Proceedings 1979 British Crop Protection Conference - Pests and Diseases

CONTROL OF PRATYLENCHUS PENETRANS AND OTHER REPLANTING DISORDERS IN RASPBERRIES WITH DAZOMET

D.L. Trudgill

Scottish Horticultural Research Institute, Invergowrie, Dundee

Summary In two field trials pre-planting treatments with dazomet and aldicarb controlled *Pratylenchus penetrans* and increased the growth and yield of raspberries. Dazomet increased cane growth more than aldicarb even when the aldicarb was reapplied each year to prevent the number of *P. penetrans* increasing. Cane growth and yield were increased only slightly by the fungicide quintozene and by increased nitrogen fertiliser. In a pot test, using soil from the untreated plots at one site, raspberry plants grew much more vigorously in soil treated with a mixture of quintozene and aldicarb than in soil treated with aldicarb or untreated.

INTRODUCTION

Stunting of raspberries infested with the root-lesion nematode (*Pratylenchus penetrans*) was first reported by Seinhorst, Klinkenberg & van der Meer (1956) in The Netherlands. McElroy (1977) in Canada reported similar damage and showed that the growth of affected plantations was improved following treatment with nematicides (McElroy, 1975). Trudgill (1977) found *P. penetrans* associated with patches of stunted raspberries in Scotland and a subsequent survey showed that *P. penetrans* was widely distributed in Scottish raspberry plantations (Trudgill, 1978).

This paper reports the results of two field trials, the aim of which was to test whether controlling *P. penetrans* with nematicides improved the growth of newly planted raspberries.

MATERIALS AND METHODS

The two field trials were in Perthshire, near Coupar Angus and Blairgowrie, respectively. The Coupar Angus trial, planted in spring, 1976 with cv. Glen Clova was sited on an area (0.06 ha) where stunted, 3 y old raspberries had been removed the previous autumn; the site was infested with approximately 700 *P. penetrans*/kg soil. The experiment was a randomised block design with five treatments, each with four replicates. Plots were three rows, 5.5 m long. Three chemicals were tested; the partial soil sterilant, dazomet (220 kg/ha), the fungicide, quintozene (88 kg/ha) and the nematicide/insecticide, aldicarb (3.3 and 6.6 kg/ha). Dazomet and quintozene were applied in November, 1975, but the aldicarb was applied immediately prior to planting in March, 1976. The dazomet and aldicarb were applied and incorporated as recommended by the manufacturers except that the dazomet treated plots were sealed by tamping rather than rolling. The plots treated with 6.6 kg/ha of aldicarb were re-treated each autumn with an amount equivalent to 3.3 kg/ha applied along the rows and raked in. All plots, including the untreated controls were rotary cultivated prior to planting.

The Blairgowrie trial, planted with cv. Malling Jewel in March, 1977, was on a 0.4 ha site infested with approximately 200 P. penetrans/kg soil and had previously grown raspberries in 1975. There were three blocks each with five main plots, 15 rows wide by 7.5 m long. Each main plot was split into three, five row sub-plots receiving nitrogen (as nitro chalk) applied in May, 1977 in amounts equivalent to 0, 45 or 90 kg/ha. One plot in each block was treated in autumn 1976 with dazomet equivalent to 330 kg/ha and another with dazomet equivalent to 220 kg/ha. A further plot was treated with aldicarb (6.6 kg/ha) immediately prior to planting and two plots were left untreated, apart from the rotary cultivation used to incorporate the aldicarb and break the seal on the dazomet treated plots.

In both experiments the length of cane in the autumn and the weight of fruit was measured from the centre row of each plot or sub-plot. Numbers of P. penetrans were estimated from samples taken in November at Coupar Angus and July at Blairgowrie in the year of planting and thereafter each spring from the top 20 cm of soil within the row.

RESULTS

At Coupar Angus, in the dazomet and aldicarb treated plots, the numbers of P. penetrans recorded in the year were decreased significantly and cane growth and yield significantly increased compared with the untreated control plots (Table 1). The most effective treatment was dazomet followed by the repeated aldicarb treatment, which controlled nematodes for the duration of the experiment. Plots treated with the fungicide, quintozene, consistently contained more cane and yielded slightly more than the untreated even though they were infested with more P. penetrans. However, the differences were too small to be significant at the 5% level.

In the Blairgowrie experiment aldicarb and dazomet again controlled P. penetrans in the first year and significantly increased the length of cane produced and yield. Dazomet improved growth and yield more than aldicarb with the 330 kg treatment being significantly more effective than 220 kg even though both controlled P. penetrans equally well. The three nitrogen treatments did not significantly affect nematode numbers, cane growth or yield although there was a trend for increased cane growth as the amount of nitrogen applied (as nitro chalk, in the dazomet or released as a result of mineralisation of soil nitrogen) increased.

DISCUSSION

The results obtained in the field trials provide further evidence that P. penetrans is a damaging pest of raspberries. Both dazomet and aldicarb controlled P. penetrans and significantly increased the harvested yield. In contrast the fungicide quintozene did not control P. penetrans or greatly increase cane growth or yield.

The trials have not yet reached their period of greatest productivity but in the second and third year at Coupar Angus the increased yield from the dazomet treated plots much more than covered the cost of treatment. From the amounts of cane at the end of the third year it also seems likely that in the fourth year the yield of the dazomet treated plots will exceed that of the untreated. Yields were also increased in the second year at Blairgowrie by dazomet and aldicarb and from the amounts of cane it seems likely that they will again be increased in the third. However, for how long dazomet and aldicarb will continue to increase yields at both sites is uncertain as populations of P. penetrans are increasing in all the treated plots, except those receiving repeated application of aldicarb (a treatment not yet cleared for commercial use).

Table 1

Numbers of *Pratylenchus penetrans* and total length of cane and fruit yields from eight stools at Coupar Angus. Means of four plots.

Year	Untreated	Quintozene (88 kg/ha)	Aldicarb (3.3 kg/ha)	Aldicarb (6.6 kg/ha)	Dazomet (220 kg/ha)
			Numbers of *P. penetrans* per kg soil†		
1976	540	630	110*	50**	30***
1977	450	1235	200	35***	5***
1978	720	1195	275	25***	160*
			Length of cane (m)		
1976	14.1	17.0	17.1	17.6*	22.8**
1977	31.7	39.6	46.8*	50.6*	64.7**
1978	72.0	87.1	98.8*	113.8*	130.2**
			Yield (kg)		
1977††	0.46	0.52	0.69	0.94*	1.35**
1978	7.48	8.00	10.94*	12.81***	12.58***

Table 2

Numbers of *Pratylenchus penetrans* and total length of cane and fruit yields from ten stools at Blairgowrie. Means of nine sub-plots.

