fig. 4) we used 4 turnip rape varieties, first Buko, a variety containing erucic acid, and later the 0-varities Hanko, Rex and Titan. It seemed to us that the new varieties were not as attractive for the stem weevil as the older ones. But comparing the 10 rape fields with Buko to the 20 fields (Fig. 4) with 0-varities (Hanko, Rex or Titan) no significant differences were revealed. One reason for the variation of these results (Fig. 4) could be that according to the actual height of the rape plants in relation to the turnip rape the stem weevil prefers the first or the latter for egg laying. Our results with randomized block design (Fig. 5 and Fig. 6) indicate that plant height at the time of egg laying may influence the degree of infestation of different rape varieties. Also Lerin (1986) stated that the phenological stage of rape has an influence on the egg laying behaviour of the stem weevil.

We also observed (results not presented here) that at the beginning of immigration adult stem weevils stay mostly in the perimeter strip, but only for a few days. Soon afterwards they enter the inner part of the field. Although our perimeter strip fields were sprayed very early, before the damage threshold was reached, in 4 fields out of 9 there were significantly more eggs and larvae of the stem weevil in the untreated compared to the treated part (Table 2). That means, that treating the perimeter strip could not prevent a greater infestation in the middle of the field. In 7 out of 9 fields we registered yield losses in the unsprayed part of the field, although we think that other factors (diseases, soil differences, weeds) also affected the yields. We conclude from these results, that the perimeter strip method is not suitable to be used generally to control the stem weevil.

4.3. Pollen beetle

In order to measure the efficiency of the perimeter strip for pollen beetle control we compared the yields of field halves with the treated perimeter strip with those of the other half homogenously treated (Table 5). In our opinion in all three cases spraying was too late, because there were already too many pollen beetles in the middle of the field. The damage by beetles may be one reason for yield reduction. In addition we had other factors influencing the yield of these and other experimental fields. The problems were increased with the new double low 00-varieties which are more susceptible to fungal diseases than the older 0-varieties and fungicides were not registered in rape in Switzerland until 1994. At harvest time some fields were so heavily damaged by *Phoma lingam* that it was impossible to measure any yield loss caused only by the pollen beetle. On the other hand for testing the method we had to use whole fields.

So we are interested in the required turnip rape percentage to concentrate a significant portion of the pollen beetle population in the perimeter strip area in order to hold the density of the beetles in the inner part of the field below the damage threshold. Fig. 7 shows for 3 fields that with turnip rape it is possible to concentrate a considerable proportion of the pollen beetle population of the field in the perimeter strip area. The damage threshold for the pollen beetle is 3-5 beetles per plant (Häni et al., 1987). If one assumes 4 beetles/plant (average of pollen beetle infestations in control plots of 24 insecticide trials for registration of insecticide during 1979-1990) 30% of the beetle population must be concentrated in the perimeter strip and controlled there with an insecticide to get 2.8 beetles/rape plant on average (4 beetles - 30% = 2.8 beetles/plant) that is below the lower value of the damage threshold. The calculations of the beetle

populations in the perimeter strip and in the inner part of the field assuming 5, 10 and 15% turnip rape in 6 fields (Table 4) showed that with 15% turnip rape 29.3 - 51.2% of the pollen beetle population is concentrated in the perimeter strip. Most fields in Switzerland are between 0.8 and 1.5 ha. In our field trials the perimeter strip was twice the width of the seed drill giving us a perimeter strip area of about 20% of the field. In field 5 an 6 in Table 5 the perimeter strip area is in this range and 15% turnip rape is needed to concentrate 30% of the beetle population in the perimeter strip. The concentration effect in the other fields is even better.

With increasing number of beetles on turnip rape they migrate to rape in the perimeter strip and to the inner part of the field. Table 3 shows that the number of beetles on rape in the strip can increase up to 4.60 beetles per plant, which is in the range of the damage threshold. To avoid this migration of the beetles and damage to rape plants we recommend farmers in Switzerland to treat the perimeter strip with insecticide when one beetle per rape plant in the perimeter strip is reached.

4.4. Other rape pests

Another insect that occurs predominantly on turnip rape before egg laying, is the cabbage seed weevil (Frei, 1986). Therefore with an insecticide treatment against the pollen beetle the cabbage seed weevil population is also reduced. Furthermore it is known (Stechmann and Schütte, 1978) that Brassica pod midge needs the holes of the cabbage seed weevil to lay its eggs in the pods. Brassica pod midge damage is also mostly concentrated in the border range. So in controlling the cabbage seed weevil, it can be assumed, that egg laying of the brassica pod midge is also reduced.

In Switzerland an outbreak of the cabbage aphid (*Brevicoryne brassicae*) occur about every 8-10 years. The infestation of the aphid begins in the border range of the fields too. We know from trials with pyrethroids against rape pests, that spraying pollen beetle with pyrethroids is partially effective against the cabbage aphid. Therefore we can assume that spraying the perimeter strip against the pollen beetle in most cases controls also the cabbage seed weevil, the brassica pod midge and the cabbage aphid with only 20% of the insecticide amount normally used to protect the whole rape field.

4.5. Beneficials

In recent years we have found a considerable amount of parasitization in blossom beetle, cabbage seed weevil and cabbage pod gall midge in certain regions of Switzerland (Büchi and Roos-Humbel, 1991; Büchi, 1993). There are two main impacts of insecticides against beneficials: 1. direct toxicity of the insecticide during or after application. 2. reduction of the pest population so that beneficials are deprived from their hosts. All pyrethroid insecticides in Switzerland have the restriction that they can only be used before the first flowers open. The parasitoids of the pollen beetle and the cabbage seed weevil appear in the fields only two to four weeks later. So insecticide treatments probably do not harm the parasitoids. Hokkanen (1988) also stated that parasitoids of the pollen beetle are not harmed by insecticide treatments two weeks before their emergence. Treatment of only the perimeter strip with an insecticide leaves enough hosts for beneficials in the inner part of the field. So the perimeter strip method is a good strategy to favour the equilibrium between pests and parasitoids in rape fields.

4.6. Conclusions

The two most important rape pests in Switzerland are the stem weevil and the pollen beetle. Both pests are usually controlled with insecticides sprayed over the whole field and every rape field in Switzerland is treated with insecticides on average 1-2 times. Our results show that only stem weevil needs to be treated over the whole field; the later emerging pollen beetle can be controlled by treating only the perimeter strip (mixture of 15% turnip rape and 85% rape, 5-6 m width) with an insecticide.

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Table 1: Number of flea beetle larvae/rape plant and larvae/turnip rape plant with and without seed dressing. Random block design with 24 plots (12.5 m^2) and 6 repetitions. Plots with rape (Arabella) with 10% turnip rape (Hanko) with and without seed dressing. Each figure is the average of 60 plants. Figures with different letters are statistically different (Duncan-Test). On 25 October, turnip rape plant not recorded.

