A PREDICTION TEST FOR PEA FOOTROT AND THE EFFECTS OF PREVIOUS LEGUMES

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ABSTRACT

A three year survey on a total of 2739 fields gave data of the incidence of soil-borne pathogens causing footrot and their relationship with the number of previous pea and bean crops in the rotation. During 1973-1975, 16% of fields had grown pea or bean crops more frequently than twice in nine years and disease incidence was significantly higher where crops had been grown more frequently than this. Studies on soil samples and plants from 70 fields of vining peas formed the basis for the development of a key for assessing footrot symptoms. There was a significant negative correlation between the footrot indices and the yield of each crop. The footrot indices of five-week old test plants grown in soil from these fields, in the glasshouse, produced significant positive correlations with the footrot indices of the crops. The usefulness of this as a means of predicting disease levels in pea fields is discussed.

INTRODUCTION

Peas (*Pisum sativum*) grown for freezing and canning occupy some 55000 ha annually in the UK and are valued at around £55M. Major advances in production over the last 20 years have been made by the adoption of more reliable varieties, the achievement of optimum plant population and improved weed, pest and disease control. There has been a recent trend towards growing a greater proportion of earlier maturing and small seeded varieties to provide high quality produce, but these types have not provided significant yield advantages and the national average yield has remained at *c* 4.5 t/ha since the mid-late 1960s. It has become apparent that a significant proportion of vining pea crops, are affected by root diseases caused by soil-borne fungal pathogens, producing 'footrot', especially where peas have been grown regularly and where both peas and beans (*Phaseolus vulgaris*) are part of the crop rotation.

It is well known that disease can affect yield and that overcropping may result in the build up of pathogens in the soil. It was appropriate, therefore, that a study should be carried out to survey current rotational practice with regard to peas and beans and that information on the incidence of soil-borne diseases should be collected and related to the frequency of legume cropping.

This paper outlines the results of such a study, carried out by the Processors and Growers Research Organisation (PGRO) during the cropping seasons of 1973-1975, which was expected to provide a sound background for advising a suitable cropping rotation for peas and beans.

Growers that had already adopted an approved rotational practice needed information to help them assess the risk remaining from past overcropping. The PGRO study was designed to develop a means of predicting the likely occurrence of soil-borne diseases before cropping and to establish this as a service for the industry.

METHODS

Rotation Survey

Questionaire forms were distributed to processor members of PGRO. In all, 19 companies participated in the survey. The forms were completed by their growers who gave details of the previous nine years cropping on those fields being cropped with peas or beans. The fields were situated in the Eastern parts of England, the majority of which were in the counties of Lincolnshire, Cambridgeshire, Norfolk, Suffolk, Essex and Kent. These data were collected at the beginning of each of the three seasons 1973-1975. Participants informed PGRO if and when any of their crops appeared to be suffering from any problem. During the course of each season, each problem reported was investigated and where footrot was suspected, plant samples were examined to identify the probable causal organisms.

Effect of footrot on yield

This part of the work was carried out during 1981 and 1982. In both years, vining pea fields were selected on the basis of past cropping, to provide a range of pea cropping frequencies. Each field was visited when the crop had reached the full flower stage "GS R4" (Gane et al. 1984) and plants were dug at random on a traverse made in a 'W' pattern. After washing, the roots and stem bases were examined for footrot symptoms. These were assessed, using a method designed to take into account the different symptoms observed by the diseases of the footrot complex, in the following way. Both the stem base and root system of each plant were separately assigned a score between 0 and 5; 0 = no discolouration and 5 = complete blackening or browning of root or stem base tissue. The two score totals were added and divided by 2 x the number of plants examined to give a footrot index. (Biddle 1983). Fungal pathogens were also isolated and identified. At the end of each season, the variety, date of sowing and crop yield of each field were obtained from information provided by the growers.

Prediction of footrot in field soil

Soil from the fields described above was collected before drilling using the same 'W' pattern sampling procedure. The soil was mixed and placed in 3 replicate plant pots, each sown with a wrinkled seeded vining pea and kept in the glasshouse. During growth, the moisture level of the soil was brought to c. field capacity each day and the temperature kept between 15 and 20°C. After 5 weeks, or when the plants had begun to produce flowers, the roots were washed and footrot symptoms were assessed using a footrot index as before.

RESULTS

Rotation survey

Data from 2739 individual fields of peas and beans had been obtained by the end of the three year survey. An analysis of the legume cropping practice employed during the 1973-1975 period is shown in Table 1.

TABLE 1 Pea and bean cropping frequency

Number of pea and bean crops grown in 9 years	Species	% of growers using each type of rotation
1	Peas	19.5
1	Beans	2.9
2	Peas	51.7
2	Beans	4.5
2	Peas and Beans	5.5
3	Peas	8.0
3	Beans	0.4
3	Peas and Beans	5.7
4	Peas and Beans	1.8

The results showed that 16% of growers' rotations included large seeded legumes three or more times in a nine year period. The crops in which diseases were identified, were related to the questionaires and an analysis was carried out at the end of each year. At the end of the three seasons 61 crops had confirmed symptoms of footrot, indicating that 2.2% of the total number of peas and beans in the survey were seriously infected.

The legume cropping history of each footrot infected crop was recorded and Table 2 shows the relationship between cropping frequency and incidence of disease and the pathogens isolated.

The results clearly showed a positive relationship between the frequency of cropping peas and beans and disease incidence and that incidence was significantly higher when more than two pea or bean crops were grown in a nine year period. The majority of pathogens were directly causing footrot symptoms, but a small and potentially important amount of *Sclerotinia sclerotiorum* was found in fields that had grown 4 pea and bean crops in nine years. This indicates that it would be unwise to grow other stem rot susceptible crops, e.g. faba beans or oilseed rape in these fields (Jellis *et al*. 1984).

Effect of footrot on yield

Twenty fields were examined in 1981 and 50 in 1982. The pathogens isolated and the percentage of the fields in which each pathogen occurred are as follows:-

	% 1981	% 1982
Phoma medicaginis var *pinodella*	40	34
Fusarium solani f.sp. *pisi*	55	50
F. oxysporum	15	8
F. culmorum	0	2
Mycosphaerella pinodes	10	8
Thielaviopsis basicola	30	2

The percentage of crops infected by each pathogen was similar in each year even though weather conditions during the growing season in those years was very different.

In each year the crops were separated into early and maincrop varieties and the footrot index for each and for a mean of all varieties was correlated with yield. The results showed that in both years, significant negative correlations between footrot index and yield were obtained. The correlation coefficients (r), the level of significance (p) and the equations of each regression line are shown in Table 3.

TABLE 2 % fields with footrot in relation to frequency of pea and bean cropping 1973-1975

No. of pea and bean crops grown in 9 years	Species	F.solani		T.basic		Aph	Ph.med	Scl.	Total
		Pea	Bean	Pea	Bean	Pea	Pea	Bean	
1	Pea	0.18	-	0	-	0	0	-	0.18
1	Bean	-	0	-	3.4	-	-	0	3.40
2	Pea	0.49		0	-	0.07	0.14	-	0.71
2	Bean	-	0	-	0	-	-	0	0
2	Pea & Bean	0	1.3	0	0	0	0	0.67	2.00
3	Pea	2.3	-	0.91	-	0	2.7	-	5.90
3	Pea & Bean	0.63	2.5	0.63	6.4	0	0	0	10.20
4	Pea & Bean	2.0	6.0	10.0	10.0	0	0	2.0	30.0

TABLE 3 Correlation coefficients (r) of footrot index and vining pea yields 1981-1982

1981	Early varieties	r = -0.81	@ p = 0.05	y = 5.53-0.85x
	Maincrop varieties	r = -0.89	@ p = 0.05	y = 5.75-0.5x
	All varieties	r = -0.54	@ p = 0.05	y = 6.13-0.84x
1982	Early varieties	r = -0.81	@ p = 0.01	y = 7.25-0.92x
	Maincrop varieties	r = -0.47	@ p = 0.05	y = 5.92-0.33x
	All varieties	r = -0.48	@ p = 0.01	y = 6.3-0.46x

The diseases had a greater effect on the early sown varieties than on the maincrop varieties. The overall average yield loss for early crops was 0.9 t/ha for each increase of 1.0 on the footrot index. The results clearly showed that the effect of both subclinical and high levels of disease on the yield of vining peas.

Prediction of footrot in field soil

Correlation analyses were carried out on the footrot indices obtained from the glasshouse test plants and the corresponding indices obtained from the crop plants grown in the field (field footrot index) from which the soil samples were taken. In 1981 the relationship between the footrot index of glasshouse test plants and their corresponding crop samples expressed as correlation coefficients (r) was $r = 0.74$ @ $p = 0.01$. The slope of the regression line was $y = 0.56 + 0.71x$. In 1982, the values were $r = 0.64$ @ $p = 0.01$, $y = 1.07 + 1.4x$.

These results, when plotted as graphs were used to derive a series of footrot categories. The mean yield loss from footrot on all crops over the two year period was plotted and the percentage loss compared with the footrot index. It could then be seen that significant yield loss, c. 20% corresponded to a field footrot index of 2.0. The corresponding footrot index obtained from the glasshouse test was 2.0 in 1981 and 0.85 in 1982. From these values a scale of footrot risk, based on the glasshouse test results, was devised;

A glasshouse test index of up to 0.85 indicated a very low risk with footrot levels unlikely to cause serious loss. Values between 0.86 and 1.25 indicated a low risk in most seasons, but yield losses of up to 20% could occur in unfavourable conditions. Values between 1.26 and 2.0 indicated a medium risk of footrot, especially in wet conditions. Values between 2.1 and 2.75 indicated a high risk of serious losses in most seasons. Values above 2.75 indicated that it may be uneconomic to grow peas.

CONCLUSIONS

The results of the complete project showed firstly, that peas and beans should not be grown more frequently than twice in a nine year period, otherwise serious yield loss from footrot can be expected. Secondly, the effect of footrot on the yield of vining peas was sufficient to give a clear appreciation of the importance of even low levels of footrot. Thirdly the glasshouse test provided a reliable guide to the levels of footrot that could occur in a crop planted in that field and has enabled PGRO to provide this test as a service to its members. The value of the test is twofold, it alerts growers to the possible danger of growing peas in infected soil and secondly it allows a reasonable estimate of the risk of yield loss where disease levels are at a more moderate level.

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SUGAR-BEET RHIZOMANIA : THE THREAT TO THE ENGLISH CROP AND PREVENTIVE MEASURES BEING TAKEN

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ABSTRACT

Rhizomania, caused by beet necrotic yellow vein virus, is now widespread in Continental Europe but is not known to occur in England. The vector (Polymyxa betae), however, occurs in most English beet fields.

Details are given of surveys being made by British Sugar plc and by the Ministry of Agriculture, Fisheries and Food (MAFF) to detect any presence of rhizomania in beet crops, and by MAFF to prevent or minimize its importation. Programmes of research at Broom's Barn Experimental Station and at the MAFF Harpenden Laboratory, especially the development of diagnostic methods, are outlined, and measures to be taken in the event of an outbreak of the disease are listed.

INTRODUCTION

Rhizomania was first recognised on beet in Italy in the early 1950's and, two decades later, its known occurrence in Europe was still restricted to Italy, Czechoslovakia and Poland (Dunning 1972). Since then it has spread extensively and now occurs in many beet growing countries (Richard-Molard 1984), although it is not known to occur in Scandinavia or the British Isles. Rhizomania now damages beet crops in the Netherlands, at the same latitude as much of the English sugar-beet root-growing area, so there is concern that it could spread to England and become as serious here as in other parts of Europe. The disease is caused by beet necrotic yellow vein virus (BNYVV) and is transmitted by the soil-borne fungus Polymyxa betae.

Patches of very stunted beet, with excessive growth of lateral roots, have been recognised in English root crops since 1962, and given the name 'Barney patch' (Jones & Dunning 1972). Although the root symptoms of Barney patch are similar to those of rhizomania (Tamada, pers. comm.), recent work suggests a consistent association between the disorder and Rhizoctonia (Payne unpublished), a result agreeing with that of P. Gladders (pers. comm.). However, at Rothamsted Ivanovic et al. (1983) examined soil from one Barney patch in Norfolk; they found Polymyxa betae and isolated a P. betae-transmitted virus which was morphologically identical to, but serologically distinct from, beet necrotic yellow vein virus.

The threat of BNYVV spreading to England from the Continent, and the presence of a similar but apparently distinct P. betae-transmitted virus in England, caused us and colleagues at the MAFF Harpenden Laboratory to start work on the problem. This work has the following main objectives:-

(a) to prevent or minimise the introduction of BNYVV to this country;

(b) to detect the first occurrence(s) of rhizomania, should this happen, so that prompt action can be taken to limit its spread;

(c) to develop improved procedures for testing beet plants and infested soil for BNYVV;

(d) to determine the incidence of P. betae and to understand its biology under English soil, rotation and climatic conditions;

(e) to determine the nature of the P. betae-transmitted virus that already occurs in England and to examine its epidemiology in the field;

(f) should rhizomania occur, to develop appropriate control measures.

PREVENTION OF IMPORT OF RHIZOMANIA

Regulations governing the import of plant material into England are administered by the Plant Health Division of the Ministry of Agriculture, Fisheries and Food (MAFF). A new Order (Anon 1984) approved by Parliament, took effect from 19 July 1984; it prohibits imports of sugar-beet plants and unprocessed sugar-beet seed except under licences issued by the Ministry of Agriculture. Licences to import sugar-beet plants (stecklings) will be issued only for plants coming from farms free of rhizomania; these farms will be subject to pre-export inspections. Licences to import unprocessed sugar-beet seed will include conditions to ensure that husks and debris of the seed are disposed of safely.

Processors of imported root vegetable crops are being advised about the safe disposal of waste washing water and soil.

DISEASE DETECTION AND LIMITATION OF SPREAD

Polymyxa betae survey

A survey was carried out in autumn 1983 to determine the incidence of P. betae. (Cooke et al. 1984) Soil samples were collected by British Sugar fieldmen from 68 randomly-selected sugar-beet fields throughout the beet-growing area, and from one field at Broom's Barn Experimental Station, and beet seedlings were grown in them. P. betae was readily found in 54 (78%) of these samples; clearly the vector of rhizomania occurs in most sugar-beet fields in England. To test for the presence of the virus Chenopodium quinoa plants were mechanically inoculated with sap from the roots of beet seedlings grown for 8 weeks in these soils but no typical BNYVV lesions (as defined by Kuszala & Putz 1977) were seen.

This survey is being repeated in 1984, with samples from 140 sugar-beet fields, taken both in late May and again in autumn. The samples will be used to determine the variation in P. betae inoculum between fields and sampling dates, and the autumn samples will again be tested for BNYVV.

Measures to detect rhizomania in field, clamp, or sugar factory tarehouse.

a) Rhizomania has been described in the Sugar Beet Review (Dunning 1983), a journal circulated by British Sugar to all 12 000 beet growers, also in Harpenden Laboratory Disease Notices (Jones & Dunning 1983, Jones 1983) and in a MAFF Leaflet (Dunning 1984). Growers have been asked to report any suspected outbreak of the disease to British Sugar or to their MAFF extension service adviser.

b) In parallel with the *P. betae* survey on 140 fields in 1984, a sample of roots was taken at the end of August from each of these fields and tested at the MAFF Harpenden Laboratory for BNYVV. The roots were taken from the part of the field most likely to have the disease (i.e. low lying areas, heavy soil, irrigated, site of beet clamp, etc.).

c) British Sugar factory fieldmen, in the course of their field inspections, will search for rhizomania during the summer and autumn, and in autumn and winter will also search clamps for roots showing symptoms of rhizomania.

d) In the autumn and early winter of 1984, 300 randomly-selected beet clamps will be inspected by the MAFF Plant Health and Seeds Inspectorate for bearded and constricted roots; at each clamp the 'tails' of 100 roots taken at random will be cut transversely and examined for vascular browning, a symptom associated with BNYVV infection. There were no positive records of vascular browning during a similar survey made in late 1983.

e) All 13 sugar factory tarehouses in England will be provided with photographs of infected roots and, during the processing season from October to January, tarehouse workers asked to report any suspect roots to the Factory Agricultural Manager. (Each year the tarehouses examine approximately 500 000 samples, each of 15 - 20 roots, i.e. one sample per delivered load of beet, and 2 - 3 loads per hectare of crop). In a preliminary tarehouse survey made in December 1983 and January 1984 some suspect roots were found, but none proved to be infected.

f) Sugar factory tarehouses will also note any root samples that give low sugar percentages and low amino-N content (both a feature of rhizomania), and the field or clamps from which they came will be inspected.

g) Any roots with rhizomania-like symptoms will be tested for the presence of BNYVV at the MAFF Harpenden Laboratory. In 1983, 26 samples (from field, clamp or factory tarehouse) were tested at Harpenden by ISEM (immunosorbent electron microscopy), using antiserum from Braunschweig, Germany; BNYVV was not detected.

Limitation of Spread

If an outbreak of rhizomania is confirmed by MAFF Harpenden Laboratory, then the infected site will come under the control of MAFF Statutory Orders. The objective will be to prevent, or limit, the spread of soil and plant material. The restrictions on the infected site will include:-

(a) limitation on access by persons and machines.
(b) marking the affected area, and fencing it if small.
(c) cleaning soil residues from farm machinery which has entered the area.
(d) Discussions with the grower and British Sugar about appropriate

conditions and methods for disposal of the crop. If a beet clamp is found to be affected then similar restrictions will apply to it as well as to the field from which the beet came.

STUDIES ON THE BIOLOGY OF THE VECTOR AND THE VIRUS

P. betae occurs in the fields at Broom's Barn Experimental Station, and soil samples have been taken on irrigated and non-irrigated plots during 1984 to determine whether population levels change during the season; a reliable method of quantifying the level of P. betae in the soil is needed, and will be sought. MAFF Harpenden Laboratory has instigated research to devise rapid and reliable routine methods for detecting BNYVV in both plants and soil, and the production of both polyclonal and monoclonal antibodies to BNYVV and to the Norfolk virus found by Ivanovic et al. (1983). Three isolates of BNYVV, from France, Germany and Yugoslavia, have been imported under licence for this work. Infested soil will also be imported, under the same quarantine regulations, for the study of virus detection in soil.

DISCUSSION

It is possible that beet necrotic yellow vein virus already exists in England, but it is unlikely that rhizomania is prevalent. Surveys made so far have failed to find symptoms typical of the disease as known in other parts of Europe. Moreover, there are no records of unexplainably low sugar contents in beet from any field, as was the experience in the Netherlands before the disease was recognised there. Furthermore, in comparison with some areas on the Continent where rhizomania is a problem, sugar-beet rotation in England tends to be wide[1], beet are grown mainly on the lighter soils, and irrigation is not common (no more than 15% of total crop area).

If the disease is found it is likely to be at a very early stage of spread, and the measures being taken should limit greatly the speed of any further spread; the relatively low soil temperatures in England will be an asset in this limitation.

Nevertheless, there is no cause for complacency; intensive survey work and improved methods of detection are being actively pursued, and research work has begun on the vector and virus under English conditions. Detailed results from these investigations will be reported as they become available.

