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SURVEYS OF PEST INCIDENCE ON OIL-SEED RAPE IN THE U.K.

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Summary Surveys of insect pests of oil-seed rape in southern and eastern England from 1966 to 1975 have shown that *Meligethes aeneus* caused considerable damage to spring-sown crops but was much less important on winter rape. *Ceuthorhynchus assimilis* infestations were highest on farms where rape had been grown regularly for several years, and, on winter rape, tended to be more important on later-flowering crops. On some farms pod infestations exceeded 40%. *Dasyneura brassicae* was a major pest on some crops. However, on average, in both sothern and eastern counties, less than 1% of pods were infested. *Psylliodes chrysocephala*, although very local, was a major pest of winter rape on some farms in Buckinghamshire, Huntingdonshire and Northamptonshire. Other insect pests, including *Ceuthorhynchus quadridens* and *Brevicoryne brassicae*, were probably of minor importance.

Résumé Des enquêtes sur les insectes ravageurs du colza à travers le sud et l'est de l'Angleterre dès 1966 jusqu'à 1975 démontraient des déprédations assez importantes par *Meligethes aeneus* sur le colza de printemps d'une part, mais, d'autre part, beaucoup plus faible sur le colza d'hiver.

Les infestations les plus elevées du *Ceuthorhynchus assimilis* se situaient sur des exploitations où la culture continue de colza a eu lieu pendant plusieurs années consecutives, et, en ce qui concerne le colza d'hiver, à un niveau plus élevé en generale lorsque la floraison fut tandive. On a trouvé sur quelques exploitations des niveaux d'infestation des cosses excédent 40 pour cent.

Dasyneura brassicae a grièvement ravagé plusieurs cultures. Néanmoins, en moyenne, à travers le sud et l'est de l'Angleterre, moins d'un pour cent des cosses étaient parasitées.

Psylliodes chrysocephala, même si bien localisé, infestait a un niveau très important des cultures de colza d'hiver sur quelques exploitations dans les comtés dits "Buckinghamshire" et "Huntingdonshire".

D'autres insectes ravageurs, y-inclus *Ceuthorhynchus quadridens* et *Brevicoryne brassicae*, étaient, selon toute probabilité, de peu importance.

INTRODUCTION

In the United Kingdom oil-seed rape has been a useful break crop for many years, particularly in areas where potatoes and sugar beet are not extensively grown. Prior to 1966 there were no more than 1,000 to 1,300 ha of rape in this country but since then the importance and extent of the crop has increased dramatically. This change has been brought about largely by increases in the contract prices offered for rape seed (from about £40/t in 1967 to over £200/t in 1974) following our entry into the European Economic Community and the support provided by Intervention buying. In the last two years rape production has shown a particularly rapid increase, rising from about 7,000 ha in 1972 to over 24,500 ha in 1974.

On the Continent of Europe, oil-seed rape yields are often seriously affected by insect pests such as pollen beetle (*Meligethes aeneus*), seed weevil (*Ceuthorhynchus assimilis*) and brassica pod midge (*Dasyneura brassicae*) (Bonnemaison, 1951; Borg, 1952; Dmoch, 1965), but there are few available data on the abundance and importance of such pests on rape crops in this country. However, over the past few years A.D.A.S. entomologists have been monitoring pests of oil-seed rape crops in various parts of the U.K., and some of the results have recently been published (Gould, 1975). The present paper summarises further results of surveys on both spring and winter oil-seed rape crops, with particular reference to the situation in southern and eastern England.

METHODS

In East Anglia, during 1974, a survey was made of insect pests and pest damage in 68 fields of winter oil-seed rape and two fields of spring rape. Pest numbers were assessed by sampling with a sweep net (aperture diameter c. 35 cm), making ten consecutive net sweeps through the uppermost portion of the plants whilst advancing at walking pace. All sampling was carried out by the same observer, in the period between mid-morning and mid-afternoon, in warm, dry weather. No sampling was done in wet conditions. Estimates of insect abundance were made on headlands and towards the centre of fields during the bud and flowering stages of the crop. Incidences of pest damage were assessed on samples of plants collected just before harvest. Ten plants were taken at random from the centre and 5 from a headland of each field. These plants were later examined for signs of pest damage. In addition, 50 pods were taken at random from each sample of plants and examined in detail for evidence of seed weevil or pod midge attack.

Survey methods adopted in southern England are fully described elsewhere (Gould , 1975). These surveys have provided data for 227 fields of spring rape and 61 fields of winter rape, for the periods 1966 to 1968 and 1971 to 1974.

In addition to the formal surveys, a number of observations were made when other opportunities arose to examine oil-seed rape crops.

RESULTS

Pest damage incidences for 68 crops of winter rape surveyed in East Anglia during 1974 are summarised in Table 1. These data indicate that compared with physiological factors pollen beetle damage was relatively unimportant.

Table 1

Pest damage recorded on winter rape in East Anglia (1974)

(68 fields sampled)

	Mean	Range
% blind stalks due to pollen beetle	4	0 - 21
% blind stalks due to other factors	36	13 - 59
% pods damaged by seed weevil	10	0 - 43
% pods damaged by pod midge	2	0 - 9

During the bud and flowering stages, adult pollen beetles were almost always present in crops of winter rape in East Anglia during 1974. However, numbers were very low (averaging below 10 beetles/10 net sweeps) until mid-May, by which time the main flowering period, which commenced around mid-April, was almost over. At no time did populations exceed 63 beetles/10 net sweeps (highest weekly mean, 27 beetles/10 net sweeps).

The level of pollen beetle damage on spring rape varied according to weather conditions. For example, in Wiltshire and Gloucestershire the cool summer of 1974 resulted in an average pod loss of 6%, compared with 20% in 1973, and this was related to the numbers of adult beetles found on the crops in the two seasons.

Table 2

Pest damage recorded on rape in Wilts. and Glos. (1974)

(8 fields of winter rape & 36 fields of spring rape)

	Mean	Range
% blind stalks due to pollen beetle		
winter rape	4	0 - 16
spring rape	7	0 - 26
% pods damaged by seed weevil		
winter rape	35	9 - 67
spring rape	15	3 - 44
% pods damaged by pod midge		
winter rape	0	-
spring rape	0.5	0 - 7

Damage caused by seed weevil in East Anglia during 1974 was high on some farms (Table 1), but was even higher on some crops in the south (Table 2). In East Anglia adults were first found on 30 April and numbers reached a peak of 68 weevils/10 net sweeps about 3 weeks later (highest weekly mean, 10 weevils/10 net sweeps). Later-flowering winter rape crops tended to have more seed weevil damage than early-flowering crops ($P = 0.01$) (correlation coefficient $r = 0.55$) (Table 3). The two spring-sown crops sampled in East Anglia had 11 and 25% pod attack, both higher than the average for winter crops. Spring crops in the southern counties of England were on average less seriously damaged than winter rape crops (Table 2), but this difference was thought to be due to many of the spring sites being in areas relatively new to rape growing. Although highest seed weevil infestations tended to occur on farms or in areas where rape had been grown for many years (see Gould, 1975) a significant trend could not be established for East Anglia.

Table 3

Relationship between date of first flower and % pods attacked by seed weevil, East Anglia (1974)

(figures in parentheses exclude infestations below 10%)

Date of first flower	% pods attacked	
9 April 1974	18.0	(18.0)
10	9.6	(10.5)
13	10.5	(10.5)
14	10.6	(10.6)
15	5.5	(14.4)
16	9.1	(15.9)
18	12.5	(12.5)
20	19.5	(19.5)
23	23.3	(23.3)
24	15.3	(37.6)
25	18.6	(28.8)
4 May 1974	42.8	(42.8)

In East Anglia, brassica pod midge was generally only a minor cause of seed loss during 1974 (Table 1). Adult midges were first seen at the beginning of June, but they were never caught in large numbers. Pod midge is important on a small number of farms which have grown rape for many years. In 1975, for example, pod attack on one such farm in Bedfordshire averaged 26%. Few important infestations of pod midge were found on spring or winter rape crops in the south west or in south central England (Table 2).

Stem weevil (*Ceuthorhynchus quadridens*) was unimportant on winter rape, infested plants being virtually absent in all samples. However, unexpectedly high infestations were found on spring rape crops in southern England (Table 4).

Table 4

% stems of spring rape infested by stem weevil (1974)

	No. of fields	Mean	Range
Wiltshire	28	61	0 - 100
Gloucestershire	6	23	0 - 80

Small numbers of lepidopterous larvae, particularly flax tortrix moth (*Cnephasia interjectana*) and diamond-back moth (*Plutella xylostella*), were found on rape crops during the summer months, but they were never considered important.

Many crops were colonised by cabbage aphids (*Brevicoryne brassicae*). Infestations usually developed after flowering, but in 1975 spring-sown crops were frequently infested at the late yellow bud stage and control measures were necessary on some crops.

A survey of the distribution of the cabbage stem flea beetle *Psylliodes chrysocephala*) on winter rape in East Anglia during 1974-1975 failed to locate any infested crops in Essex, Hertfordshire, Norfolk or Suffolk, but several lightly attacked crops (maximum levels of 10% plant attack and 5 larvae/plant) were found in north west Bedfordshire, west Cambridgeshire and north Huntingdonshire. Highest infestations, some extremely severe with up to 100% plants attacked and 40 or more larvae/plant, were recorded from east and west Huntingdonshire. Elsewhere in England serious damage to winter rape was recorded from parts of Buckinghamshire (Graham, personal communication); the pest is also well established in Northamptonshire (Brock, personal communication).

Excluding standard gamma-BHC seed dressings for the control of seedling pests, surveys in 1974 indicated that in Wiltshire and Gloucestershire insecticides were applied to about 41% of rape crops; in East Anglia only 32% of crops were sprayed (Table 5).

Table 5

Pesticide usage on surveyed oil-seed rape fields (1974)

(35 fields in Wilts., 8 in Glos., 62 in East Anglia)

Treatment	No. of fields	
	Winter rape	Spring rape
Azinphos-methyl + demeton -S-methyl sulphone	12	0
BHC	6	8
Malathion	0	13
Phosalone	3	2
Others	1	6
Untreated	46 (68%)	8 (22%)
Treated once	13	27
Treated twice	2	2
Treated more than twice	7	0

Pest monitoring in East Anglia suggested that many rape crops were sprayed unnecessarily and a similar picture emerged in 1975. However, control measures were more frequently considered to have been justified in the south of the country. Most sprays were applied before flowering to control pollen beetle, seed weevil or brassica pod midge but, particularly on winter rape, where it was necessary to treat fields several times against weevil or midge some spraying during the flowering period, with some risk to pollinating insects, was unavoidable. Azinphos-methyl + demeton-S-methyl sulphone was the most widely used material in East Anglia, whereas crops in the south were mostly treated with malathion. As in previous years (Gould, 1975) gamma-BHC was also widely used on both spring and winter rape.