Treatment		Number of flea beetles larvae/plant					
		25.10.1990		20.11.1990		14.3.1991	
turnip rape dressed	rape dressed	turnip rape	rape	turnip rape	rape	turnip rape	rape
-	-	-	0.8 A	0.5 A	1.0 AB	0.9 A	1.1 B
+	-	-	0.5 AB	0.5 A	1.3 B	0.5 A	0.9 AB
-	+	-	0.2 AB	0.2 A	0.4 A	0.5 A	0.5 A
+	+	-	0.1 B	0.4 A	0.4 A	0.4 A	0.4 A

Table 2: Infestation of plants with rape stem weevil eggs and larvae in fields with a perimeter strip of turnip rape and rape. Comparison of yields of the two halves of the field, with perimeter strip and without perimeter strip (Experimental design see Fig. 1). Each figure is the average number of eggs and larvae of 40 plants. The untreated samples of plants 5-12 (Fig. 1) were compared to the treated samples 13-20 (Fig. 1) using the Kruskal-Wallis Test for significance. Figures with (*) are significantly different.

Location	% turnip rape	Number of eggs and larvae in each plant						Rel. yield of fields with a perimeter strip; treated half = 100%
		treated perimeter strip		untreated inner part		treated part		
		Site of sampling (Fig. 1)						
		1-4		5-8	9-12	13-16	17-20	
		rape	turnip rape	rape	rape	rape	rape	
Flaach 1989	5.9	0.3	0.2	0.9*	0.7*	0.3	0.3	99.25
Bülach 1989	15.7	0.1	0.1	1.5*	1.0*	0.3	0.1	94.2
Nassenwil 1990	5.0	0.1	0.2	0.3*	0.3*	0.1	0.1	93.5
Flaach 1990	5.0	0.3	0.7	1.2	0.6	0.8	0.3	82.6
Flaach 1991	8.3	0.6	0.2	0.2	1.6	0.2	0.3	83.5
Buchberg 1991	11.2	0.4	0.6	1.7	0.5	0.7	0.8	93.4
Flaach 1992	15.0	0.2	0.8	0.2	0.3	0.3	0.6	90.9
Buchberg 1992	19.9	0.6	0.3	0.4	0.2	0.3	0.2	103.4
Trasadingen 1992	15.0	0.0	0.4	0.4*	0.2*	0.0	0.2	102.1
Average	11.2	0.3	0.4	0.8	0.6	0.3	0.3	93.65

Table 3: Dynamic of immigration of the pollen beetle into 6 rape fields with a perimeter strip containing different ratios of turnip rape. Each figure is the average of number of beetles on 30-60 plants.

Field Nr.	% turnip rape in peri-meter strip	Date of counting	Number of pollen beetle/plant		
			in perimeter strip		in inner part of field 4-8 m from perimeter strip
			rape	turnip rape	
1	2.7	24.4.1986	0.30	4.5	0.30
		3.5	1.10	19.4	2.60
		7.5	1.40	6.8	2.80
		10.5	1.20	4.2	2.40
2	6.5	16.4.1987	0.07	2.6	0.00
		24.4.	0.93	9.4	1.30
		28.4	2.00	6.3	1.60
		1.5.	2.50	3.5	1.60
3	10	7.4.1992	0.00	0.1	0.00
		24.4.	1.60	10.3	2.70
4	17.2	15.4.1993	0.00	3.5	0.02
		20.4.	2.50	23.2	1.30
		22.4.	4.60	16.4	2.10
		28.4.	1.80	2.7	2.90
5	27.3	5.4.1993	0.14	4.6	0.26
		11.4.	0.60	7.0	0.80
		15.4	1.70	7.5	1.50
6	14.7	10.4.1993	0.40	5.30	0.08
		15.4.	0.90	9.40	0.30
		19.4.	1.20	7.80	0.30
Average	13.1.	First count	0.15	3.4	0.11
		2nd count	1.27	13.1	1.50
		3rd count	2.18	8.9	1.66
		4th count	1.83	3.5	2.30

Table 5: Infestation of rape fields with the pollen beetle. Perimeter strip with turnip rape and the other half of the field sprayed with insecticide. Comparison of yields of the two halves of the field, with perimeter strip and without perimeter strip. Each figure is the average of 30-60 plants

Location	% turnip rape in perimeter strip	Number of pollen beetles per rape plant before spraying			Rel. yield of fields with a perimeter strip; treated half = 100%)
		within perimeter strip	in middle of the field	border without perimeter strip	
Buchberg 1990	5%	10.8	3.2	6.0	88.3
Buchberg 1991	20%	3.8	2.7	2.4	94.4
Kriessern 1992	10%	1.6	2.5	1.7	99.0
Average	11.7%	5.4	2.8	3.4	93.9

Table 4: Distribution of the pollen beetle population in the turnip rape perimeter strip and in the inner part of the field. The percentages of population are estimations from counted beetles/plant in 6 different fields. For each field 3 estimations are given: with 5, 10 and 15% turnip rape in the perimeter strip.

Field Nr. and assumed portion of turnip rape in perimeter strip	**Portion of pollen beetle population in perimeter strip**	**Portion of perimeter strip area**
Field 1 15%	51.2%	10.6%
10%	42.0%	
5%	32.4%	
Field 2 15%	43.4%	16.3%
10%	33.3%	
5%	23.5%	
Field 3 15%	30.6%	15.4%
10%	24.1%	
5%	17.5%	
Field 4 15%	32.2%	11.0%
10%	22.3%	
5%	12.6%	
Field 5 15%	31.1%	18.9%
10%	25.1%	
5%	19.1%	
Field 6 15%	29.3%	21.0%
10%	21.9%	
5%	13.5%	

Figures

Figure 1: Schema of trials in rape fields to control the stem weevil by treating the perimeter strip with an insecticide. Nr. 1-20 point with removal of 10 plants to record the egg and larval infestation. The shaded area is sprayed with an insecticide.

Figure 2: Rape field (1 ha) with a perimeter strip (15% turnip rape, 85% rape). Areas where flea beetles were caught with the sweep net.

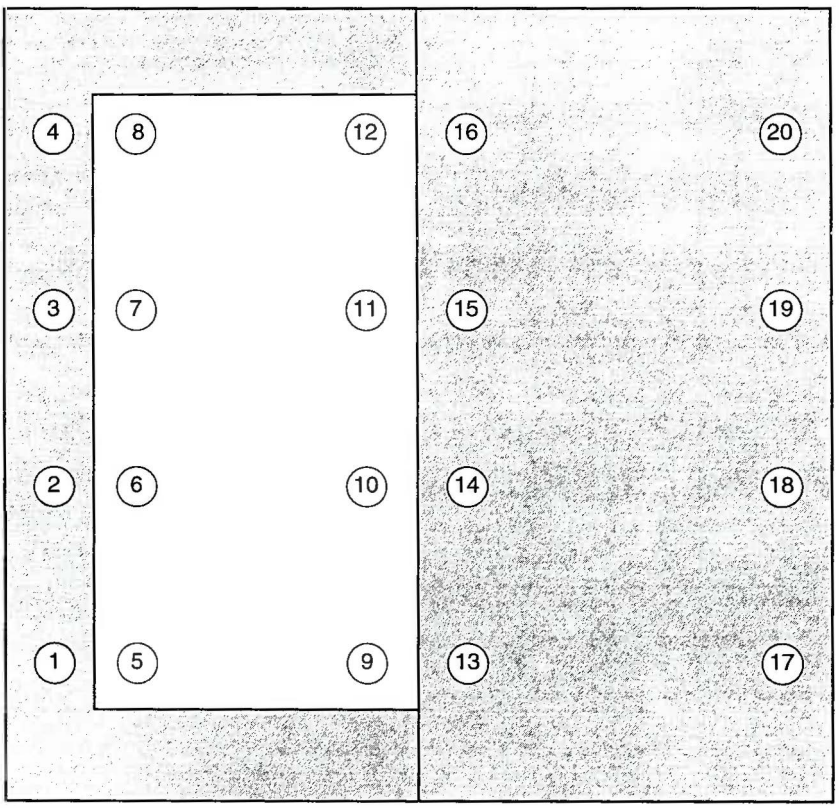
Figure 3: Number of flea beetle larvae in turnip rape and rape in mixtures of turnip rape (2-16.4%) and rape. Results of 22 rape fields, 1985-1990.