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[1] British Sugar Statistics record that only 1% of the 1984 crop followed a beet crop in 1983, and that 2% followed a one-year break, 29% two years, 34% three years, 14% four years, and 20% followed a break of five years or more.

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NEW SUGAR BEET SEED TREATMENTS: POTENTIAL FOR BETTER SEEDLING-PEST CONTROL

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ABSTRACT

The availability of several newer insecticides and changes in the seed pelleting material used in the U.K. have stimulated a re-examination of insecticide treatment of sugar beet seed. Tests indicate that most of these treatments, including relatively high doses of carbofuran, carbosulfan and CGA 73102, had little or no detrimental effect on seed viability and were at least as good as the current commercial methiocarb treatment in the field.

INTRODUCTION

Most sugar beet crops are now "sown-to-stand" approximately 17 cm apart in rows 50 cm apart in an endeavour to achieve a final plant population of 70 000 plants/ha. Establishment differs greatly due to many factors, but averages only 65% (Durrant 1981), and is often irregular (Jaggard 1979) leading to loss of yield. Pest damage is one of the prime causes of poor establishment, and is exacerbated by wide seed spacing. The main soil-inhabiting pests are springtails (*Onychiurus* spp.), symphylids (*Scutigerella immaculata*), millepedes (mainly Blaniulidae), pygmy beetle (*Atomaria linearis*), and wireworm (*Agriotes* spp.), whilst the main seedling foliage pests are pygmy beetle, flea beetle (*Chaetocnaema concinna*) and birds.

As a partial insurance against pest damage methiocarb at 0.2% a.i. by weight of seed is incorporated during seed pelleting and is particularly effective against pygmy beetle damage but is less effective against other pests (Dunning & Winder 1971). The reasons for the use of methiocarb have been reviewed (Dunning & Byford 1978).

On soils where sugar-beet crops are prone to soil pest damage, which are mainly the heavier and/or structured soils (clay, silt, chalk, limestone), growers are recommended to supplement the seed treatment by applying granular insecticide in the seed furrow. The most frequently used products are systemic and give some control of foliage pests (Winder 1971; Green 1980), but they are expensive (average £30/ha) and there are some fears about their environmental hazards.

The advent of several new pesticides and a change in the seed pelleting material from one with a high clay content ('Filcoat' - BB or British Blend pellet) to a lighter material containing a proportion of wood flour (EB3 or European Blend pellet, used commercially in Europe) which may affect the stability and activity of insecticides, has stimulated a re-examination of insecticide seed treatments as a control measure.

This paper describes laboratory and field trials made in 1982-3 on insecticide seed treatments incorporated in the two types of seed pellet.

MATERIALS AND METHODS

Treatments

In 1982 the pelleted seed came from three sources namely Messrs. Germains UK Ltd., KWS Kleinwanzlebener Saatzucht AG and Ciba-Geigy Agrochemicals Ltd. Each seed batch had its own control treatment. All seed was treated with thiram (TMTD) to control seed-borne Phoma betae. In 1983 all seed was of the same variety and batch (Monoire) steeped in ethyl mercury phosphate (EMP) solution to control Phoma. The insecticide treatments were incorporated during pelleting by Germains UK Ltd. by either the BB or EB3 process. Insecticide treatments rates are expressed as g a.i. per unit of 100 000 seeds. (Tables 3 and 4)

Laboratory germinations

Standard tests were conducted by British Sugar soon after pelleting using methods specified by the Official Seed Testing Station (Anon 1976) to ascertain whether the insecticide treatments had any phytotoxic effects. Percentage germination was assessed after seven and fourteen days and the numbers of abnormal seedlings noted; differences between the two assessments were insignificant and only the fourteen day results are outlined.

Field Trials

In 1982 there were two field trials, one at Broom's Barn, the other at Headley Hall near York. The latter site was chosen because of its previous history of pest attack and Onychiurus spp., Blaniulus guttulatus, Archeboreoiulus pallidus and Atomaria spp. were found, whereas the incidence of pest damage at Broom's Barn was low as expected. The two trials in 1983 were sited at Broom's Barn and Ramsey Mere near Peterborough, the latter a site of known high pest incidence with Onychiurus spp., B. guttulatus and Brachydesmus superus present. All trials were sown at 16.5 - 17.8 cm seed spacing and were of replicated block design; details are given in Table 1.

TABLE 1

Details of the four field trials

	1982		1983	
	Broom's Barn	Headley Hall	Broom's Barn	Ramsey Mere
Sowing date	1 April	15 April	28 April	15 April
No. of treatments	8	8	33	34
No. of replicates	4	5	5	6
No. of rows/plot	5	2	1	1
Plot length (m)	15	15	24	17
Soil type*	CL	SL - SCL	SCL	Org ZyCL
pH	7.5	7.4 - 8.0	7.5	7.5

* CL, clay loam; SL, sandy loam; SCL, sandy clay loam; Org ZyCL, organic silty clay loam.

Field Observations

The number of seedlings was recorded at least twice after emergence, and expressed as a % of the number of seeds sown. Each plot was scored for phytotoxicity if symptoms were apparent on a scale 0 = no phytotoxicity to 5 = serious phytotoxicity. Each plot was scored for seedling vigour, if differences were apparent, using a scale 0 = very poor to 9 = very good.

RESULTS

Laboratory germinations

The laboratory germination of the 1982 seed was satisfactory (Table 3). Satisfactory germinations of 90 - 95%, plus 1 - 4% abnormals, were also obtained with the 1983 seed except with carbosulfan at 90 and 120 g in BB pellets where germinations were 89% + 8% abnormals and 81% + 14% abnormals respectively. Also in 1983, samples of BB pellets containing UC 51762 and UC 27867, each at 50 and 100 g, only became available after trial designs had been finalised, and were tested in subsidiary trials adjacent to each main trial. Laboratory germination of seed treated with UC 51762 was unsatisfactory at both rates, with over 92% abnormals, but was satisfactory with seed treated with UC 27867 or without insecticide.

Bioassay of contact activity using Drosophila

To confirm insecticidal activity seed pelleted for 1983 was bioassayed using *Drosophila melanogaster*. Using 4 replicates of each treatment 25 flies were added to 3 cm diameter petri-dishes each containing 25 moistened pellets. Percentage mortality was assessed at intervals up to 24 hours: all rates of bendiocarb and JF 9147 with BB pellets and all rates of carbofuran and carbosulfan in either pellet gave 100% mortality within one hour. Mortality at 1, 2 and 5 hours is given in Table 2. The low activity of permethrin (2g) persisted for 24 hours, and may account in part for its poor performance at Ramsey Mere (Table 4).

TABLE 2

Percentage mortality of *Drosophila* at intervals after introduction onto moist pellets

Treatment (g a.i. per unit)	BB pellets 1 h	BB pellets 2 h	BB pellets 5 h	EB3 pellets 1 h	EB3 pellets 2 h	EB3 pellets 5 h
no insecticide	7	7	7	3	4	6
methiocarb (2)	47	100	*	48	100	*
carbofuran (15,30,60)	100	*	*	100	*	*
carbosulfan(30,60,90,120)	100	*	*	100	*	*
bendiocarb (2)	100	*	*	80	100	*
bendiocarb (4)	100	*	*	94	100	*
bendiocarb (8)	100	*	*	100	*	*
permethrin (2)	1	4	10 - 11% mortality at 24 h			
permethrin (4)	1	2	66 - 100% mortality at 7 h			
JF 9147 (2,8,40)	100	*	*			

* 100% mortality at earlier assessment

1982 Field Trials

At Headley Hall methiocarb and both carbofuran treatments improved seedling establishment but CGA 73102 had no effect (Table 3). Phytotoxicity symptoms were visible on some plants of the carbofuran treatments on 11 May but were not apparent at later counts, and no significant differences in seedling vigour were observed. At Broom's Barn methiocarb and CGA 73102 (140 g) significantly increased seedling numbers but, in contrast to Headley Hall, carbofuran (30 g) significantly decreased seedling numbers; no phytotoxicity or differences in seedling vigour were observed in this trial.

TABLE 3

Treatments, laboratory germinations and seedling establishment 1982

Treatment (g a.i. per unit)*	% germination at 14 days Spring 1982 %	% abnormals	% seedling establishment Headley Hall 15 June	Broom's Barn 25 May
Germains EB3 pellets				
no insecticide	94	1	68	75
methiocarb (4)	94	1	77+	79+
carbofuran (15)	91	1	76+	72
KWS pellets (Kawemono)				
no insecticide	94	1	68	75
carbofuran (30)	93	3	73	69-
Ciba-Geigy pellets				
no insecticide	97	0	77	80
CGA 73102 (90)	97	0	77	79
CGA 73102 (140)	94	0	76	84+
S.E.D.	-	-	3.6	1.9

* Wt of unit of unpelleted seed not known, but assumed approximately 1 kg
\+ significantly better than the relevant no-insecticide pellets (P = 0.05)
\- significantly poorer than the relevant no-insecticide pellets (P = 0.05)

1983 Field Trials

At Broom's Barn none of the treatments improved on the standard methiocarb (2 g) BB pellet although on average, the EB3 pellets gave 5% greater establishment than the equivalent BB pellets (Table 4). No phytotoxicity symptoms or differences in vigour were recorded at this trial. Establishment was extremely low with UC 27867. At Ramsey Mere with BB pellets carbofuran (15 g) and carbosulfan (60 and 90 g) were significantly better than the standard methiocarb treatments but permethrin gave significantly poorer plant establishment at both rates tested (Table 4). With EB3 pellets the overall average establishment was 3% greater than with the equivalent BB pellets. All treatments except bendiocarb (2 g) were significantly better than the EB3 no-insecticide treatment, but not the methiocarb (2 g). Phytotoxicity symptoms were not observed in this trial, but seedling vigour with permethrin (4 g) was significantly poorer than most other treatments. Both carbofuran (15 g) and carbosulfan (15 g) in EB3 pellets significantly increased vigour when compared with the EB3 no-insecticide treatment. As at Broom's Barn, establishment was extremely low with UC 27867.

TABLE 4

Seedling establishment and vigour scores, 1983 field trials

Treatment (g a.i./unit)	% Seedling establishment Broom's Barn 8 June BB	EB3	Ramsey Mere 9 June BB	EB3	Vigour Score Ramsey Mere 9 June BB	EB3
no insecticide	74		68	62	5.2	5.0
methiocarb (2)	75	76	66	74^{+}	5.5	5.3
carbofuran (15)	70	75	75^{+}	76^{+}	5.7	6.3
carbofuran (30)	75	80	73	73	5.7	5.3
carbofuran (60)	70	73	70	73	5.5	5.3
carbosulfan (15)	73	74	70	76^{+}	5.8	6.3
carbosulfan (30)	71	78	71	72	6.0	5.5
carbosulfan (60)	75	77	75^{+}	77^{+}	6.0	5.8
carbosulfan (90)	73	75	74^{+}	72	5.8	5.0
carbosulfan (120)	69	73	69	75^{+}	5.5	6.0
bendiocarb (2)	68^{-}	71	71	68	5.7	4.8
bendiocarb (4)	74	77	72	75^{+}	5.2	5.3
bendiocarb (8)	71	77	73	75^{+}	5.5	5.7
permethrin (2)	75		55^{-}		4.7	
permethrin (4)	74		51^{-}		3.8^{-}	
JF 9147 (2)	75		66		4.8	
JF 9147 (8)	74		63		4.8	
JF 9147 (40)	74		69		5.0	
S.E.D.	2.91		3.75		0.52	

+ or - significantly greater or poorer than methiocarb (2g) in BB pelleted seed

Subsidiary Trials	Broom's Barn	Ramsey Mere
no insecticide	67	53
UC 27867 (50)	5^{-}	27^{-}
UC 27867 (100)	4^{-}	3^{-}
UC 51762 (50)	68	69
UC 51762 (100)	73	71
S.E.D.	3.5	4.3

- significantly worse than no-insecticide

DISCUSSION AND CONCLUSIONS

These trials indicate that some of the insecticide treatments tested are at least as good as the standard methiocarb (2g) used at present and that it may be possible to use them at much higher rates without undue phytotoxicity or adverse effect on vigour. Where pest attack is expected, or as further insurance against possible pest attack, the insecticide in the pellet may be augmented by the application of insecticide granules in the seed-furrow applied at 0.3 - 1.03 kg a.i./ha the equivalent of 250-860 g a.i. per unit of 100 000 seeds (e.g. 500 g a.i. per unit with carbofuran). It is feasible that a large proportion of this insecticide could be incorporated in the pellet if a suitable insecticide of low phytotoxicity is found, in the same way that quantities of seed for use in areas where manganese deficiency is prevalent are pelleted with 50% of the pelleting clay (BB pellets) replaced by manganous oxide. However, it is unlikely that the full amount would be needed because at 17 cm seed spacing a large proportion of the active ingredient of a granule applied to the seed-furrow is outside the root zone. This is because the lateral roots of the seedlings only explore within a radius of about 4 cm by the beginning of June (K.F. Brown personal communication) at which time the need for protection starts to diminish. The trials also indicate that these insecticides can probably be incorporated into the new EB3 pellet without significant decline in activity. Further field trials, especially at sites where pests are prevalent, are required to aid the choice of insecticide and dose rate; nine such trials, organised by Broom's Barn and British Sugar in 1984, are already in progress, and a further series is planned for 1985.

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PRESENT AND POTENTIAL DISEASE INTERACTIONS BETWEEN OILSEED RAPE AND VEGETABLE BRASSICAS

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ABSTRACT

The incidence of diseases in winter oilseed rape and Brussels sprouts in England and Wales is compared. There was some evidence for disease interactions between these crops in 1983 as both downy mildew and light leaf spot were more common in Brussels sprout crops adjacent to oilseed rape than in crops more distant from oilseed rape. *Alternaria brassicae*, however, was less common in 'adjacent' crops possibly because most of these Brussels sprout crops had received sprays for Alternaria control. In future, interactions between oilseed rape and other crops are likely to include persistent soil borne diseases such as Sclerotinia and clubroot and airborne diseases such as Alternaria in seasons favourable for epidemic development.

INTRODUCTION

The continued expansion and intensification of the oilseed rape crop in the UK has brought pest (Gould 1975; John & Holliday 1984) and disease (Evans & Gladders 1981) problems for the crop itself. The area harvested in 1984 is estimated to be more than 260,000 ha (Fig. 1). In Northamptonshire, the most intensively cropped county, oilseed rape is now grown on about 10% of the arable area.

Many of the pests and diseases found in oilseed rape also affect other crops, particularly brassicas, thus providing considerable potential for interactions between oilseed rape and other crops. This potential is more likely to be realised as oilseed rape extends into areas where fodder and vegetable brassicas are grown. Recent problems with Alternaria in horticultural brassicas has enlivened interest in disease interactions between oilseed rape and vegetable crops. This paper reviews the disease situation in oilseed rape (Evans *et al*. 1983, Evans *et al*. 1984) and Brussels sprouts and the evidence for disease interactions.

METHODS

Disease assessments were made on samples of 25 plants collected from winter oilseed rape crops selected by ADAS advisers, using methods described by Evans & Gladders (1981). The results in Table 1 are the mean values from 192 (spring) or 204 (July) crops in 1982 and 137 crops (spring) or 148 crops (pod ripening stage) in 1983. Results from eastern England only are given in Fig 3. All the main areas of production were represented (Evans *et al*. 1983, Evans *et al*. 1984). Brussels sprouts crops were selected by ADAS advisers to represent the main areas of production using sites immediately adjacent to oilseed rape crops harvested in 1983 whenever possible (Gladders *et al*. 1984).

Growth stages have been identified using the key of Harper & Berkenkamp (1975).

RESULTS

In the spring, foliar diseases on oilseed rape were present at low levels, rarely affecting more than 5% leaf area. Downy mildew (Peronospora parasitica) was the commonest disease (Table 1) but light leaf spot (Pyrenopeziza brassicae) was the main foliar pathogen in parts of south-east England in 1982 and 1983 and in the west midlands in 1983. Alternaria species (mainly A. brassicae) were present at low levels on affected plants in the spring but spread to the pods late in the season in 1982. In 1983, dry weather immediately after flowering checked the development of Alternaria, and in addition, the extensive use of dicarboximide sprays (c. 80% of crops surveyed were sprayed in 1983) is also likely to have reduced disease incidence. Canker (Leptosphaeria maculans) was common in central and eastern England but not in other areas, particularly in 1983. Sclerotinia sclerotiorum was particularly common in 1982 but only affected more than 20% plants in each of five crops. Powdery mildew (Erysiphe cruciferarum) was present at very low levels mainly in crops sown before 20 August.

In 1984 there were several significant features in disease levels in oilseed rape. Light leaf spot caused stunted patches in a few commercial crops of Jet Neuf for the first time but cv Bienvenu was less seriously affected. Cauliflower mosaic virus which caused stunting of plants and black spotting of stems and pods was much more common than usual. Some foci of infection were seen, particularly in Essex, but most crops had less than 1% plants affected. Several cases of S. sclerotiorum killing plants during the winter were reported, an unusual occurrence described by Jellis et al. (1984).

TABLE 1

Mean % plants with disease in winter oilseed rape crops, England 1982 and 1983

Disease	Assessment Date			
	Spring (GS 3.1 - 3.2)		July (GS 5.3 - 5.4)	
	1982	1983	1982	1983
Alternaria	13 (L)	14 (L)	55 (P)	24 (P)
Botrytis	-	-	6 (S)	2 (S)
Downy mildew	41 (L)	63 (L)	2 (P)	6 (P)
Light leaf spot	32 (L)	45 (L)	24 (S)	72 (S)
Light leaf spot	-	-	5 (P)	58 (P)
Phoma canker	6 (L)	14 (L)	28 (S)	12 (S)
Powdery mildew	<0.1 (L)	0	1 (S)	0 (S)
Sclerotinia	0	0	2 (S)	0 (S)

L - leaf, S - main stem, P - pod

Diseases in Brussels sprouts (Table 2) were also present at very low levels (<1% leaf area) in most crops. Alternaria brassicae was the commonest pathogen but Alternaria brassicicola occasionally caused severe spotting of buttons. Overall 81% crops showed Alternaria leaf spot and 49% crops had button symptoms. Lincolnshire was the worst affected area with

11.4% buttons affected. Downy mildew and powdery mildew were both common in eastern counties from Kent to Yorkshire. Ringspot (*Mycosphaerella brassicicola*) was largely confined to southern and western counties where growers often used MBC fungicide sprays to control the disease. In 1983, white blister (*Albugo candida*) was more common than usual and caused most damage in traditional vegetable brassica areas (eg Lancashire and West Midlands) where brassica rotations were shorter than one year in five. Light leaf spot was present on buttons in 12% of crops and was most prevalent in north Yorkshire and north Humberside where 23 crops showed a mean of 11% buttons affected.