Year	Untreated	Aldicarb (6.6 kg/ha)	Dazomet (220 kg/ha)	Dazomet (330 kg/ha)
		Numbers of *P. penetrans* per kg soil†		
1977	288	16***	16***	32***
1978	237	84***	0***	3***
1979	513	70***	93***	53***
		Length of cane (m)		
1977	6.2	8.6***	9.0***	10.2***
1978	30.3	45.3*	57.9***	72.7***
		Yield (kg)		
1978	1.02	1.69***	1.94***	2.13***

*, **, *** significantly different from the untreated, $p < 0.05$, 0.01 and 0.001, respectively

† transformed to $\log_e$ for analysis, de-transformed results presented

†† results from a single harvest pick. There were four further harvests, the weight of which were not recorded.

At both sites dazomet increased cane growth more than aldicarb. This is probably partly due to the additional nitrogen generated by the dazomet treatment, but the small response to increasing amounts of nitrogen fertiliser indicates that this does not account for all the differences.

Another possibility is that dazomet was controlling another, unrecognised soil-borne pathogen, perhaps a fungus, not controlled by the aldicarb. This possibility was tested by comparing the growth of small raspberry plants cv. Glen Clova in pots (15 cm diam.) of soil from the untreated plots at Coupar Angus after the soil had been treated with aldicarb (10 mg/pot) with a mixture of aldicarb (10 mg) and quintozene (200 mg/pot) or left untreated. The aldicarb treatment eliminated the P. penetrans but when it was used without quintozene it increased root and top growth only slightly (Table 3). The combined aldicarb quintozene treatment significantly increased both top and root growth compared with the untreated and top weight compared with the aldicarb treated plants. Similar effects are being obtained in a more comprehensive experiment now in progress using benomyl as the fungicide.

Table 3

Effect of aldicarb and aldicarb and quintozene treatments on the top and root weight of raspberry plants grown in pots of soil from the untreated plots at Coupar Angus. Results are means of eight replicates.

	Untreated	Aldicarb	Aldicarb & Quintozene
Top weight (g)	5.78	7.83	14.43***
Root weight (g)	9.22	10.85	12.87*

*,*** significantly different from the untreated, $p < 0.05$ and 0.001, respectively

From these results it seems possible that where raspberries have been repeatedly grown two distinct replanting disorders may occur. The first is caused by P. penetrans and the second is caused by an organism(s) controlled by dazomet and by the fungicides quintozene and benomyl. Further investigations are required to test this hypothesis but it is already clear that P. penetrans is widely distributed in Scotland and that some growers could apply pre-planting treatments of dazomet (or similar soil sterilising chemical) with advantage.

Acknowledgement

D.J.F. Brown for assistance with the field trials.

References

McELROY, F.D. (1975) Nematode control in established raspberry plantations. Nematode Vectors of Plant Viruses. Ed. F. Lamberti, C.E. Taylor and J.W. Seinhorst. NATO Advanced Study Institute Series, Series A : Life Sciences 2, 445-446.

McELROY, F.D. (1977) Effect of two nematode species on establishment, growth and yield of raspberries. Plant Disease Reporter 61 (4), 277-279.

SEINHORST, J.W.; KLINKENBERG, Mej. C.H.; V.d. MEER, F.A. (1956) Aantasting in frambozen door Pratylenchus penetrans (Cobb) Sher et Allen. Tijdschrift over plantenziekten 62, 5-6.

TRUDGILL, D.L. (1977) Nematodes: a hidden pest of raspberries. Proceedings of Symposium on Problems of Pest and Disease Control in Northern Britain. Ed. R.A. Fox, Scottish Horticultural Research Institute, 56-57.

TRUDGILL, D.L. (1978) Pratylenchus penetrans : a potential pest of raspberries in Scotland. Plant Pathology 27 (2), 101.

Proceedings 1979 British Crop Protection Conference - Pests and Diseases

SOME OBSERVATIONS ON THE BIOLOGY OF THE TURNIP MOTH (AGROTIS SEGETUM) RELEVANT TO ITS CONTROL WITH INSECTICIDES

Rosemary H. Kay and G.A. Wheatley

National Vegetable Research Station, Wellesbourne, Warwick CV35 9EF

Summary Cutworm infestations of 3.1 larvae/m^2 severely damaged potatoes cv. Desirée but cv. Pentland Dell in the same field supported fewer larvae (1.3/m^2) and was less damaged. 34% of red beet were damaged by 14 larvae/m^2 whereas 17% of young lettuce were killed by 3.5 larvae/m^2 but 34/m^2 did no serious damage to nearly-mature lettuce. Female moths laid eggs on various objects and preferred areas of sparse crop cover. Tungsten lamps were not effective in traps but mercury vapour lamps in sheltered sites caught large numbers of turnip moths and monitored the flight period satisfactorily. The D^o accumulation between the times of peak moth activity in successive years may enable the period of activity to be predicted and temperature and rainfall data the likelihood of damaging infestations occurring. Either rain or irrigation can greatly reduce the numbers of larvae surviving and hence crop damage.

Résumé Les chenilles "Agrotis segetum" ont attaqué à raison de 3,1 par m^2 et ont sévèrement abîmé les pommes de terre Desirée, mais les pommes de terre Pentland Dell dans le même champ ont été attaquées par moins de chenilles (1,3 par m^2) et ont été moins abîmées. 34% des betteraves ont été abîmées par 14 chenilles par m^2, tandis que 17% des jeunes laitues ont été détruites par 3,5 chenilles par m^2, mais 34 chenilles par m^2 n'ont pas sérieusement détruit les laitues presque prêtes à être cueillies. Les oeufs ont été déposés sur divers objets et surtout dans des endroits où la culture est moins dense.

Les lampes tungstène n'étaient pas efficaces dans les pièges, mais les lampes à vapeur de mercure dans les endroits à l'abri du vent ont attiré beaucoup d'agrotides des moissons et ont contrôlé leur activité de façon satisfaisante. On pourra peut-être prédire la période d'activité en employant les degrés de jour accumulés entre les périodes d'activité maximum dans des années successives, et les indications météorologiques prédiront la probabilité d'attaques sévères. Et la pluie et l'irrigation peuvent sévèrement réduire le nombre des chenilles qui survivent et ainsi l'importance des dégâts subis par les récoltes.

INTRODUCTION

The larva of the turnip moth (*Agrotis segetum*) damages a wide range of crops in the U.K. and other European countries such as Denmark (Zethner, 1977). Cutworm damage tends to occur sporadically and unpredictably so that the use of prophylatic insecticide treatments may not be justified. Even where local attacks occur more consistently on high-value crops, there is no information available to guide insecticide application strategies. Forecasting methods are needed to give warning of cutworm attacks and a better knowledge of the biology and behaviour of the pest in particular host crops is required to enable insecticide treatments to be applied rationally and effectively.

Following the severe cutworm attacks experienced in the U.K. in 1976, investigations of aspects of the pest's biology and behaviour in crops such as potatoes, lettuce, red-beet, onions and carrots were undertaken at Wellesbourne. This paper summarizes some of the information accruing from the study which may help in guiding strategies for controlling the pest with insecticides.