Figure 4: Number of stem weevil larvae in turnip rape and rape in mixtures of turnip rape (2-20%) and rape. Results of 30 rape fields, 1985-1992.

Figure 5: Number of stem weevil eggs and larvae in different rape varieties at two locations and different dates of sampling. Randomized block design (plots 12.5 m^2) with 6 repetitions for each variety. Each bar is the average of 60 plants. Bars with the same letter are not statistically different from each other (Duncan Test).

Figure 6: Number of stem weevil eggs and larvae in different rape varieties (21.4.1993 Zollikofen). Randomized block design (plots 12.5 m^2) with 5 repetitions for each variety. Dependence of egg laying of the stem weevil from the plant development. Each bar is the average of 50 plants. Bars with the same letter are not statistically different from each other (Duncan Test).

Figure 7: Pollen beetle population in the perimeter strip and in the inner part of the field in three diffferent fields (17.2%, 27.3% and 14.7% turnip rape).


4
8
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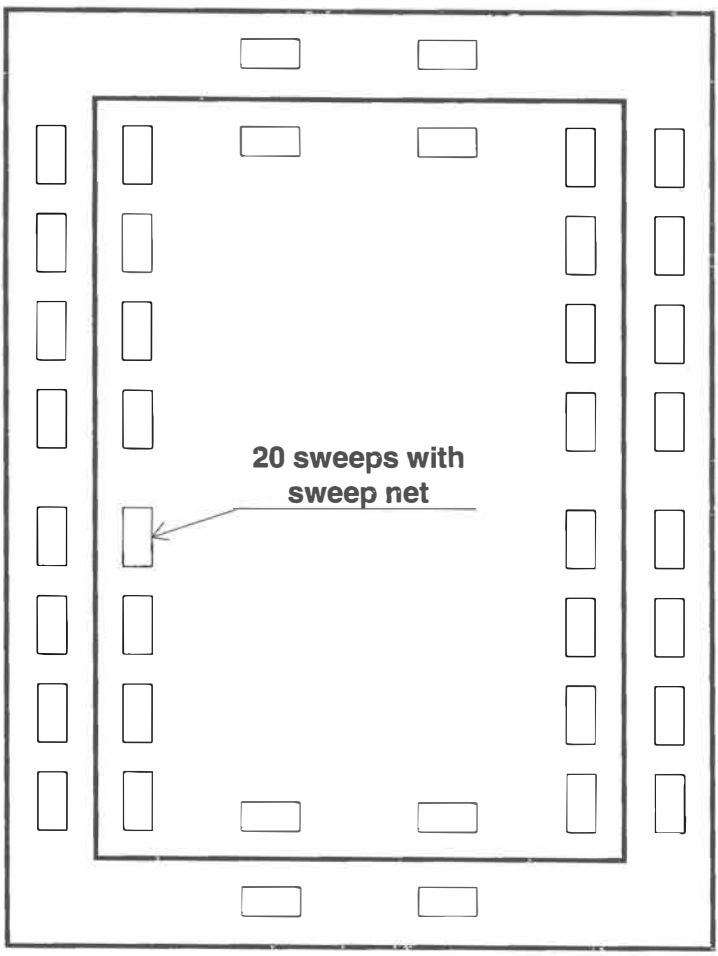
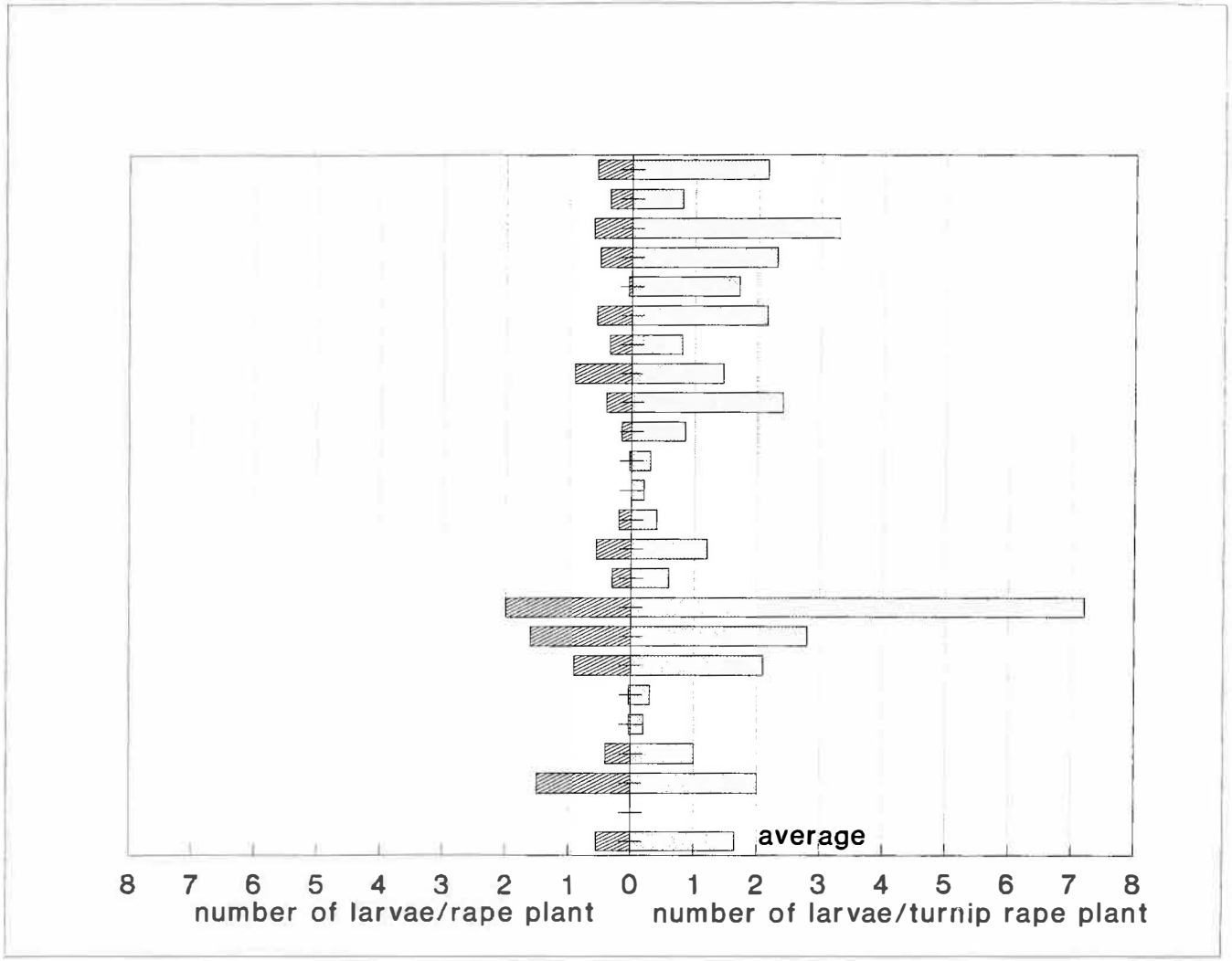
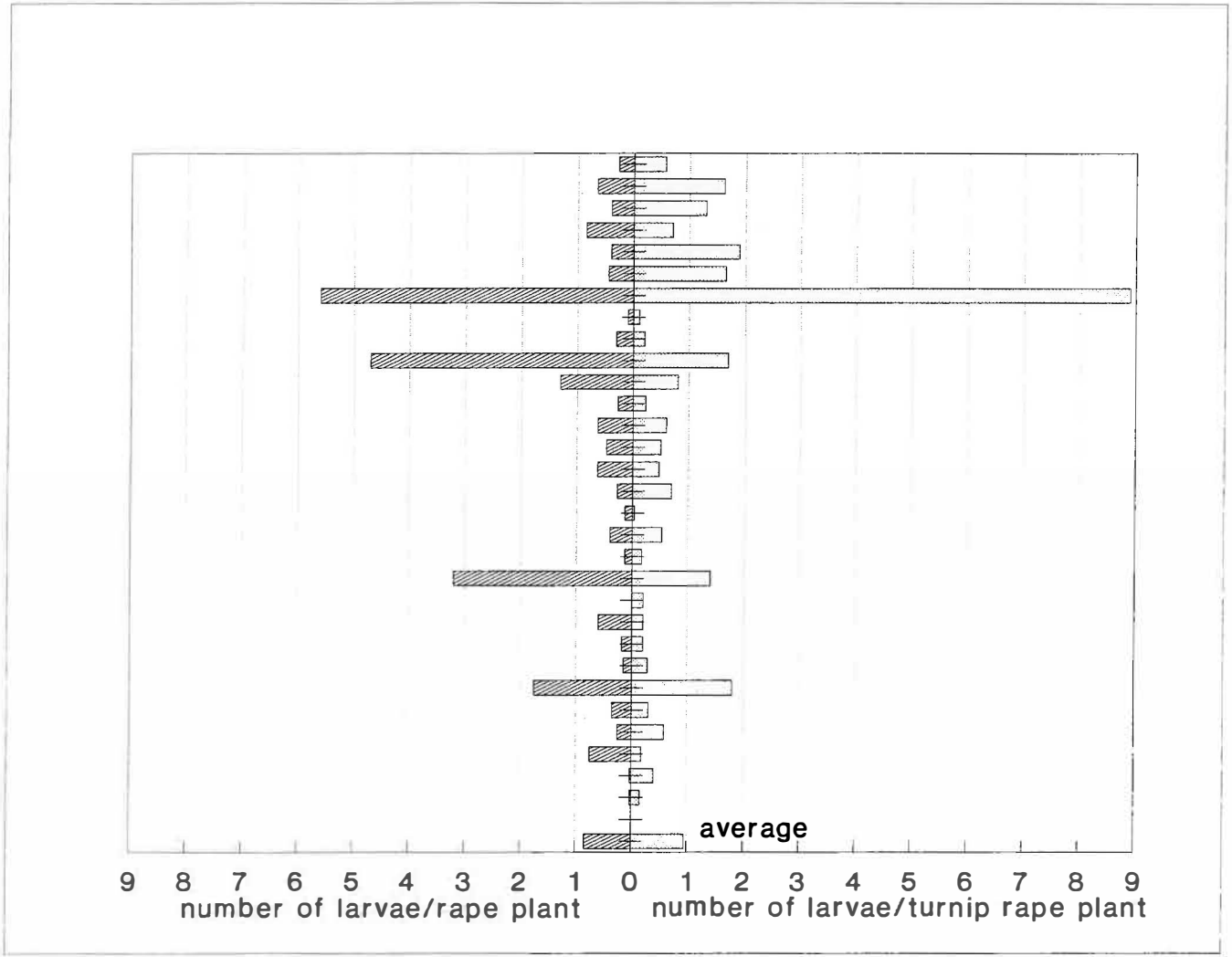
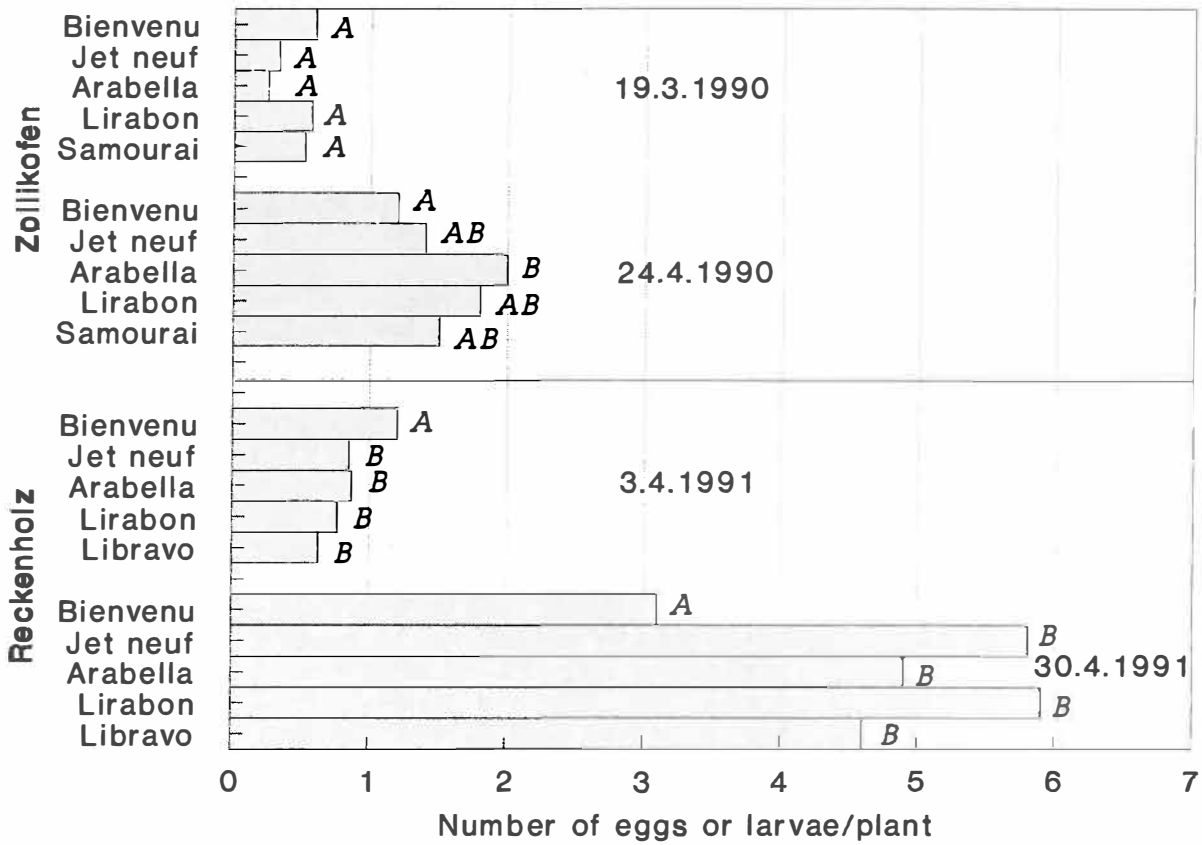
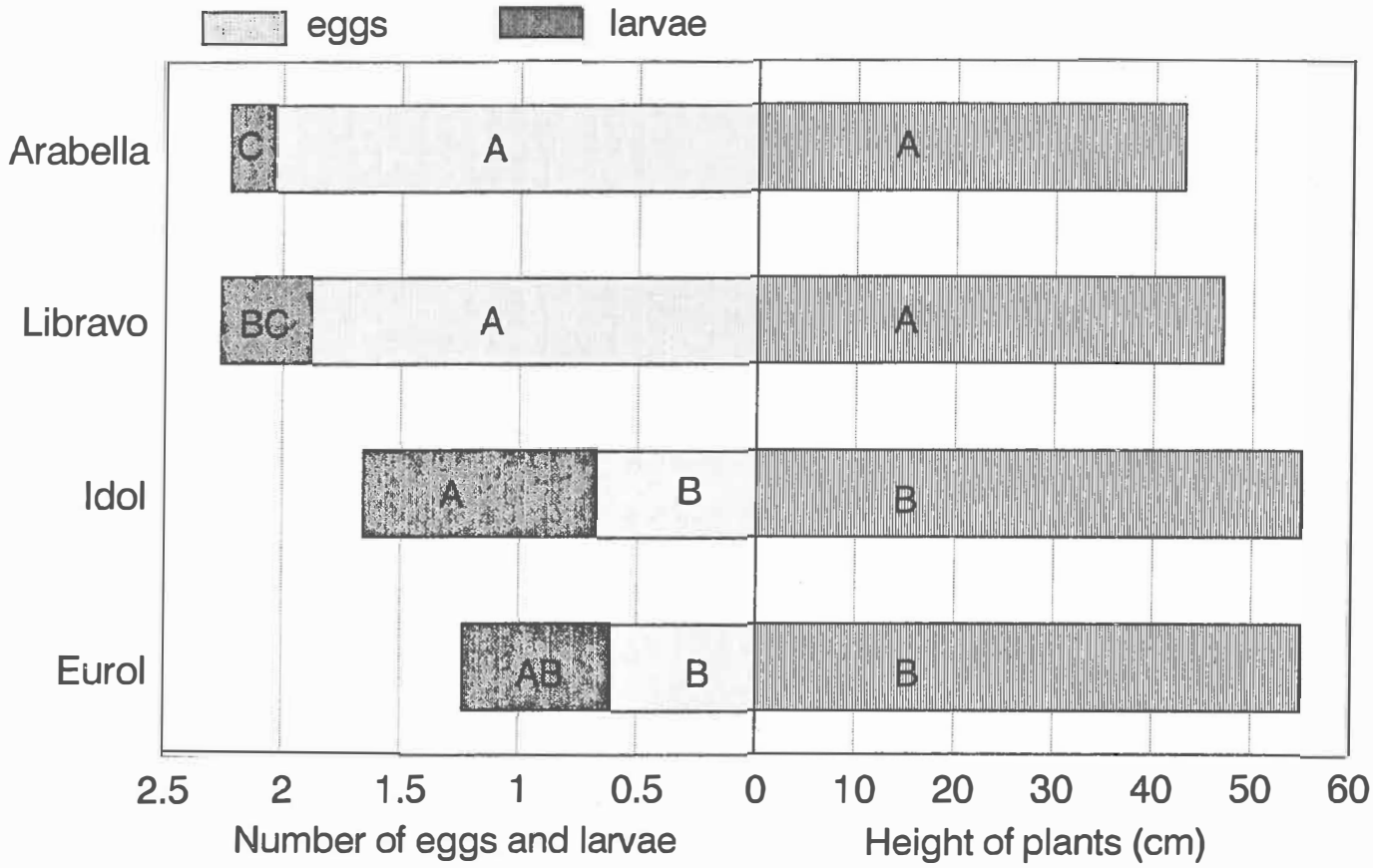
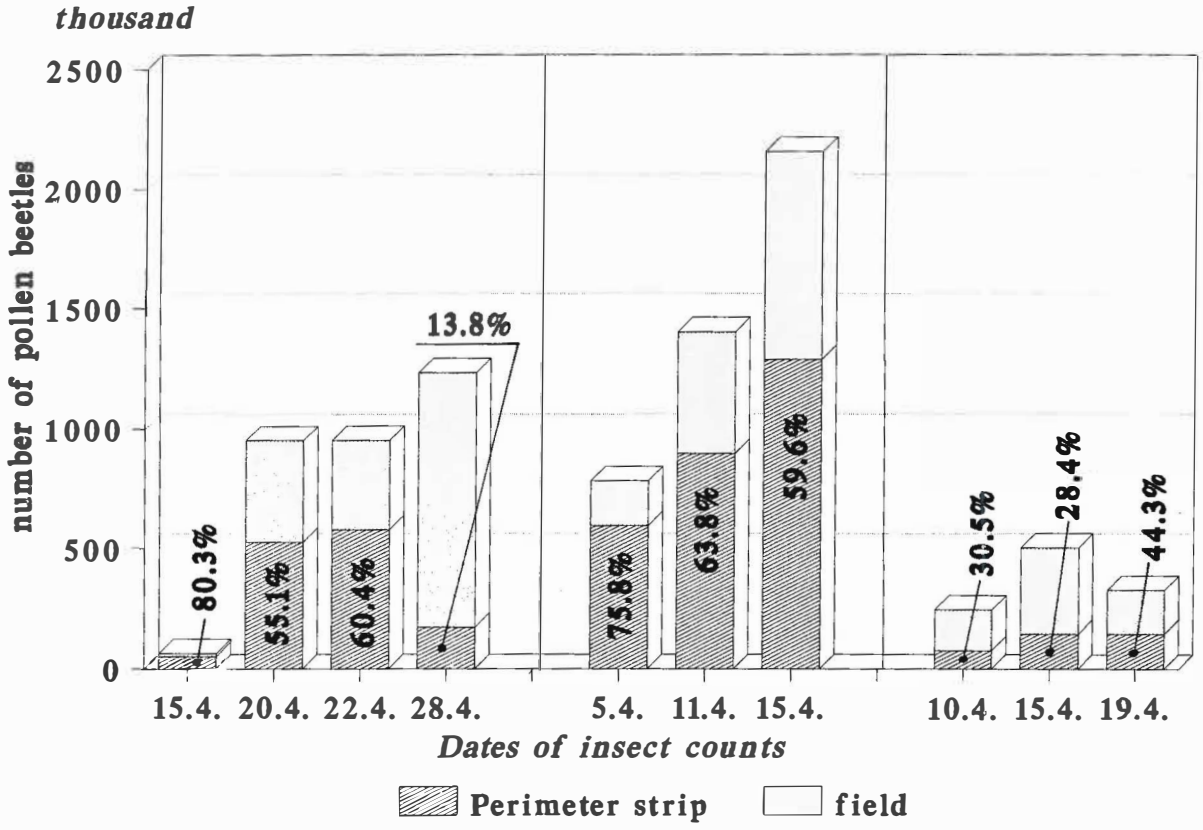