TABLE 2

Mean incidence of diseases (139 crops) of Brussels sprouts in England and Wales, in 1983

Disease	% plants with leaf disease	Mean % Buttons affected
Alternaria	45	2.7
Botrytis	10	0.5
Downy mildew	40	0.4
Light leaf spot	3	1.8
Phoma	2	0
Powdery mildew	28	1.6
Ringspot	14	1.1
White blister	21	2.2
Viruses	0.04	-

The incidence of diseases common to both oilseed rape (Table 1) and Brussels sprout (Table 2) has been averaged for crops adjacent to and more distant from oilseed rape in Table 3. The incidence of Alternaria in crops adjacent to oilseed rape may have been reduced by the use of chlorothalonil or iprodione sprays which were more widely used on 'adjacent' than 'non adjacent' crops. There was some indication that downy mildew and light leaf spot may have spread from oilseed rape to Brussels sprouts.

TABLE 3

Incidence of diseases in Brussels sprouts adjacent to and more distant from winter oilseed rape crops in 1983

Disease	% plants with leaf disease		% buttons affected	
	Adj	Non-adj	Adj	Non-adj
Alternaria	37.5	46.9	1.5	3.0
Downy mildew	55.2	35.7	1.1	0.2
Light leaf spot	5.2	1.7	2.6	1.6

Adj - Adjacent to oilseed rape (29 crops surveyed)
Non-adj - Non-adjacent crops (110 crops surveyed)

Fig 1. Area of oilseed rape in England and Wales 1973-84 (MAFF June Census)

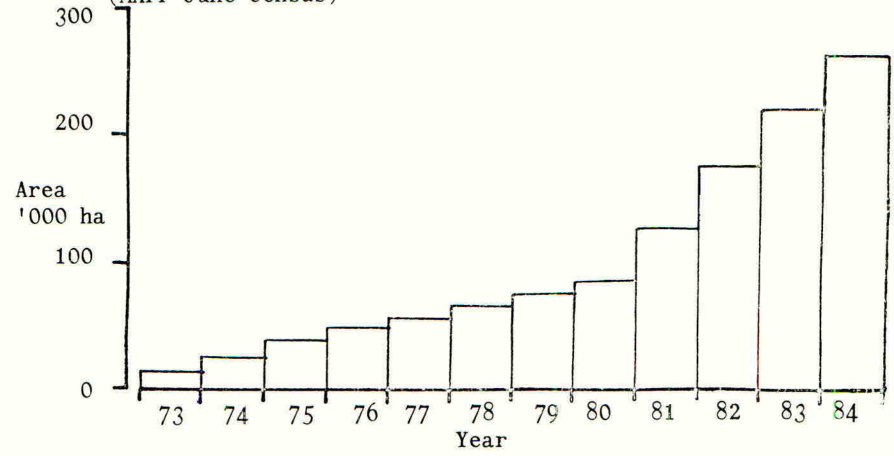
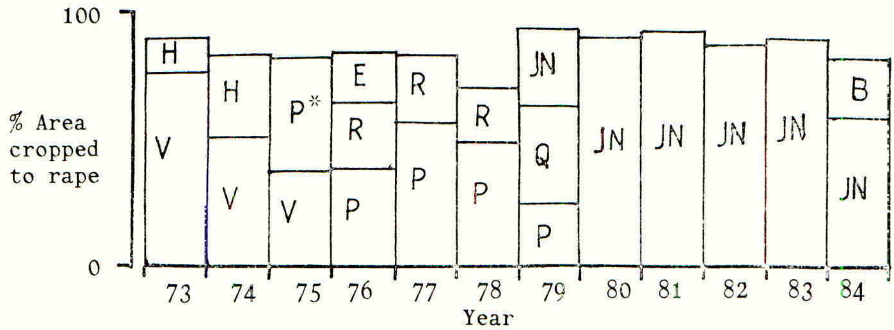


Fig 2. Oilseed rape varieties in Cambridgeshire 1973-84



Key V-Victor H-Hector P-Primor P*-Low Erucic Type
Q-Quinta E-Expander R-Rapora JN-Jet Neuf
B-Bienvenu (Source: ADAS, Anstey Hall)

Fig 3. Mean Disease Incidence in oilseed rape in Eastern England July 1977-84

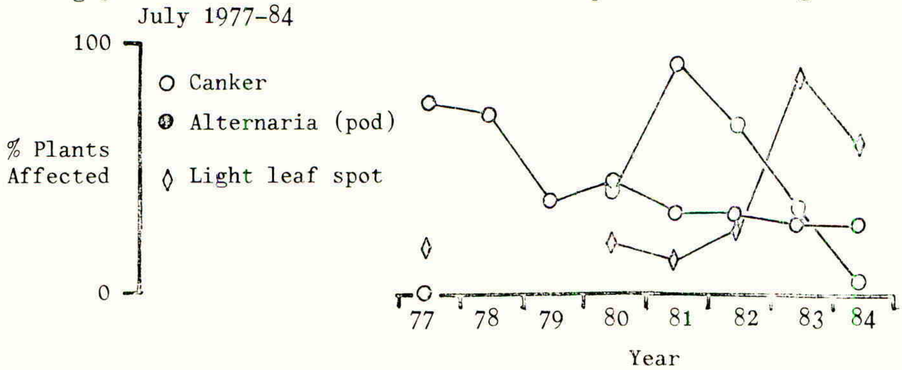


TABLE 4

Effect of number of fungicide sprays on the incidence of Alternaria spp. in Brussels sprouts 1983

Number of sprays for Alternaria	Number of crops	% plants with leaf disease	% buttons affected
0	58	33.6	1.11
1	26	44.0	2.01
2 or more	27	7.7	0.31

Alternaria incidence appears to have been reduced by the use of 2 or more spray treatments (Table 4). 'Adjacent' crops received a total of 41 sprays between them with 4 crops remaining unsprayed and 11 crops receiving 2 or more sprays.

DISCUSSION

During the expansion of oilseed rape (Fig. 1) there have been rapid changes in variety (Fig. 2) from high erucic acid types (cv Victor & Hector) to low erucic acid types with first, poor canker resistance (cv Primor) then good canker resistance (cv Jet Neuf). At the same time there have been changes in herbicide usage (Gladders & Musa 1982) and a trend towards earlier sowing (Evans & Gladders 1981) which could also have affected disease incidence. The introduction of resistant varieties appeared to be the major factor reducing canker levels (Fig. 3) but further diversification of canker resistance would be an advantage given that virulent strains are present (Humpherson-Jones & Maude 1983) and occasionally cause premature ripening on cv Jet Neuf in eastern England.

The use of seed treatments and resistant varieties should delay the establishment of this disease in new areas of production.

In view of the widespread distribution of L. maculans and the prolonged release of ascospores (Gladders & Musa 1979) it is surprising that so little Phoma leaf spot and canker has occurred in horticultural brassicas. Very few symptoms have been seen on Brussels sprouts possibly because ascospores are unable to infect mature leaves. Leaf symptoms of both L. maculans and A. brassicae are common in Chinese cabbage (Brassica pekinensis) which may be particularly vulnerable to these pathogens because crops are often irrigated. However, the most significant route for the introduction of virulent canker strains into other brassicas is likely to be via their seed crop as seed-borne infection.

The initial rise of Alternaria in Hampshire (Evans & Gladders 1981) has been attributed to an interaction with stubble turnip crops in that county. This may be difficult to prove retrospectively, particularly as Alternaria spp. are commonly seed-borne (Maude & Humpherson-Jones 1984) and also likely to be widely distributed on a range of brassica crops and weed hosts. There are likely to be some seasons which are particularly favourable for Alternaria but the use of fungicide sprays to protect pods should prevent a recurrence of the 1981 epidemic. A further refinement would be a forecasting system based on an 'Alternaria infection period'. This is currently under investigation (F.M. Humpherson-Jones pers. comm.).

The timing of sprays to control diseases in Brussels sprouts is currently under investigation by ADAS. In the longer term resistant varieties and/or fungicide treatment should reduce the risks of severe epidemics and hence of interactions of diseases such as powdery mildew, light leaf spot and Alternaria.

Although observations in 1983 did not show a direct effect of oilseed rape on Alternaria levels in Brussels sprouts (Table 3), an interaction may have occurred in previous years enabling the pathogen to become established in vegetable brassicas. In many cases debris of vegetable brassicas was closer to Brussels sprouts than was oilseed rape. If Alternaria levels are examined on a county basis (Gladders et al. 1984) there appears to be a link with oilseed rape cropping with the highest incidence of Alternaria in the eastern counties and the lowest incidence in the west of England. However, Alternaria caused problems more widely in December 1982 including parts of Wales where no oilseed rape was grown which suggested that seasonal factors were particularly important. Nevertheless Alternaria diseases remain strong candidates for inter crop interactions because of the peak of spore liberation at harvest (Humpherson-Jones & Maude 1982) and because of their lack of host specialisation (Humpherson-Jones & Hocart 1983).

The use of dicarboximide fungicides on seed crops, as seed treatments, on commercial oilseed rape and on vegetable crops probably exposes pathogens to repeated selection pressure. Some monitoring of the sensitivity of *Alternaria* spp. and *Botrytis cinerea* to the dicarboximides should be considered. The use of small modules to produce vegetable brassica seedlings could also favour the establishment of fungicide resistant pathogens in field crops if transplants are affected by resistant strains normally surviving in the glasshouse environment.

The vegetable brassica grower is likely to be faced with a dilemma as he tries to produce a high quality product with a (decreasing) level of pesticide acceptable to the consumer. Current trends are for greater specialisation by growers, often by increasing and intensifiying cropped areas. These factors increase disease risks and disease interactions are likely to present still greater problems particularly where the producion of some crops is highly localised, eg cauliflower production in Lincolnshire.

Two common diseases of vegetable brassicas are still uncommon in oilseed rape but may become more important. The recent confirmation of ringspot in oilseed rape (Evans et al. 1984) could indicate future problems as the rape crop extends into areas where ringspot is prevalent. White blister has not been recorded on oilseed rape in the UK though it has been reported in Spain (Romero-Munoz & Gonzalez-Torres 1983) and Canada (Platford & Bernier 1975). *Brassica napus* appears to be more resistant than *B. campestis* (Verma et al. 1975) and is less severely affected (R. Morrall pers. comm.).

Sclerotinia has caused few problems to date in oilseed rape in the UK but probably represents the next disease threat to the crop as fields return to rapeseed cropping. Certainly the disease is already widely distributed, particularly in southern England, and there is good evidence from France on the effects of crop rotation and the persistence of sclerotia (Leval 1979). Sites with Sclerotinia have often had a history of pea cropping and this appears to be the crop most likely to interact with oilseed rape to give Sclerotinia problems. Sclerotinia trifoliorum was particularly common on winter beans (Vicia faba) in 1984 but no cases were confirmed in oilseed rape although Saur & Locher (1983) reported that it could affect oilseed rape. Further work is needed to establish whether oilseed rape and field beans can be grown safely in the same rotation. Jellis et al. (1984) provide more detailed discussion of Sclerotinia outbreaks in the UK.

Clubroot (Plasmodiophora brassicae) like Sclerotinia is a persistent soil-borne disease which is likely to increase in importance. Recent outbreaks of the disease described by Clarkson & Brokenshire (1984) implicate other brassicas and further interactions in Scotland, western and northern England are likely as oilseed rape is grown on land with a history of brassica cropping.

Virus diseases appear to have caused little damage in winter oilseed rape to date although the significance of the luteo virus reported by Smith & Hinckes (1984) has not been established. The appearance of cauliflower mosaic virus in 1984 gives cause for concern for both vegetable brassica and oilseed rape growers as the overlap of their crops provides a 'green bridge' for perpetuation of the virus. More detailed monitoring of aphid movement between crops may be needed before rational control of virus vectors on rape can be considered.

In summary there is evidence of interactions between diseases of oilseed rape and other crops but effects on yield and quality have been small. Experiences in Europe have often provided an early warning of problems to come and suggest that Sclerotinia could become a more serious problem. However given sensible integration of factors such as choice of variety, crop rotation, stubble hygiene, seed treatment, sowing date, herbicides, insecticide and fungicide sprays, problems should not be insoluble.

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SEED-BORNE DISEASE INTERACTIONS BETWEEN OILSEED RAPE AND OTHER BRASSICAS

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ABSTRACT

Since 1978 outbreaks of canker (Leptosphaeria maculans) have occurred annually in a range of vegetable brassicas grown at Wellesbourne. Serious damage has been recorded on ware crops of broccoli and swede and on seed production crops, in which up to 100% of plants have been killed. Since 1980 dark leaf spot caused by Alternaria brassicae has also become a major disease of seed crops. Spore trapping studies indicated that A.brassicae spores released from infected rape crops during harvest were widely dispersed and were potential agents of infection for other crops. With the increased cultivation of oilseed rape in the traditional seed growing areas of south-east England the incidence of both fungi has also increased in commercial vegetable and forage brassica seed produced in these areas. The implications of transfer of these pathogens from oilseed rape to other commercial brassica seed crops is discussed.

INTRODUCTION

The National Vegetable Research Station is unusual in being sited in a predominantly arable area. In recent years there has been a marked increase in cultivation of oilseed rape on nearby farms and, as in other areas, this intensified cropping has been accompanied by an increase in disease incidence especially in the seed-borne fungal diseases, canker (Leptosphaeria maculans) and dark leaf spot (Alternaria brassicae and to a lesser extent A.brassicicola) (Evans & Gladders 1981, Evans et al. 1984). During this period both L.maculans and A.brassicae, which were previously uncommon in vegetable brassicas at Wellesbourne, have become recurrent problems in ware crops of swede and broccoli and in seed crops of cabbage, Brussels sprouts, broccoli and swede. Nearby infected oilseed rape crops were considered to be a major source of these pathogens. The wide range of brassicas grown at Wellesbourne in close proximity to commercial rape crops presented an opportunity to study the interactions between oilseed rape and other brassicas in respect of cross contamination by these fungi.

This report examines the evidence that oilseed rape is a source of these diseases for infection of vegetable and forage brassica seed crops at Wellesbourne and considers the wider implications of cross-infection of canker and dark leaf spot from this crop to other commercial brassica seed crops.

LEPTOSPHAERIA MACULANS

In the past canker was a serious problem in the UK especially on broccoli, swede and turnip (Moore 1948). Infected seed was the main source of infection but the introduction of a hot water seed treatment in the 1950s and later the use of benzimidazole seed treatments resulted in a marked decrease in the disease (Moore 1959, Maude et al. 1973). Now it only occasionally causes damage in ware brassicas. Variability for pathogenicity occurs in L.maculans and the different pathotypes can be placed in two broad groups, virulent types that cause severe canker and plant death and non-virulent types that produce only superficial lesions and do not affect plant vigour (e.g. Cunningham 1927, Pound 1947). Elsewhere the frequency of each type may vary considerably; in oilseed rape in Australia virulent strains predominate and have been responsible for widespread crop damage (Bokor et al. 1975), whereas in Canada virulent types only occur occasionally and crop damage is minimal (McGee & Petrie 1978). A limited survey of isolates of L.maculans from brassica seed crops in south-east England indicated that virulent strains occurred commonly on oilseed rape in that area but were infrequent on other brassica seed crops. Virulent strains were not host-specific and under field conditions such strains from oilseed rape caused severe canker and high levels of seed infection in a range of other brassicas (Humpherson-Jones 1983). Only relatively low incidences of seed infection by virulent strains of L.maculans may cause damage in vegetable crops. In Germany the threshold infection level for cabbage seed is considered to be as low as 0.2%. If infection is above that level serious crop losses may occur (Cruger 1979). There is therefore a danger that cross-infection from oilseed rape to other brassica seed crops may increase the incidence of virulent pathotypes of L.maculans in these crops and so threaten the health of the seed.

Oilseed rape as a source of L.maculans

Although infected seed is the primary source of L.maculans in oilseed rape crops, once the disease is established in an area, as it now is in the main oilseed rape growing areas in England (Evans et al. 1984), wind-disseminated ascospores produced on infected stubble become the major agents of dispersal to other crops (Gladders & Musa 1980). Ascospores are produced on stubble in the autumn and continue to be produced until spring of the following year. The types of crops that are growing during this period and are therefore at risk include broccoli, Brussels sprouts, winter cauliflower, spring greens, swede, oilseed rape and other brassica seed crops.

Canker in brassica seed crops at Wellesbourne

L.maculans first became a problem in brassica seed crops at Wellesbourne in 1978. Since then disease assessments have been made annually on a total of between four and eight seed production crops of Brussels sprouts, broccoli, cabbage, kale and swede. In each crop the number of L.maculans leaf infections/plant was recorded on 50 plants in mid-December and the incidence of severe stem cankers was recorded on a similar number of plants in the following June. Some crops were matured outdoors and from others, selected plants were transplanted between December and March into polythene tunnels. High levels of leaf infection and stem canker occurred each year in all crops (Table 1).

In each year leaf infection in December was uniform within crops suggesting that the disease source was airborne not seed-borne. Stem cankers developed earliest (end-February to mid-March) and were most severe on plants matured under polythene. In 1982 in one crop of swede all plants were killed before maturity. In seed crops matured outdoors severe cankers did not develop until late April but up to 75% of plants were killed or ripened prematurely. Pathogenicity tests on isolates from the seeds of these crops showed that up to 2.5% of seeds were infected with virulent strains of the fungus. No L.maculans was detected in

2,4-dichlorophenoxyacetic acid (2,4-D) blotter tests (Anon. 1966) on seed from which six severely infected crops were grown indicating that infected seed was an unlikely disease source. The only source of ascospores on the Research Station during this period were single small (50x20 m) plots of oilseed rape stubble on isolation sites. In each year however high incidences of disease occurred on the stubble of nearby oilseed rape crops and it is considered that these crops were the major source of infection.

Table 1

Leptosphaeria maculans leaf infection in December and stem canker in June in vegetable and forage brassica seed crops at Wellesbourne

Harvest year	Mean no. of leaf spots/plant	% of plants with severe cankers[1]	
		Plants matured under polythene	Plants matured outdoors
1979	2.1	10.0	6.5
1980	6.5	26.5	8.0
1981	0.7	18.0	13.0
1982	2.2	31.5	26.5
1983	1.3	6.0	8.5

[1]More than 50% of stem section necrotic.

The occurence of virulent strains of L.maculans in Warwickshire and Essex

Although it was known that virulent strains of L.maculans occurred on oilseed rape in the seed growing areas of Essex (Humpherson-Jones, 1983) the occurrence of such pathotypes in the Wellesbourne area was not known. In 1982 and 1983 a survey was made of isolates of L.maculans from both oilseed rape crops and vegetable and forage brassica seed crops in Essex and from oilseed rape crops in Warwickshire. The work was part of an extensive survey of pathotypes of L.maculans made in collaboration with Agricultural Development and Advisory Service regional plant pathologists. Isolates of the fungus were obtained from diseased leaves or stems and their pathogenicity was determined by wound inoculating the hypocotyls of canker susceptible cabbage seedlings (cv Avon Coronet) with a pycnidiospore suspension ($5x10^6$ - $1x10^8$ spores/ml). Virulent isolates usually killed test plants within 28 days whereas non-virulent types caused only superficial lesions.

There was a contrast between Warwickshire and Essex in the frequency of virulent pathotypes on oilseed rape; more than 96% of isolates from Warwickshire were virulent compared with only 16% from Essex (Table 2). In other brassica seed crops in Essex on average 21% of isolates were virulent, however, almost all of these were derived from a single swede seed crop from which 36 out of 38 isolates were virulent. This crop was sown in 1982 adjacent to a diseased oilseed rape crop. Out of 147 isolates from 12 other seed crops of cabbage, kale, broccoli and turnip only two were virulent.