OBSERVATIONS AND EXPERIMENTS

Larval density and crop damage

In 1976 a cutworm infestation was observed in a potato field of approximately 6 ha near Wellesbourne, about 4.5 ha being planted with cv. Desirée and the remainder with cv. Pentland Dell. The two crops were sampled by excavating 1-m lengths of row in a stratified random pattern across the field, taking 73 samples from the crop of Desirée and 27 from the other. Damage to the tubers was recorded and the soil was hand-sorted for larvae. Similarly, in 1977 and 1978 the cutworm populations and damage to crops of cv. Desirée were recorded in other fields on the same farm. The dates of the assessments and the numbers of tubers examined are shown together with the results in Table 1. In 1976, the crop of Desirée was more severely damaged than

Table 1

Cutworm infestations on potatoes at Wellesbourne in early October 1976-8

Year	Cultivar	Weight of tubers (kg/m^2) Total	Damaged	% Damaged	Larvae/m^2
1976	Desirée	3.3	0.64	19	3.1
	Pentland Dell	2.5	0.08	3	1.3
1977	Desirée	2.5	0.06	2	0.4
1978	Desirée	5.2	0	0	< 0.05

that of Pentland Dell and supported more than twice as many larvae per unit area. With three larvae/m^2, 19% of the total weight of Desirée were damaged by October, corresponding to about 1.7 damaged tubers/larva. In 1977, the population of cutworms was about one-eighth of that in 1976 and the percentage of gross yield damaged was correspondingly less. By 1978 the cutworm infestation was insignificant and no damaged tubers were found.

In 1977, cutworm damage occurred on a small (150 m^2) area of red beet (cv. Detroit Red Globe) at Wellesbourne. Eleven plots each 2 x 1.7 m were sampled when the beet was harvested. The roots were assessed for damage and the numbers of cutworms present determined by hand-sorting the soil in each plot. More were found per unit area (Table 2) than in the potato crops and 34% of the beet were damaged, corresponding to about 0.8 damaged beet/larva.

In the autumn of 1977 numerous larvae were also observed beneath maturing lettuce (cv. Avoncrisp) in a 50 m^2 plot on the Research Station. The damage was assessed at harvest and soil in two sub-plots totalling about 10 m^2 was excavated to a depth of 8 cm and hand-sorted immediately afterwards to determine the numbers of larvae present. Despite finding a large population (Table 2), none of the maturing lettuce was killed and the damage was mostly confined to the lower leaves resting on the soil. Severe damage was also observed in a late-transplanted, 14 m^2 plot of

Table 2

Cutworm infestations on red-beet and lettuce at Wellesbourne in 1977 and 1978

Crop	Year	Date sampled	Plants			Larvae/m^2
			No. examined	Density (No./m^2)	Damaged (%)	
Red beet	1977	8 September	1025	33	34	14
Lettuce	1977	10 September	140	14	0	34
	1978	5 September	276	20	17	3.5

cv. Avoncrisp on the Research Station in 1978, 17% of the plants being killed within a few days of being transplanted. The number of cutworms present were determined by searching the soil around the plants (Table 2) and was found to average 1/damaged plant. However, further damage accrued subsequently as the larvae moved to other plants.

Oviposition in the field

Depending on their size and longevity, female moths may each lay more than 1000 eggs in the laboratory. Although wild moths may be less fecund, those caught early during the oviposition period laid 687±340 eggs in the laboratory at 19±1° C when fed on a 10% glucose solution. The reproductive capacity of wild females is therefore also relatively high.

The female turnip moth lays its eggs singly or in groups of up to 10, mainly on sticks, earth clods and crop debris, but some are also laid on plants. To determine the influence of plant spacing on oviposition preferences, potatoes (cv. Desirée) were grown in two 3 x 15 m plots, each confined within a large Tygan-mesh cage (15 x 3 x 2 m high). They were planted 30 cm apart within each row but the space between successive rows was systematically increased by a factor of x 1.07 along the length of the cage to give 27 row-spacings ranging from 20 - 120 cm. The two plots were adjacent and parallel to one another with their long axes orientated approximately north - south, but with the row spacings increasing in opposite directions. 100 female moths and an excess of males were released into the cages initially and more were added as needed to maintain the population. Objects known to be accepted as oviposition sites were evenly spaced along each cage and comprised five of each of a 23 x 12 x 8 cm building brick, a 170-cm length of string and a vertical muslin barrier 170 cm long x 38 cm high supported by three canes. The eggs laid on the objects, and also on the 5 x 3-m side-wall panels of the cage, were counted after 4 days and the procedure was then repeated.

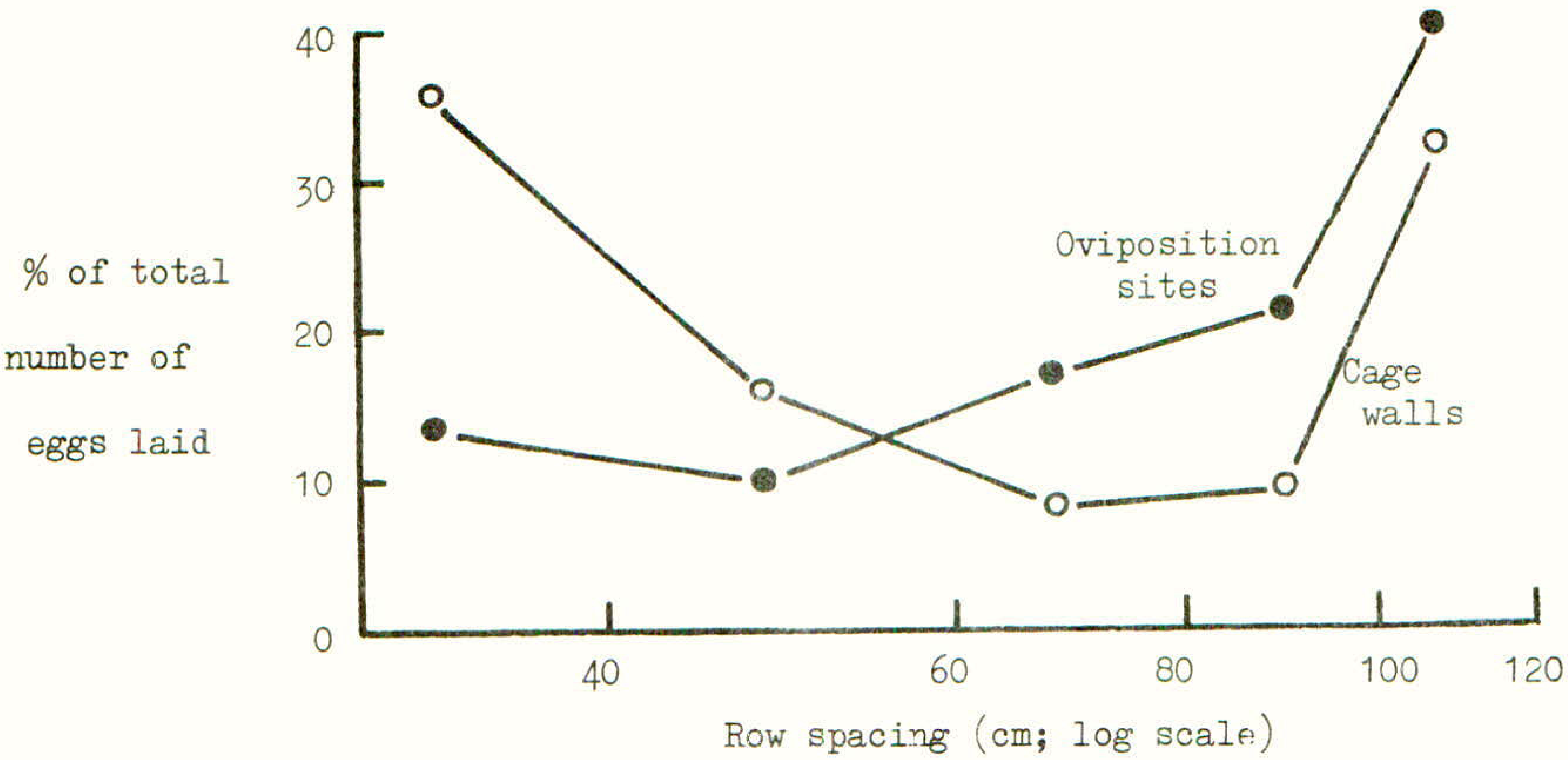
Figure 1 shows the % of the total eggs laid on the cage wall-panels and on the oviposition sites. The panels at the ends of the cages were preferred to those in the centre but on the introduced oviposition sites there was an increase in the % of eggs laid as the row-spacings increased, indicating a preference for oviposition sites at the wider row spacings where there was least ground cover. Further evidence of the importance of ground cover in relation to damage to potato crops was obtained from another experiment at Wellesbourne (D. Wurr pers. com) in which the foliage growth was modified by a growth regulator. The subsequent cutworm damage was greatest where the foliage was least dense.