DISCUSSION

Pollen beetle is a common pest on rape crops in the United Kingdom, but it is usually only an important contributor to yield loss on spring-sown crops. Most serious damage is caused during the green to yellow bud stages, and winter rape is usually past the susceptible stage before large populations of adult pollen beetles invade the crop. Winter rape also has stronger bud bundles than spring rape and unless very backward will withstand far greater attacks without the need for insecticidal treatment. The generally accepted treatment threshold levels for adult pollen beetles at the susceptible bud stages are 20/plant for winter rape and 5/plant for spring rape, indicating the difference in importance of this pest to the two crops.

In the present surveys pod loss attributable to pollen beetle on winter rape was usually low and, compared with other factors leading to pod abortion (physiological damage, and perhaps herbicide damage or disease), comparatively insignificant. In assessing the importance of pollen beetle damage it should also be borne in mind that plants are likely to compensate to some extent for early pod loss (Winfield, 1961).

Seed weevil is a widely distributed pest in the U.K. and is at least potentially damaging to both winter and spring rape. In the surveys heaviest populations tended to occur on farms where rape had been grown for a number of years; the apparent absence of such a trend in East Anglia during 1974 was the result of an inevitable sample bias towards first or second-year growers and to the fact that in several 'new' rape areas sampled other host crops had probably been grown for many years.

Farms with the highest incidences of pod midge damage had all grown rape for many years, and until comparatively recently were virtually free from attack. This coupled with the generally low levels of pod midge damage found in the surveys, suggests that economically important populations of midge become established much more slowly than those of either pollen beetle or seed weevil.

Stem weevil, although widely distributed, has not been regarded as an important pest of rape in the U.K., although very high incidences of plant attack were found on spring rape in southern England. The economic significance of this pest is not clearly understood but it seems likely that any adverse effect on crop growth and vigour will only be important on young plants or where some other factor is also affecting the growth of the crop.

Few other insect pests of oil-seed rape appear to be important. Lepidopterous larvae were not found in sufficient numbers to cause economic damage, while the cabbage aphid although sometimes numerous, particularly on headlands, rarely seemed sufficiently serious to affect yields. However, damage assessment work on the effect of this pest, particularly on spring-sown rape, is considered desirable. The cabbage stem flea beetle is an important but local pest of winter rape, and on some farms in Buckinghamshire, Huntingdonshire and Northamptonshire it is regarded as a major contributory factor to yield loss. Fortunately, however, effective chemical control is possible and the pest is slow to spread from farm to farm.

Rape yields are affected by many factors other than pests, both before and during harvesting, and for this reason it is usually difficult to assess the extent to which they are limited by insects. The survey results show that the importance of pests such as pollen beetle and seed weevil varies considerably from farm to farm and from one area to another, and that at present control measures may be more frequently justified in south central England than in East Anglia. However, there are farms in all the major rape-growing areas which already have acute pest problems, particularly seed weevil, brassica pod midge or cabbage stem flea beetle, and it is logical to predict that insect pests such as these will become even more important in the future, particularly if rape continues to be grown intensively.

References

BONNEMAISON, L. (1951). Les ceuthorrhynques des cruciferes olegineuses. Phytoma 4, 6-10

BORG, A. (1952). Rapsvinelangrepp i Vastergoland. Vaxtskyddsnotiser, Stockholm 2, 23-26

DMOCH, J. (1965). The dynamics of a population of the cabbage seedpod weevil (*Ceuthorhynchus assimilis* (Payk.)) and the development of winter rape Part I-II. Ekologia Polska, Series A, 13, 249-287, 463-489.

GOULD, H. J. (1975). Surveys of pest incidence on oil-seed rape in south central England. Annals of Applied Biology 79, 19-26

WINFIELD, A. L. (1961). Studies on the relationship between three species of coleoptera and certain species of annual mustard and rape. Entomologia experimentalis et applicata 4, 123-132

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OIL SEED RAPE AND HONEYBEE POISONING

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Summary The increased cultivation of oil seed rape in England may result in greater pest problems and more insecticide applications, sometimes during flowering. The flowering crop is extremely attractive to foraging honeybees, and surveys of honeybee poisoning confirm that these applications present a serious hazard, which may be reduced by careful timing of treatments and the use of selective insecticides.

Résumé Une forte augmentation de la culture du colza en Angleterre pourrait agraver les problèmes du contrôle des ravageurs de cette culture au point qu'il soit necessaire de pulvériser même pendant la floraison. Le réglage judicieux des traitements et l'emploi d'insecticides selectifs devrait diminuer les risques que courrent les abbeilles qui butinnent les champs de colza en pleine floraison.

INTRODUCTION

Flowering oil seed rape is extremely attractive to many foraging insects including honeybees (*Apis mellifera*) which will visit crops up to several kilometres from their hives. The crop is also an attraction to beekeepers anxious to place their colonies to obtain the full benefit of the nectar flow. However, the varieties of oil seed rape presently grown in the United Kingdom give good yields without insect pollination (Free and Nuttall, 1968; Williams, personal communication). Because bees are likely to be present, spraying insecticides to control insect pests when the crop is in flower should be avoided. It should often be possible to control pollen beetle (*Meligethes aeneus*) and seed weevil (*Ceuthorhynchus assimilis*) by spray application before flowering. However, Alford and Gould (1975) state that "particularly on winter rape, where it was necessary to treat fields several times against weevil or midge, some spraying during the flowering period, with some risk to pollinating insects, was unavoidable".

Alford and Gould also point out that seed weevil and pod midge (*Dasyneura brassicae*) damage is heavier on farms where rape has been grown for many years, and that if rape continues to be grown intensively, insect pests and their control are likely to become even more important in the future. The hazard of insecticide spraying to foraging honeybees may therefore be expected to increase. This paper summarises recent surveys of honeybee poisoning resulting from spraying of oil seed rape.

METHOD AND MATERIALS

The incidence of honeybee poisoning by practical application of insecticides is investigated by examining samples of allegedly poisoned bees at Rothamsted. The samples and information about circumstances relating to them are collected by the Bee Advisory Unit of ADAS (Needham et al., 1966; Stevenson and Walker, 1974). The coverage is not completely comprehensive, but the scheme is probably now sufficiently well known among beekeepers to ensure that enough samples are received for the principal hazards to honeybees to be identified.

The acute toxicity of pesticides likely to be used where bees are at risk is determined in the laboratory (Stevenson, 1968; Anon., 1969). Experience has shown that these results provide a useful guide to the potential dangers of compounds when used under field conditions. Standard methods are also available for determining the toxicity of pesticide formulations applied under field conditions (Anon., 1973).

RESULTS

The total numbers of poisoning incidents verified by us and those definitely associated with spraying of field beans or oil seed rape are shown in Table 1. Investigations for 1975 are not yet complete, but the final figures will not differ substantially from those quoted. Also, only approximate figures for area of rape grown are available at the time of writing.

Table 1

Confirmed incidents of honeybee poisoning in Britain 1971-75 reported to the Bee Advisory Service and incidents attributed to spraying of field beans and oil seed rape

	1971	1972	1973	1974	1975*
Total bee poisoning incidents	40	43	41	87	64
Associated with field beans	3	19	21	35	2
Associated with oil seed rape	3	5	4	13	23
Area of rape grown (hectares)	5,100	6,900	13,700	24,500	c.40,000

*provisional figures

The comparison with field beans is made because the application of insecticides to this crop has been the principal cause of honeybee poisoning in England and Wales in recent years (Stevenson and Walker, 1974).

The acute laboratory toxicity of some insecticides used to spray oil seed rape is shown in Table 2 (Stevenson, 1968; and unpublished data).

Table 2

Acute laboratory toxicity of insecticides to honeybees

	Contact toxicity LD50 µg/bee	Oral toxicity LD50 µg/bee
Azinphos methyl	0.063	0.15
gamma BHC	0.46	0.45
Endosulfan	7.1	6.9
Fenitrothion	0.38	0.18
Malathion	0.27	0.38
*Phosalone	8.9	8.3

*Data provided by May and Baker Ltd.

DISCUSSION

The avoidance of honeybee poisoning

Crop pests can be controlled by insecticides without poisoning foraging honeybees either by ensuring that the insecticide does not contact the bees, or by using selective chemicals with low toxicity to honeybees. For pests of oil seed rape these objectives might be achieved as follows:

A. By keeping the insecticide and the foraging bees apart

1) Spraying before flowering. Pollen beetle should be controlled before flowering for maximum benefit. This is not always possible for seed weevil control, particularly on winter sown crops; but when it is, any of the insecticides listed in Table 2 can be used.

2) Avoiding unnecessary spraying. Alford and Gould (1975) report that pest monitoring in East Anglia suggested that many rape crops were sprayed unnecessarily in 1974 and 1975. Regular observations should be made in the crop and sprays should not be applied unless the pest levels reach the threshholds indicated by these authors. However, it might also be argued that, in areas where rape is grown intensively, it is prudent to spray routinely in the early years of rape growing in an effort to restrict pests to a low level and reduce the rate of build-up.

3) Spraying early or late in the day or in dull weather when bees are less active. In practice this often involves considerable organisational problems.

4) Closing bee hives during spraying. This involves close co-operation between beekeeper and farmer, and it is often not possible for the beekeeper to reach his colonies at the required times. In hot weather, closure and consequent inadequate ventilation can cause suffocation and total loss of the colony.

B. By using chemicals with low toxicity to honeybees

Table 2 shows the acute toxicity to honeybees of some insecticides used against oil seed rape pests. The figures suggest that azinphos-methyl, gamma-BHC and malathion would be much more damaging than endosulfan or phosalone. Field work confirmed that malathion and azinphos-methyl applied to flowering rape during foraging killed many bees, while endosulfan was very much safer (Needham and Stevenson, 1973). Our records of bee poisoning incidents confirm that gamma-BHC is dangerous.

