

SPATIO-TEMPORAL DYNAMICS OF INSECT DISTRIBUTIONS IN OILSEED RAPE

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ABSTRACT

Parasitoids can provide effective control of some pests of oilseed rape. Their efficiency is influenced by their spatio-temporal coincidence with their host. Any dissociations between their spatial or temporal distributions can provide opportunities to target insecticide against the pest without harming the parasitoid. The cabbage seed weevil, *Ceutorhynchus assimilis* Paykull, is attacked by the larval ectoparasitoid, *Trichomalus perfectus* Walker, and parasitism rates often exceed 70%. The spatio-temporal distributions of *C. assimilis* and its parasitoid within a crop of winter rape were investigated over two years. Insects were sampled using two-dimensional arrays of spatially referenced sampling points. Spatial Analysis by Distance IndicEs (SADIE) and a randomisation procedure were used to describe and compare the patterns of distribution across time and between species. During immigration, adult *C. assimilis* were aggregated at the edges of the crop, but later were more widespread. Adult parasitoids migrated to the crop later than the host and were not aggregated at the crop edge except briefly during the early phase of immigration. Female adult *C. assimilis* and *C. assimilis* larvae were spatially associated, as were densities of *C. assimilis* larvae and *T. perfectus* larvae. Integrated pest management strategies for oilseed rape seek to employ judicious use of chemical pesticides, targeted in space and time, together with the enhancement of natural enemies for biological control. The implications of the observed distributions of *C. assimilis* and *T. perfectus* for improving such strategies are discussed.

KEYWORD pest, parasitoid, *Ceutorhynchus assimilis*, *Trichomalus perfectus*, insecticide targeting

INTRODUCTION

The pteromalid wasp, *Trichomalus perfectus* (Walker), is an important natural enemy of *Ceutorhynchus assimilis* Paykull (the cabbage seed weevil) throughout Europe, often killing more than 70% of host larvae (Murchie & Williams, 1998). In the UK, a commercially viable low-cost strategy for the management of *C. assimilis* populations on winter rape, incorporating *T. perfectus*, was recently proposed (Alford *et al.*, 1996). It aims to conserve natural populations of *T. perfectus* by the temporal targeting of insecticide treatments, i.e. the avoidance of post-flowering applications, to reduce their direct impact on the parasitoid. It is based on work by Murchie *et al.* (1997), who compared the effects on parasitism of two standard

insecticide treatments, *viz.* the pyrethroid insecticide, alphacypermethrin, targeted against adult *C. assimilis* and applied during flowering, and the organophosphate insecticide, triazophos, targeted against the larvae of *C. assimilis* and applied post-flowering. Whereas the former treatment had little effect on parasitism rates, being applied before the main migration of *T. perfectus* into the crop, the latter treatment, applied during the main immigration flight of the parasitoid, reduced parasitism rates substantially. In commercial crops in the UK, the recent decline in the use of triazophos appears to have resulted in substantially increased rates of parasitism of *C. assimilis* by *T. perfectus* (Alford *et al.*, 1996). Targeting insecticide treatments to crop area, as well as in time, could offer even greater potential for the reduction of pesticide use and the conservation of *T. perfectus*. In this paper, we report on two studies of the spatio-temporal distributions of *C. assimilis* and *T. perfectus* on winter rape and discuss the implications of our findings for the spatial targeting of insecticide treatments to minimise insecticide use and to conserve the parasitoid.

METHODS

Adult insects were sampled, from late April to mid-July, using traps arranged on selected intersections of a grid (10 m in 1992; 43.5 m in 1995) across crops of winter rape (1.1 ha in 1992; 6.6 ha in 1995). In 1992, water traps (n=23) were used and, in 1995, flight traps (n=36), baited with the host plant volatiles 2-propenyl isothiocyanate and 2-phenylethyl isothiocyanate, were used. Traps were emptied weekly. In early July 1995, numbers of *C. assimilis* larvae and their parasitism by *T. perfectus* were assessed in a sample of 400 pods from each of 19 of the trap sites. To visualise the spatial distributions of trapped insects, counts were mapped using Unimap 2000 software (Uniras Ltd., Slough, UK). In 1992, frequency distributions of species were investigated by fitting Taylor's Power Law (Taylor, 1961) to sample variances and means derived from weekly trap counts. To determine the strength of edge effects, a randomisation test of permuted rearrangements of the counts was used (Perry, 1995; Murchie, 1996). In 1995, the spatial patterns were described using Spatial Analysis by Distance Indices (SADIE; Perry & Klukowski, 1997; Perry 1998a); this describes the spatial pattern of a single set of counts using three indices (I_a , J_a and K_a), for which values greater than unity indicate aggregated arrangement of the counts. Another index, I_r , (Perry, 1998b) was used to compare two sets of counts; again, values greater than unity indicate positive spatial association.

