

Spatial population dynamics of a pest and its parasitoid in an oilseed rape crop

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Summary

The analysis of insect spatial population dynamics is an essential foundation for the development of IPM strategies in which insecticide treatments are spatially or temporally targeted to conserve parasitoids and reduce insecticide use. The spatio-temporal distribution of *Ceutorhynchus assimilis* adults caught in flight traps in a winter oilseed rape crop was mapped, analysed and compared with the distribution of their larvae and that of the parasitoid, *Trichomalus perfectus*, using Spatial Analysis by Distance IndicEs (SADIE). Invasion by *C. assimilis* began at two field boundaries and the two foci almost merged to give a single cluster at the peak of infestation. The spatial distribution was aggregated on all dates. The spatial distributions of adult and larval *C. assimilis* were strongly associated as were those of *C. assimilis* larvae and *T. perfectus* larvae. These distributions are discussed in relation to pest and parasitoid movement, implications for the development of targeted IPM strategies, and pest sampling for risk assessment.

Key words: *Ceutorhynchus assimilis*, *Trichomalus perfectus*, cabbage seed weevil, parasitoid, oilseed rape, spatio-temporal distribution, SADIE

Introduction

Parasitoids can have a major impact in the control of insect pests of field crops but the application of insecticides often seriously reduces parasitoid survival. Information on the spatio-temporal population dynamics of pests and their parasitoids could be used to develop IPM strategies which conserve parasitoids, enhancing their role as biological control agents. The effectiveness of a parasitoid is dependent on good coincidence in time and space between adult parasitoids and the host stage attacked; disparities in the within-crop spatial or temporal distributions of host and parasitoid would enable treatments to be targeted at pest populations, minimising impact on the parasitoid.

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The cabbage seed weevil, *Ceutorhynchus assimilis* Paykull (syn. *C. obstrictus*[Marsham]), is an important pest of oilseed rape and is subject to widespread attack in Europe by the pteromalid parasitoid, *Trichomalus perfectus* (Walker), which often kills more than 70% of seed weevil larvae

(Murchie & Williams, 1998). Recently, a commercially viable IPM strategy, which incorporates *T. perfectus*, has been proposed for the management of seed weevil populations on winter oilseed rape (Alford *et al.*, 1996). This strategy aims to conserve natural populations of *T. perfectus* by the temporal targeting of insecticide treatments, exploiting the time lag between pest and parasitoid immigration into the crop. It recommends that seed weevil adults are controlled by an application of a pyrethroid insecticide during flowering, and that post-flowering applications to control seed weevil larvae are avoided to reduce the direct impact on the parasitoid. The recent decline in the post-flowering use of triazophos in commercial crops in the UK has been accompanied by substantially increased rates of seed weevil parasitism by *T. perfectus* (Alford *et al.*, 1996).

A strategy by which pesticide treatments are targeted not only in time but also to the area of the crop which is most infested (Evans *et al.*, 1998) could offer additional potential for parasitoid conservation and reduction of pesticide use. The changing spatial patterns of insect populations within a crop are likely to reflect the manner in which the insects locate the crop and subsequently redistribute themselves within it. Accurate description and understanding of the relative movements of pests and parasitoids into crops and within crops is a prerequisite for a spatio-temporal targeting strategy. Furthermore, it is recognised that the standard sampling method for *C. assimilis* in the UK, using a transect into the crop, is an unreliable basis for decision support (Walters & Lane, 1994). Information on the spatial characteristics of pest populations can be used to develop improved sampling techniques (Perry, 1994) and thus ensure more appropriate use of insecticide.

Spatial patterns for a single species have previously been measured using the relationship between variance and mean (e.g. Taylor, 1984; Clark & Perry, 1994), and associations between species have been measured by the correlation coefficient (Murchie, 1996), but in both cases the information concerning the locations of the counts is discarded. Spatial Analysis by Distance IndicEs (SADIE; Perry, 1995, 1998a,b) enables the spatial information in a two-dimensional array of sample counts to be used as part of the analysis. Here we report a study using SADIE to characterise the spatial population dynamics of adult *C. assimilis* in a crop of winter oilseed rape and to compare their distribution with those of their larvae and of *T. perfectus*. The observed distributions are discussed in relation to the movement of the pest and the parasitoid and the implications for the development of targeted IPM strategies which minimise insecticide use and conserve *T. perfectus*.