Future trends

If the increased cultivation of oil seed rape in England leads to a build up of pests, more insecticide spraying will be necessary, and some application during the flowering period will be difficult or impossible to avoid. The data in Table 1 reflects a link between bee poisoning and area of rape cultivated, subject to the qualification that not all bee poisoning incidents are reported. The small numbers of incidents associated with field beans in 1971 and 1975 reflect the low *Aphis fabae* infestations in those years. In 1974, incidents involving treatments of oil seed rape were about a third of those involving field beans, but the average numbers of colonies affected per incident (14 compared with 8.6) was higher with oil seed rape and the extent of the colony damage was substantially greater.

The problem of honeybee poisoning as a result of oil seed rape spraying is therefore likely to grow. At present it seems that careful control of insecticide application and the use of selective compounds provide the best hopes for avoiding trouble.

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References

ALFORD, D.V. and GOULD, H.J. (1975) Surveys of pest incidence on oil seed rape in U.K. *Proceedings 8th British Insecticide and Fungicide Conference (1975)*

ANONYMOUS (1966) Laboratory testing of pesticide products for toxicity to honey bees, *Ministry of Agriculture, Fisheries and Food. Working Document No.13 to the Pesticides Safety Precaution Scheme*, 1-5.

ANONYMOUS (1973) Testing pesticide products for toxicity to foraging bees under field conditions, *Ministry of Agriculture, Fisheries and Food. Working Document No.15 to the Pesticides Safety Precaution Scheme*, 1-9

FREE, J.B. and NUTTALL, P.M. (1968) The pollination of oil seed rape (*Brassica napus*) and the behaviour of bees on the crop, *Journal of Agricultural Science*, *71*, 91-94.

NEEDHAM, P.H., SOLLY, S.R.B. and STEVENSON, J.H. (1966) Damage to honey bee colonies (*Apis mellifera*) by insecticides in Great Britain, 1956-65, *Journal of the Science of Food and Agriculture*, *17*, 133-137.

NEEDHAM, P.H. and STEVENSON, J.H. (1973) The toxicity to foraging honeybees, Apis mellifera, of endosulfan, malathion and azinphos-methyl applied to flowering oil seed rape, Brassica napus, Annals of Applied Biology, 75, 235-240.

STEVENSON, J.H. (1968) Laboratory studies on the acute contact and oral toxicities of insecticides to honeybees, Annals of Applied Biology, 61, 467-472.

STEVENSON, J.H. and WALKER, J. (1974) Bee poisoning by insecticides in Britain, Bee World, 55, 64-67.

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THE REACTION OF SOME OIL RAPE CULTIVARS TO SOME FUNGAL PATHOGENS

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Summary Resistance and susceptibility to the pathogens downy mildew (*Peronospora parasitica*) and light leaf spot (*Pyrenopeziza brassicae*) have been investigated using trials undertaken by the National Institute of Agricultural Botany (N.I.A.B.) to assess agronomic merit in winter oil rape cultivars. The following cultivars, which are on the UK National List, were resistant to downy mildew:- Eurora, Janetzki, Kubla, Lesira, Mogul, Primor, Rapol, Rapora and Sinus; susceptible cultivars were Argus, Hector, Sonnengold, Tonus and Victor. Similarly Sonnengold and Victor were resistant to light leaf spot, but Janetzki, Lesira, Primor and Rapora were moderately susceptible and Eurora very susceptible to the disease.

Résumé Resistance et sensibilite aux pathogenes mildiou des cruciferes (*Peronospora parasitica*) et tache legere des feuilles (*Pyrenopeziza brassicae*) ont ete examinees a l'aide des essais entrepris par l'Institut National de Botanique Agricole pour evaluer la valeur agronomique des varietes du colza d'hiver. Les varietes suivantes, qui etaient inscrites sur la Liste Nationale de la Grande Bretagne, etaient resistantes au mildiou des cruciferes: Eurora, Janetzki, Kubla, Lesira, Mogul, Primor, Rapol, Rapora et Sinus; les varietes sensibles etaient Argus, Hector, Sonnengold, Tonus et Victor. Sonnengold et Victor etaient resistantes a la tache legere des feuilles aussi, mais les varietes Janetzki, Lesira, Primor and Rapora etaient moyennement sensibles et Eurora etait tres sensible a la maladie.

INTRODUCTION

Oil rape has been a little grown crop in Britain but increased prices for vegetable oil products have induced many farmers to consider using the crop as a possible part of their rotations. This is especially so since it can be grown and harvested with the same equipment used for cereals, thus requiring little extra capital outlay. For the last 5 years at the National Institute of Agricultural Botany (NIAB) the merits of oil rape cultivars have been studied to indicate to farmers those which might be of greatest value. As with other *Brassica* crops, fungal diseases are likely to influence yields once large acreages are regularly grown. Because of its longer growing season the winter oil rape crop is possibly at greater risk than that sown in spring. Studies have been made at NIAB of pathogens occurring on winter sown crops, in particular results will be described in this paper for downy mildew (*Peronospora parasitica*) and light leaf spot (*Pyrenopeziza brassicae*), (*Gloeosporium concentricum*). Downy mildew has been studied in trials for 5 seasons at the NIAB Trialground, Cambridge. The disease is apparent from early November through to late March, this is while the plant is in the rosette stage. Symptoms occur as expanding chlorotic areas on the upper leaf surface while on the undersurface typical white mycelial fructifications grow from the stomata.

Light leaf spot has been studied for one season only on oil rape, although work has been in progress at NIAB for some years to study its effects on Brussels sprouts in south-western England. In the 1974-75 season a severe epidemic built up on winter oil rape and studies of cultivar reaction were made in performance trials at Cambridge and in southern England. Typical symptoms of the disease are the development of blanched areas generally on the upper surface of the foliage. These areas increase in size until the whole leaf withers; meanwhile concentric rings of acervuli erupt from the leaf surface, from which spores may be spread by rain splash. As the inflorescence expands the pathogen can spread to the pedicel, girdling it and causing it to wither before the flowers open.

METHOD AND MATERIALS

The trials used in this work were designed to evaluate the agronomic merit of oil rape cultivars submitted to NIAB for testing. Over the 5 year period of these trials techniques have varied considerably. Generally plot size was within the range 30-40m x 2.5-3.5m. Trials were either drilled into a prepared seedbed or direct drilled into the stubble of a preceding cereal crop in the latter part of August - first two weeks of September and each cultivar was replicated 4 times. Fertilizer was added either to the seed bed or placed with the seed at the rate of 20-30 units of nitrogen and 50-60 units of phosphate and potassium; a further 150 units of nitrogen were added in March just prior to expansion of the inflorescence. Herbicidal sprays were applied between November and February using either dalapon or carbetamide at 2kg a.i./ha. Pollen beetle (*Meligethes annus*) was controlled using DDT at 0.8kg a.i./ha or azinphosmethyl at 0.1 l a.i./ha in late April. Seed weevil (*Ceutorhynchus assimilis*) and stem weevil (*C. quadridens*) were controlled using gamma-BHC at 0.4 l a.i./ha, malathion at 0.8 l a.i./ha applied frequently as headland sprays in June.

Downy mildew was assessed by estimating the leaf area infected in five 30cm^2 quadrat samples in each plot. Assessment of the actual amount of infection is difficult since sporulation takes place on the lower leaf surface. It was found, however, that assessment of leaf chlorosis equated well with the area of sporulation on each leaf.

Light leaf spot was assessed by taking five single plant samples in each plot and estimating the percentage leaf area per plant showing any symptoms (ie leaf scorch, withering or sporulation caused by light leaf spot).

Assessments of downy mildew were made only at Cambridge, while those for light leaf spot were made at Cambridge and at three other sites in the NIAB Southern Region:- Overton, West Tisted and Bridget's Experimental Husbandry Farm.

RESULTS

Data for the resistance of winter oil rape cultivars to downy mildew are available for 5 seasons. These have been combined, as is standard NIAB practice, by the method of Doling (1965) to rate resistance to downy mildew on a 0-9 scale where 0 = susceptible and 9 = resistant (Table 1).

Table 1

Resistance of winter oil rape cultivars to downy mildew (*Peronospora parasitica*)

Cultivar	Resistance 0 - 9 scale*	Cultivar	Resistance 0 - 9 scale*
Argus	2	Primor	7
Eurora	8	Rapol	6
Hector	1	Rapora	6
Janetzki	7	Sinus	5
Kubla	5	Sonnengold	3
Lesira	5	Tonus	1
Mogul	5	Victor	2

* 0 = susceptible, 9 = resistant

One year's data only, are available for resistance to light leaf spot, these are shown in Table 2 as the mean percentage leaf area infected for the four sites investigated.

Table 2

Resistance of winter oil rape cultivars to light leaf spot (*Pyrenopeziza brassicae*)

Cultivar	% leaf area infected	Cultivar	% leaf area infected
Eurora	40	Primor	15
Janetzki	23	Rapora	19
Lesira	18	Sonnengold	6
		Victor	7

Standard error = 3.9
Significant difference (P = 0.1) = 11.1

DISCUSSION

These investigations have shown that there are sources of resistance to both downy mildew and light leaf spot available in commercial cultivars of oil rape. Of the cultivars which have so far been put on the UK National List, and can therefore be marketed in the UK, Eurora, Janetzki, Kubla, Lesira, Mogul, Primor, Rapol, Rapora and Sinus were resistant to downy mildew, while Argus, Hector, Sonnengold, Tonus and Victor were highly susceptible.

Sonnengold and Victor were resistant and Janetzki, Lesira, Primor and Rapora moderately susceptible to light leaf spot while Eurora was highly susceptible. The resistance in existing cultivars, could undoubtedly be used by breeders to produce even higher levels of resistance in future cultivars. Potential cultivars which have not yet been added to the National List and cannot therefore be marketed, have shown marked differences in their resistance to these two pathogens. Other diseases, particularly pod spot (*Alternaria brassicicola*) and powdery mildew (*Erysiphe sp.*) have been identified in NIAB trials but there has so far been little evidence of a range of cultivar resistance to them.

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References

Doling, D. A. D. (1965). A method for the transformation of field data for comparing the mildew resistance of cereal varieties and the systematic derivation of the values in NIAB Farmers' Leaflets. J.Natn. Inst. Agric. Bot. 10, 169-179.