RESULTS

1992

Distribution of *C. assimilis* adults. *Ceutorhynchus assimilis* adults first invaded the crop in late April, reached maximum numbers in early/mid June and declined from early July, with few caught after mid-July; the numbers caught from 8 May to 10 July are given in Table 1. Regression of variance against mean indicated heterogeneity of catches ($a = 0.420$; $b = 1.556$). Numbers at the edge were greater than at the centre in early/mid-May, but less so during the second half of May when densities stabilised. In early June, there was a similar marked edge effect. This declined in late June and early July when densities became greatest in two longitudinal regions parallel with the northern and southern edges of the crop.

Distribution of *T. perfectus* females. Only female *T. perfectus* were identified from trap samples, because identification of male Pteromalids is difficult. The first females were caught during the first week of May; numbers remained small until early June and then increased steadily until mid-July (Table 1). Regression of variance against mean indicated strong heterogeneity of catches ($a = 0.229$, $b = 1.824$). There was a similar marked edge effect in mid-May only, but thereafter more were caught from the centre than from the edge of the crop.

Comparison of distributions of *C. assimilis* adults and *T. perfectus* females. The numbers of *T. perfectus* caught on most occasions were negatively correlated with those of *C. assimilis*

except during mid-May and mid-July. They were also negatively correlated with those of *C. assimilis* females three weeks earlier, when the host larvae attacked by *T. perfectus* would have been at the egg stage (*T. perfectus* on 3 July v. *C. assimilis* on 12 June $r = -0.4855$, $P = 0.02$).

Table 1. Mean numbers of *C. assimilis* adults and *T. perfectus* females caught weekly in water traps in 1992; * indicates a significant ($P < 0.05$) edge effect.

Date trap emptied	Mean no. of <i>C. assimilis</i> per trap	Mean no. of <i>T. perfectus</i> per trap
8 May	19.5*	0.5
15 May	10.9*	2.3*
22 May	12.2	0.9
29 May	15.0	0.6
5 June	13.3*	3.3
12 June	50.1	5.1
19 June	36.7	4.5
26 June	37.4	9.0
3 July	39.7	8.3
10 July	7.1	13.4

1995

Distribution of *C. assimilis* adults. Mapped counts of *C. assimilis* adults suggested two main phases of crop colonisation. Invasion began at the south-east and south-west field boundaries (20-25 April) and appeared to spread to other parts of the crop, the two foci almost merging to give a single cluster covering most of the south and, less densely, parts of the north of the crop. Maximum numbers were caught from 16-23 May. Thereafter numbers caught from all parts of the crop declined, with those parts most heavily infested being the last to maintain a population.

Table 2. Analyses of the spatio-temporal distributions of *C. assimilis* adults caught weekly in flight traps in 1995. * indicates a significant ($P < 0.05$) degree of aggregation of counts (I_a , K_a) or the presence of a single cluster (J_a).

Date trap emptied	Mean no. per trap	SADIE index		
		I_a	J_a	K_a
25 April	0.44	1.62*	1.22	0.99
2 May	0.88	1.49*	0.91	1.03
9 May	1.06	1.94*	1.08	1.08*
16 May	3.50	1.71*	1.14*	1.03
23 May	4.92	1.63*	1.09	1.05
30 May	2.92	1.57*	1.02	1.09*
6 June	1.31	1.40*	1.06	1.01
13 June	0.19	1.52*	1.47	1.03
20 June	0.14	1.51*	3.05*	1.00

SADIE analyses of these distributions (Table 2) indicated that they were strongly and significantly aggregated on all dates ($I_a > 1$). The invasion on two fronts resulted in the index J_a being not significantly greater than unity (Perry, 1998) except near the peak of abundance (9-16 May) and at the end of colonisation (13-20 June). There was also noticeable pattern of smaller scale aggregation, within the south

of the field where most *C. assimilis* were caught, as shown by values of index K_a which were greater than unity especially during May (Perry & Klukowski, 1997).