Traps and trapping

During the summers of 1977 and 1978, a Rothamsted (tungsten-lamp) light trap and four to six Robinson (mercury vapour) light traps were operated at Wellesbourne

Figure 1

Influence of row-spacing of potatoes on the numbers of eggs laid within a large cage

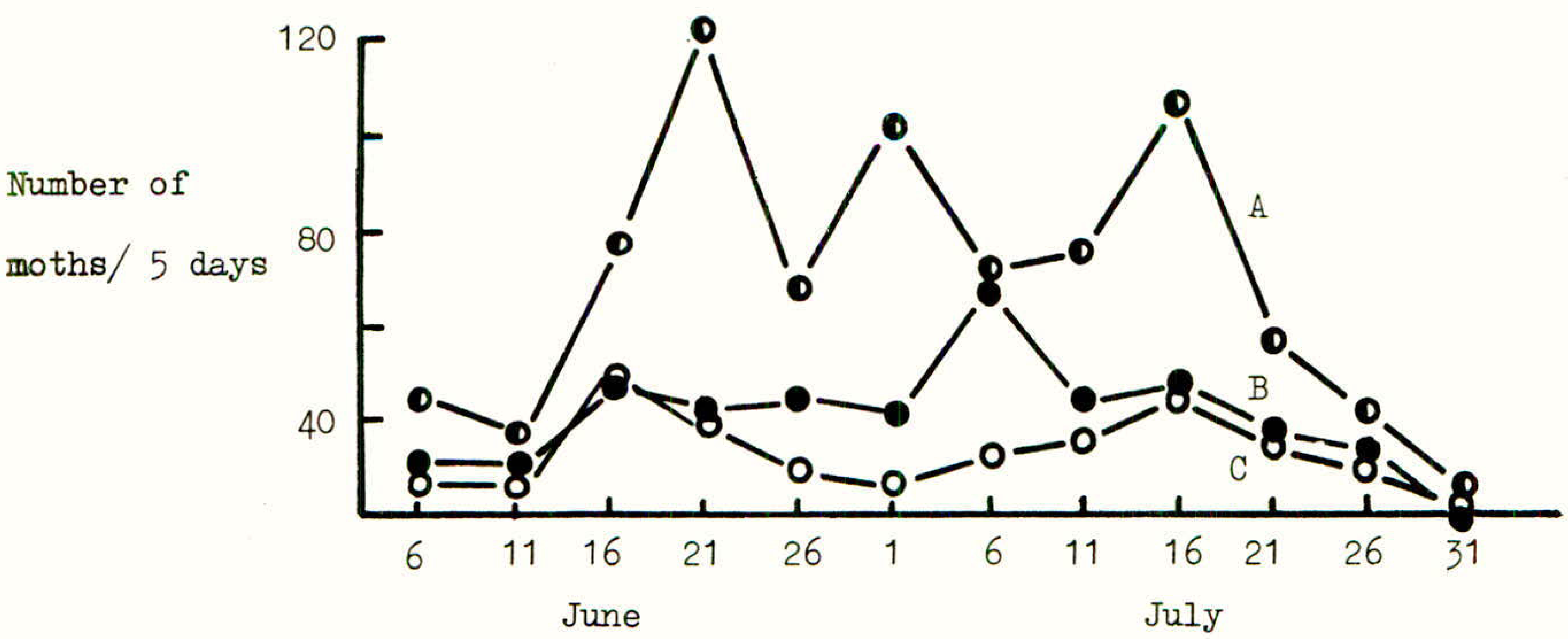


together with a Robinson trap at nearby Charlecote, all being within 1 km of each other. Results were also available for another Robinson trap near Croydon, Surrey. The traps were deployed in different environments, some relatively exposed and others more sheltered.

Few A. segetum moths were caught by the Rothamsted trap at Wellesbourne, supporting the findings of the Rothamsted Insect Survey (Bowden & Sherlock, 1979) that this type of trap is not suitable for catching this noctuid. More turnip moths were

Figure 2

Numbers of turnip moths caught at Wellesbourne during 1978 in three traps representing extremes of shelter; A— well-sheltered; B and C relatively exposed