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SOME OBSERVATIONS ON THE CONTROL OF CYLINDROSPORIUM CONCENTRICUM (GLOEOSPORIUM CONCENTRICUM), THE CAUSE OF LIGHT LEAF SPOT ON OIL SEED RAPE

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Summary Trials on the fungicidal control and effect on yield of light leaf spot in autumn sown oil seed rape crops were done in Warwickshire, Suffolk and Kent during 1975. Plots of infected plants were sprayed once, twice or four times at fortnightly intervals during April and May with benomyl, captafol, captan or maneb.

Neither one nor two applications of fungicide had an effect on disease incidence. Four benomyl sprays reduced both leaf and pod infection. Some reduction in pod infection followed four captafol or captan applications. No treatment significantly increased yield.

Observations on herbicide trials indicated a higher incidence of the disease in dalapon treated plots, compared with other herbicides, either alone or in combination.

Resume Des essais sur le contrôle fongicide de l'infestation par le *Cylindrosporium concentricum* (*Gloeosporium concentricum*) et l'effet sur le rendement des récoltes de terrains de colza semés l'automne ont été faits dans les comtés de Warwickshire, Suffolk et Kent pendant 1975. Les terrains de plantes infestées ont été pulvérisés un, deux ou quatre fois à des intervalles d'une quinzaine pendant la période d'avril à mai avec le bénomyle, le captafole, le captane ou le manèbe.

Ni un ni deux applications de fongicide n'ont pas eu d'effet sur l'indicence de l'infestation. Quatre pulvérisations de bénomyle ont reduit l'infestation tant des feuilles que des cosses. Une certaine réduction de l'infestation des cosses a suivi quatre applications de captafole ou de captane. Aucun traitement n'a produit d'augmentation signifiante du rendement.

Les observations sur les essais herbicides ont démontré une incidence plus élevée de l'infestation chez les terrains traités avec le dalapone, en comparaison avec neuf autres herbicides, soit seules ou en association.

INTRODUCTION

Light leaf spot known in the imperfect stage as Cylindrosporium concentricum Grev (syn Gloeosporium concentricum (Grev) Berk and Br) was first recorded on cabbage in Scotland in 1822 and has subsequently been found on other Brassicae crops in Britain including cauliflower, broccoli, Brussels sprouts and marrow stem kale. The disease, also recorded on cauliflower in New Zealand and cabbage, broccoli, and Brussels sprouts in Australia and Tasmania, is usually considered to be of minor importance.

In Ireland in 1964 and 1965 severe outbreaks of the disease in Brussels sprouts reduced yields by an estimated 60-65%. Fungicidal control was unsatisfactory (Staunton 1967).

During March and April 1975, autumn-sown oil seed rape crops in several parts of England showed leaf symptoms similar to those described by Hickman, Schofield and Taylor (1955) and were associated with the light leaf spot fungus. The disease was also associated with stem splitting, and was present on flower bracts, flowers and pods.

METHODS AND MATERIALS

Replicated plots at sites in Warwickshire, Kent and Suffolk were sprayed at intervals during April and May with benomyl, captafol, captan or maneb (Suffolk only), at 225 l/ha (20 gal/ac) and 500 l/ha (45 gal/ac) in Suffolk. Site details and the results are given in Tables 1, 2 and 3.

Light leaf spot was assessed on samples of at least 50 plants per plot (10 plants x 5 observation points) at intervals from early May using a key developed by the three authors.

0. No visible infection.

0.1 Trace of infection generally confined to lower leaves, one plant in 10 or fewer with lesions.

1. Some plants infected, often in small patches, but only one or 2 lesions/plant, generally on lower leaves, occasional bracts or flower buds affected.

2. Most plants affected with about 10% leaf area infected on lower leaves. Up to 5% infection on upper stem leaves and bracts. A low level of stem infection may be present.

3. About 20-25% of lower leaf area infected; infection frequent on bracts and stem leaves (with up to 10% area infected) and on flower buds.

4. About 50% of lower leaf area infected, about one in five bracts and stems infected or a mean of 20% leaf area infection. Over 10% stems show lesions and some inflorescences killed.

5. Approximately 75% lower leaf area and most bracts and stem leaves infected. Inflorescence and stem infection frequently present.

Pod infection was assessed on all pods of 10 random plants/plot in the Kent and Warwickshire experiments during July. Growth stages (GS) referred to are those developed by Berkenkamp (1973).

RESULTS

Fungicide trials

In Warwickshire (Table 1), foliar infection, which developed slowly during May, was not reduced by two applications of fungicides made in late April and early May. Pod infection was low and yield differences were not significant.

Table 1

Effect of fungicides on Light Leaf Spot infection and yield of Oil Seed Rape

Cultivar:- Lesira   Sown:- 28 August 1974   Sprays applied:- 23 April, 7 May 1975

Treatment	Rate (kg ai/ha)	Disease Assessments: Disease Index GS 3.2 (7 May)	Disease Index GS 4.1 (4 June)	Pod Infection (%) GS 4.3 (2 July)	Yield* t/ha (cwt/ac) at 85% dm
Benomyl	0.56	1.9	3.3	<1	2.92 (23.2)
Captan	1.10	1.9	3.5	<1	2.63 (20.9)
Captafol	1.40	2.0	3.7	<1	2.77 (22.1)
Control	-	2.1	3.3	<1	2.61 (20.8)
SE (Treatment Mean)		0.14	0.36		0.13

*Based on area harvested = 0.008 ha (0.02 ac) per plot

In Kent (Table 2), fungicides were applied four times. Benomyl reduced both leaf and pod infection, but captafol and captan reduced pod infection only. Yield and 1000 grain weight differences were not significant.

Table 2

Effect of fungicides on Light Leaf Spot infection and yield of Oil Seed Rape

Cultivar:- 'Lear'   Sown:- 15 September 1974
Sprays applied:- 3 April, 16 April, 30 April, 16 May 1975

Treatment	Rate (kg ai/ha)	Disease Assessments: Disease Index GS 3.2-3.3 (12 May)	Disease Index GS 3.4-4.0 (4 June)	Pod Infection** GS 4.5 (16 July)	Yield* t/ha (cwt/ac) at 91% dm	1000 grain wt (g)
Benomyl	0.56	1.5	1.3	2.8	3.82 (30.4)	4.57
Captan	1.10	2.5	2.5	4.2	2.96 (23.7)	4.78
Captafol	1.40	2.3	2.1	7.2	3.31 (26.4)	4.56
Control	-	2.7	3.3	15.8	3.22 (25.6)	4.76
SE (Treatment Mean)		0.27	0.11	2.2	0.51	

*Based on area harvested = 0.84 m^2 (1 yd^2) per plot
**Transformed data

In Suffolk (Table 3) 2 applications of fungicides did not significantly reduce foliar infection or increase yield, but the plots were severely infected by *Avena fatua* and *A ludoviciana*.

Table 3

Effect of fungicides on Light Leaf Spot infection and yield of Oil Seed Rape

Cultivar:- Mogul   Sown:- 10 September 1974   Sprays applied:- 23 April, 12 May 1975

Treatment	Rate (kg ai/ha)	Disease Index GS 3.2-3.3 (12 May)	GS 3.4-4.0 (20 May)	GS 4.1 (2 Jun)	GS 4.4 (23 Jun)	Yield* t/ha (cwt/ac) at 92% dm
Benomyl	0.28	2.3	1.5	2.9	4.3	1.87 (14.8)
Benomyl	0.56**	1.5	1.7	3.3	4.4	1.52 (12.1)
Maneb	1.80	3.0	2.4	3.5	4.4	1.58 (12.6)
Captafol	1.40	2.8	2.0	3.4	4.1	1.45 (11.6)
Captafol	2.80**	2.0	2.0	3.3	4.1	1.77 (14.1)
Control	-	2.8	2.3	4.2	4.9	1.97 (15.7)
SE (Treatment Mean)		0.57	0.69	0.41	0.25	0.28 (2.2)

*Based on area harvested = 3 x 1 m^2 (1.196 yd^2) per plot
** Sprayed once - 23 April

Herbicide trials

Observations made on replicated trials at Ousden, Suffolk, and Meldreth, Cambs, are given in Table 4.

Single applications of dalapon, early and late, at the high rate (2.86 kg ai/ha) and double applications at the low rate (1.43 kg ai/ha) were followed by significantly higher foliar infection in May. At the same time disease levels following other herbicide treatments were not significantly different from the control. However by the end of June disease indices were similar in all treatments.

In an unreplicated trial on cv Lesira in W Sussex, dalapon treated plots showed a slightly higher disease level (2.2) than other herbicides (1.4 to 1.8) and control plots (1.7) in late May.

Field observations made on crops in Warwickshire, Kent and Sussex suggested that the incidence of light leaf spot was higher in crops sprayed with dalapon compared with those sprayed with carbetamide, propyzamide, or no herbicide.

DISCUSSION

Disease development was unaffected by one or two applications of the fungicides but four benomyl sprays reduced both foliar and pod infection in one trial. Pod infection was also reduced by either four captafol or four captan sprays in the same trial. No fungicide treatment significantly increased yield, although the best yields were obtained with benomyl treatments in two of the trials. However all the fungicide trials were substantially affected with light leaf spot when spraying commenced.

Table 4

Herbicide Trial - Assessments of Light Leaf Spot

	Treatment	Rate (kg ai/ha)	Time applied	Disease Index GS 3.2-3.3 (12 May)	Disease Index GS 4.4 (23 Jun)	Yield t/ha	Time applied	Disease Index GS 3.1 (9 May)
		Site:- Suffolk cv:- Mogul					**Site:- Cambs cv:- Rapol**	
1	Dalapon	1.43	E	3.0	4.8	1.59	E	1.4
2	Dalapon	2.86	E	3.3	4.7	1.57	E	3.2
3	Dalapon + Dalapon	1.43 1.43	E L	4.0	5.0	1.10	E L	3.3
4	Dalapon	2.86	L	3.7	5.0	1.38	L	2.5
5	Dalapon + Carbetamide	1.43 1.37	L L	3.0	4.8	1.63	L L	1.0
6	Dalapon + Propyzamide	1.43 0.42	L L	3.0	4.5	2.07	L L	2.0
7	Carbetamide	2.1	L	2.3	4.7	1.82	L	1.0
8	Propyzamide	0.7	L	1.7	4.2	2.35	L	1.2
9	Propyzamide + Diuron	0.7 0.11	L L	2.3	4.5	2.03	L L	0.3
10	Dalapon + Benazolin	1.43 0.7	E XL	2.7	4.5	1.53	E L	1.1
11	Carbetamide + Benazolin	1.37 0.7	L XL	1.3	4.0	2.05	L L	1.9
12	Propyzamide + Benazolin	0.42 0.7	L XL	1.3	4.2	2.00	L L	1.1
13	Carbetamide + RP 23465	1.5 0.75	L L	2.0	4.3	2.22	L L	0.3
14	Control 1	-	-	2.3	4.7	1.57		0.3
15	Control 2	-	-	2.0	4.3			1.5
	SE (Treatment Mean)			0.37	0.19			0.58

E = 7/11/74 (Suffolk) 24/10/74 (Cambs)

L = 6/12/74 (Suffolk) 3/12/74 (Cambs)

XL = 9/1/75 (Suffolk)

Observations on a W Sussex farmer-sprayed trial with carbendazim and captafol showed some reduction in the disease, but no yield data was obtained.