20 sweeps with
sweep net


average
8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8
number of larvae/rape plant
number of larvae/turnip rape plant


average
9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9
number of larvae/rape plant
number of larvae/turnip rape plant


Zollikofen
Reckenholz
Bienvenu
Jet neuf
Arabella
Lirabon
Samourai
Libravo
A
AB
B
19.3.1990
24.4.1990
3.4.1991
30.4.1991
0
1
2
3
4
5
6
7
Number of eggs or larvae/plant


eggs
larvae
Arabella
Libravo
Idol
Eurol
C
A
A
BC
A
A
A
B
B
AB
B
B
2.5
2
1.5
1
0.5
0
10
20
30
40
50
60
Number of eggs and larvae
Height of plants (cm)


thousand
2500
2000
1500
1000
500
0
number of pollen beetles
80.3%
55.1%
60.4%
13.8%
75.8%
63.8%
59.6%
30.5%
28.4%
44.3%
15.4.
20.4.
22.4.
28.4.
5.4.
11.4.
15.4.
10.4.
15.4.
19.4.
Dates of insect counts
Perimeter strip
field

OBSERVATIONS ON THE IMPACT OF STANDARD INSECTICIDE TREATMENTS ON *TRICHOMALUS PERFECTUS*, A PARASITOID OF SEED WEEVIL ON WINTER OILSEED RAPE IN THE UK

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Summary

In field experiments done in the UK 1992 in Bedfordshire (IACR Woburn), Cambridgeshire (ADAS Boxworth) and North Yorkshire (ADAS High Mowthorpe), *Trichomalus perfectus* [Hymenoptera: Pteromalidae] was the most important ectoparasite of the cabbage seed weevil (*Ceutorhynchus assimilis*) [Coleoptera: Curculionidae]. At all sites, a triazophos spray at the end of flowering, the standard timing for a commercial application of this insecticide, reduced the incidence of parasitism. The effect of alphacypermethrin applied at the recommended time during flowering was less clear, although phenological studies of *Trichomalus perfectus* indicated that this was unlikely to have any direct effect on numbers of parasitoids.

1. Introduction

Trichomalus perfectus (Walker) [Hymenoptera: Pteromalidae] is a well-known ectoparasitoid of the cabbage seed weevil, *Ceutorhynchus assimilis* (Paykull) [Coleoptera: Curculionidae] (von Rosen, 1964; Laborius, 1972; Dmoch, 1975; *see also* Lerin, 1987). In the mid-1970s, large numbers (often over 70 per cent) of seed weevil larvae inside pods of commercial rape crops in England were parasitised by this insect (Alford, D. V., *in litt.*). More recent studies, including data generated by the ADAS Pest Monitoring Scheme (Walters, K. F. A., *unpublished*), indicate that although seed weevil parasitoids are widespread in England and Wales levels of parasitism tend to be low. The widespread use of broad-spectrum insecticides on oilseed rape, throughout the late 1970s and 1980s, may have caused the decline in natural control of *C. assimilis* by parasitoids. Oilseed rape crops in the UK have frequently been sprayed unnecessarily against pests such as *C. assimilis* (Alford, Cooper & Williams, 1991) but, with changes in support prices for the crop, it is becoming increasingly uneconomic to justify prophylactic treatments (Lane & Walters, 1993).

In 1992, a collaborative, three-year, study was begun on winter oilseed rape at three sites, with the aim of determining the effect of insecticides applied during and

after flowering on parasitoids of *C. assimilis*. Possible strategies are being sought for farmers to exploit parasitoid populations in the control of *C. assimilis*.

2. Methods

In 1992, three fields of winter oilseed rape were selected: site **A** - Bedfordshire (IACR Woburn); site **B** - Cambridgeshire (ADAS Boxworth); site **C** - North Yorkshire (ADAS High Mowthorpe). At each site, three plots (each *c.* 48 × 48 m) were demarcated on a headland, each separated by buffer zones of 48 m (12 m at site **C**, because of lack of space). Plots were unreplicated.

At each site, one plot was treated with alphacypermethrin (as 'Fastac') at 200 ml/ha at 20 per cent pod set (Growth Stage 4.8); a second plot was treated at the end of flowering (Growth Stage 6.1) with triazophos (as 'Hostathion') at 1 litre/ha; both treatments were applied in 200 litres of water/ha. The third plot was left untreated.

Adults of *C. assimilis* were monitored weekly in each plot from green-bud (Growth Stage 3.3) until one week after the triazophos treatment. On each occasion, 20 plants were beaten over a white tray and the adults present counted. Beating points were spaced evenly (2.5 m apart) along a central transect across the plot. At site **A**, yellow-bowl water traps (21 cm diam.; 1.5 litre water volume) were used to monitor adult *C. assimilis* and female *T. perfectus*.

To assess the effects of treatment, 20 plants were removed from each plot along the transect two weeks after flowering; the following were determined from samples of 20 pods (10 from the main raceme and 10 from the third lowest secondary raceme) per plant:

a) The number of pods with *C. assimilis* larval exit holes;

b) The number of pods containing live, dead or ectoparasitized *C. assimilis* larvae.

3. Results

Overwintered adults of *C. assimilis* migrated into crops during the latter half of April and early May, and declined from mid-June onwards. Numbers of weevils exceeded the economic damage threshold of 1 per plant at site **C** only (Table I). Subsequent larval pod infestation in untreated plots was positively correlated with infestation levels of adults.

Table 1. *Ceutorhynchus assimilis* infestation levels in unsprayed plots, 1992.

Site	Maximum average number of adults	Average pod infestation
A - Bedfordshire	0.50/plant	4.9%
B - Cambridgeshire	0.65/plant	2.4%
C - North Yorkshire	1.40/plant	22.5%

The water traps indicated that the phenology of *T. perfectus* lagged about two weeks behind that of its host in all plots. In untreated plots, maximum numbers occurred on late June and early July.

Levels of parasitism of *C. assimilis* varied between treatments (Table 2).

Table 2. Effect of pesticide application on parasitism of *Ceutorhynchus assimilis* by *Trichomalus perfectus*.

Site	Treatment	Average level of parasitism
A - Bedfordshire	alphacypermethrin	76%
	triazophos	37%
	untreated	73%
B - Cambridgeshire	alphacypermethrin	60%
	triazophos	0%
	untreated	21%
C - North Yorkshire	alphacypermethrin	22%
	triazophos	20%
	untreated	54%

4. Discussion

At all three sites, triazophos reduced the incidence of parasitism of *C. assimilis* by *T. perfectus*. This is not unexpected, as the timing of the application coincided with the main flight period of *T. perfectus* egg-laying females. Thus, commercial 'end of flowering' or 'post-flowering' treatments, commonly applied on winter rape crops in the 1980s, may have accounted for the decline in populations of this parasitoid

Experimental data for alphacypermethrin were variable but suggest that this insecticide, the commercial application of which would normally be in advance of *T. perfectus* activity in winter rape crops, should not cause undue mortality.