Comparison of distributions of *C. assimilis* adults, their larvae and *T. perfectus* larvae. The sampled distributions of the cumulative total of *C. assimilis* adults and of their larvae showed some inconsistencies, especially in the northern quarter of the crop where traps caught few adults but plants contained relatively many larvae. Although the correlation coefficient between numbers of adult female and larval *C. assimilis* was only 0.30, they were spatially associated ($I_r = 1.09$, $P = 0.025$). The distributions of both *C. assimilis* larvae and *T. perfectus* larvae appeared to be aggregated into regions at c. 0-80m from crop edges and were strongly associated ($I_r = 1.35$, $P < 0.003$). The mean percentage parasitism was 57% and this did not vary with host density.

DISCUSSION AND CONCLUSIONS

Grid sampling, together with novel analyses of spatial distributions, has revealed, for the first time, the complexity of the pattern of crop colonisation by *C. assimilis*, with invasion on multiple fronts, significant aggregation throughout colonisation and on different scales, and a simultaneous decline in infestation from all areas of the crop towards the end of flowering. The pattern of colonisation undoubtedly reflects the interplay of environmental factors, such as the location of overwintering sites and windbreaks relative to the position of the crop and the direction of the wind, with the behavioural responses of the pest, particularly those involved in crop location and host plant selection. Greater understanding of the ways in which these factors determine the distribution patterns of *C. assimilis* could lead to ways of predicting which areas of a crop are most at risk of infestation.

Although the distributions of adult female and of larval *C. assimilis* were spatially associated, they were not coincident in all parts of the crop, possibly because flight traps sampled flying rather than ovipositing females. Despite the negative correlations between the numbers of *C. assimilis* adults and *T. perfectus* females caught, there was a close spatial association between their respective larvae, with no areas where larvae were not attacked. The latter indicates that presence of the host was the main factor limiting the distribution of the parasitoid; any disparity would have indicated that other factors were also affecting parasitoid distribution. The uniform and large proportion of larvae parasitised over the crop area occupied by the host shows that *T. perfectus* was effective both in dispersing throughout its host range and in finding its host within that range.

The aggregated nature of the distribution of *C. assimilis* adults in the crop studied also suggests a potential for targeting insecticide treatment to crop areas where pests are densest, thereby maximising control of the pest while minimising pesticide use. The recommended time for the application of pyrethroid to kill adult *C. assimilis* on winter rape is during flowering, between 20 pod set and 80% petal fall on the main raceme; this timing avoids the main immigration flights of *T. perfectus* (Alford *et al.*, 1996). In this study, the crops were between these stages during early- to mid-May. During this period, *C. assimilis* adults infested only part of the crop area, particularly the crop edge and their density varied considerably within the infested areas. Application of insecticide to the crop edge, would have targeted the pest better than application to the whole crop. At present, determination of within-field densities of crop infestation and the strength of the edge effect is not yet a feasible proposition for the grower or advisor and, therefore, temporal rather than spatio-temporal targeting of insecticide treatments against *C. assimilis* must remain the prime strategy for protecting *T. perfectus* (Alford *et al.*, 1996). However, in the future, advances in our knowledge of the environmental factors and behavioural responses determining the spatio-temporal distributions of this pest and its parasitoid, may lead to the development of integrated pest management strategies for oilseed rape incorporating spatially targeted treatments, for example, push-pull or stimulo-

deterrent diversion strategies which would incorporate not only spatially targeted insecticides, but also spatially targetted semiochemicals to manipulate the movements and distributions of pest and parasitoid on the crop.

Acknowledgements

We thank HGCA (Oilseeds) and MAFF (LINK Programme: Technologies for Sustainable Farming Systems and MAFF Arable Crops and Horticulture) for financial support. IACR - Rothamsted receives grant-aided support from the Biotechnology and Biological Sciences Research Council.

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