No evidence was found that the disease was seed-borne, and the reason for the high incidence of light leaf spot this year is not clear although the mild winter often with wet periods may have been a significant factor. The effect of herbicide applications on the incidence of this disease requires further study.

At present it is not known whether this disease will be a problem on oil seed rape but crops should be examined regularly during winter and early spring. In future trials it is suggested that fungicides be applied before, or as soon as, the first signs of the disease are observed.

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References

BERKENKAMP, B. (1973) A Growth-stage key for Rape, Canadian Journal of Plant Science, 53, 413

HICKMAN, C.J., SCHOFIELD, ELIZABETH R. & TAYLOR, R.E. (1955) Light Leaf Spot of Brassicae, Plant Pathology, 4, 129-131

STAUNTON, W.P. (1967) Studies of Light Leaf Spot (Gloeosporium concentricum) of Brassicae, Irish Journal of Agricultural Research, 6, 203-211

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EFFECTIVENESS OF SOIL APPLIED INSECTICIDES ON MAIZE SOIL INSECTS

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Summary The need for alternative insecticides as substitutes for organochlorines, has led us to evaluate a number of new pesticides as soil treatments for the protection of young maize plants against soil insects. The performance of the pesticides was assessed 34 and 64 days after application on the basis of (a) the number of emerged plants and (b) the number of emerged plants in relation to the number of the expected ones and the extent of their development. Terbuthioate and chlormephos were found the most effective with adequate residual action, while phorate and fonofos were effective at 34 days but unsatisfactory at 64 days. Prophos and AG chlordane did not give statistically significant control.

INTRODUCTION

Soil insects, particularly wireworms, have been controlled successfully in Greece by organochlorine insecticides and only limited investigational work has been carried out on these insects in recent years.

In Greece restrictions on the use of organochlorines on certain crops were imposed the end of 1968. Since March 1972 a more complete prohibition of persistent agricultural chemicals was enacted to conform with the regulations of importing countries, as well as to safeguard and to protect our environment. Of the organochlorines, only the use of lindane and endosulfan is allowed.

In view of these developments wireworms may again become important pests and every opportunity should be taken to screen new materials against soil insects in order to find suitable alternative and improved methods of application.

Field trials carried out by Griffiths and Scott (1965) with newer pesticides were inconclusive. Gair (1971) reported that a number of insecticides such as trichlorphon, fenitrothion, tetrachlorvinphos and methiocarb give excellent in vitro results against soil pests, but field trials are often disappointing and suggest that we are faced with problems of how to apply the alternatives effectively. The importance of the method of application was also underlined by Read (1971) in studies with trichloronate.

The method of assessment of the performance of soil chemicals is critical, especially when experiments are carried out under conditions of moderate natural infestation. The establisment of a suitable method helps not only in obtaining a clear picture of the results achieved but also in comparing results of related studies carried out by other workers. The performance of the treatments in field experiments with maize has been evaluated by different workers on the basis of various parameters, namely the number of surviving plants (Maceljski, 1973; Kovacs et al, 1973), the extent of root damage and the percentage of lodged plants at harvest (Hills and Peters, 1972), the rate of growth, the ultimate height of the plants and the yield of grain, as reviewed by Furness (1971).

In the present study we evaluated the comparative effectiveness of newer soil applied insecticides for the protection of spring sown maize. Special attention was given to the method of assessment of insecticide performance under moderate natural infestation and other conditions prevailing during the experiment.

METHOD AND MATERIALS

The trial was done in a field situated in Aliartos (Central Greece) with a clay soil of bulk density 1.20 g/cm^3 (clay 47%, silt 37%, sand 16%, organic matter 7.6%). The pH was 7.9 and water capacity 57%; total base exchange capacity 49.2 meq/100 and electroconductivity < 3 (EC x 10^3, 25 $^\circ$C).

A randomised block design was used with a 2 m wide band between the blocks. Plots were 24 m^2 separated by a 1.5 m untreated strip and each plot consisted of 5 rows 0.75 m apart with groups of 4 seeds spaced at 0.5 m and planted at a depth of 3 cm. No thinning was done after emergence and all observations were made on the middle 3 rows of each plot. All treatments were replicated 3 times except for the control which was replicated 6 times.

Details of treatments and application rates are shown in Table I. The organochlorine AG chlordane contained 95% of octachloro-4,7-methanotetrahydroindane as a mixture of two isomers, 70% cis or α-isomer and 25% trans or γ-isomer.

Table I

Treatments and rates of application

Pesticides	Formulation	Rate (Kg a.i./ha)
phorate	10% granules	5.0
terbuthioate*	5% "	4.0
fonofos	10% "	4.0
chlormephos	5% "	4.0
prophos	10% "	2.5
AG chlordane	48% e.c.	6.0

*Suggested common name for S-(tert-butylthio)methyl 0,0-diethyl phosphorodithioate.

All treatments were applied as broadcast applications. The granular pesticides were distributed by hand with about 2 kg of fine soil per plot and the chlordane was applied as a spray in 480 ml of water per plot (200 l/ha). The pesticides were incorporated into the soil to a depth of 5 cm by harrowing in 2 directions with a spike-tooth harrow.

The performance of the treatments was assessed by using two parameters, recording the number of emerged plants and the degree of development 34 and

64 days after treatment and sowing (2nd May).

As the number of seeds in the three rows of each plot was known (204 seeds), the mean number of emerged plants could be expressed as a percentage of the expected maximum (204).

Degree of development was assessed in the field by assigning a visual rating of 0 to 5 to each plant, with 0 indicating a complete lack of plant emergence and 5 maximum development (about 0.50 m in the first observation and I.50 m in the second).

The percentage effectiveness of the chemicals was expressed by using the formula of Townsend and Heuberger (I943):

$$P = \frac{\text{Sum of } (n \times v)}{Z \times N} \times 100$$

Where, n= number of groups in each category, v= numerical value of each category, N= total number of expected plants, Z= value of the higher degree of development (i.e. 5).

The mean number of plants in treated and control plots and the mean percentage effectiveness of the treatments were tested according to Duncan's multiple range test at the 5% level of significance.

RESULTS

The number of plants emerged in plots treated with phorate, terbuthioate and chlormephos was significantly higher (P=0.05), than in untreated control plots, both 34 and 64 days after application (Table 2). Results with fonofos were significantly higher than the control only in the observations made after 34 days.

Table 2

Emerged plants 34 and 64 days after application

Treatment	34 days		64 days	
	Number of plants*	Emerged % of expected	Number of plants*	Emerged % of expected
phorate	I81.3 a	88.9	I71.0 a	83.8
terbuthioate	I76.3 ab	88.0	I73.6 a	85.I
fonofos	I75.3 ab	85.9	I66.6 ab	8I.7
chlormephos	I74.3 ab	85.4	I74.3 a	85.4
prophos	I60.0 bc	78.4	I56.0 abc	76.5
AG chlordane	I52.7 c	74.8	I4I.3 c	69.3
Untreated	I44.3 c	70.7	I42.2 bc	69.6

*Means of 3 replicates for all chemicals and of 6 for the control

In plots treated with pesticides which offered a good protection to young maize plants, there was, as expected, a higher number of groups with 3-4 plants, both 34 and 64 days after application, compared to less effective chemicals and the untreated controls (Fig. I). The slight decrease of the number of groups with 3-4 plants after 64 days in all pesticides except chlormephos, possibly suggests a phytotoxic action of the pesticides rather than a continuation of the action of soil pests, since the number of the above mentioned groups of plants in the control remained the same.

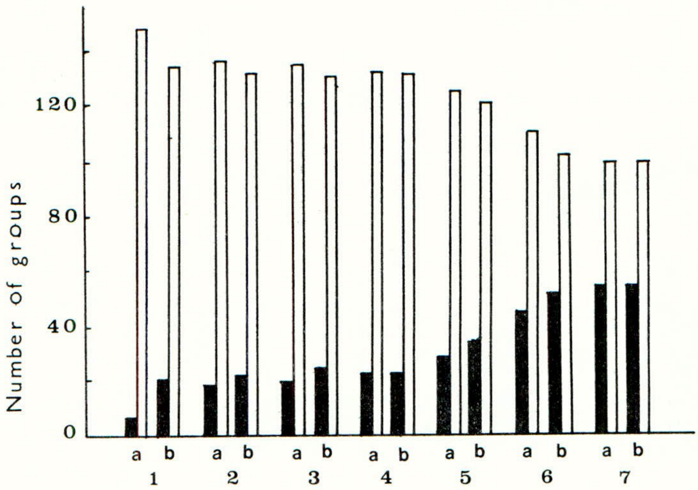

Fig. I Number of groups with 0-2 and 3-4 plants/group, per chemical and observation (total of 3 replicates).

groups with 0-2 plants
" " 3-4 "
a, Ist observation (34 days)
b, 2nd observation (64 days)

I, phorate 2, terbuthioate
3, fonofos 4, chlormephos
5, prophos 6, AG chlordane
7, Untreated

The effectiveness of the treatments (estimated with the above mentioned formula) is shown in Table 3. Chlormephos and terbuthioate appeared to be effective throughout the period of the test, whereas phorate and fonofos were effective only up to 34 days after application.