TABLE 2

Occurrence of virulent strains of Leptosphaeria maculans in brassica seed crops in Warwickshire and Essex

County	Crop type	No. of crops sampled	No. of isolates	
			tested	virulent
Warwickshire	Oilseed rape	37	238	229
Essex	Oilseed rape	22	201	32
Essex	Vegetable and forage brassica seed crops	12	185	38

ALTERNARIA BRASSICAE

Dark leaf spot first caused serious damage in vegetable brassica seed crops in the UK in the 1950s (Schimmer 1953). Since then the disease has become endemic in the major seed production areas and is one of the major constraints to B.oleracea seed production in this country. A serious effect of crop infection, apart from reduction in seed yield, is the ready transmission of disease to seed and the consequent marked reduction in germination. In contrast with dark leaf spot of oilseed rape in which the main Alternaria species involved is A.brassicae, the species present in vegetable brassica seed crops has been almost exclusively Alternaria brassicicola and only rarely has A.brassicae been implicated (Maude & Humpherson-Jones 1980).

Dark leaf spot infection of cabbage seed crops at Wellesbourne

Since 1967 cabbage seed crops have been grown at Wellesbourne for studies on fungicidal control of dark leaf spot. The severity of the disease was measured by testing seeds on agar directly after harvest for internal infection by Alternaria (Maude & Humpherson-Jones, 1980). Until recently the only fungus involved in dark leaf spot attack was A.brassicicola. However, in 1980 A.brassicae caused severe pod and seed infection in these crops and in each subsequent year attack by this fungus has resulted in varying degrees of seed infection (Table 3). 1979 was the first year that A.brassicae was detected at significant levels in local oilseed rape crops.

Oilseed rape as a source of A.brassicae

Volumetric spore traps are used in leek and onion crops at Wellesbourne in disease epidemiology studies. The crops are grown on isolation sites distant from experimental brassica crops. Tapes from these traps were examined for the period 1981-1983 for the presence of A.brassicae spores. In each year substantial numbers of A.brassicae spores were trapped during a short period in July and August but not at other times (Table 4). The times when spores were trapped coincided with the period when rape crops were being harvested in the Wellesbourne area.

TABLE 3

Alternaria infection of cabbage seed produced at Wellesbourne

Harvest year	% seeds infected by	
	A.brassicicola	A.brassicae
1967-1974[1]	31.0	0
1977	56.1	0
1978	38.2	0
1980	13.1	24.0
1981	1.7	13.6
1982	0.7	7.5
1983	24.5	4.8
1984	10.0	26.5

[1]Mean values for 1967, 1969, 1970, 1971, 1972, and 1974.

TABLE 4

Number of Alternaria brassicae spores trapped/week in volumetric spore traps on isolation sites at Wellesbourne between 3 July and 21 August 1981-1983

Year	July				August		
	3-9	10-16	17-23	24-31	1-7	8-14	15-21
1981	0	1	0	83	36	1	0
1982	0	6	98	6	3	0	0
1983	0	0	7	67	0	0	0

The viability of spores released from diseased oilseed rape crops at harvest was tested in 1984. Cyclone spore traps were run at 700 litres/min for up to 6h 100-200 m downwind of four commercial crops on 8 and 9 August at the time that they were being combined. Although only trace levels of disease were present in these crops substantial numbers of A.brassicae spores were trapped at each site. The collected spores and other debris were dusted onto silicone coated glass slides. For each crop the initial viability of spores was determined by placing two slides in moist chambers at 21^{o}C for 16h followed by staining with lactophenol-cotton blue. The presence of germination tubes was determined on 200 A.brassicae spores. The influence of weather on spore viability was studied by exposing slides uncovered, outdoors, in an unshaded area and spore germination was similarly determined at daily intervals for 6-7 days.

The initial viability of A.brassicae spores released from all crops was high (>90%) but this decreased progressively in spores that were exposed to the hot dry weather that occurred following harvest. Nevertheless more than 30% of spores from each crop were still viable after 6-7 days. The dissemination of A.brassicae spores from oilseed rape at harvest coupled with their resistance to adverse weather conditions implicates them as potent agents of disease spread.

Alternaria and L.maculans infection in commercial vegetable and forage brassica seed

Since 1976 over 250 samples of vegetable and forage brassica seed (cabbage, broccoli, kale, swede, forage rape and turnip) produced in south-east England have been tested for Alternaria infection and since 1979 197 have been tested for L.maculans infection. A.brassicicola was the most frequent seed-borne pathogen, occurring in 94% of samples and on average in 7% of seeds. A.brassicae was not present in seed harvested in 1976 but occurred on average in 42% of samples in the following six years. The mean incidence of seed infection by this fungus was relatively low (2.1%) but in two cabbage samples 13% of seeds were diseased and in a third 36% of seeds were affected. L.maculans occurred in 59% of samples and on average in 0.2% of seeds with up to 4.6% affected seeds in the most heavily diseased lot. However, pathogenicity tests on 215 isolates of the fungus from 40 infected samples indicated that only five (from a single sample of swede) were virulent and it is unlikely therefore that diseased seed would cause damage in the subsequent crops.

DISCUSSION

It is clear that at Wellesbourne wind-disseminated spores from nearby diseased oilseed rape crops have been responsible for attacks by L.maculans and A.brassicae on vegetable and forage brassica seed crops. The high levels of seed infection resulting from these attacks highlights the potential problems that may arise in similar commercial crops which are grown in areas of intensive oilseed rape cultivation. It is of particular concern that in experimental seed crops these attacks have resulted in infection of the seed by virulent strains of L.maculans. If cross-infection by these strains occurred from oilseed rape to other commercial brassica seed crops the consequences for the seed trade and growers could be serious. In North America the use of imported cabbage seed infected with virulent L.maculans recently caused extensive crop losses (Gabrielson et al. 1977) and now seed importers invariably insist on a growing season inspection of the maturing seed crop and a declaration that the crop is free from canker. Since 1977 few brassica seed crops grown in Essex have passed this inspection. The introduction in 1979 of oilseed rape cultivars with high canker resistance reduced both disease incidence and the damage caused by L.maculans in this crop (Evans & Gladders 1981) but although not damaging, the fungus still occurs in all of the main oilseed rape growing areas (Evans et al. 1984) so that the crop continues to present a potential source of infection for other crops. In contrast with the rape crops in the Wellesbourne area, in which in 1982/3, almost all pathotypes of the fungus were virulent, in Essex there was a much lower frequency of these pathotypes on both oilseed rape and other brassica seed crops. This may account for the absence of virulent pathotypes of L.maculans from most commercial vegetable and forage brassica seed lots produced in that area.

Between 1968 and 1976 tests on samples of vegetable and brassica seed produced in Essex revealed no A.brassicae infection except in samples of stubble turnip (Maude unpublished) but since then this fungus has become a common pathogen of such seed and has reduced germination in some seed lots. The incidence of seed-borne infection by this fungus in commercial seed is not as high as in seed from experimental crops at Wellesbourne but the fungus must be considered an additional threat to the health of UK-produced seed, not only because of its adverse effect on germination but also because infected seed may be a primary inoculum source for subsequent crops. It is interesting that in tests on over 100 samples of imported B.oleracea seed between 1977 and 1983 the only Alternaria species detected was A.brassicicola.

Although oilseed rape may be a major source of L.maculans and A.brassicae for infection of other seed crops, the danger of cross-infection has been minimised in recent years by the disease control measures used by both rape growers and the seed trade. The extensive use of fungicide sprays to control dark leaf spot has not only reduced the incidence of this disease in the growing crop (Evans et al. 1984) but it has also led to a marked decrease in seed infection in seed multiplication crops. Tests on samples of rape seed grown for farm sowings indicated a progressive reduction in the mean incidence of seed-borne infection by A.brassicae from 8.9% in 1981 to 1.6%, 0.3% and 0.1% in 1982, 1983 and 1984 respectively. Such sprays do not appear to be effective in reducing pod attack by L.maculans; the mean incidence of infection by this fungus in rape seed for farm sowings has exceeded 0.2% in each year between 1981 and 1984. Moreover, over 20% of isolates derived from these seed stocks were virulent. The recent widespread use of fungicide seed treatments that are effective against L.maculans and Alternaria spp. (Maude et al. 1984) has however minimised the danger of introducing, by means of infected seed, virulent strains of L.maculans into areas where they are absent or infrequent. Continuation of such action may restrict the introduction of virulent types into the traditional seed growing areas where they are at present infrequent and so reduce the danger of exposing vegetable and forage brassica seed crops to these potentially damaging strains.

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EFFECTS OF OILSEED RAPE ON THE STATUS OF INSECT PESTS OF VEGETABLE BRASSICAS

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ABSTRACT

Oilseed rape now covers about five times the area of vegetable brassicas in England and Wales, constituting about 98% of cultivated brassicas. It can harbour large numbers of cabbage root fly (*Delia radicum*) pupae, may also be a source of overwintering, viruliferous aphids (*Brevicoryne brassicae* and *Myzus persicae*) and may be aiding build-up of larger populations of the small white butterfly (*Artogeia rapae*). Cabbage stem weevil (*Ceutorhynchus pallidactylus* = *quadridens*) damage has increased on vegetables and cabbage seed weevils (*C. assimilis*) and pollen beetles (*Meligethes* spp.) from rape browse on cauliflower and calabrese, a new problem. The cabbage stem flea beetle is becoming more serious on brassicas in autumn but there is little evidence of problems with other pests.

INTRODUCTION

The area of oilseed rape in England and Wales has increased about 10-fold since 1974, from c. 24 500 to c. 260 000 ha. Meanwhile, the area of vegetable brassicas, totalling about 55 000 ha, has not changed appreciably so the vegetables are now overshadowed five-fold by oilseed rape.

Although the same range of insects is potentially common to all brassicas, the incidence of individual species differs according to how well their biology synchronises with the cultural practices for each type of crop (Fig. 1). The potential of the various insects to spread and to build-up to damaging levels on the many different types of vegetable brassicas will determine their relative importance. Since Gould (1975) and Free & Williams (1978) reported on pest incidence on oilseed rape, spring-sown crops have become rare whereas winter oilseed rape has spread from central England into the established vegetable-brassica growing areas (see Lane & Norton 1984).

The traditional status of some insect pests of vegetable brassicas seems to be changing, though quantitative evidence is scanty. It is therefore timely to consider which pests are likely to spread from rape in numbers sufficient to affect production systems of high quality vegetable produce. Before discussing changes in populations of individual pests, however, several agroecological factors common to all species need to be considered. These include the influences of different plant populations, changes in crop areas and the effectiveness of insecticidal methods of control.

AGROECOLOGICAL FACTORS

Plant density

When crops with different plant spacings within the dispersal zone of a pest are sampled to determine absolute pest numbers, plant densities must be taken in account. Winter oilseed rape is sown to achieve a theoretical stand of 100-110 plants/m^2 (Anon. 1984), 60-100 plants/m^2 surviving to maturity (Scarisbrick *et al*. 1984). Swede, turnip and calabrese are less densely spaced at from 14-43 plants/m^2 but most other vegetable brassicas have only 1.2-17 plants/m^2. There are therefore up to 80 times more plants per unit area

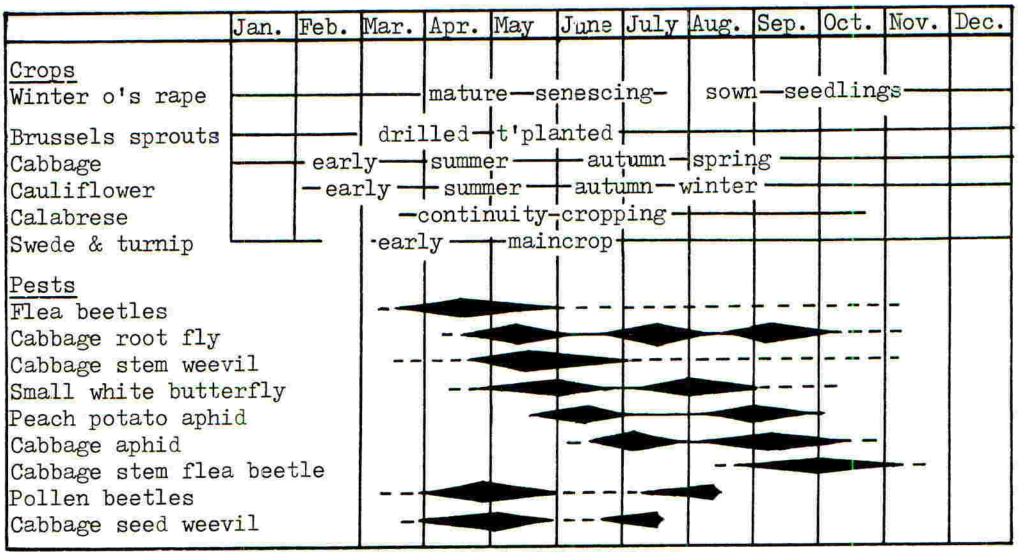

Fig.1. Synchrony of the main periods of brassica vulnerability and the times of pest attacks.

TABLE 1

Crop areas (1983-4), plant densities and populations, and estimated cabbage root fly densities and populations on vegetable brassicas and oilseed rape.

	Brussels sprouts	Cauliflower	Cabbage	Calabrese	Swede & turnip	Oilseed rape
Crop area (ha)	12 104	16 068	19 962	*919	4048	260 000
			55.2			
Plants/m^2	1.2-4.1	1.6-3.6	2.7-17	14-43	16-34	60-110
Relative no. plants/m^2	1-3.4	1.3-3	2.1-14	12-36	14-28	50-92
Relative no. plants/crop	1	1.2	4.6	0.6	3.3	600
			1			50
% of total no. of cultivated brassica plants	0.16%	0.19%	0.75%	0.10%	0.55%	
			1.8%			98.2%
Pupae/m^2	5-8	11-19	9-29	49-117	52-103	30-63
Pupal population (millions)	790	2400	3800	760	3200	
			10 950			80 000
% of total pupae			12%			88%

*Estimate: Anon. (1984b)

of oilseed rape crops than in other brassicas and, overall, about 50 times more rape plants than all other cultivated brassicas in England and Wales.

As an example, pupal populations of the cabbage root fly commonly found in the different brassica crops are shown in Table 1. The pupal densities are lowest in brussels sprouts (5-8/m^2) and highest in swede/turnip or calabrese (<117/m^2). The high populations (<63/m^2) now present in some rape crops imply that it may already harbour up to 88% the overall cabbage root fly population in some areas.

Changes in crop areas

While the area of winter oilseed rape is rapidly increasing within a region several considerations arise. It will be acting as a "sink", absorbing residual populations of pests from previous crops and probably suffering little economic damage, the pest populations in the rape being as yet relatively sparse. Vegetable brassica crops may be little, if at all, affected while fields of the two types of crop are sufficiently far apart to limit the dispersal success of the pest populations. At this stage interactions will be minimal. The distances permitting significant immigration is an important factor for each pest species. Small but measurable proportions of marked cabbage root fly populations have been detected up to 2.5 km from the emergence site of the flies (Finch & Skinner 1975), implying that its potential dispersal zone is at least 2000 ha around a source crop. Comparable estimates for other relevant pests are not available but in favourable conditions aphids, butterflies, moths and many beetles also have at least the same potential to disperse. Winter oilseed rape may draw some pests from vegetables while it is young and attractive during September. In contrast, many of the pests leave the old senescing rape crop in June/July. From mid-July to September rape is no longer available as a host-crop.

After the area of oilseed rape has stabilised in a region, pest populations will be greatly enhanced (cf. Table 1) and attacks on vegetables are likely to intensify. Any tendency for the area of rape to decline, however, could leave resident pest populations temporarily at exceptionally high levels (cf. Table 1) and jeopardise nearby vegetable brassicas at susceptible stages of development.

Changes in area of the rape crop from year to year will alter the relative status of insect pests on nearby vegetable brassicas. Indications of risks to vegetables should therefore accrue from monitoring the absolute numbers of insects in populations on oilseed rape and noting whether the rape is increasing or decreasing locally.

Pest populations and insecticide performance

There are two distinct facets to insecticide performance (Wheatley & Thompson 1981). Firstly, an insecticide treatment has a proportional effect on a pest population, a measure of the treatment "efficiency" which, for practical purposes, is largely independent of the pest population density. Secondly, the net effect, or "effectiveness", of a treatment also depends on the size of the surviving pest population in relation to the plant density of the host-crop (the number of insects per plant) and on the many other factors affecting plant growth. No treatment entirely eliminates pests from a crop so more insects per unit area survive in a severe attack than in a light attack, and the economic importance of the damage they cause differs from crop to crop.

Most of the available insecticide treatments reduce pest populations on vegetable brassicas by only 70-90% (Wheatley & Thompson 1981) and therefore have little in reserve to combat enhanced pest attacks. If pest attacks intensify, the yields of high quality vegetables will be impaired. There is little evidence, unfortunately, that treatment efficiencies can be improved sufficiently to combat enhanced insect attacks, so their effectiveness in protecting vegetables must decline if pest densities increase on vegetables.

STATUS OF INSECTS ON BRASSICA CROPS

Insect pests of brassicas are grouped in Table 2 according to their importance on vegetables and whether changes in their status have been observed or are suspected. Pests which consistently threaten vegetable brassicas include the cabbage aphid, cabbage root fly, cabbage moth and small white butterfly. Growers generally regard the cabbage aphid as the most

TABLE 2

Insect pests on brassica crops (*, **, *** = increasing severity)

Names		Relative importance on:-			
		Oilseed rape		Vegetables	
Common	Latin	1974	1984	1974	1984
Consistent pests of vegetables					
Small white butterfly	Artogeia (Pieris) rapae	-	-	**	***
Cabbage aphid	Brevicoryne brassica	-	-	***	***
Cabbage root fly	Delia radicum	-	**	***	***
Cabbage moth	Mamestra brassicae	-	-	**	**
Peach-potato aphid	Myzus persicae	-	-	*	*
Becoming more serious on some vegetables					
Cabbage seed weevil	Ceutorhynchus assimilis	**	***	-	*
Cabbage stem weevil	C. pallidactylus = quadridens	**	-	***	***
Cabbage whitefly	Aleyrodes proletella	-	-	*	**
Flea beetles	Phyllotreta spp.	**	-	*	**
Pollen (blossom) beetles	Meligethes spp.	***	***	-	*
No change observed on vegetables: or (?) possibly more frequent					
Cabbage leaf miner	Phytomyza rufipes	-	-	*	*
Cabbage stem flea beetle	Psylliodes chrysocephala	*	*	*	?*
Diamond-back moth	Plutella xylostella	-	-	*	?*
Garden pebble moth	Evergestis forficalis	-	-	*	?*
Large white butterfly	Pieris brassicae	-	-	*	*
Turnip gall weevil	Ceutorhynchus pleurostigma	-	-	-	?
Unimportant on vegetables; no changes observed					
Brassica pod midge	Dasineura brassicae	***	***	-	-
Mustard beetle	Phaedon cochleariae	*	-	-	-
Rape winter stem weevil	Ceutorhynchus picitarsis	-	**	-	-
Turnip sawfly	Athalia rosae	-	-	-	-
Turnip stem weevil	Ceutorhynchus contractus	-	-	-	-

important pest (Tait 1983), probably because existing insecticidal control is barely adequate. The cabbage root fly, however, has a greater potential to destroy summer brassica crops and would do so regularly, but for the many available control methods. The caterpillars of the small white butterfly and the cabbage moth also occur consistently on leaf brassicas in summer but insecticidal control is usually effective.