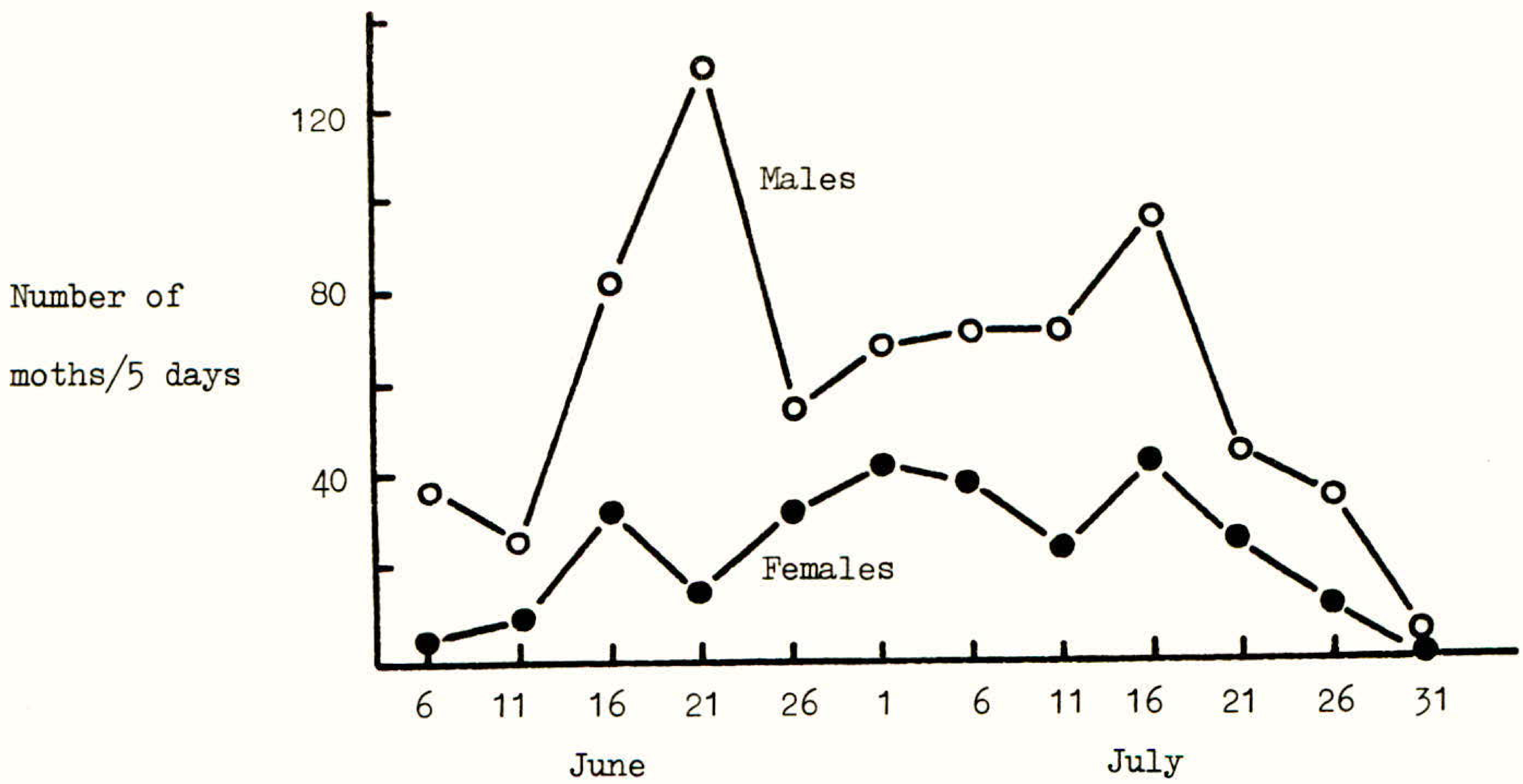
caught by the Robinson traps, however, although the total numbers depended on the trap site (Figure 2) and particularly whether or not it was sheltered from the wind. Site A was sheltered on a river bank in a hollow surrounded by hedges and trees. Sites B and C were more exposed, the available shelter being to the south-west for B and to the north-east for C. The influence of the shelter on the numbers of moths captured, however, depended on the direction and intensity of the prevailing wind. A statistical analysis of the trapping data revealed that these effects rarely modified the performance of the trap more than about two-fold. The numbers of turnip moths captured were generally greater during nights following high maximum daily temperatures, but there was no consistent relationship with the minimum temperature which usually occurred near dawn after the main nocturnal flight.

The traps consistently caught about twice as many males than females, though relatively more females were caught towards the middle of the annual flight period, as also noted by Bowden and Sherlock (1979). The overall patterns of trapping for the two sexes were nevertheless similar (Figure 3), except for the large peak of males early in the flight period. Any difference in timing of the male and female flight periods, as indicated by the times when the median numbers of each sex were caught, was less than 2-3 days and not statistically significant in the years studied.

The first female moths caught each year were virgins. Later the mated females caught subsequently laid large numbers of eggs in cages; they were presumably in the early stages of ovipositing when captured.

Figure 3

Trapping patterns for male and female turnip moths at Wellesbourne in 1978



Day-degree accumulation between successive peak captures of first generation moths

The date when the peak numbers of first generation moths were captured at Wellesbourne and at Croydon were estimated from the trapping curves for the two sites. Data was available from Wellesbourne for 1970-78 inclusive, and from Croydon for 1972-78 inclusive. The numbers caught in the traps were a function of the numbers available and the prevailing activity of the moths, usually referred to as the number-activity product and is referred to here as 'activity'. The moth activity at the two sites was considered in relation to the numbers of day-degrees (D^o) accumulated. These were calculated as proposed by the Meteorological Office in Britain (Anon. 1946) using 7° as the lower and 30° C as the upper limit. The results are summarised in Table 3.

Table 3

The mean dates of peak moth activity in relation to the accumulated day-degrees (D^o)

Site	Years	Time of peak activity		Accumulated D^o	
		Date(±c.l.)	Range	Jan.-to-peak	Peak-to-peak
Wellesbourne	1970-78	29 June±25	10 June-14 July	452;(4.61±0.17)*	1449; (6.17±0.11)*
	1972-78	3 July±22	15 June-14 July	478;(4.67±0.12)*	1428; (6.15±0.12)*
Croydon	1972-78	4 July±17	26 June-14 July	591;(4.93±0.16)*	1616; (6.34±0.19)*

c.l. = 95% confidence limit
* Mean and variance for $x^{0.25}$ transformation to stabilise variance

Although at Wellesbourne the mean date for peak activity of the first generation of moths was 29 June over the years 1970-78, from 1972-78 it was 3 July as compared with 4 July at Croydon for the same period. From 1 January to the date of peak activity there were more than 100 additional D^o accumulated at Croydon than at Wellesbourne or, alternatively, about 150-200 D^o more between two consecutive first generation peaks. A relationship was established for Wellesbourne between the D^o total accumulated between 1 January and peak activity of the first generation and the accumulated D^o experienced during the late-summer and autumn by the developing population after the peak of moth activity in the previous summer. In general, the more D^o experienced up to 1 January, the less were required afterwards. The relationship was not, however, simple since D^o accumulated prior to 1 January seemed not to be equivalent in their effect on development to those acquired later. In some years at both Wellesbourne and Croydon the accumulation of D^o by late summer was sufficient for the larvae to complete development, pupate and for a partial second generation of moths to emerge in the early autumn. When this occurred, the peak activity of the first generation of moths in the following year appeared to be slightly delayed, requiring a greater accumulation of D^o after 1 January than in other years.

Other environmental factors

The severity of a cutworm attack is influenced by weather, particularly prevailing rainfall and temperature when the eggs are being laid and the first instar larvae are seeking or have just found host plants. At Wellesbourne after young larvae were released onto lettuce plots a heavy rainstorm occurred and many were drowned. Similar effects were observed by D. Gray (Pers. comm.) when potato plots were irrigated; this reduced cutworm damage to the tubers by an estimated 93-100% compared with non-irrigated plots.