Table 3

Percentage effectiveness of pesticides assessed with the Townsend and Heuberger formula

Chemical	Days after application 34	64
chlormephos	50.6 a	50.7 a
terbuthioate	49.8 a	50.3 a
phorate	47.0 ab	43.I ab
fonofos	45.6 ab	43.6 ab
prophos	39.6 abc	4I.6 ab
AG chlordane	37.0 bc	33.8 b
Untreated	3I.8 c	33.4 b

There was no plant competition, influencing the rate of development. As can be seen in Fig. 2, the mean degree of development in groups with 3-4 plants was not inferior to the degree of development in the case of groups with I-2 plants. This suggests that in groups with few surviving plants, the action of soil pests also influenced the development of the remaining plants. In other groups the absence of soil pests was underlined not only by the higher number of plants but also by the higher degree of their development.

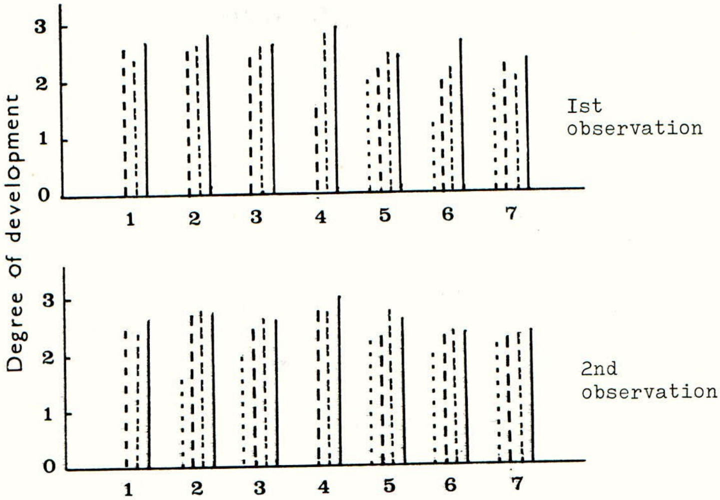

Fig. 2 Mean degree of development according to the number of plants/group

Development with I plant .... , 2 plants - - - , 3 plants - - - and 4 plants ——— per group; I-7: see footnote Fig. I.

DISCUSSION

Observations were confined to young maize plants. The action of soil pests on young plants is more apparent and there is usually no additional attack by other non soil pests in this stage. Up to the end of observations no folliage or stem attack by pests appeared on the plants in this experiment

The number of emerged plants and the degree of their development seems to be two parameters which alone or properly correlated can give a picture of the protection given by pesticides against soil pests.

The emerged plants were expressed as a percentage of the number of seed sown, both in the control and in the treated plots. This assessment in the control gives some information about the level of attack and therefore the results can be better evaluated. The method used by other workers to express the number of plants in the control as IOO and the number in treated plots as > IOO, does not give this picture. However the latter method has to be used where the number of seeds or expected plants is not known.

The Townsend and Heuberger formula, used so far mainly for the assessment of fungicidal action, also seems to give a picture of the effectiveness of soil applied chemicals.

As emphasized by Wheatley (I97I), there is a strong tendency to blame the present problems on the inadequacies of the "new generation" of chemicals. These do not have the innate capacity for protecting crops by means of a single application. However it is also recognized that this very characteristic of the organochlorine pesticides (i.e. persistence) which enhanced their performance was at the same time one of the principal reasons for their downfall. Seeking greater stability in chemicals in order to prolong the protection of our crops from pests is unlikely to be an acceptable cure for present problems. The solution at the moment seems to be in more skillful application of the available knowledge on pest ecology and in more judicious use of available insecticides.

Under the conditions of moderate natural infestation in this trial, terbuthioate and chlormephos proved statistically better than the control. The good results given by phorate and fonofos 34 days after application did not last after 64 days. This possibly is an indication of a shorter residual action of these chemicals.

All chemicals studied, except chlormephos, showed indications of phytotoxicity 64 days after application. This point may need more attention in experiments with newer insecticides applied in the soil, even under the recommended doses.

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References

FURNESS, W. (1971) Properties of chlordane which justify new experiments with the alpha- and gamma-isomers. Proc. 6th Br. Insectic. Fungic. Conf. 541-546

GAIR, R. (1971) Organochlorine alternatives- A review of the present position in the UK. Proc. 6th Br. Insectic. Fungic. Conf., 765-770

GRIFFITHS, D. C. and SCOTT, G. C. (1965) Some tests on organophosphorus and carbamate insecticides for the control of wireworm and wheat bulb fly. Proc. 3rd Br. Insectic. Fungic. Conf., 190-193

HILLS, T. M. and PETERS, D. C. (1972) Methods of applying insecticides for controlling western corn rootworm larvae. J. Econ. Entomol., 65, 1714-18

KOVACS, A. I., MAINI, P. and FURNESS, W. (1973) AG chlordane as soil insecticide, residues in sugar beet, maize, potato, carrot and soil. Proc. 7th Int. Velsicol Symp.

MACELJSKI, M. (1973) Problems of suppression of soil insects after prohibition of the use of chlorinated hydrocarbons. 4th Balkan Conf. on Plant Protection (Athens)

READ, D. C. (1971) Bioactivity and persistence of some new insecticides in a mineral soil. J.Econ. Entomol., 64, 800-804

TOWNSEND, G. R. and HEUBERGER, I. W. (1943) Methods for estimating losses caused by diseases in fungicide experiments. Plant Disease Reporter, 27, 340-343

WHEATLEY, G. A. (1971) Pest control in vegetables: Some further limitations in insecticides for cabbage root fly and carrot fly control. Proc. 6th Br. Insectic. Fungic. Conf., 386-395

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OBSERVATIONS ON MAIZE DISEASES IN SOUTH-EAST BRITAIN

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Summary Fusarium culmorum was found to be pathogenic to maize. In a two year survey this was the most widely distributed pathogen and was responsible for reductions of up to 16% in 1,000 grain weight and 21% in grain weight per plant. The survey data suggested that stalk rot was more severe in second or subsequent crops.

Résumé F culmorum a été trouver comme pathogen du maïs. Dans un examen il y a deux ans, ce pathogen a été responsable pour les reductions de 16% dans mille grains de poids et 21% en poids de grain per plante.

Les résultats ont indiqués que les pourritures de tiges ont été plus sevères dans la deuxième récolte que dans la première recolte.

INTRODUCTION

About 50 fungal diseases of maize have been reported (Anon 1973) but the stalk rot pathogens are the most widely distributed and are of greatest economic importance.

In the United States yield losses of up to 25% have been reported as a result of stalk rot caused by Diplodia zeae and Fusarium spp but the mean loss is usually about 7.5% (Christensen and Wilcoxson, 1966). In Europe where D. zeae has not been recorded, Rintelen, 1967, reports that bushel weights and dry cob weights can be reduced by up to 21% and that the dry weight of aerial parts of affected plants can be reduced by up to 40%.

Fusarium culmorum is the most widely distributed stalk rot pathogen and this is the most common in Britain (Cook, 1973). To demonstrate the pathogenicity of this fungus to maize, pathogenicity tests were made on two hybrids. Trials using seed treatment and fungicide drenches were conducted to compare the effect of the available seed treatments on crop emergence and to observe the effect of benomyl drenches on stalk rot development. A survey was also made to assess the distribution of stalk rot and other pathogens and to obtain information on the yield losses caused by stalk rot.

PATHOGENICITY OF FUSARIUM CULMORUM TO TWO MAIZE HYBRIDS

Twenty-four plants each of Anjou 210 and Kelvedon 59A, noted respectively for their tolerance and susceptibility to stalk rot, were grown under glass in 25 cm pots. When 75% of the plants had silked (114 days after sowing) half of the plants of each hybrid were inoculated with a spore suspension of Fusarium culmorum.

The inoculum used in the trial had been obtained four months earlier from diseased maize plants and was maintained and bulked on potato dextrose agar (PDA). The spore suspension was made by washing the surface of 14 day old cultures with 10 ml sterile distilled water and bulking the suspensions. Each plant was inoculated by injecting 1 ml of the spore suspension into the lowest internode with a hypodermic syringe. Immediately before inoculation a hole was made with a sterile needle to facilitate entry of the syringe needle. Control plants were inoculated with 1 ml sterile distilled water using the same technique. Lesion development was assessed 58 days later, by splitting stems longitudinally and estimating pith necrosis in the inoculated internode according to a 0-6 scale devised by Foley, 1960.

In each of the inoculated plants oval-elongate dark chocolate brown lesions had developed within the pith of the inoculated internode. Staining of the vascular tissue above and below the point of inoculation was visible in several of the plants. The mean infection rating of the two hybrids is shown in Table 1. Lesion development was substantially greater in plants of the stalk rot susceptible hybrid Kelvedon 59A.

Table 1
Stalk rot pathogenicity test

Hybrid	Infection index	
	Inoculated	Uninoculated
Anjou 210	2.5	0.2
Kelvedon 59A	3.5	1.0

CHEMICAL CONTROL TRIALS 1972

Seed Treatments

The effect of a range of seed treatment chemicals on crop emergence was compared. The trial comprised single row plots 20 m long with 20 cm between plants and 76 cm between rows. Each treatment was replicated six times. Seed was sown with a standard maize drill, cleaned between treatments. Treatments were applied to seed of Cargill Primeur 170 by mixing seed and pesticide for 10 min. in 0.5 l. conical flasks with 2 ml 4% methyl cellulose as a sticker. The final emergence count was made 85 days after drilling (Table 2). Thiram, captan and benomyl increased the stand significantly (P = 0.05).

Table 2
Seed treatment trial - rate of application and emergence

Treatment	Rate/100 kg seed (g)	emergence (plants/row)	% germination (OSTS test)
Captan, 75%	276	108.5	98
Benomyl, 50%	276	111.7	99
Benomyl, 30% + thiram, 30%	334	121.7	96
Organo-mercury, 1.5% mercury	276	95.0	98
Thiram 50%	223	123.0	99
Gamma-BHC, 80%	140	67.7	2*
Dimethoate, 40% w/v	56 ml	37.2	21**
Methiocarb, 50%	1000	105.8	97
Commercial treatment (captan + anthraquinone)	-	118.7	98
Untreated	-	93.3	99
SED		± 5.40	-

* 80 abnormal seedlings
** 4 abnormal seedlings

Drench treatments

Benomyl was applied to the hybrid Cargill Primeur 170 either as a single drench in early September or as a double treatment applied in early and late September. 9 l. of 0.05% benomyl was applied to each 20 m of row as a drenching spray to the plant bases in a randomised block with three replicates. Stalk rot assessments were made on 13 November and cobs were collected from 10 healthy and 10 stalk rot infected plants in each plot. The results (Table 3) suggest that cobs on diseased plants are lighter than those on healthy plants, following drench treatment.