The most serious changes, however, concern attacks by the cabbage stem weevil on summer brassicas and the browsing of cabbage seed weevils and pollen beetles on maturing summer cauliflowers and calabrese. Possible local changes may also be occurring in the prevalence of the diamond-back moth, the garden pebble moth and the cabbage stem flea beetle on leaf brassicas and the numbers of turnip gall weevils on swedes and turnips. The remaining pests listed do not seriously affect vegetable brassicas and have not been reported to be increasing in incidence.

Aphids

Colonies of the cabbage aphid overwintering on oilseed rape produce alatae as the crop begins to senesce in June. The winged aphids can remain airborne for at least 1-2 h and move considerable distances downwind (Johnson 1969). The migrants are potentialy viruliferous and could transmit cauliflower mosaic virus alone and in combination with broccoli necrotic yellows or turnip mosaic viruses (Walsh & Tomlinson 1984). In oilseed rape crops, plant severely infested with cabbage aphid occur mainly around the edges of fields. Nonetheless, the aphid is usually also well distributed throughout a crop in spring. Very large populations may therefore be present and be a source of viruses affecting vegetables when the spring is warm, with consequent impairment of quality and yield. The importance of oilseed rape crops as over-wintering sites for this aphid requires investigation.

The peach-potato aphid occurs widely on vegetables. Though rarely sufficiently numerous to cause direct damage, it is a potent vector of many viruses. Immigrants from oilseed rape may be able to transmit beet western yellows virus on sugar-beet (Smith & Hinckes 1984); the virus was prevalent, for example, on summer cauliflowers at Wellesbourne during 1984 (Walkey; personal communication).

Cabbage root fly

In the the UK this pest has generations in spring, mid-summer and early autumn but control measures are designed primarily to deal with a peak attack by the first generation in May. Near Wellesbourne, samples of soil under oilseed rape crops at the end of the spring generation had a maximum of 4 pupae/m^2 in 1976 compared with 63/m^2 in 1984 (Finch & Skinner unpublished). Four fields sampled in 1984 had 0, 26, 31 and 63 pupae/m^2 showing that not all rape crops are as yet infested, but the populations in those that are must be a cause for concern. Indeed, establishment of the earliest August-sown rape would itself be threatened by the highest populations; a soil insecticide treatment may be warranted and is already being recommended in some circumstances. Populations of >10 pupae/plant on most untreated vegetable brassicas would cause measurable damage. Hence risks from nearby oilseed rape crops are considerable if a significant proportion of the root fly population successfully disperses onto vegetables in mid-summer.

Although the spring generation of flies is normally the most serious, there were severe attacks by the mid-summer generation of flies at Wellesbourne in 1984, above-average late-season damage being noted by September. This occurred when the efficacy of insecticide applied at sowing or transplanting was waning. Such attacks particularly threaten turnips and swedes which already are difficult to protect from cabbage root fly/turnip fly (*Delia floralis*) late in the season. Cabbage root fly populations in oilseed rape now warrant close monitoring as some may be reaching levels threatening the rape itself and are therefore likely to be disastrous for the more susceptible vegetables such as cauliflower which may not then be adequately protected by available control measures.

Lepidoptera

At present, there are no reports of lepidopterous pests attaining high numbers in oilseed rape crops in the UK. However, observations suggest that the small white butterfly is becoming more troublesome on leaf brassicas. As it lays its eggs singly and moves to another plant each time, a pair of butterflies developing on oilseed rape has a potential to infest about 100-150 plants in a crop. Hence, 1 caterpillar surviving on 5000 rape plants (about 50 m^2) would be sufficient to cause severe problems on nearby vegetables.

The cabbage moth has only 1 generation/year, laying eggs in mid-summer when winter oilseed rape is unattractive. It is therefore unlikely to be much affected by the rape crop. The large white butterfly is not serious on field crops and seems unlikely either to complete its first generation before the rape becomes unsuitable or to find a young rape crop in time to lay its second brood of eggs.

For the past 30 years the diamond-back moth has occurred rather sporadically and mainly in eastern England. It establishes its first generation during May and June and builds up to a large second generation in mid-summer, just when rape is senescing. Although it has potential to become serious on certain leaf brassicas in mid-summer there is as yet no firm evidence that it is becoming more widespread on vegetables in the UK.

As yet, oilseed rape seems not to have greatly influenced the prevalence of lepidopterous pests on vegetables.

Cabbage seed weevil and pollen beetles

These pests occur in very large numbers on oilseed rape before and during flowering. Neither has been troublesome on vegetables until the past 3-4 years when they have dispersed from rape onto maturing cauliflower and calabrese in several areas. The feeding of the adult beetles on the developing florets causes brown scars which ruin the quality of the produce and may make it unmarketable. Furthermore, the presence of beetles in the produce, dead or alive, is not acceptable. This damage can be prevented by applying an insecticide but this is an additional operation for which the recommended minimum intervals before harvest must be observed to avoid undesirable residues and safeguard those handling and eating the produce.

Cabbage stem weevil

Although this pest has been distributed widely for many years it was not often serious on vegetable brassicas before 1980. The incidence of the weevil larvae in stems and petioles of summer brassicas has now increased dramatically in several areas. Finch & Skinner (1976) recorded 35% infested early summer cauliflower plants at Wellesbourne in 1974; in 1984 they found 100% of plants were affected. Similar observations have been made in experiments by Percivall et al. (1983) who recorded 25% of radish plants infested with weevil larvae in 1982, probably in excess of 70 weevil larvae/m^2. In cauliflower in 1983 and 1984 respectively, the same authors (personal communication) recorded 50-95% and 85-100% untreated cauliflowers infested in late June at Wellesbourne. The systemic carbamate insecticides were especially effective in controlling this pest which now threatens young, mid-summer vegetable brassicas in some areas. Of all insect pests of vegetables, this weevil has been affected most by the spread of oilseed rape. Although present in large numbers on oilseed rape approaching maturity, it has not been considered sufficiently damaging on this crop to warrant treatment, though it may be checked if insecticides are used against pollen beetles or cabbage seed weevil. However, Newman (1984) has implicated damage by the cabbage stem weevil, and possibly also by the cabbage stem flea beetle and rape winter stem weevil, in the severity of stem canker (Leptosphaeria maculans) infection during May-July, insecticide treatments greatly reducing canker as well as the pest damage.

Cabbage stem flea beetle

This pest has sporadically damaged late-planted brassicas for many years but the greatly enhanced numbers now affecting oilseed rape threaten severe autumn attacks on young brassicas nearby. Particularly at risk are maturing autumn cauliflower crops, seedbeds and freshly transplanted crops. It has become prudent to use routine preventative treatments in some areas. Autumn applications of insecticides may still have some residual effects against flea beetles or cabbage stem weevil in the following spring.

Flea beetles

The several species of flea beetle which attack brassicas have only one generation each year. The winter oilseed rape crop is sown largely out-of-phase with the flea beetle life cycle and does not seem to be supporting large populations at present. Although, all rape seed is treated with HCH it seems to be largely ineffective in preventing flea beetle damage in spring. It is as yet uncertain, however, whether, this pest will become more serious on early summer vegetables than it has been in recent years.

Other insect pests

The cabbage leaf miner has been serious on calabrese in early and mid-summer for at least 20 years and we are not aware of any change in its status at the present time. However, together with Scaptomyza flava, it occurs on oilseed rape in autumn, control measures not being necessary. The turnip gall weevil appears to be increasing. Although reported numerous on roots of cauliflowers in southwest England during the 1970's, attempts to demonstrate economic losses were generally unsuccessful. On swedes and turnips for human consumption, the galls are disfiguring and these crops may need protection to maintain quality if infestations of the weevil become severe.

Brassica pod midge damages all brassica seed crops and can cause considerable loss of seed, though it does not trouble vegetables in any other way. The mustard beetle damages mustard crops and also watercress; any use of insecticides must be precise on watercress to avoid contamination of waterways. In contrast to the cabbage stem weevil, the rape winter stem weevil kills plants and any large increase or spread of its population would threaten winter/spring cabbage and broccoli plants attacked at susceptible stages of crop growth. There are no reports yet of damage by this pest to vegetables. The turnip stem weevil is uncommon and the turnip sawfly, although serious on swedes and turnips before the advent of modern insecticides, now seems to have disappeared.

Very large populations of whitefly have frequently been reported on brassicas during autumn and early winter but there does not seem to be any direct association with oilseed rape.

CONCLUSIONS

The cabbage stem weevil has increased drammatically in status and is now prevalent on many summer brassica crops. Large numbers of cabbage seed weevils and pollen beetles are migrating from rape onto summer brassicas and are particularly damaging on cauliflower and calabrese. The role of oilseed rape has yet to be evaluated as a source of cabbage aphid and peach-potato aphid and consequently of viruses affecting brassicas. It is doubtful whether the more frequent attacks by caterpillars are associated with the increase in oilseed rape. Cabbage stem flea beetle is now prevalent in some areas and some rape crops have such large populations of the cabbage root fly that it constitutes a serious threat to nearby vegetable brassicas. It has become important to monitor pest populations on the rape to determine those that may threaten vegetables in the future.

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THE EFFECTS OF INSECT LARVAL DAMAGE UPON THE INCIDENCE OF CANKER IN WINTER OILSEED RAPE

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ABSTRACT

The influence of insect damage on canker infection was studied during two seasons, 1982-83 and 1983-84. Two cultivars resistant to canker (Jet Neuf and Rafal) and two susceptible (Elvira and 76/315/1) were sown in a field trial. Half the plots were treated with insecticide (carbofuran in 1982-83; deltamethrin in 1983-84) and half remained untreated. Considerably less insect damage was found in the treated than in the untreated plots, and the pattern of canker infection reflected that of insect damage for cankers of both the upper stems and, to a lesser extent, of the crown. Nearly all cankers of the upper stems were associated with insect damage. Crown canker infection in 1984 was reduced in the treated plots compared with the untreated such that the disease score of the resistant cultivars in untreated plots was similar to that of the susceptible cultivars treated with insecticide.

INTRODUCTION

Winter oilseed rape is commonly attacked by the larval stages of several insect pests, including *Psylliodes chrysocephala* (cabbage stem flea beetle), *Ceutorhynchus quadridens* (cabbage stem weevil) and since 1983 also by *Ceutorhynchus picitarsis* (brassica winter stem weevil). Larvae of these insects tunnel into the centres of the stems of plants, either directly or by first mining into leaf petioles and thence into the stem.

Stem canker (*Leptosphaeria maculans*) has been observed frequently to be associated with such damage, but little published data are available. Ndimande (1976) artificially infested plants with *C. quadridens* and *P. chrysocephala*, with or without simultaneous infection with *L. maculans*. Canker infection was observed to follow along the path of larval damage after combined infestation and infection, whereas the tunnels produced by larvae alone remained uninfected. Plants infected alone produced much less canker than those also infested with larvae.

Field trials at the Plant Breeding Institute, in which breeding material is screened for canker resistance, generally suffer severe damage by insect larvae. The following work was carried out to determine the effects in the field of insect damage on canker and, in particular, any influence of insect damage on cultivar ranking for canker resistance.

MATERIALS AND METHODS

Field trials were carried out in 1982-83 and 1983-84. Each trial consisted of four cultivars, two of which (Jet Neuf and Rafal) were resistant to canker, and two susceptible (Elvira and 76/315/1). Half the number of plots were treated with insecticide: carbofuran ('Yaltox', Bayer UK) in 1982-83; and deltamethrin ('Decis', Hoechst UK) in 1983-84, while the other half remained untreated. Each combination of treatment and cultivar was replicated three times in each season. Carbofuran was applied manually with a granule applicator, at a rate of 30 g product/100 m row, on 29.10.1982 and 8.4.1983. Deltamethrin was applied using a knapsack sprayer at a dilution of

TABLE 1

Scoring systems used for assessing canker and insect damage

Score	Crown cankers[a]		Upper stem cankers - length external lesions (mm)		Insect damage[b] to crown
	% Girdling (C)	% Penetration (P)	1983	1984	
0	None	None	None	None	None
1	<25	Superficial only	<10	<50	External only
2	26-50	<25	11-50	51-100	Stem centre damaged
3	51-75	26-50	>50	>100	
4	76-100	51-75			
5	100 + weak stem	76-100			
6	100 + dead plant	100 + dead plant			

a Crown canker score, S = C + P (data for S only are presented in this paper).
b Assessed in 1983-84 season only.

300 ml/600 litre and a rate of 0.6 l/m^2 on 20.10.1983 and 21.3.1984.

The plots were sampled from early stem extension until maturity, at fortnightly and later at weekly intervals. Twenty plants were selected at random from each plot and assessed individually for external and internal crown cankers, for external cankers of the upper stems and for insect larval damage (Table 1). Plants were also split longitudinally along the main stem from just above the crown to the region of the lower pods, and the length of stem centre tunnelled by insects, and length infected by canker, was measured to the nearest 5 mm. The larvae present were identified but not counted.

RESULTS

All results were subjected to analyses of variance. Differences with $p \leq 0.05$ were regarded as significant.

Insect damage

In both seasons, the larvae found in stem centres initially were those of *P. chrysocephala*, but these were later superceded by those of *Ceutorhynchus* species. Carbofuran gave good control of insect larvae throughout the 1982-83 season, although there was a slight increase in the amount of damage to the stem centres on the treated plots from early in July (Fig. 1(a)). Deltamethrin control was less complete, and an increase in larval damage was observed from early in June 1984 (Fig. 2(a)). However, damage in this season was still significantly lower on the treated than on the untreated plots at all sampling dates except 16 April and 16 July. There were no significant differences in 1982-83 among the treated cultivars in the amount of damage to the stem centres, nor among the untreated cultivars except on 31 May and 11 July (Fig. 1(a)). In 1983-84, there were again no significant differences among the treated cultivars, nor among the untreated except on 14 May and 2 July (Fig. 2(a)).

Insect damage of the crowns was scored only in 1983-84. The amount of damage was again lower in the treated than the untreated plots, although the difference reached statistical significance only towards the end of the season.

Canker infection

Canker of the upper stems

In both seasons, the external symptoms on the upper stems were less severe in the treated than in the untreated plots, although this difference was greater in 1983-84 (Fig. 3), possibly largely due to the scoring method used (Table 1). There were no consistent differences among cultivars for either the treated or untreated plots in either season.

The amount of canker infection inside the upper stems was markedly lower on the treated plots compared with the untreated throughout both seasons, and the pattern of infection reflected that of insect damage (Figs. 1(b) and 2(b)). Infection remained low throughout the 1982-83 season, while in 1983-84, the amount of canker rose sharply from early in July, following the increase in insect damage. There was very little canker unassociated with insect damage in the upper stems. There was no significant difference between the treated cultivars at any sampling date in 1982-83. However, in untreated plots Rafal was more susceptible than the other cultivars throughout the season; the difference was significant for all sampling dates except 13 June and 27 July.

In the 1983-84 trial, there was again little difference between the

Fig.1 Insect damage and canker infection on upper stems of oilseed rape,treated or untreated with carbofuran.