The relative sizes of the populations of first generation moths at Wellesbourne and at Croydon were estimated for 1972-78 by graphing the numbers caught and calculating the area under each curve. Logarithms of the ratios of the population sizes in consecutive years correlated with some weather parameters, particularly the D^o total and the annual rainfall. The populations were largest when the mean temperatures were highest (more D^o) and when least rain fell.

Significant ($P < 0.05$) correlations were found between the population size and both the winter temperature and total rainfall at Wellesbourne, and the summer temperature at Croydon.

DISCUSSION

Low populations of larvae (30 000/ha) found in potatoes can cause sufficient damage to reduce the marketable value of a crop. The fecundity of the moth is such that 30 females/ha could cause serious damage if all their progeny survived. The unpredictable choice of oviposition sites suggests that there is high mortality of larvae between eclosion, finding host plants and causing economic damage. While the first and second instar larvae are feeding on the aerial parts of the plants they are especially vulnerable to excess moisture and are readily drowned. Varying combinations of several factors contribute to the mortality of the young larvae, making it difficult to predict the likelihood of a damaging infestation in a crop by considering only moth captures.

The low cutworm density capable of causing economic damage presents sampling problems and it may be difficult to devise reliable methods for monitoring or detecting populations sufficiently early for corrective insecticide treatments to be applied. Cutworm damage on crops such as potatoes, carrots or beet is not often noticed until late in the summer when the larvae are large and the earliest crops are being lifted. The susceptibility of Euxoa messoria to insecticides diminishes when they exceed the 3rd instar (Harris and Gore, 1971), so that late treatment of cutworm infestations is unlikely to be effective. To protect high value crops, damaging infestations must be detected and treated at an early stage. D^o accumulation can indicate the flight period, optimally-sited mercury vapour light traps in conjunction with meteorological factors may indicate the intensity of attack, but prevailing weather seems to dictate the natural survival of larvae and therefore their economic importance on any occasion. If weather and other conditions favour a high survival of larvae, even a small population of moths may put crops at risk and protective treatments may be advisable.

The relative sizes of both the crop plants and the attacking larvae should also be taken into account. A large population of larvae under nearly-mature lettuce did not cause economic damage at Wellesbourne whereas a smaller population in a newly-transplanted crop caused a serious loss of plants. This consideration does not arise with crops such as potatoes, carrots, onions or beet which are in the ground throughout the flight period of the moth and provide food for the larvae throughout their development.

The preferences of ovipositing females for areas with little ground cover suggests that some sowings or plantings will be more susceptible to attack than others. Cultivars with an upright habit may be more susceptible to attack than those which are recumbent, provide a dense ground cover quickly and so favour predatory arthropods that may increase the mortality of eggs and young cutworms.

The peak activity of the moths occurred on different dates each year, ranging from about mid-June to mid-July in southern Britain. Mercury vapour light traps seem satisfactory for monitoring when the peak activity occurs, provided they are sited in relatively sheltered places. They catch the females in a pre- or early-ovipositional stage and so the numbers trapped indicate the reproductive potential of the population. The catches must also be interpreted, however, in relation to other factors, particularly the prevailing weather.

It may be possible to predict the peak activity of the moths, or even the onset of activity which is of greater practical importance, by considering the time of the peak in the previous year and the intervening weather. The mean dates of peak moth activity at Wellesbourne and Croydon were similar despite an apparent difference of 150-200 D^o between the two sites. Specific D^o equations for each site should enable the times of peak moth activity to be predicted, although the difference may be an artifact which could be reduced or eliminated by refining the method for calculating the D°. However, if the larvae at the two sites have differing thermal requirements to complete development, for example associated with differing times of onset of diapause as observed by Druzelyubova (1973), then specific equations may be needed at least regionally for sufficiently accurate predictions to be achieved in practice.

It is probably advisable to protect high-value crops with insecticides when large numbers of moths are caught, as in 1976. The treatments can be timed in relation to the moth flight period each season but they may not, of course, always be necessary. The non-specific egg-laying sites used by the females suggests that broadcast applications during peak egg-laying may be more effective than only treating along crop rows. Since the young larvae usually feed on the foliage before descending into the soil, some insecticide should also be directed at the lower parts of the plants.

The present study confirmed Zethner's (1977) findings that young larvae are vulnerable to drowning by rain or irrigation. Where available, irrigation should be an effective method of minimising cutworm damage particularly if, in the absence of heavy rain, it can be applied every 2-3 days for perhaps 2 weeks over the period of peak moth activity which can probably often be anticipated from trapping records.

There is not yet sufficient information available to offer firm guidance for forecasting cutworm attacks on any particular crop in any year but further refinement of techniques should help towards more rational employment of control measures than is possible at present.

Acknowledgements

We thank Mr D. Brown of Charlecote,Warwick and Mr E.Wild of Croydon, Surrey for kindly supplying records of their captures of A.segetum and also our colleagues Drs D.Gray and D.C.E.Wurr for their observations on the effects of irrigation and of plant growth regulators on cutworm damage to potatoes which arose incidentally in their field experiments.

References

ANON. (1946) Tables for the evaluation of daily values of accumulated temperature above 42° F from daily values of maximum and minimum temperatures. Meteorological Office Leaflet No.10, HMSO,5 pp.

BOWDEN, J.; SHERLOCK,P.L. (1979) Entomology Department— Cutworm biology and migration. Report of Rothamsted Experimental Station for 1978, Pt 1, 89-90.

DRUZHELYUBOVA,T.S. (1973) Reactions of geographical populations of Agrotis segetum Schiff. to temperature and light (in Russian). Trudy Vsesoyuznogo Nauchnoissledovatel'skogo Instituta Zaschity Rastenii No 39, 159-174. In Review of Applied Entomology, Series A, 1976, 64, 1186.

HARRIS,C.R.; GORE,F. (1971) Toxicological studies on cutworms. VIII.Toxicity of three insecticides to the various stages in the development of the darksided cutworm. Journal of Economic Entomology, 64, 1049-1050.

ZETHNER, O. (1977) Losses caused by cutworms (Agrotis segetum Schiff.) and approaches to their control in Denmark. Proceedings of the 1977 British Crop Protection Conference — Pests and Diseases, 1, 271-277.

Proceedings 1979 British Crop Protection Conference - Pests and Diseases

PROBLEMS IN THE CONTROL OF THE PEA AND BEAN WEEVIL (SITONA LINEATUS)

R. Bardner, K.E. Fletcher and D.C. Griffiths

Rothamsted Experimental Station, Harpenden, Herts. AL5 2JQ

Summary Injury by *Sitona* larvae to the roots of pea and bean plants caused a significant crop loss. Injury has been prevented in trials by applying granules of chlorfenvinphos or phorate in the seed furrow, or phorate on the seeds, or spraying permethrin on the foliage.