Table 3

Effect of benomyl drenches on cob weight of maize

Treatment	Cob weight (kg) Mean dry wt 10 cobs healthy	diseased
Single drench	5.5	5.0
Double drench	5.9	5.0
Control	5.1	5.1

SURVEY

During October 1973 and 1974, 30 and 23 maize crops respectively were examined to record the incidence of diseases in Essex, Kent, Surrey and Sussex. Diseases were assessed when crops were in the dough or just denting stages, growth stage 9.2-9.3 (Hanway, 1966) or 85-87 (Zadoks, 1974), by recording disease infection in five random 50 plant lengths of row in each field. Stalk rot infection was assessed by visual symptoms or by squeezing the lowest internode between thumb and forefinger. Samples of plants showing stalk rot were returned to the laboratory and the bottom nodes were plated on PDA.

(i) Stalk Rot

The range of fungi isolated from the basal nodes of plants with stalk rot symptoms is shown in Table 4 and the percentage of plants infected with stalk rot is shown in Table 5. (This table includes data from ADAS/NIAB trial sites).

Table 4

Number of stalk rot samples from which each fungus was recovered

Fungus	Year 1973	1974
Number of samples	22	23
Fusarium avenaceum	1	-
F. culmorum	22	8
F. flocciferum	1	-
F. graminearum	-	3
F. oxysporum	1	1
F. poae	1	-
F. sambucinum	-	1
F. semitectum	-	1
Pythium oligandrum	1	-
Pythium spp.	-	2

Table 5

Mean per cent plants infected with stalk rot 1973 and 1974

Hybrid	1973 % infection	1973 arc sin transformation	1974 % infection	1974 arc sin transformation
Anjou 196	-	-	5.0	12.9*
Anjou 210	7.2	14.9	24.5	27.8
Cargill Primeur 170	63.0	52.5*	51.0	45.6*
De Kalb 202	44.7	41.7	23.0	28.7*
INRA 200	46.5	43.0*	23.0	28.7*
Julia	60.5	51.1*	41.0	39.8*
Kelvedon 59A	39.4	38.9	31.4	33.8
LG 7	22.8	27.8	16.3	23.2
LG 11	23.0	28.2	12.1	19.9
Maris Carmine	27.2	31.3	22.8	27.2
Maris Jade	-	-	19.5	26.2*
Maris Saffron	-	-	3.5	10.8*
MV 201	-	-	18.8	25.4
Pioneer 131	17.8	24.3	8.5	16.9*
Mean	32.5		20.5	
SED	-	± 8.05	-	± 3.9

* NIAB/ADAS trials data, one site only assessed

Following the identification of *F. culmorum* associated with dark brown root and hypocotyl lesions on maize plants during 1972 and 1973, routine isolations from the stem bases of plants from a crop of Kelvedon 59A were made at intervals during 1974. On each occasion samples of five plants were collected at random and the stem base and crown tissue was plated on PDA. *F. culmorum* was isolated from plants collected on 17 June, 15 July, 21 August (when *F. graminearum* was also present) and 27 September when *F. oxysporum* var *redolens* was also isolated from root lesions.

Infected plants showed a pale and later dark brown colouration of the crown with brown lesions often present at the base of the withered coleoptile, below ground level. Lesions were also occasionally detected on the roots and hypocotyls.

Yield estimates on the survey crops were made by collecting cobs from each of 20 healthy and stalk rot infected plants scattered at random across the field. The results (Table 7) showed a 16% reduction in 1000 grain weight and a 21% reduction in grain weight/cob in 1973 compared with 2.1% and 10.6% respectively in 1974.

Table 6

Effect of stalk rot on 1000 grain weight and cob weight of maize 1973 and 1974

Hybrid	No. crops	1000 grain wt (g dry grain) healthy	diseased	SE	Mean cob weight (g 85% DM) healthy	diseased	SE
1973							
De Kalb 202	2	254.5	185.4	16.0	117.9	73.6	12.3
LG 11	7	236.9	209.1	8.0	107.4	90.8	6.2
Kelvedon 59A	1	286.5	211.6	21.1	134.5	86.8	16.3
Pioneer 131	2	221.1	200.5	16.0	101.0	91.5	12.3
Mean		241.3	203.9	6.1	110.3	87.7	4.7
1974							
Anjou 210	4	207.0	178.9	20.0	97.6	110.6	14.2
Kelvedon 59A	3	181.8	198.1	20.0	106.8	101.5	14.2
LG 7	5	191.9	196.6	8.9	90.0	88.5	6.4
LG 11	5	170.4	164.2	8.9	97.1	83.5	6.4
Maris Carmine	4	165.6	164.6	20.0	107.4	86.7	14.2
MV 201	3	225.3	200.5	20.0	132.7	115.2	14.2
Mean		188.4	183.0	3.5	103.5	96.6	2.5

In 1973, a mean stalk rot infection of 18.2% was recorded on 19 of the fields in their first year of maize compared with a mean infection of 39.5% on 12 fields which were in their second or subsequent year of maize.

(ii) Other diseases

Trace levels of rust (*Puccinia sorghi*) were found in 14 of the 30 crops visited in 1973 and in only two of the 23 crops surveyed in 1974. Infection was present in an ADAS/NIAB grain maize trial near Chichester in West Sussex in 1973 and Cargill Primeur 170, LG11 and De Kalb 202 showed most infection, although less than 1% was recorded on the leaf subtending the cob.

Holcus spot (*Pseudomonas syringae*) In both years oval bleached leaf spots up to 0.5 cm across often with a pronounced chlorotic halo and later becoming pale brown with a reddish brown margin were noted on leaves in many crops. The disease was confirmed during 1974. Lesions are later colonised by *Epicoccum* and *Alternaria* spp.

Purple leaf sheath was widely distributed in both years. It is reported to be harmless (Anon 1973) and comprises irregular purple brown blotches which occur when saprophytes, such as yeasts, bacteria and often *Fusarium* spp. develop on pollen lodged between the leaf stalk and the leaf sheath. Small dry pale brown spots up to 1 mm diameter on the upper leaves are believed to have a similar origin.

Smut (*Ustilago maydis*) was noted on two of the crops surveyed in 1973 and none in 1974. The disease is generally sporadic in occurrence and rarely affects more than a few plants in each crop, although in 1971 a severe outbreak was recorded in part of a NIAB trial at Sparsholt, Hampshire, when more plants were infected in part of a field where maize was the preceding crop. The infection count shown in Table 8 is based on two adjacent 48 m rows, 76 cm apart. Infection was generally confined to the last node up the stem or the tassel and only a few cobs were infected.

Table 7

Mean number of plants affected by smut, Sparsholt, 1971

Previous crop (following grass)	Hybrid: Anjou 196	Anjou 210	De Kalb 202	INRA 200	Kelvedon 59A	Pioneer 131	Mean
Maize	7.5	19.0	15.5	30.0	42.5	8.0	20.4
Barley	2.0	4.0	0	2.0	1.0	0	1.5

Barley yellow dwarf virus In 1974 some of the survey crops showed a golden yellow discolouration of the distal parts of the leaves on scattered plants. The virus was confirmed in virus tests and was reported in other parts of the country during September.

Eyespot A leaf, cob and stem spotting disease caused by the fungus (*Kabatiella zeae*) was not recorded.

DISCUSSION

Fusarium culmorum is the most widely distributed cause of stalk rot in Britain and its detection on root and crown tissue early in the growing season supports other evidence (Whitney and Mortimore, 1961) of early infection and suggests that the fungus can remain latent until the plant becomes susceptible later in the growing season. This does not necessarily preclude the possibility of later infections of the nodes and stem bases or damage as entry points for the fungus (Christensen and Wilcoxson, 1966; Mensah and Zwatz, 1975).

The susceptibility rating for the different hybrids to stalk rot is consistent in the two years of the survey except for Anjou 210. The high incidence of stalk rot in this hybrid in 1974 (which was sampled only in Essex), and the lower 1000 grain weights and grain yields for all hybrids in 1974 compared with 1973 suggests that seasonal factors may be involved. The autumn of 1974 was cold and wet and growth of many crops stopped early, either due to frost or low temperature injury. This may have allowed stalk rot to develop in crops which might otherwise not have been affected, particularly if colonisation by saprophytes occurred. The early cessation of growth would also explain the lower yields recorded in 1974 compared with 1973.

The seed treatment trial supports the French work (Molot, 1969) that captan and thiram are the most effective seed treatment fungicides.

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References

ANON (1973) A compendium of corn diseases, The American Phytopathological Society.

CHRISTENSEN, J. J. and WILCOXSON, R. D. (1966) Stalk rot of corn, American Phytopathological Society, Monograph 3

COOK, R. J. (1973) Diseases of grain maize, ADAS Quarterly Review, 11; 113-117

FOLEY, D. C. (1960) The response of corn to inoculation with Diplodia zeae and Gibberella zeae, Phytopathology, 50; 146-150

HANWAY, J. J. (1966) Growth stages of maize, Spec. Rep. 48, Iowa State University. Also in Crop loss assessment methods, FAO, Rome, 1970

MENSAH, R. A. and ZWATZ, B. G.(1975) [Studies on stalk rot of sweet corn] Plant Protection Report. National Institute of Plant Protection, Vienna. 44 (11/12): 161-194

MOLOT, P. M. (1969) [The treatment of seeds of maize and sorghum] Inst. Tech. des céréales et des fourrages, Paris

RINTELEN, J. (1967) [Studies of Fusarium stem rot on ripening maize plants in Southern Germany] Phytopathologische Zeichschrift, 60 (2); 141-168

WHITNEY, N. J. and MORTIMORE, C.G. (1961) Root and stalk rot of field corn in Southwestern Ontario II Development of the disease and isolation of organisms. Canadian Journal of Plant Science 41; 854-861

ZADOKS, J. C., CHANG, T. T. and KONZAK, C. F. A decimal code for the growth stages of cereals. Eucarpia bulletin 1974

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CHEMICAL CONTROL OF USTILAGO MAYDIS IN MAIZE

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Summary Six systemic fungicides were evaluated in the greenhouse and field for the control of smut galls of *Ustilago maydis* in Spring White maize. The fungicides were applied as a seed treatment, a soil drench or a combination of both. Subsequently the plants were inoculated with a sporidial suspension of two sexually-compatible monosporidial lines of *Ustilago maydis*. Three fungicides were effective in suppressing gall smut development. Seed treatment with carboxin plus one soil drench with benomyl resulted in 100% smut control in the greenhouse. Similarly, two benomyl or two thiophanate-methyl drenches were highly effective in controlling smut galls in maize.