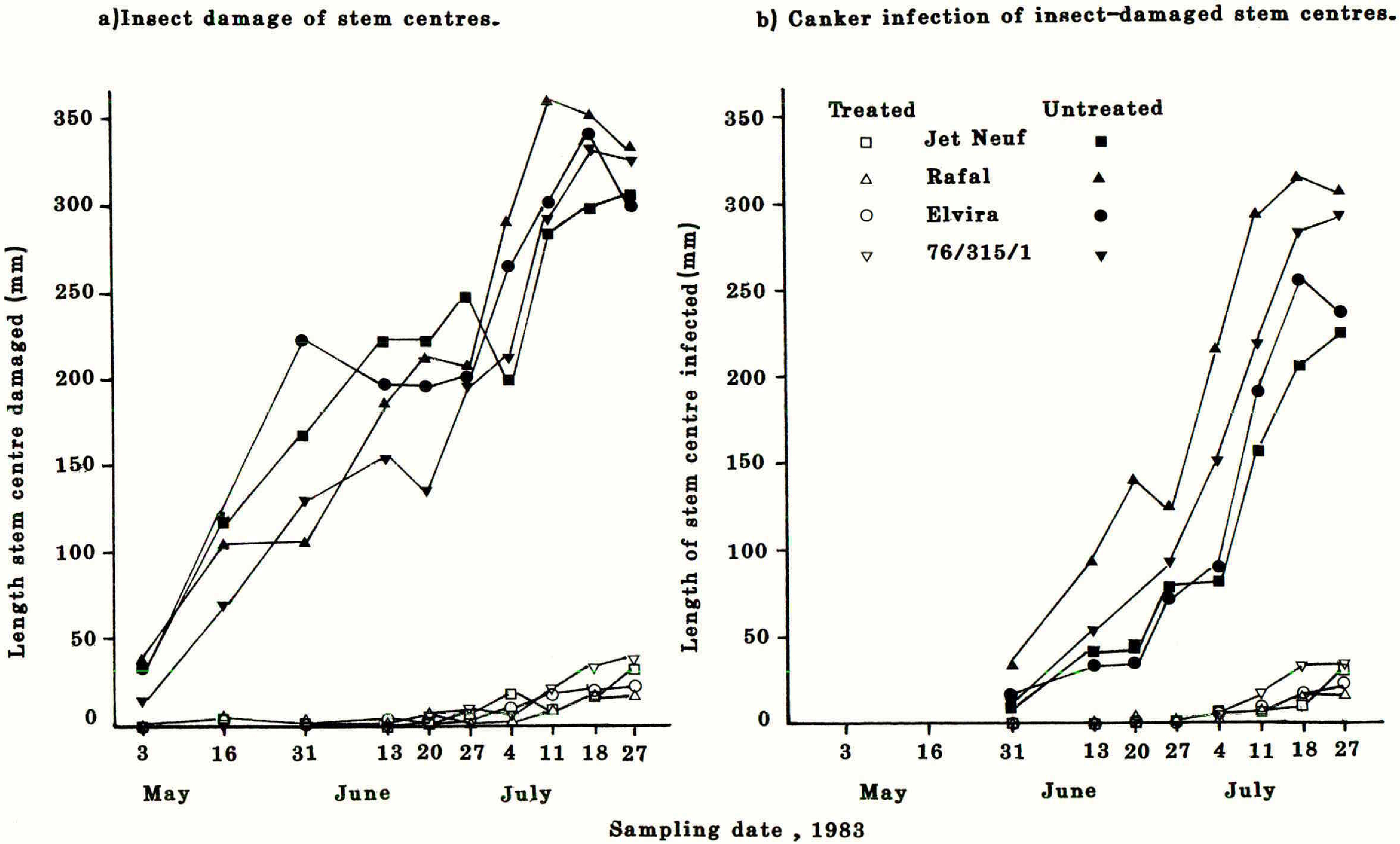
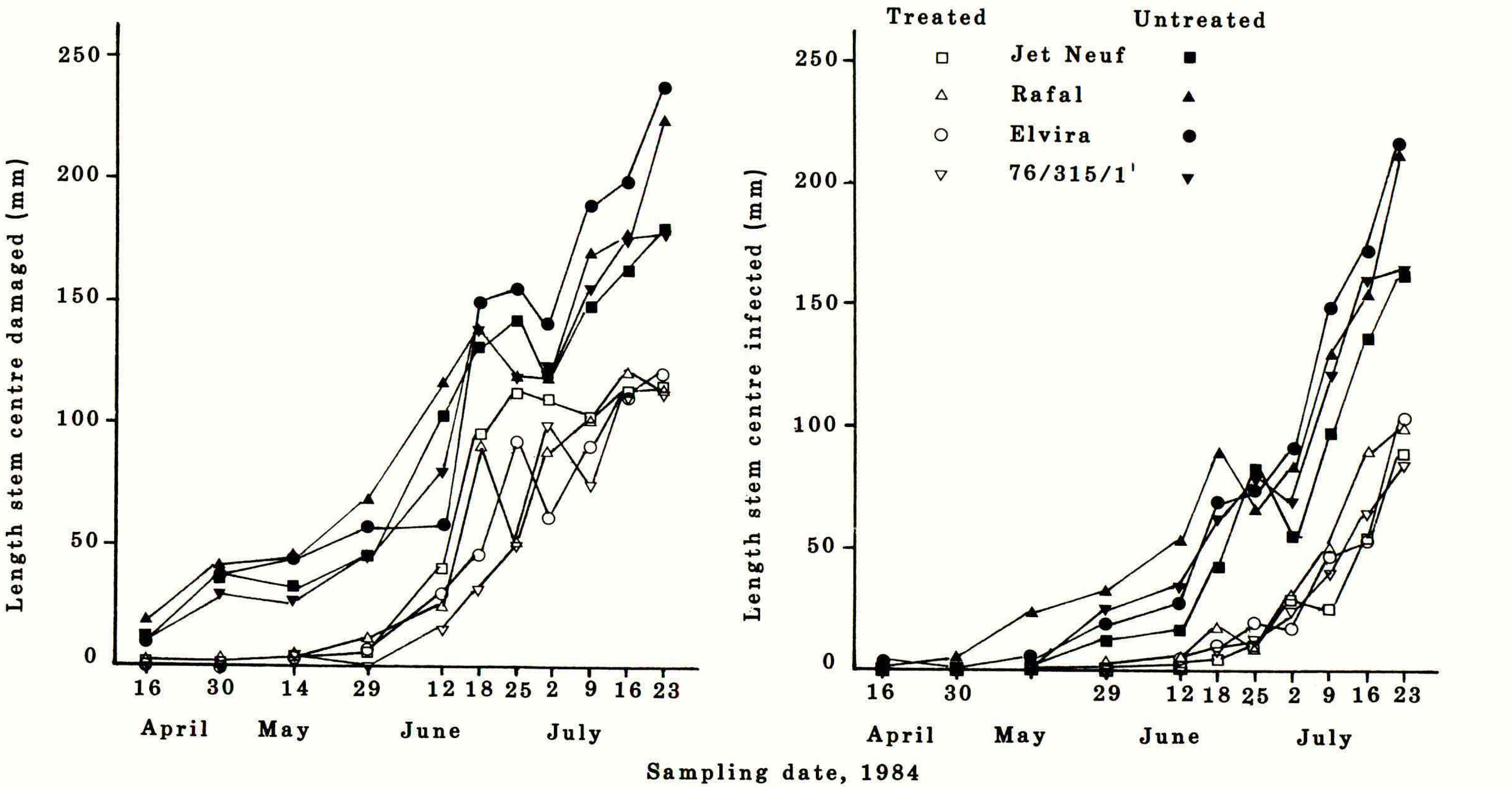


Fig.2 Insect damaged and canker infection on upper stems of oilseed rape plants treated or untreated with deltamethrin.

a) Insect damage

b) Canker infection of insect-damaged stem centres.



8B—4

Fig.3 External symptoms of canker on upper stems, treated or untreated with deltamethrin.

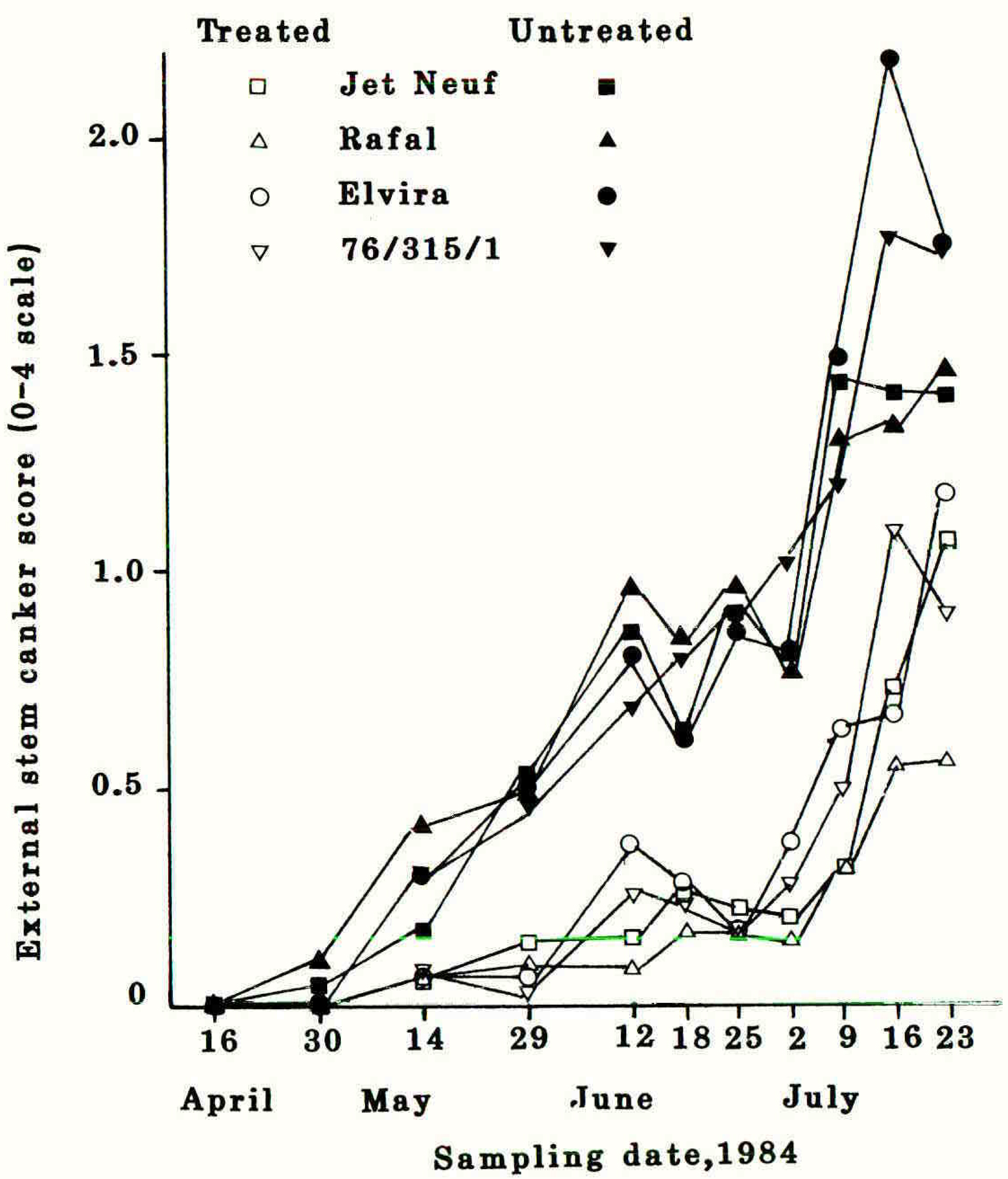
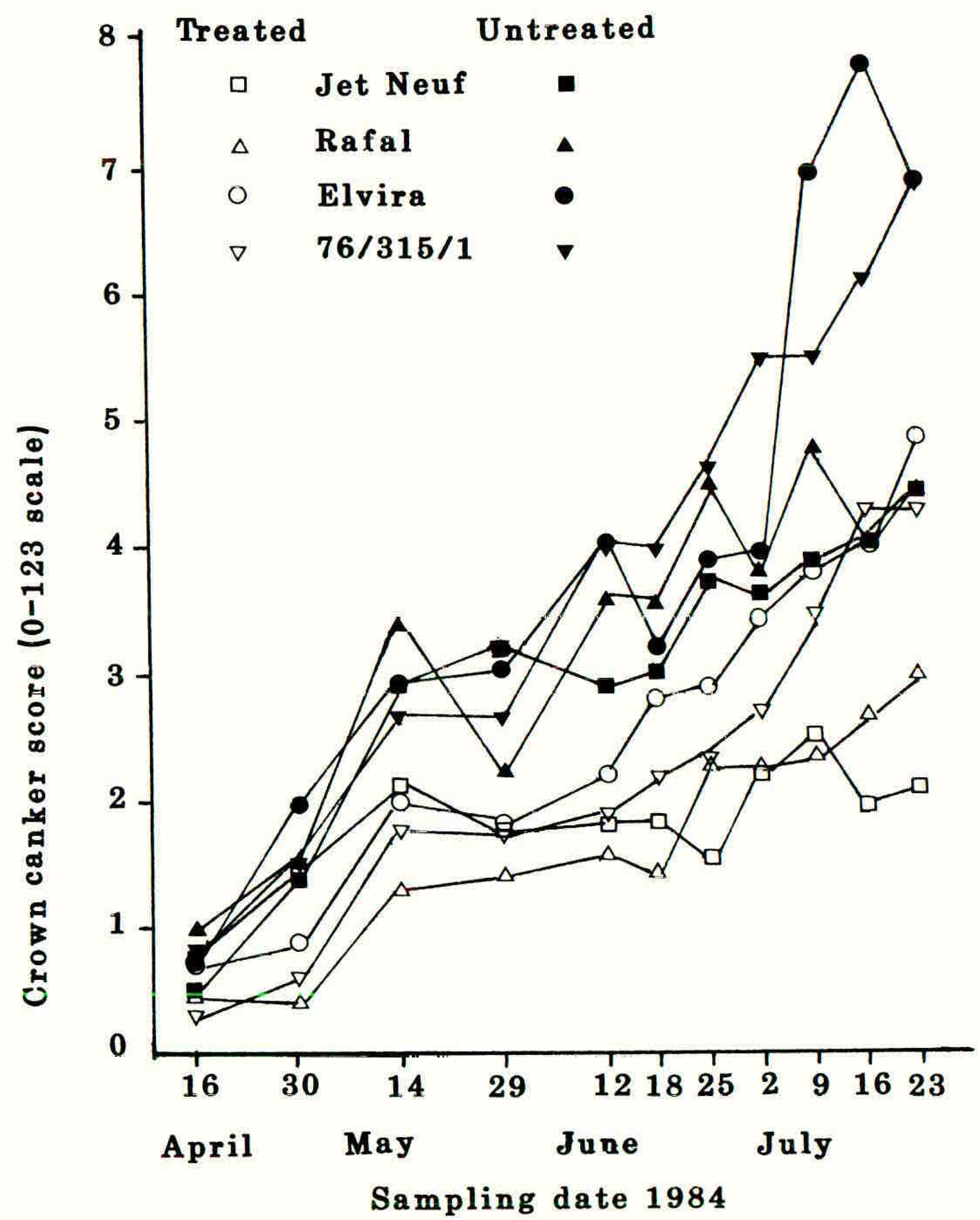


Fig.4 Crown canker of oilseed rape,treated or untreated with deltamethrin.



treated cultivars. On the untreated plots, Rafal again had a higher disease score than the other cultivars, but only until mid-June, and the difference was significant only from 14 May to 18 June inclusive. The higher score for canker in the upper stem centres of Rafal in 1982-83 was not the result of a corresponding higher level of insect damage (Fig. 1), suggesting that this cultivar is more susceptible to canker infection after injury. However, this result was not substantiated in 1983-84 because Rafal showed a higher level of insect damage for the same sampling dates on which it had a higher disease score (Fig. 2).

Crown canker

The crown canker scores were only slightly higher on the untreated than on the treated plots in 1982-83, and there were only small differences between the cultivars within each treatment. However, untreated plots were markedly more susceptible than treated plots in 1983-84 (Fig. 4), and in both the susceptible and resistant cultivars were significantly different.

DISCUSSION

Aphid-transmitted viruses are the classic examples of plant pathogens dependent upon insect pests to gain entry into their hosts. However, several fungal diseases are also influenced by plant pests. In many tropical crops fusarium wilts are enhanced by the synergistic interactions of nematodes (Waller & Bridge 1984). Insect damage has been implicated in the exacerbation of several diseases of cotton; Brown (1976) observed that insect damage provided practically all the entry points for weak pathogens causing boll rotting.

The work reported here demonstrates the close relationship that can occur between insect damage and canker infection in oilseed rape, confirming the earlier work of Ndimande (1976) who used artificially infested and infected plants. Canker infection of the upper stems is almost totally dependent upon previous damage to the plant by tunnelling insect larvae. Very little upper stem canker was found in either season that was not associated with insect damage, and the pattern of canker infection closely followed that of insect damage on both the treated and untreated plots.

There were no large differences between cultivars in either season in the amount of insect damage to either the upper stems or to the crown. Correspondingly, there were few differences between the cultivars in the amount of upper stem canker present, assessed by either external or internal symptoms, the degree of infection depending primarily on the amount of insect damage present. The observation in 1982-83 that Rafal appeared more susceptible to infection after injury was not substantiated in 1983-84.

The development of canker on the crown was not so dependent upon insect damage, but nevertheless was influenced by it. The level of crown canker was generally low in 1982-83, so that there was little difference between treated and untreated plots, and within each treatment the susceptible and resistant cultivars were not distinguishable. However in 1983-84, when crown canker scores were higher overall, the treated plots had less crown canker than the untreated throughout the season. Within each treatment, resistant and susceptible cultivars were only distinguishable at the end of the season, but this is common for this disease, in which the largest cultivar differences are seen at plant maturity. By the two final scoring dates in 1984, the untreated resistant cultivars (Jet Neuf and Rafal) had similar crown canker scores to those of the treated susceptible cultivars (Elvira and 76/315/1).

The ranking of cultivars for severity of upper stem cankers appeared unrelated to that for crown cankers. Unfortunately no data are available concerning the affects of upper stem cankers upon yield. However, crown cankers are generally considered to be more damaging to the crop, and are probably a better guide to cultivar resistance. Cultivar ranking of the crown canker scores was little affected in 1983-4 by the level of insect damage, and therefore the presence or absence of insect damage is immaterial when screening for canker resistance.

Concern about canker on rape in Europe is less now that high yielding, resistant cultivars are widely grown. However, there is little room for complacency in view of the existence of highly virulent isolates (Humpherson-Jones, 1983) and the recent significant changes in status of some brassica pests consequent on the increase in area of rape grown in the UK (Wheatley & Finch, 1984). Reducing insect damage in oilseed rape would appear to control canker on the upper stems, and to reduce the amount of crown canker. It seems likely that other diseases of rape may also be influenced by insect damage, in particular *Botrytis* infection of the stems and pods, the latter often following damage to pods by the seed weevil (*Ceutorhynchus assimilis*). It is probable that this type of interaction is common, meriting further collaborative study by entomologists and pathologists.

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SOME RECENT NEMATODE PROBLEMS IN OILSEED RAPE

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ABSTRACT

Several species of nematodes are known to be capable of attacking and damaging oilseed rape. They include ectoparasitic nematodes, migratory endoparasitic nematodes and cyst nematodes. Two species of cyst nematodes (*Heterodera cruciferae* and *H. schachtii*) which are common in Great Britain are capable of parasitising oilseed rape and have other crop and weed hosts in common. Some instances of severe damage by *H. cruciferae* have already been reported and the increase in area sown to oilseed rape along with other changes in cropping policies may exacerbate this situation. Trichodorid nematodes, which occur in lighter soils, can also decrease oilseed rape yields. Field trials have shown that treatment with nematicides can improve growth and yield of crops suffering attack by cyst nematodes or trichodorid nematodes.

INTRODUCTION

A recent report of nematodes associated with oilseed rape crops in France (Scotto la Massese 1983) listed five as the most important known to be harmful to the crop. The species, all of which occur in Great Britain, were: *Ditylenchus dipsaci*, *Heterodera cruciferae*, *H. schachtii*, *Meloidogyne artiellia* and *Pratylenchus neglectus*. Two others, *Pratylenchoides ritteri* and *P. laticauda*, were also thought to be capable of affecting the development of oilseed rape but only the first is known to occur in Great Britain.

Cyst nematodes are among the most important pests of temperate crops. The brassica cyst nematode, *H. cruciferae*, is the only cyst nematode so far identified by the Agricultural Development and Advisory Service as causing damage to oilseed rape in Great Britain (Evans 1984); about 12 damaged crops (mainly in Kent and East Anglia) have been reported. Two other species of cyst nematodes will parasitise oilseed rape: the beet cyst nematode, *H. schachtii*, and the yellow beet cyst nematode, which is a host race of *H. trifolii*, the clover cyst nematode, and has not been reported from Great Britain. If host crops are grown in a short enough rotation when cyst nematode parasites are present, nematode numbers will build up and severe crop damage will result. The five year rotation followed by most oilseed rape growers would probably not allow cyst nematode numbers to reach damaging levels unless a second host crop were grown in the rotation. *Heterodera cruciferae* has many hosts within the Cruciferae, including all brassica crop plants. Sugar beet, however, is not a host for *H. cruciferae* but is a host for *H. schachtii* and *H.*

trifolii. A rotation which included both oilseed rape and sugar beet would provide two host crops for these latter two species of cyst nematodes. The Beet Cyst Nematode Order 1977 revoked existing statutory restrictions on crop rotations for sugar beet growers and, in 1983, British Sugar decided to remove restrictions on cropping with hosts of *H. schachtii* as part of a policy of simplifying the sugar beet contract (Cooke 1983). The effects these changes have on the growers' choice of rotation may increase cyst nematode infestation levels and thereby result in more and greater crop losses. In addition, all three of the cyst nematode parasites of oilseed rape have many weed hosts in common; the role of weeds in maintaining population levels in the absence of host crops is unknown and will depend on their type and number.

Cyst nematode damage to winter oilseed rape is characterised by patches of stunted seedlings seen soon after emergence. If the infestation is sufficiently severe the stunting persists into spring and the crop fails to grow normally and may suffer severe competition from weeds. Brassica cyst nematode is not widespread through the country because brassica growing is concentrated in certain areas, mainly Lincolnshire and Bedfordshire. About 40 000 ha of vegetable brassicas are grown each year in England and Wales and the 300 000 ha of oilseed rape expected to be grown by 1988 (Anon. 1983) represents a great increase in the area of potential host crops for this nematode. Similarly, the beet cyst nematode has a restricted distribution corresponding to some of the areas where sugar beet is grown. It is not possible to predict whether cyst nematode problems will become common on oilseed rape but both of these species could spread into areas where oilseed rape is grown.