Resume Les dégats causés aux racines de pois et fevres par larves de *Sitona* entrainent des pertes importantes a la moisson, qui peuvent être evités par l'emploi de granules de chlorfenvinphos ou phorate en sillon, phorate sur semis ou pulverisation de perméthrine sur feuillage.

INTRODUCTION

There is growing evidence that *Sitona lineatus* causes economically important damage to pea and bean crops. Earlier, Bardner and Fletcher (1979) showed that dieldrin or γ-HCH cultivated into the soil at 1.12 to 4.48 kg a.i./ha before sowing decreased numbers of *Sitona* larvae by 70-80% and increased yields of field beans (*Vicia faba*) by a mean of 0.15 t/ha (6.6%). The maximum yield increase in one experiment was 0.5 t/ha (15.5%). Similarly, in three seasons' work on factors affecting the yield of spring beans, aldicarb at 10 kg a.i./ha and other insecticides increased yields by 8.8 to 53% mainly by controlling *Sitona* (McEwen, 1977; McEwen and Yeoman 1978, 1979). Control of *Sitona* with aldicarb gave similar yield increases with leafless peas (McEwen *et al.* 1979).

In comparison, the most notorious insect pest of beans, *Aphis fabae*, causes losses of £16.1/ha to untreated spring bean crops (Cammel & Way, 1977) (12.4% of the yield). Although most growers know of the need to avoid damage by *A. fabae* only a few are concerned about damage by *Sitona* and even then only because of the conspicuous feeding injury caused by the adult.

Do the yield increases so far obtained justify controlling *Sitona* larvae? If so, on what crops, at what stage of the pest's life history, with what insecticides and how applied? Some emerging answers to these problems are discussed here.

LIFE HISTORY OF SITONA LINEATUS

Adults (one generation a year) infest pea and *Vicia* bean crops in spring, making characteristic feeding notches on leaf margins. They move slowly inwards from the edges of fields in cold weather, but fly on warm, sunny days in March or April; myriads of beetles suddenly appear and infest fields uniformly. Once a suitable crop is found, beetles do not move far, and crops emerging late may escape serious attack. Egg-laying may start at once and continues until June. In an infested crop there may be more beetles than plants. Adult females are known to lay more than 1000 eggs in laboratory conditions (Anderson, 1931) but in the field even the largest infestations have only about 30 larvae per root, and it is more usual to find 8-12, so unknown factors must limit numbers. Diseased adults or larvae are not common, but large populations of carabids are found in bean fields and some will attack adult Sitona and immature stages.

Sitona larvae are commonly found from late May to mid August, usually in greatest numbers when spring-sown beans are setting pods in late June to mid July. After pupating in the soil, the new generation of beetles emerge in August and start feeding on the bean leaves until they senesce; then beetles disperse and hibernate.

HOW LOSSES ARE CAUSED

Larvae feed mainly on the root nodules, which they enter and excavate, and destroy in severe cases. This decreases nitrogen fixation and the foliage sometimes develops the yellowing characteristic of nitrogen deficiency (El-Dessouki, 1971). Pathogens may be able to enter damaged roots easily (Salt & Hornby, 1971), for severely attacked tap roots of bean plants are often badly blackened.

Adults also injure plants by feeding on the leaves but the damage is probably less important. George et al. (1962) removed 12.5% of the total leaf tissues of peas at the 4-leaf stage and thus decreased yields by 8%, but concluded that such severe injury was rare. Beans have a relatively long growing season with ample time for compensatory growth; for instance they can tolerate frost damage to the foliage and still yield well, so they may also tolerate leaf notching.

THE PROBLEM OF CONTROL

Attacks by Sitona cause measurable loss of yield but are variable. Rational control schemes require accurate prediction of severe attacks, a knowledge of economic thresholds for control treatments and information on which treatments are most effective and economically justified.

(1) Prediction of attacks

If more were known about population dynamics of Sitona, severe attacks might be predicted from counts of adults dispersing in late summer, overwintering adults, or adults that have survived the winter and are moving back to pea and bean fields in spring. Unfortunately, few Sitona are caught in the Rothamsted Insect Survey light and suction traps and the use of pheromone traps, such as used for pea moth predictions (Greenway et al. 1976) has so far not been investigated.

(2) Defining thresholds for control

It may be possible to define economic thresholds for control measures from the number of feeding notches per leaflet but mortality varies and large populations of beetles do not always produce many larvae. When prediction indicates that control measures are needed these must be applied quickly to prevent much egg-laying.

(3) Effectiveness of different treatments

We have now tested 21 insecticides, applied to the foliage or the soil. The soil insecticides have included granules or sprays broadcast and cultivated into the soil before sowing, granules applied in the seed furrow, seed treatments and barrier treatments with insecticides intended to prevent adults moving into a crop from the field edge. In all experiments on Sitona, aphicides were applied when needed, to prevent later infestations of Aphis fabae.

Table 1 gives results from earlier work (Bardner & Fletcher, 1979) to find replacements for dieldrin and γ-HCH. Except for a fenitrothion spray, non-systemic insecticides cultivated into the soil before sowing were used. Chlormephos decreased numbers of larvae as much as dieldrin, and the effect of fonofos was encouraging. Fenitrothion was sprayed on leaves several times during the season at the rate recommended by MAFF (Anon, 1978) but did not significantly decrease numbers of larvae/root.

Table 2 summarises the effects on larval numbers of several insecticides applied in different ways in three experiments. Furrow treatments with carbofuran or phorate at 2.24 kg a.i./ha were very effective against Sitona larvae and on some occasions gave complete control. Phorate seed treatment at 0.75 kg a.i./ha also performed well but adhesion between treated seeds resulted in a gappy crop in 1979 when a conventional seed drill replaced the practice in earlier trials of sowing by hand. Permethrin sprayed on foliage was very effective in 1979. Fonofos granules were more effective applied in the seed furrow at 2.24 kg a.i./ha than broadcast at double this dose. Aldicarb in the furrow was relatively ineffective in 1977 and 1978 at 2.24 kg a.i./ha but significantly decreased larvae/root in 1979 when the dose was raised to 10 kg a.i./ha. The other oxime carbamate, oxamyl, was not effective at the rates tested either on seeds or in furrows.

Foliar sprays of permethrin were tested also in separate trials (Table 3), which showed that timing was critical and that delay in applying permethrin greatly decreased its effectiveness.

A barrier of aldicarb cultivated into strips of soil 4.9 or 9.8 metres wide, at 10 kg a.i./ha, surrounding an area 21.4 x 21.4 metres prevented adults feeding on plants in the treated strips but did not stop them infesting the inner untreated area as heavily as the outside area, probably because temperatures were high enough for flight.