There were unexpectedly large numbers of dead *C. assimilis* larvae in untreated plots, possibly because adult females of *T. perfectus* 'host-feed' as well as deposit eggs (Jervis & Kidd, 1986). Host-feeding by hymenopterous parasitoids can exert considerable mortality on host populations and such behaviour, if confirmed in this species, would enhance the economic significance of *T. perfectus* as a natural enemy of *C. assimilis* in oilseed rape crops.

Lowered prices for oilseed rape within the European Union have increased pressure on farmers to reduce agrochemical inputs. However, many UK farmers are worried about the consequences of leaving crops largely unsprayed against pests, diseases and other problems. The industry will require clear guidance if low-input strategies for controlling pests such as *C. assimilis*, in which survival of *T. perfectus* is seen as a key component, are to become acceptable and viable commercially.

5. Acknowledgements

We thank Dr K A Raw, Mr D B Turley and other ADAS colleagues for technical assistance, and HGCA (Oilseeds) and MAFF (LINK Programme: Technologies for Sustainable Farming Systems) for financial support.

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A RAPID METHOD FOR ASSESSING INFESTATIONS OF CABBAGE STEM FLEA BEETLE LARVAE IN WINTER OILSEED RAPE AND IMPLICATIONS FOR CONTROL.

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Abstract

Analysis of data from over 300 fields demonstrated a highly significant curvilinear relationship between percentage leaf petioles with feeding scars and numbers of cabbage stem flea beetle larvae per plant, found in the autumn. The relationship was less good for samples taken in late winter/early spring. Insecticides applied in late winter gave up to 70 per cent control of recently hatched larvae but were less effective against older larvae. There was a trend to yield response following treatment but responses were not always consistent with flea beetle control. Results suggest that spraying with insecticide in late winter/early spring is not justified unless there are 10 or more larvae per plant.

1. Introduction

Cabbage stem flea beetle (CSFB), *Psylliodes chrysocephala* (L) (Coleoptera Chrysomelidae) is a widespread pest of winter oilseed rape (Lane and Cooper, 1989) and is probably the most important autumn/winter pest of the crop (Cooper and Lane, 1991). As egg laying can occur over a prolonged period between September and early winter and egg hatch is temperature dependent (Alford 1979), larvae can invade plants at anytime from October until April the following year. However, in most seasons, it is the damage done by larvae invading crops in the autumn, which is thought to be most serious. Experimental studies together with the results of surveys have led to the adoption of a treatment threshold of five or more larvae per plant at anytime between October to December (Purvis 1986). Data on the economics of controlling infestations found on crops in the spring have not yet been obtained, although Purvis (1986) found that in the absence of previous autumn treatments, spring applications of an insecticide sometimes gave a worthwhile yield response when larval infestations exceeded five per plant, although this may have reflected the greater damage potential of the larger larvae present in spring. Consequently, effective autumn treatments preventing mining

by large overwintering larvae produced the largest yield responses. Other experiments (Lane and Cooper 1989) failed to demonstrate yield responses to spring control at levels of five larvae per plant when only small, newly-hatched larvae were present. Further work was required to investigate the economic justification for control of spring infestations of CSFB larvae and the criteria by which control decisions should be made.

The adoption of an improved approach to autumn pest management in winter oilseed rape depends, in part, on the development of new, user-friendly assessment techniques. Alternatives to the currently used plant dissection assessment techniques for CSFB have been investigated and validated (Cooper and Lane, 1991; Walters and Lane, 1994).

This paper reports the development of an improved method for rapidly assessing autumn and spring CSFB infestations in the field,and a series of experiments to determine the effect of CSFB attack during winter/early spring and crop responses to later winter treatment.

2. Development of rapid method for CSFB assessment

Traditionally, during the period of larval infestation, a sample of 20 plants is taken at random from a diagonal transect across each field. The plant samples are returned to the laboratory where leaves and stems are dissected and the number of CSFB larvae recorded. The need to dissect plant samples is labour intensive and so increases the cost of giving advice; there is also a time delay in getting the results and consequent advice to the farmer (Walters and Lane, 1994). Previous studies have indicated that during the autumn, an assessment of externally visible symptoms of larval tunnelling in leaf petioles offers a more rapid and less laborious alternative (Cooper and Lane, 1991). Subsequently, analysis of data from almost 300 fields collected during the last five years from many areas of England and Wales, has indicated a highly significant curvilinear relationship (Fig.1) between the percentage of leaf petioles showing "scarring" damage, ie internal tunnelling by CSFB larvae, and the number of larvae per plant during the autumn/early winter period (Walters and Lane, 1994).

A similar relationship is obtained both between years and between different areas of England and Wales in the autumn. The data suggests that about 60 per cent of leaf stalks scarred equates with the 5 larvae per plant threshold.

The relationship, however, is less good for late winter/early spring samples where there is more variation above the 5 larvae per plant infestation level (Fig. 2).

The lack of a good relationship at the higher infestation levels in spring can largely be explained by the death of leaves damaged by CSFB in the autumn, before samples are taken.

The adoption of the leaf scarring method for use in the field to establish autumn infestations of CSFB and the need to spray, has great potential. It is a quick and straightforward monitoring method which can help to reduce the cost of advising on

CSFB control, speed up the rate at which advice can be delivered and therefore help to reduce prophylactic spraying.

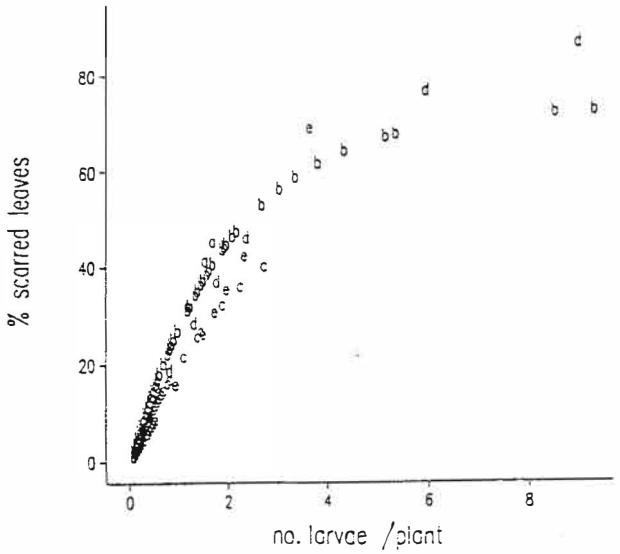

Fig. 1 The relationship between percentage leaf petioles with scarring damage and the number of CSFB larvae per plant (autumn/early winter samples) in 1988 (a), 1989 (b), 1990 (c) 1991 (d) and 1992 (e).