Meloidogyne artiellia has occasionally been associated with poor growth of oilseed rape in Great Britain (M.E. John & J.A. Bennison, personal communication). Scotto la Massese (1983) also found *Trichodorus* and *Longidorus* spp. associated with oilseed rape in small numbers but not causing any apparent damage. Nematodes of these last two genera are ectoparasites with wide host ranges and are only common on lighter, sandy soils.

This paper describes field trials with oilseed rape in which nematicides were applied either to crops already suffering damage by *H. cruciferae* or at drilling to land heavily infested with trichodorid nematodes. We also give results of a survey of endoparasitic nematode species associated with oilseed rape crops growing in sugar beet or vegetable brassica growing areas.

MATERIALS AND METHODS

Field trial with cyst nematodes

A large area of stunted plants of cv Jet Neuf in a field near Newmarket, Cambridgeshire, was inspected in February 1983. Females of *H. cruciferae* were found on the roots of affected plants and not on the roots of plants outside the stunted area. The nematicide aldicarb and an extra top-dressing of nitrogen (in addition to the dressing of 250 kg nitrogen/ha given in March) were applied to the crop to determine whether either treatment would improve crop growth and whether the nematicide would affect nematode reproduction.

TABLE 1

Effect of aldicarb and additional nitrogen on yield of winter rape and final population density of Heterodera cruciferae.

	Nitrogen (kg/ha)	Aldicarb (kg a.i./ha)			
		0	5	10	Mean
Yield (t/ha)	0	1.86	2.90	2.75	2.50
	60	2.10	2.97	3.37	2.81
	120	1.94	2.41	3.43	2.59
	Mean	1.97	2.76**	3.18***	
H. cruciferae (eggs/g soil)	0	109	29	17	52
	60	86	64	35	62
	120	86	46	26	53
	Mean	94	47***	26***	

, *, indicates a significant difference from untreated at at $P<0.01$ and $P<0.001$ respectively

Three blocks of nine plots (each 6 rows x 2 m) were marked out and weeded. Aldicarb ('Temik 10G') at 0, 5 and 10 kg a.i./ha and nitrogen (as Nitrochalk) at 0, 60 and 120 kg nitrogen/ha were applied on 22 April and incorporated by raking between the rows. Plants were harvested by hand on 19 July and seed yield corrected to 92% dry matter content. Ten soil cores (20 cm deep x 2.5 cm diameter, 5 cores in row and 5 cores between rows) were taken on the same day. Cysts of H. cruciferae were extracted using a flotation column (Trudgill et al. 1973) and their egg contents estimated.

Field trial with trichodorid nematodes

Oxamyl was applied in early September to plots 2.5 x 4 m on light sandy soil at Holme-upon-Spalding Moor, North Humberside, a site heavily infested with trichorid nematodes, chiefly Trichodorus cylindricus but with some T. primitivus and Paratrichodorus teres. Basal fertiliser (70: 70: 70 kg/ha of $N:P_2O_5:K_2O$) was applied and nematicide was either broadcast or applied in row, at rates of 0, 1, 2, or 4 kg a.i./ha with cv Jet Neuf drilled at 6.5 kg/ha on 6 September. The area was then lightly harrowed and rolled. Subsequent treatments were: top-dressings of

60 and 120 kg nitrogen/ha at the end of February and beginning of April respectively; Carbetamide (2.1 kg a.i./ha in November and a mixture of benazolin (0.3 kg a.i./ha) and clopyralid (0.05 kg a.i./ha) in early March to control weeds. Crop development was assessed on four plants per plot on 12 April by using a growth stage key (Sylvester-Bradley & Makepeace 1984) and the central square metre of each plot was hand-harvested on 10 July 1984. Seed yield was corrected to 92% dry matter content.

TABLE 2

Effect of oxamyl, applied at 3 rates to soil, on numbers of ectoparasitic nematodes per litre of soil on three sampling dates in a winter rape trial 1983-4.

Sampling Date	Oxamyl rate (kg a.i./ha)	*Tylenchorhynchus* spp.	trichodorids	Total plant parasitic nematodes
September 1983	Mean	2720	8290	12210
February 1984	0	4590	9300	14020
	1	2690	4570	7860
	2	3590	3660	7770
	4	3710	2300	6670
July 1984	Mean	12080	2560	15050

Soil samples were taken to a depth of 20 cm using a 4 cm diameter auger at drilling, at the end of February and in July at harvest. Migratory soil nematodes were extracted from a 200 ml subsample by a method based on Seinhorst (1955) and the extracts cleaned by centrifugation in sucrose (Coolen & d'Herde 1977).

Survey

Samples of soil and roots were taken from 47 fields of winter rape growing in three areas: South Lincolnshire, where vegetable brassicas but little sugar beet are grown; North Norfolk, where sugar beet but few vegetable brassicas are grown; Cambridgeshire and Huntingdonshire where both vegetable brassicas and sugar beet are grown. Cysts were extracted from soil by flotation (Trudgill *et al*. 1973) and *Pratylenchus* spp. were extracted from finely chopped roots in a modified Baermann funnel.

RESULTS

Field trial with cyst nematodes

The mean number of *H. cruciferae* in soil samples taken in-row on 25 April 1983 from plots receiving no aldicarb was 48 eggs/g soil. The first reproductive cycle of the nematode was probably complete by this time so the pre-planting population density was probably much less than that in April. Table 1 shows that additional nitrogen had no significant effect on yield or nematode multiplication but that aldicarb at 10 kg a.i./ha significantly increased yield (from 1.97 to 3.18 t/ha, P<0.001) and significantly decreased final nematode population (from 94 to 26 eggs/g soil, P<0.001). Yields and nematode multiplication in plots receiving aldicarb at 5 kg a.i./ha were also significantly different from the control and were intermediate in value between the control and the high rate of application.

Field trial with trichodorid nematodes

The total numbers of all plant parasitic nematodes in soil samples taken at drilling in September were 12 210/litre soil; this included 2720

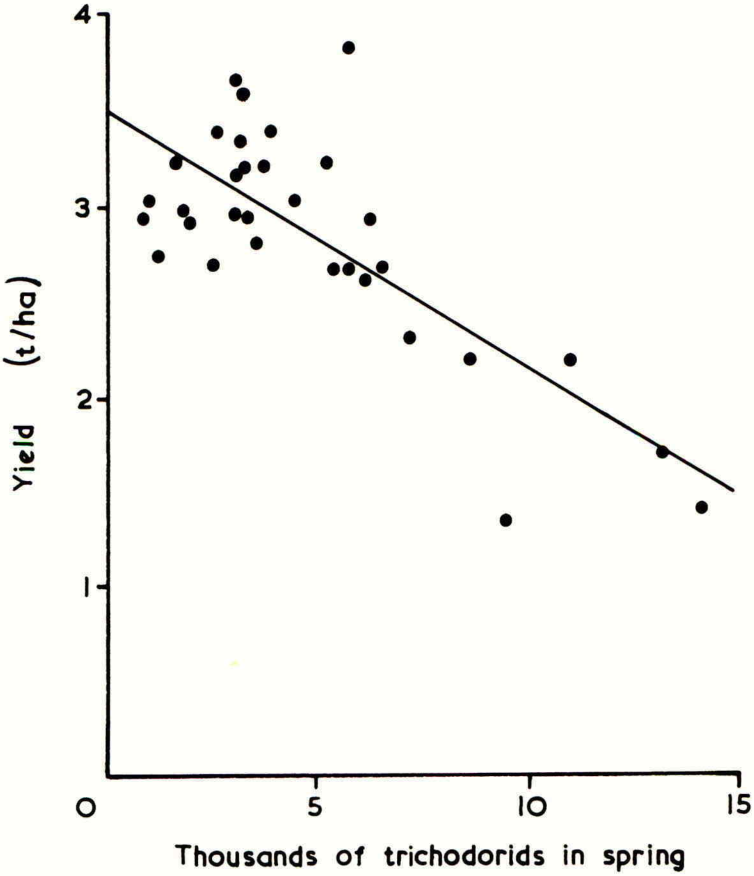

Fig. 1. Yield (t/ha) of winter oilseed rape in plots containing different numbers of trichodorid nematodes in spring, following application of oxamyl at drilling. (r = -0.7611).

Tylenchorhynchus/litre (mainly T. dubius), 730 Pratylenchus/litre, 7260 Trichodorus cylindricus/litre, 690 T. primitivus/litre and 340 Paratrichodorus teres/litre (total trichodorids 8290/litre or c. 70% of the plant parasitic nematodes see Table 2). By February, nematode numbers had declined on treated plots but, of the dominant genera, only the trichodorids showed a progressive reduction in numbers with increasing rate of nematicide (Table 2). Trichodorid numbers were smaller on plots receiving broadcast applications of oxamyl at 2 and 4 kg a.i./ha than on plots receiving in-row applications at the same rates, but Tylenchorhynchus numbers could not be related to the method of application. There was no significant difference between treatments at harvest. Tylenchorhynchus numbers increased on all plots during the trial but fewer trichodorids were extracted at harvest than at drilling. However, there had been a prolonged dry spell before harvest and these nematodes are particularly susceptible to drought (Wyss 1970).

Plant growth seemed better on treated plots throughout the year and assessments of growth stage in April showed that plants from treated plots were significantly ($P<0.001$) more advanced (GS 1.13) than those from untreated plots (GS 1.10). There were no differences in stage of development between rates of nematicide or methods of application. Results for seed yield were similar: there was no significant difference in yield between rates or methods of nematicide application, but treated areas yielded consistently more (mean of 3.0 t/ha) than untreated areas (mean of 2.3 t/ha).

Testing the regression of seed yield upon numbers of nematodes found in spring showed that total plant parasitic nematode numbers accounted for 49% of the variance, Tylenchorhynchus for none and trichodorids for 57%. The regression of yield against trichodorid numbers (Fig. 1) indicated a yield loss of 0.13 t/ha for every thousand trichodorids, with $r = -0.7611$ (significant at $P<0.001$).

Survey

The frequency with which fields had previously grown brassicas (hosts of H. cruciferae and H. schachtii) or sugar beet (a host for H. schachtii), reflected the traditional cropping of the three areas surveyed (Table 3). Surprisingly, no H. schachtii infestation and only one H. cruciferae infestation (34 eggs/g soil in April 1984) was found. Pratylenchus was found in 44 of 46 root samples and 10 samples contained more than 200 Pratylenchus per 5 g of root. No identification to species was made.

DISCUSSION

Cyst nematodes will almost complete their first reproductive cycle by December on a crop sown in late August/early September, as shown by data for H. schachtii (Jones 1983) and for H. cruciferae (Lewis 1971). Between December and the end of February development is very slow but speeds up again as the soil warms. Development rate is highly dependent on soil temperature but the first reproductive cycle will certainly be completed by April on a crop sown in early September. Treatment with nematicide in April would, therefore, control only the second generation of nematodes and would not lessen the damage done by the first, although it might allow the crop to compensate for the early damage. Despite the late application of aldicarb (22 April) in our trial there was a large yield response. However, the application rates used were much greater than those approved (eg 3.3 kg a.i./ha for control of potato cyst nematodes) and which are effective when efficient methods of mechanical incorporation are used.

No insect pests were found on the rape crops in the two field trials and the large proportion of variance accounted for by trichodorid nematodes in the regression of yield on nematode numbers suggests that these nematodes were the most important pests controlled by oxamyl application. The regression in Fig. 1 indicates a yield loss of about £35/ha/thousand trichodorids.

TABLE 3

Incidence of *Heterodera cruciferae*, *H. schachtii* and *Pratylenchus* in soil and plant samples taken from oilseed rape fields in three areas, 1984.

	South Lincolnshire	North Norfolk	Cambridgeshire and Huntingdonshire
Number of fields	20	18	9
Fields which had grown brassicas or oilseed rape previously	8	1	3
Fields which had grown sugar beet	1	14	6
Samples with *H. cruciferae*	1	0	0
Samples with *H. schachtii*	0	0	0
Samples with *Pratylenchus*	18	17	9
Crops with > 200 *Pratylenchus*/ 5 g root	5	3	2

The widespread occurrence of *Pratylenchus* species and the occasional high numbers in which they were found in plant roots probably means that they occasionally cause yield losses and may even cause visible stunting. However, we have no evidence to suggest that it would be worth controlling them with nematicides. Trichodorids are clearly capable of causing significant damage but only occur in large numbers in certain sandy soils. The main nematode threat to oilseed rape production in Great Britain must be that from cyst nematodes and the likelihood of significant yield losses occurring in the future must depend on whether the crop is grown in areas where its two main cyst nematode parasites are already established as field pests, although their indigenous distribution may be more extensive. The Wissington sugar factory area includes a number of H. schachtii infested farms and of 1649 sugarbeet growers approximately 80 grow both oilseed rape and sugar beet within the rotation; a further 50 farms that do not grow sugar beet do grow oilseed rape (J.H. Armstrong, personal communication). This means that c. 3000 ha of oilseed rape are grown in rotation with sugar beet and a further 2500 ha are grown within this factory area. The results of the potential for cyst nematode multiplication and spread will not be known for some time.

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LUTEOVIRUS INTERACTIONS BETWEEN OILSEED RAPE AND SUGAR BEET

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ABSTRACT

The relationships between the luteoviruses beet western yellows virus (BWYV) and beet mild yellowing virus (BMYV) are outlined.

Overwintered crops of oilseed rape have been found to be extensively infected with BWYV which is introduced to and spread within the crops in autumn by Myzus persicae.

BWYV has been transmitted from oilseed rape and from the common weed Capsella bursa-pastoris to sugar beet, although the low transmission rate would preclude oilseed rape as a major direct source of infection for the sugar-beet crop. The overlap in host ranges between strains of BWYV and BMYV is, however, likely to contribute to the survival of these viruses in the field.

M. persicae, the principal vector of the sugar-beet yellowing viruses, has been shown to overwinter on oilseed rape, producing winged forms in spring.

INTRODUCTION

The luteovirus group contains a number of economically important viruses, such as barley yellow dwarf virus (BYDV), potato leaf roll virus (PLRV), beet western yellows virus (BWYV), and beet mild yellowing virus (BMYV). The external symptoms are a secondary expression of phloem degeneration caused by these phloem-limited viruses, and tend to be less distinct than those caused by other viruses. Infected plants are usually stunted, leaves may show yellowing, reddening, brittleness or rolling. Environmental factors such as light and temperature affect symptom development; sugar beet infected with BWYV or BMYV develop more pronounced symptoms in bright sunlight, whilst low temperatures enhance the symptoms shown by oats infected with BYDV. All the viruses in this group have small, isometric particles, and have a circulative persistent relationship with their aphid vectors which enables them to be carried long distances.

The luteovirus BMYV was first identified as part of the sugar-beet virus yellows complex in England in 1955 (Russell 1958). In the United States of America radish yellows virus was described as a cause of yellowing in sugar-beet (Duffus 1960), and was subsequently re-named BWYV (Duffus 1961). The properties of BMYV and BWYV appear to be identical, except that the American strains of BWYV have much wider host ranges than the English BMYV (Duffus 1974).

In 1968, virus isolates from commercial crops of lettuce in England were identified as BWYV on the basis of host range and serological relationships but it was found that these isolates did not infect sugar-beet (Duffus & Russell 1970). BWYV has subsequently been identified in England on experimental field plots of sunflower (Russell *et al*. 1975), and on field plots of oilseed rape (Gilligan *et al*. 1980).

BWYV is therefore known to occur in England. This paper describes work in which it has been shown that overwintered commercial crops of oilseed rape are commonly infected with BWYV, that beet-infecting strains exist in oilseed rape, and that *Myzus persicae*, the principal vector of the sugar-beet yellowing viruses, can overwinter on oilseed rape crops.

METHODS

Enzyme-linked immunosorbent assay (ELISA)

A standard ELISA procedure (Clark & Adams 1977) was used to detect virus in oilseed rape leaves, using antiserum prepared to BMYV by Dr. D.A. Govier (Govier & Woods 1982).

Host-range studies

A strain of *M. persicae*, known to be an efficient vector of BMYV, was used in the transmission studies. Aphids were allowed to feed on infected plants for 3 days before being transferred in batches of 10 to test seedlings. After feeding for a further 3 days, they were killed by nicotine fumigation. Test plants were grown in aphid-proof glasshouses at temperatures of 20 - 25°C, and under a 16 hour photoperiod. Symptoms on *Capsella bursa-pastoris* and on *Montia perfoliata*, which are both indicator plants for BWYV and BMYV, were recorded after 5 weeks. Oilseed rape, sugar-beet and lettuce, which show no symptoms under glasshouse conditions, were tested by ELISA and by further transmission tests to *C. bursa-pastoris* and *M. perfoliata*.

RESULTS

Virus infection of oilseed rape

Plants collected from nine commercial crops of overwintered oilseed rape in spring 1982 were found to be infected with a virus which reacted positively in ELISA tests with antiserum to BMYV, and which gave symptoms when transmitted by *M. persicae* to the indicator plants *C. bursa-pastoris* and *M. perfoliata*. In a more detailed study random samples of 160 plants were collected from a commercial crop of oilseed rape in Suffolk at monthly intervals from October 1982 to April 1983 and tested by ELISA for this BMYV-related virus. Approximately 4% of the plants sampled in October were infected and this proportion rose to 40% in December, following an increase in numbers of *M. persicae* within the crop. A study of an experimental plot of oilseed rape at Broom's Barn Experimental Station from September 1983 to July 1984 showed a similar pattern of development of virus infection following invasion by *M. persicae*, with the proportion of plants infected rising to 90% by October.

During spring 1983, a survey of 80 autumn-sown oilseed rape crops in the eastern part of Great Britain from Essex to Aberdeenshire was carried out in co-operation with British Sugar Factory Agricultural Staff, ADAS regional pathologists, and North and East of Scotland Agricultural Colleges. The survey showed that, by testing 25 plants per field, virus was detected in 78 fields, implying a high generalised incidence of infection with a virus related to BMYV.

Preliminary analysis of data from a field trial in 1984 shows that seed yield may be decreased by 12% on plots with high incidence of virus infection compared with yield of those with low incidence.

Transmission studies with the luteovirus in oilseed rape

The BMYV-related virus in oilseed rape was transmitted by *M. persicae* from oilseed rape to lettuce (cv All The Year Round), to *C. bursa-pastoris* and to *M. perfoliata*, indicating that the virus was BWYV. When aphids were fed on infected oilseed rape plants and transferred to sugar-beet seedlings, approximately 10% of the seedlings became infected. A similar rate of transmission was obtained when sugar-beet infected with BMYV was used as a source of infection for oilseed rape seedlings. This low rate of transmission from oilseed rape to sugar-beet was reflected in a field trial in which less than 1% of sugar-beet plants inoculated at the 4 - 6 leaf stage with BWYV from oilseed rape developed symptoms by early September. When aphids were fed in the glasshouse on *C. bursa-pastoris* infected with BWYV and transferred to sugar-beet seedlings, approximately 40% of the seedlings became infected, indicating that BWYV could be transmitted more readily to sugar beet through *C. bursa-pastoris*.