(4) Possibilities for practical control measures

The above results have shown that granules of carbofuran or phorate drilled with the seed are most effective, but semi-persistent insecticide sprayed on leaves can decrease damage by Sitona if applied soon after adult beetles invade the crop. Carbofuran is expensive but 10% phorate granules applied at 2.24 kg a.i./ha cost £16.16/ha. The current price of the crop is about £125/t so an average yield increase of 0.13 t/ha would be needed to justify treatment, smaller than the average increase of 0.15 t/ha obtained with dieldrin or γ-HCH. A phorate furrow treatment would probably be more effective than these materials and has the additional advantage of rendering plants toxic to other foliage insects for some weeks after sowing; for example, in 1979 the phorate treatment applied at sowing on 21 April was still killing A. fabae on 12 June. Furthermore, application rates could probably be decreased; the rate recommended in the MAFF advisory leaflet (Anon, 1978) is only 1.7 kg/ha.

Permethrin sprayed at 0.15 kg a.i./ha increased yields by 0.7 t/ha in the 1978 Rothamsted experiment on factors affecting the yield of field beans (McEwen &

Yeoman, 1979). The cost of chemical at this rate is £21.5/ha plus the additional costs inherent in spraying. Further experiments are needed to show whether lower rates are effective. Experiments are in progress to determine the pest status of Sitona in pea and in winter bean crops; soil insecticides are unlikely to be effective for Sitona control on winter crops because of the long period between sowing and Sitona attack.

The results reported here are sufficiently encouraging to justify further development work on insecticide dosage/yield responses for soil insecticides and foliar sprays to establish practical methods of control.

References

ANDERSON, K.T. (1931) Der linierte Graurussler oder Blattrandkafer. Monograph Pflanzenschutz, no. 6. Review of Applied Entomology (A) 19, 588.

ANON (1977-1980) Yields of the field experiments 1974-1979 Harpenden: Rothamsted Experimental Station.

ANON (1978) Pea, Bean and Clover Weevils. Leaflet HVD 56 London: Ministry of Agriculture, Fisheries & Food.

BARDNER, R.; FLETCHER, K.E. (1979) Larvae of the pea and bean weevil, Sitona lineatus, and the yield of field beans. Journal of Agricultural Science, Cambridge 92, 109-112.

CAMMEL, M.E.; WAY, M.J. (1977) Economics of forecasting for chemical control of the black bean aphid, Aphis fabae, on the field bean, Vicia faba. Annals of Applied Biology 85, 333-343.

EL-DESSOUKI, S.A. (1971) Der Einfluss von Larven der Gattung Sitona (Col. Curculionidae) auf einige Leguminosen. Zeitschrift fur angewandte entomologie 67, 411-431.

GEORGE, K.S.; LIGHT, W.I.St.G.; GAIR, R. (1962) The effect of artificial defoliation of pea plants on the yield of shelled peas. Plant Pathology 11, 73-80.

GREENWAY, A.R.; LEWIS, T.; MACAULAY, E.D.M.; STURGEON, D.M.; WALL, C. (1976) Pea moth: sex attractants for early warning and control. ARC Research Review 2, 80-83.

McEWEN, J. (1977) Spring beans (Vicia faba), seasonal variation and maximum yields. Rothamsted Experimental Station Annual Report for 1976, pt. 1, 150-152.

McEWEN, J.; COCKBAIN, A.J.; FLETCHER, K.E.; SALT, G.A.; WALL, C.; WHITEHEAD, A.G.; YEOMAN, D.P. (1979) The effects of aldicarb, triazophos and benomyl plus zineb on the incidence of pathogens and on the yields and nitrogen uptake of leafless peas (Pisum sativum L.). Journal of Agricultural Science, Cambridge (In press)

McEWEN, J.; YEOMAN, D.P. (1978) Spring beans, (Vicia faba), seasonal variation and maximum yields. Rothamsted Experimental Station Annual Report for 1977, pt. 1, 123-124.

McEWEN, J.; YEOMAN, D.P. (1979) Spring beans, (Vicia faba), seasonal variation and maximum yields. Rothamsted Experimental Station Annual Report for 1978, pt. 1, 117-119.

SALT, G.A.; HORNBY, D. (1971) Root rot and wilt of field beans (Vicia faba). Proceedings of the 6th British Insecticide and Fungicide Conference 1971, 251-257.

Table 1

Non systemic soil insecticides (broadcast and cultivated in) compared with fenitrothion spray (Experiments 76/R/BE/6 and 77/R/BE/6, Anon, 1977-80)

	a.i. (kg/ha)	Larvae/root (log n+1)	
		1976	1977
No insecticide	-	0.804	0.767
dieldrin	2.24	0.539	
	4.48	0.321	
chlorfenvinphos	2.24	1.007	
	4.48	0.594	
chlormephos	2.24	0.639	0.616
	4.48	0.259	0.163
chlorphyrifos	2.24	0.826	
	4.48	0.739	
fonofos	2.24	0.710	0.345
	4.48	0.580	0.044
isofenphos	2.24	0.761	
	4.48	0.663	
permethrin	2.24	1.060	
	4.48	0.781	
carbophenothion	2.24		0.607
	4.48		0.827
diazinon	2.24		0.784
	4.48		0.652
γ-HCH	2.24		0.698
	4.48		0.897
methiocarb	2.24		0.376
	4.48		0.523
triazophos	2.24		0.445
	4.48		0.676
fenitrothion spray (applied 12/4, 28/4, 17/5, 7/6)	0.75	0.622	
S.E.D. Between untreated and treated		0.140	0.136
Between any two treatments		0.161	0.158

Table 2

Effects of several insecticides on numbers of *Sitona* larvae (Experiments 77/R/BE/9, 78/R/BE/9 and 79/R/BE/9, Anon 1977-80)

	a.i.(kg/ha)	Larvae/root (log n+1)		
		1977[a]	1978[a]	1979[b]
No insecticide	-	0.729	0.678	0.733
aldicarb (F)	2.24	0.410	0.420	
aldicarb (B)	10.0			0.190
carbofuran (F)	2.24	0.075	0	0
oxamyl (F)	2.24	0.595		
phorate (F)	2.24	0.044	0.075	0
oxamyl (S)	0.25	0.619		
oxamyl (S)	0.75	0.649		
phorate (S)	0.25	0.263	0.673	
phorate (S)	0.75	0.075	0.219	0.048
fonofos (F)	2.24		0.490	
fonofos (B)	4.48		0.710	
permethrin (SP)	0.15			0.311
S.E.D. Between untreated and treated		0.153	0.153	0.069
Between any two treatments		0.177	0.177	

(F) = granules applied to seed furrow

(B) = granules broadcast and cultivated in

(S) = seed treatment

(SP) = spray applied to foliage

[a] Microplot experiments

[b] Experiments in plots 0.007 ha

Table 3

Effectiveness of permethrin at different dates of spraying
(Experiments 78/R/B//4 and 79/R/BE/10, Anon 1977-80)

	larvae/root 12.7.78 log (n+1)		larvae/root 11.7.79 log (n+1)
unsprayed	0.966	unsprayed	0.834
sprayed 11.5.78	0.477	sprayed 18.5.79	0.541
sprayed 9.6.78	1.022	sprayed 18.6.79	0.927
sprayed 6.7.78	1.067	sprayed 2.7.79	0.695
sprayed all 3 dates	0.694	sprayed all 3 dates	0.584
S.E.D.	0.112		0.113