Résumé Six fongicides systémiques ont été évalués en serre et en plein champ pour la lutte contre *Ustilago maydis* sur la variété de maïs doux Spring White. Les fongicides ont été appliqués en traitement de semences, par arrosage du sol ou par la combinaison des deux types de traitements. Ensuite les plants ont été inoculés à l'aide d'une suspension contenant les spores de deux lignées sexuellement compatibles de *Ustilago maydis*. Trois de ces fongicides ont empéché très efficacement le développement de tumeurs du charbon. Un traitement de semences avec carboxin suivi d'un arrosage du sol avec bénomyl ont controlé le charbon a 100% en serre. Deux arrosages avec bénomyl ou avec méthylthiophanate ont de même été très efficaces pour le control du charbon sur le maïs doux.

INTRODUCTION

Maize gall smut, *Ustilago maydis* (DC) Cda., is more prevalent in sweet maize than in field maize. Infection is localized in various aerial parts of the maize plants, especially those with meristematic tissues, and smut galls containing teliospores develop at the site of infection. Other symptoms include distortion, dwarfing, tissue swelling, anthocyanin pigmentation of the leaf and occasionally the collapse of the entire plant.

Substantial economic losses due to gall smut in the form of failure to set seed, destruction of the ears or deterioration of the silage are sustained by growers in years of severe infection. The extent of loss in yield depends on the number, size and location of smut galls (Johnson and Christensen 1935). With the advent of resistant and semi-resistant varieties, losses in yield have been decreased.

Gall smut of maize has been known and studied for more than 250 years. The literature is replete with control measures which have been tested but with little or no success (Christensen 1963, Fischer and Holton 1957). However, satisfactory control of the disease using systemic fungicides was recently reported (Enyinnia, 1974, Enyinnia and Halisky 1974). Maize is important in world food production. Since gall smut causes severe losses in maize, this study was conducted to determine whether it could be controlled with systemic fungicides.

METHODS AND MATERIALS

Seed of Spring White maize, a variety susceptible to gall smut was planted in steam sterilized soil in each of five 0.138 m^2 greenhouse flats per treatment. After germination, the number of seedlings was thinned to 20/flat. Six systemic fungicides:- benomyl, carboxin, thiabendazole, thiophanate, thiophanate-methyl and triarimol, were evaluated for controlling maize smut in the greenhouse at the rate of 0.4 g/flat of plants. Five trials were done using seed treatment, soil drenches and a combination of both.

With seed treatment, 10 ml. of carboxin (i.e. the 34F formulation except in Trial No. II, Table 1, where 2.0 g of the 75 WP was used) was applied to 125 seeds and sown immediately in 5 flats and the seedlings thinned to 20/flat. Also 2.0 g of each of the other chemicals in 2.5 l of water were used to drench 100 seedlings in 5 flats of 20 plants each. Where seed treatment and soil drenches were combined, drenches were applied 7-10 days after planting. Single drenches of a particular chemical were applied 7 days after the seedlings had emerged and where two drenches were used, the second was applied about 7 days after the first. One and one-half ml of sporidial suspension of two sexually-compatible monosporidial lines of *U. maydis* prepared according to Enyinnia (1974) were injected into each maize plant at the 5 leaf stage using a hypodermic syringe. Distilled water was injected into control plants and the percentage of plants that developed gall smut was recorded 14 days after inoculation. Each treatment was replicated 5 times. Periods of short day-length were supplemented with artificial lighting to give a 14-hour day.

These experiments were conducted in a greenhouse between January and June 1973. During the 1973 growing season, those chemicals showing superior performance in the greenhouse were further evaluated in the field on both naturally infected and artificially infected Spring White maize plants.

RESULTS

Greenhouse Trials

No phytotoxicity was observed on the maize plants at the concentration of the chemicals used. In the first trial, benomyl as a soil drench was the most effective and in the second trial, carboxin as a seed treatment gave the best results (Table 1). In the third trial, carboxin seed treatment plus a benomyl soil drench resulted in complete control of gall smut in Spring White maize. In the fourth trial, almost complete control was obtained with the same combination. Additionally, two soil drenches with benomyl or a single thiophanate-methyl soil drench gave substantial control of gall smut. The best combinations for control of gall smut were carboxin seed treatment plus a benomyl drench, two benomyl drenches or two thiophanate-methyl drenches.

Carboxin delayed maize seed germination for a few days and reduced seedling vigour the first 7-10 days after emergence; however, the seedlings eventually recovered.

Table 1

Effect of systemic fungicides on suppressing infection of Spring White maize experimentally-inoculated with Ustilago maydis in greenhouse trials

Trial No.	Fungicides	Method of Application	Percent Smut-free
I	Benomyl	Drench	38
	Carboxin	Drench	15
	Thiabendazole	Drench	11
	Control	-	16
II	Benomyl	Seed Treatment	9
	Carboxin	Seed Treatment	20
	Thiabendazole	Seed Treatment	14
	Control	-	4
III	Benomyl	Drench	57
	Carboxin	Seed Treatment	76
	Carboxin + Benomyl	Seed Treatment + Drench	100
	Triarimol	Seed Treatment	26
	Triarimol	Drench	11
	Control	-	11
IV	Benomyl	Drench	74
	Benomyl	Two Drenches	88
	Carboxin	Seed Treatment	80
	Carboxin + Carboxin	Seed Treatment + Drench	77
	Carboxin + Benomyl	Seed Treatment + Drench	95
	Thiophanate	Drench	16
	Thiophanate-methyl	Drench	94
	Control	-	8
V	Carboxin + Thiophanate-methyl	Seed Treatment + Drench	87
	Thiophanate-methyl	Drench	76
	Thiophanate-methyl	*Drench	75
	Thiophanate-methyl	Two Drenches	96
	Thiophanate-methyl	Seed Treatment	11
	Control	-	11

* This drench was 4.0 g/2.5 l water/100 plants.

Field trials

In the field 26% of plants were infected and seed treatment with carboxin followed by a benomyl drench gave 94% smut control. Also two benomyl drenches and two thiophanate-methyl drenches each gave 89% smut control. However, under experimentally-induced infection, carboxin seed treatment plus one benomyl drench gave 81% smut control. Two benomyl or two thiophanate-methyl drenches gave 84% and 80% smut control respectively, while only 16% of the control plants were smut free. A comparison of the best results in the greenhouse and in the field is given in Table 2.

Table 2

Average percent control of Ustilago maydis with systemic fungicides in greenhouse and field trials*

Fungicide	Application Method	No. of Trials	Greenhouse Results % Smut Control	No. of Trials	Field Results % Smut Control
Benomyl	Dr.	3	58	3	73
Benomyl	2-Dr.	1	85	3	85
Carboxin	S.T.	2	78	3	77
Carboxin	S.T. + Dr.	1	77	3	81
Carboxin + Benomyl	S.T. + Dr.	2	98	3	86
Thiophanate-methyl	Dr.	2	85	3	72
Thiophanate-methyl	2-Dr.	1	96	3	83
% disease free plants in Control plots		5	0	3	16

* In each trial, each treatment was replicated five times.
S.T. = Seed Treatment
Dr. = Single soil drench
2-Dr. = 2 soil drenches at 7-day intervals.

DISCUSSION

No satisfactory control measures have been found for the gall smut of maize despite the extensive published literature on U. maydis (Christensen 1963). This fungal pathogen is highly variable and genetically complex. Meiosis is obligatory each time a teliospore germinates. Ease of hybridization, high rates of mutation especially among the sporidia leading to culture sectors, morphological variants, new pathogenic entities, occurrence of solopathogens, all account for the presence of many variants of U. maydis (Fischer and Holton 1957, Halisky 1965). With numerous variants occurring naturally,satisfactory control of U. maydis has been impossible for the last 250 years. Furthermore, no pathogenic races have been pedigreed for this organism using tester varieties probably because maize is largely open-pollinated.

Three of the systemic fungicides evaluated in this study controlled maize smut satisfactorily when appropriate formulations and methods of application were used. The mechanism of activity of the systemic fungicides has not been clearly determined. Chin et. al. (1970) wrote that carboxin as a seed treatment is absorbed by seedlings of wheat and barley and converted in the plant into its oxidation products such as the sulfoxide and/or sulfone. Carboxin, according to them is not hydrolysed and extractable residues from it form complexes with plant lignin. It is possible that these oxathiin-lignin complexes are toxic to smut mycelium. Results obtained from this study indicate that those systemic fungicides that controlled gall smut were toxic to the fungus either as the original compounds or their "derivatives". It is hoped that these results will be evaluated in other States or countries of the world and additional studies conducted to determine the lowest effective dosages of these chemicals and to devise suitable methods for their commercial application. Thus the current world food supply could be increased if maize production is enhanced by controlling U. maydis with these systemic fungicides.

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References

CHIN, Wei-Tsung, STONE, G.M., and SMITH, A.E. (1970) Metabolism of carboxin (Vitavax) by barley and wheat plants, Journal of Agricultural and Food Chemistry, 18 (4) 709-712

CHRISTENSEN, J.J. (1963) Corn smut caused by Ustilago maydis, Monograph No. 2, The American Phytopathological Society

ENYINNIA, T. (1974) Biology and control of Ustilago maydis (DC) Cda. causing gall smut of sweet corn, Ph.D. Thesis, Rutgers University, New Brunswick, New Jersey, U.S.A.

ENYINNIA, T. and HALISKY, P.M. (1974) Control of Ustilago maydis with systemic fungicides, Phytopathology, 74, 580

FISCHER, G.W. and HOLTON, C.S. (1957) Biology and control of the smut fungi, The Ronald Press Company, New York

HALISKY, P.M. (1965) Physiologic specialization and genetics of the smut fungi III, Botanical Review, 31, 114-150

JOHNSON, I.J. and CHRISTENSEN, J.J. (1935) Relationship between number, size and location of smut infections to reduction in yield of corn, Phytopathology, 25, 223-233