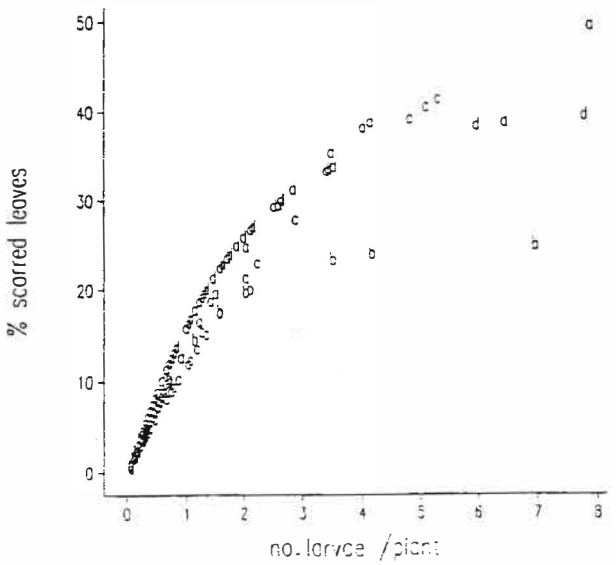

Fig. 2 The relationship between percentage of leaf petioles with scarring damage and the number of CSFB larvae per plant (late winter/early spring samples) in 1989 (a), 1990 (b), 1991 (c) and 1992 (d)

3. Assessing the significance of CSFB attacks during winter/early spring and response to control measures

Since the late 1970s, a wide range of insecticides have been tested and compared for the management of CSFB larvae (Alford, 1977; John & Holliday, 1984), and many of these were shown to give effective control. Subsequent work led to the development of the autumn treatment threshold of 5 larvae per plant. The validity of this threshold was confirmed by Purvis (1986) who related yield responses to autumn applications of a range of carbamate, organophosphate and pyrethroid insecticides. To assess the significance of CSFB infestation in late winter/early spring, 11 field experiments were carried out between 1987-1990.

3a. Materials and Methods

The experiments were sited in commercial crops of winter oilseed rape in areas where damage due to CSFB had occurred in previous years. All sites were checked during the autumn/early winter to ensure that the autumn threshold had not been exceeded. The insecticides used were deltamethrin (Decis 2.5% ec) and gamma-HCH (Gamma-Col, 57.1% col) and were applied over the period 26 January to 18 March, depending on when infestations of CSFB were found. The trials were of a randomised block design with six or seven-fold replication. Numbers of CSFB larvae were assessed in March by dissecting 25 plants per plot, approximately three weeks after insecticide application. First and second/third instar larvae were recorded separately. Plots were harvested and yields corrected to 91 percent dry matter.

3b. Results

i. Larval populations and control

At 9 of the 11 sites, numbers of CSFB larvae in untreated plots (all instars) were well above the autumn treatment threshold when assessed in March. Both insecticides significantly reduced numbers of larvae, deltamethrin being more effective than the gamma-HCH (Table 1).

Table 1 Mean number of live larvae assessed 3 weeks after insecticide treatment

Treatment	Mean no. larvae per plant	% control
Unsprayed	10.7	
deltamethrin	4.2	57
gamma-HCH	5.7	47

Low numbers of first instar larvae were found in untreated plots in March indicating that there was some late winter egg hatch. However, at most sites most of the larval invasion occurred in the autumn/early winter. Both insecticide treatments

significantly reduced numbers of first and second/third instar larvae. As expected, control of the smaller first instar larvae was greater (Table 2).

Table 2 Mean number of live larvae by instar assessed 3 weeks after insecticide treatment

Treatment	Mean no. 1st instar larvae/plant	Mean no. 2/3rd instar larvae/plant
Unsprayed	1.9	8.8
deltamethrin	0.5	4.2
gamma-HCH	0.9	4.7

ii. Yield loss relationships

On a cross-site analysis, both insecticide treatments gave a significant yield response but with no significant difference between treatments (Table 3).

Table 3 Mean yield response to treatment

Treatment	Yield t/ha
unsprayed	2.77
deltamethrin	2.97
gamma-HCH	2.90
SED	0.03
cv %	6.81

At individual sites, yield response was not always consistent with control of CSFB, and the relationship between numbers of larvae per plant and response to insecticide treatment was generally poor across all sites (Fig.3).

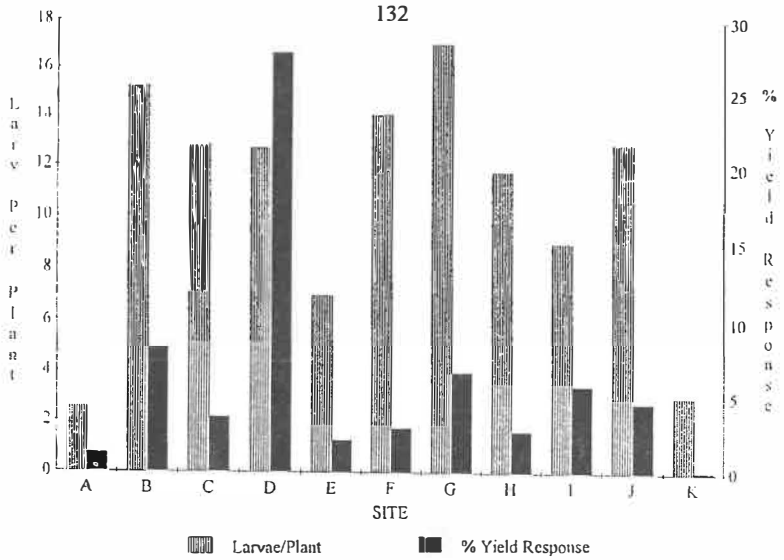

Fig. 3 Relationship between numbers of CSFB larvae per plant and percentage yield response to treatment at 11 sites.

4. Discussion

The establishment of a rapid method for assessing infestations of CSFB larvae in the field using the scarring technique is a major step forward. However, this work has demonstrated that the technique is only of relevance when assessing autumn/early winter infestations and is of limited value for late winter/early spring sampling.

The control and importance of CSFB infestations in late winter/early spring requires further investigation. Whilst insecticide treatments have given significant reductions in numbers of larvae, the degree of control is inferior to that of autumn applied treatments. This is probably due to the presence of larger plants in late winter making spray penetration more difficult and the likelihood of the CSFB population consisting of a greater proportion of older second and third instar larvae.

It has been established that when 5 or more CSFB larvae are present in the autumn, which can be determined rapidly using the scarring index method, that it will generally be cost effective to apply an insecticide (Lane & Walters, 1993). In addition, once the autumn treatment has been made, it is unlikely that a further late winter/early spring application will be necessary (Purvis, 1986). Where an autumn insecticide has not been applied because CSFB infestations are below the treatment thresholds, it is possible that in some years a late winter hatch of larvae will result in the overall CSFB infestation (both first instar larvae and older second and third instar larvae which hatched the previous autumn), exceeding 5 per plant. In this situation, the leaf scarring method is unlikely to give a reliable estimate of the CSFB infestation level as an aid to control decision making. It is recommended, therefore, that plants will need to be removed from the field and dissected in the laboratory to establish the infestation level.

The experimental work reported here has demonstrated that applying insecticides in late winter/early spring can give useful control of CSFB larvae; up to 70% control of recently hatched larvae was recorded but only 40-50% control of older, larger larval stages. However, it has not been possible to establish a treatment threshold for control at this time of year. From the results, it would seem that larval infestations in excess of 5 per plant would be needed to justify insecticide treatment. Bearing in mind that a yield response of at least 3% is needed to cover the cost of treatment, it is suggested that a guideline threshold of 10 or more larvae per plant is set for the control of CSFB larvae in late winter.

5. Acknowledgements

Financial support for this work from the Ministry of Agriculture, Fisheries and Food (MAFF) is gratefully acknowledged.

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