Oilseed rape as an overwintering host for M. persicae

In the studies of virus infection in a commercial crop of oilseed rape during 1982/83, samples of 50 plants taken at monthly intervals were also searched for *M. persicae*. In October 1982, 30% of the plants sampled were infested, with an average of 1.7 *M. persicae* per plant. This proportion rose to 52% infestation in November, dropped to 4% by December, and did not increase in this crop the following spring, possibly because it had been sprayed with triazophos in April.

On a plot of oilseed rape at Broom's Barn Experimental Station, samples of plants were searched for *M. persicae* from September 1983 to July 1984. The proportion of plants infested with *M. persicae* increased from 1% in September to approximately 100% in October, when an average of 12 aphids per plant were found. Numbers of aphids declined during the winter, and by May only 6% plants were infested; numbers then increased, and in July 50% of plants were infested, with an average of 6 aphids per plant. Winged forms were first observed in June. Of the total number of *M. persicae* counted during June and July, 16% were winged forms.

These observations establish that *M. persicae* can overwinter on oilseed rape and produce winged forms in spring.

DISCUSSION

An important aspect of the research programme to improve control of sugar-beet virus yellows is a study of the overwintering hosts of viruses and vector. Surveys of the relative incidence of beet yellows virus (BYV) and BMYV within the sugar-beet root crop have been carried out by Broom's Barn Experimental Station in co-operation with British Sugar from 1981 to 1983. Although these were years of comparatively low virus yellows infection, field incidence varied from less than 1% to more than 75%; BMYV was the main cause of this yellowing and could be found in most crops. Several instances were recorded of sugar-beet fields heavily infected with BMYV growing close to oilseed rape crops found to be infected with BWYV. Transmission studies have shown that strains of BWYV in oilseed rape can infect sugar-beet, and that BWYV in C. bursa-pastoris, a common weed, can also be transmitted to sugar-beet. This overlap in host ranges of the closely related BWYV and BMYV must contribute to the widespread distribution of these viruses in the field, even though there seems to be little danger of much direct movement of BWYV from oilseed rape to sugar-beet.

The potential importance of oilseed rape as an overwintering host for M. persicae has long been recognised (Hull 1974). The studies reported in this paper have shown that M. persicae can overwinter on oilseed rape producing winged forms in spring; although many oilseed rape crops receive spray treatments such as phosalone or triazophos, which may in addition control aphids, unsprayed crops and volunteer or weed oilseed rape are overwintering hosts for M. persicae.

Evidence of virus infection of oilseed rape is beginning to accumulate. Outbreaks of cauliflower mosaic virus (CaMV) have been reported in 1984 (Gladders 1984); BWYV, CaMV and turnip mosaic virus have been found in experimental plots of oilseed rape at Rothamsted Experimental Station (C.J. Rawlinson pers.comm.). The studies reported in this paper have shown that M.persicae carry BWYV into oilseed rape crops at emergence in late summer, and then spread the virus rapidly and extensively within the crops. A preliminary trial on the effect of the virus on yield has indicated that there is a seed yield loss as a result of these high levels of infection; therefore further trials are needed to confirm the economic importance of this virus to the oilseed rape crop. In August and September of 1982 and 1983, the seasons during which these studies were carried out, exceptionally large numbers of M.persicae were caught in the 12.2 m suction trap operated at Broom's Barn Experimental Station for the Rothamsted Insect Survey. It may be that the natural incidence of BWYV in autumn-sown oilseed rape crops was unusually high in these two seasons, and information over a number of seasons is therefore required to determine annual fluctuations in levels of virus infection within the crops.

If the disease proves to be prevalent then control measures should be sought. Since the virus is introduced very early in the growth of the crop, the best prospects for control may be offered by the use of soil-incorporated granular insecticides rather than frequent spraying in September and October.

Since it has been shown that winged M.persicae can leave overwintered crops of oilseed rape in spring, the importance of the crop as a source of aphids for sugar beet and other crops, and the potential need to control this source, should be examined.

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BEET RHIZOMANIA DISEASE: THE PROBLEM IN EUROPE

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ABSTRACT

Rhizomania is a disease of sugar beet that is caused by beet necrotic yellow vein virus, the vector of which is the root-invading fungus *Polymyxa betae*. Since its first discovery in Italy in the 1950s the disease is developing in an increasing number of countries. Because rhizomania is so damaging, considerable research and experimentation has been undertaken; no practical solution has yet been found, but tolerant lines of beet gave promising results in France last year. In view of the threat that the disease presents various precautions can be taken to check its spread, and it is essential that beet growers and sugar manufacturers are sufficiently informed.

INTRODUCTION

Rhizomania is a new beet disease which is developing in an increasing number of countries. Because it is so damaging, producing a loss of both weight and sugar content up to 70%, the crop has to be abandoned on infested soils. Since it is infectious and contagious, various precautions can be taken to check its spread and it is essential that beet growers and sugar manufacturers are sufficiently informed. The search for efficient methods of controlling this disease is increasing rapidly in the countries concerned.

The disease is caused by beet necrotic yellow vein virus (BNYVV)(Tamada & Baba 1973), which is transmitted to the beet by a root-invading fungus, *Polymyxa betae* - an obligate parasite of the cells on the surface of the roots of the family Chenopodiaceae (Tamada *et al*. 1974). The fungus is also responsible for the long life of the virus in the soil; the virus persists in the resting spores (cystosori, "cysts": 4 microns diameter) of the fungus, with no apparent reduction in its virulence over 10 years in France and over 18 years in Japan.

In the presence of host plants, these cysts release flagellate zoospores which are the only ones which can infect the plant with the virus. In warm, moist conditions, development of the fungus is rapid and, within a few days, further zoospores spread the virus to other rootlets and beets. A longer life cycle leads to the production of resting spores which are confined to the rootlets. Decay of the rootlets releases the cysts into the soil volume that has been explored by the roots. *P. betae* is, in fact, found in most beet regions, even in northern ones (Dunning et al. 1984), but causes little or no damage as long as it does not combine with the virus.

SYMPTOMS

The beet usually appear normal during the early stages of growth, but subsequently growth slows down and wilting and senescence is accelerated during the hot summer months.

The leaf symptoms are rarely characteristic. When infection is slight or moderate, patches can be observed where the beet foliage is light green, more transparent and sometimes yellowing, upright and with long petioles; this type of symptom is particularly apparent towards the end of the harvesting period after rainfall or irrigation. In the event of an early and severe attack, in dry conditions, foliage can appear dark green but thinner and crinkled. In some cases, although extremely rarely, there is veinal yellowing and necrosis (a "tiger" appearance) as a result of the movement of the virus into the leaves.

The root symptoms are far more characteristic. When infection is severe, there is an unruly mass of fibrous roots giving a "salt and pepper", beard-like appearance around the storage root, which is usually constricted. A transverse or longitudinal cut shows the necrosis of the vascular rings at the root tip. A late attack may only affect secondary roots which become thickly covered with fibrous roots ("hairs") at the root tip, making them look something like a fox's tail.

All these symptoms, which are difficult to recognise during the early stages of infestation of the field, can remain unnoticed for a long time, giving rhizomania its deceptive nature.

However, with a good knowledge of the symptoms, a specialist can usually make a correct diagnosis. When in doubt, root samples are sent to laboratories where the virus can be detected. The ELISA test (Enzyme Linked Immuno Sorbent Assay), which is an immuno-chemical method suitable for testing many samples, is carried out in various countries using serum supplied by virology research stations.

FACTORS FAVOURING RHIZOMANIA

The development of rhizomania is favoured by: an excess of soil water due to irrigation, flooding, heavy summer rainfall, poor drainage, or soil compaction; high temperatures (20 to 25^{o}C in the soil); and a high pH (Kanzawa 1974a). Other factors include a short beet rotation, spinach growing, and the presence of Chenopodiaceous weeds which could act as a reservoir for the disease. Conditions in France in 1983, for example, were extremely favourable to rhizomania and help to explain why it has spread to such a considerable extent.

ORIGIN, SPREAD, DISSEMINATION

Rhizomania is becoming rife in more and more countries. Since it was first detected in Italy in the fifties (Canova 1959) it has spread extensively, viz. (in chronological order): 1964 Japan (Hokkaido), 1971 France (Alsace) (Putz & Vuittenez 1974), 1972 Yugoslavia and Greece, 1974 Germany F.R. (Hessen) (Hamdorf et al. 1977), 1977 France (southern Paris Basin), 1978 Czechoslovakia, 1979 Austria (the Danube Valley), Rumania and U.S.S.R., 1983 France (Picardy, Champagne), the Netherlands, Switzerland, Bulgaria and U.S.A. (California). It will always be difficult to know the real facts about its increasing incidence - has rhizomania spread from south to north in Europe, is there more because we are investigating and learning more about this disease from one year to the next, or are we discovering infestations which already existed but which had not developed because climatic conditions were unfavourable?

Several years of observation in both Germany F.R. and France have shown that the disease has spread from its initial source of infection and grown in area and intensity. The Gottingen Institute analysed 35 fields in Hessen in 1979 and 1982 and found that infestation had spread from 11 to 27 fields and, on average, the percentage of diseased beet per field had increased from 10% to 50% (Schaufele 1983). Every year in France the I.T.B. precisely maps out the infested fields in the south Paris communes: in Pithiviers, infested areas increased from 252 ha in 1978 to 800 ha in 1983; in Artenay from 200 ha in 1980 to 1 450 ha in 1983. In Greece, infested areas in the vicinity of the Larissa sugar factory rose from 1% in 1976 to 18% in 1982.

Spread of rhizomania must be caused by machinery used on contaminated land, and transportation of infested soil in other ways must also be suspect. The virus-infected fungal cysts are prevalent in the fine roots and contaminated soil. Thus spread can occur through erosion due to flood or wind, by animals, and on boots; it can also result from soil contamination of seeds which have been produced in infested areas (the virus is not directly transmitted by seeds).

However, major local dissemination is by farm machinery, the transportation of beet to the sugar factory, and the disposal of polluted effluents (water, soil and root particles) from the factory. The disease usually spreads fairly slowly (e.g. in France, 15% per year between 1978 and 1982) but this largely depends on climatic conditions; in a favourable year its spread can suddenly speed up (e.g. 50% in 1983 near Pithiviers in France).

INFESTED AREAS

Obviously the knowledge of infested areas can only be an approximation, and relatively accurate figures are available only for Germany F.R., Austria and France where, in 1983, 24 000 ha, 2 700 ha and 6 000 ha, respectively, were known to be infested. The total, which is probably underestimated, is now at least 50 000 ha in the 14 countries listed earlier in this paper.

Until very recently it was thought that rhizomania was limited to hot regions where there was an excess of temporary water (valley land liable to flood, high rainfall area, irrigation). It is now realised that the disease also develops in less characteristic conditions (plateau, and northern regions with no particular excess water). Climatic and soil conditions undoubtedly play an important part but it can no longer be assumed that rhizomania will be confined only to certain beet regions.

In view of these developments, the serious nature of the disease, and the lack of methods for controlling it, studies on rhizomania have become a major priority in several countries; this is particularly so in Germany F.R. and France, where considerable financial investment in research has been made.

POSSIBLE WAYS OF CONTROLLING THE DISEASE

Agronomic

Numerous field trials have been made in France and other countries to find ways of making conditions less suitable for the fungus, i.e. reducing irrigation, sub-soiling, soil cultivations, changing the fertilisation, reducing the pH, different drilling dates. None of these techniques cures the problem but they remain a means of decreasing the damage caused.

Positive results have been obtained by transplanting beet in paper pots (Table 1). They indicate that a delay in infection of a few weeks enables almost normal development of the beet. However, except in specific cases, this technique cannot be used generally because it is too expensive. These results should, nevertheless, encourage research into fungicides; if suitable ones can be found they would enable temporary and localised protection against the fungus vector in the early growth of the crop and hence improve yield, similar to that achieved by transplanting.

Chemical

The only satisfactory results obtained were by disinfection of the soil with methyl-bromide (Table 2); this destroyed the vector but the cost (over 30 000 francs/ha) and unavoidable reinfestation of the treated soil layer prohibits its use. Numerous fungicides have been tried; some revealed partial activity in controlled conditions (greenhouses) but no results were obtained in the field where soil conditions (composition, structure) were unfavourable.

TABLE 1

Effects of transplanting sugar beet on numbers of infested roots, sugar yield and root shape, Rougement (Loiret), France, 1981. (Heavily infested site).

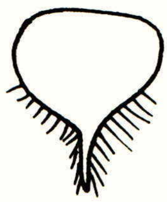
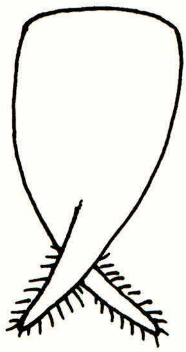
	Plots sown (21 April)	Plots transplanted (23 April)
Seriously infested roots	91%	8%
Sugar yield (t/ha)	2.64	5.64
Shape of root		

TABLE 2

Effects of soil disinfection in autumn 1978 on disease incidence and sugar yield in 1979 and 1981 at Rougemont (Loiret), France.

	1979		1981	
	% diseased roots	Sugar yield (t/ha)	% diseased roots	Sugar yield (t/ha)
Untreated control	77	2.12	99	4.51
DD (150 l/ha) (applied by Rumpstadt machine 11.10.78	18	4.19	95	5.52
Methyl bromide (900 kg/ha) (applied under plastic sheeting 25.10.78)	3	6.85	93	6.58

Breeding

In this field, selection really began in 1978 based on multigerm material of Italian origin which was tolerant to *Cercospora*. After slight amendments, this material gave tolerant hybrids which under strong infestation yielded 4 to 5 t sugar/ha, compared with less than 1 t/ha from the very susceptible varieties from north-west Europe.

From 1982 onwards, a diploid monogerm hybrid was selected with a tolerance level which proved far higher in tests carried out by I.T.B. in conditions of strong and homogenous infestation. In 1983, with the same seed, the results obtained (Table 3) surpassed all hopes, the sugar yield reaching 8 t/ha. In the absence of the disease, the potential yield can reach 90% of the most productive varieties. This variety could therefore be a temporary solution for the most highly infested regions from 1985 or 1986 onwards.

TABLE 3

Sugar yield (t/ha) of tolerant varieties in fields with different levels of rhizomania infestation (I.T.B., France. 1983).

Variety	Infestation level Very high (Erstein, Bas-Rhin)	Average (Rougement, Loiret)	None (Leouville, Eure et Loir)
SES IR1	8.0	8.6	10.2
Dora	2.3	6.0	10.6
Ritmo	3.7	6.9	8.9
Monosvalof	0.7	5.5	11.5

CURRENT RESEARCH IN EUROPE

Research is currently developing on a large scale in Europe, with the aim of improving our basic knowledge and seeking methods of controlling the disease. It is conducted by research institutes, professional technical bodies, breeders, and phytosanitary firms; the Pests and Diseases Group of the I.I.R.B. (Institut International de Recherches Betteravieres) are helping to co-ordinate some of this research.

Virology

Diagnostic techniques are being developed in the countries concerned, especially the ELISA test; virology institutes (Colmar in France, and Braunschweig in Germany) produce the necessary antiserum.

More specific possiblities are in progress: production of monoclonal antibodies (perfectly specific and continuously reproducible antibodies) in Austria and England, and production of DNA probes in Strasbourg (France) where molecular biology is studied.

The epidemiology of BNYVV is also being studied to determine the host range, to compare different strains or isolates, and to study the risk of transmission by the seed.

Mycology

The effect on the development of P. betae of soil temperature, humidity and pH, and the physical, chemical and biological nature of the soil, needs to be better understood. We hope to be able to measure the infection potential of the soil, which depends on the number of fungal cysts and the soil type (Kanzawa 1974b). This measuring technique, which entails soil dilution, should enable investigation of the effect any one technique has on the fungus, and the evaluation of how receptive the soil is to this fungus (perhaps some soils are suppressive?). This type of study is being done in Germany F.R. (Gottingen) and France (Dijon), and is being started in England.

There is also interest in the conditions for cyst germination: it is supposed that the roots of the beet exude substances into the soil which initiate germination and attract zoospores. This aspect is being studied in Nancy (France), and the work being done could result in the growth in vitro of the fungus; this would greatly facilitate its study and make a pure, standard inoculum available in large quantities.

Breeding for resistance or tolerance

In view of the results already obtained this must be given priority and sugar-beet breeders encouraged to work in infested fields - some are already doing so. However, breeders must be helped to avoid taking infection back to the research centre if this is located in a healthy area; this avoidance has been developed and practised in France since 1979 and will begin in Germany F.R. around a new research centre (Gross-Gerau) devoted especially to rhizomania. New origins of tolerance, other than the current ones, must be found, and it must be ensured that material is constantly improved and adapted to suit all the regions concerned.

Fungicides

Most existing products have already been tested and found to be ineffective or uneconomic in the field. New molecules must, therefore, be hoped for; these can only be produced by private companies and several of these are now aware of the problem. Fundamental research must provide rational methods for evaluation and screening, and specialised institutes must conduct experiments in the field.

Biological control

Some plants (Salsola sp., Chenopodium album) seem able to multiply the fungus without multiplying the virus. Such plants, if grown on infested soil, could perhaps be used as trap-plants to rid Polymyxa of virus infection (Vuittenez 1980). The use of bacteria which are Polymyxa antagonists is also being studied (Angers, INRA, France).

THE VALUE OF PROPHYLAXIS

In view of the rapid spread of rhizomania and its serious nature, precautionary measures should be taken to avoid contamination of healthy areas, which are fortunately still in the majority, and if possible to check the spread of the disease in areas already contaminated (Koch 1982).

Technicians and scientists all agree that spread is caused by movement of infested soil, beet, and factory waste. They also agree that no efficient measures can be proposed for the most contaminated areas. However, it is essential that we protect ourselves against spread of the disease to new areas, especially isolated ones. During autumn 1983 a list of measures was proposed in France (Putz & Richard-Molard 1984):

- the mapping of all contaminated fields.
- the destruction of limited infected areas in otherwise "clear" zones.
- lifting suspect plots only at the end of the beet harvesting season and transporting them using special, regularly-cleaned equipment.
- preventing infected beet factory waste being returned to the field, or disinfection of such waste.
- stopping beet growing in certain areas until technical solutions are available.
- requesting breeders to avoid seed multiplication in contaminated areas.

These measures must be accompanied by precautionary actions on crops in healthy areas, especially when they are near contaminated areas, but also in more distant regions to discourage any development of the disease, viz: avoid external contamination, lengthen rotation, avoid excess water by improved drainage and maintain good soil structure in order to favour soil drying, avoid field work in conditions which are too wet and cause compaction, and limit irrigation by only applying two-thirds of the soil water deficit.

CONCLUSION

Rhizomania is an extremely serious beet disease but research into possible methods of controlling it is now highly developed in many countries. There are good hopes of finding solutions but they have yet to become reality. In the meantime, it is essential that we know how to recognise the symptoms and make a diagnosis to enable the necessary preventive measures to be taken to check its spread.

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