Materials and Methods

Insects were sampled from an approximately rectangular field (6.6 ha) in Bedfordshire, UK, in 1995. Adult *Ceutorhynchus assimilis* were sampled from 20 April (10% flowers open, main raceme growth stage [G.S.] 4.1; Sylvester-Bradley, 1985) to 11 July (G.S. 6.5 - 6.7) using 36 insect flight traps arranged at crop height in a rectangular 43.5m grid. Each trap was baited with two host plant volatiles, 2-propenyl isothiocyanate and 2-phenylethyl isothiocyanate, and was emptied weekly. On 3 July (G.S. 6.3 - 6.5), numbers of *C. assimilis* larvae and their parasitism by *Trichomalus perfectus* were assessed in a random sample of 20 mature plants (20 pods per plant) taken 5 m to the north of each of 19 flight trap locations. Contour maps of insect density were drawn using Unimap 2000 software (Uniras Ltd., Slough, UK). The spatial distributions of insects were analysed and compared using SADIE (Perry, 1998a, b). Three SADIE indices were used to measure the spatial pattern in single sets of counts. Values of the indices I_a and K_a greater than unity indicate aggregation at large and small scales, respectively, and when these are observed with values of J_a close to or less than unity, this signifies the presence of more than one cluster (Perry, 1998a). The SADIE index I_m was used to compare the distributions of two populations. Values of I_m greater than zero indicate spatial association (Perry, 1998b). Associated with each SADIE index is a formal exact significance probability, derived from a randomisation process.

Results

Crop colonisation by *Ceutorhynchus assimilis* occurred over nine weeks from 20 April (G.S.4.1) to 20 June (G.S. 6.3). Invasion began from the south-east and south-west field boundaries, where the insects were clearly edge distributed in the early colonisation phase, and the two foci almost merged to give a single cluster covering most of the south and parts of the north of the crop at the peak of the colonisation period (16 - 23 May; G.S. 5.8 - 5.9). The density patterns during the phase when numbers were in decline showed that abundance decreased simultaneously in all parts of the crop, those parts most heavily infested being the last to maintain a population. SADIE analyses showed that the spatial distribution was aggregated on all dates, I_a always significantly exceeding unity (Table 1). Values of the index K_a which were substantially larger than unity confirmed that there was also noticeable smaller scale pattern in *C. assimilis* distribution within the south of the field where almost all of these insects occurred. The invasion on two fronts was confirmed by the index J_a , which was rarely significantly greater than unity.

Table 1. SADIE analysis of the spatio-temporal distribution of *C. assimilis* adults caught weekly in 36 flight traps. * 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	No. adults per trap		SADIE index		
	Mean	SE (35 df)	I_a	J_a	K_a
25 April	0.44	0.216	1.62*	1.22	0.99
2 May	0.88	0.303	1.49*	0.91	1.03
9 May	1.06	0.225	1.94*	1.08	1.08*
16 May	3.50	0.678	1.71*	1.14*	1.03
23 May	4.92	0.961	1.63*	1.09	1.01
30 May	2.92	0.634	1.57*	1.02	1.09*
6 June	1.31	0.287	1.40*	1.06	1.01
13 June	0.19	0.105	1.52*	1.47	1.03
20 June	0.14	0.101	1.51*	3.05*	1.00

SADIE analysis of the aggregate seasonal catch of male and female *C. assimilis* indicated a similar spatial pattern to that found for most of the weekly catches, with strong aggregation ($I_a > 1$), evidence for more than one cluster ($J_a \sim 1$) and the existence of small-scale pattern ($K_a > 1$). The cumulative distribution of females is illustrated (Fig. 1a), the distribution of males being almost identical. The distributions of adult female *C. assimilis* and of their larvae were strongly spatially associated within the whole crop ($I_m = 3.48$, $P = 0.003$). However, there were

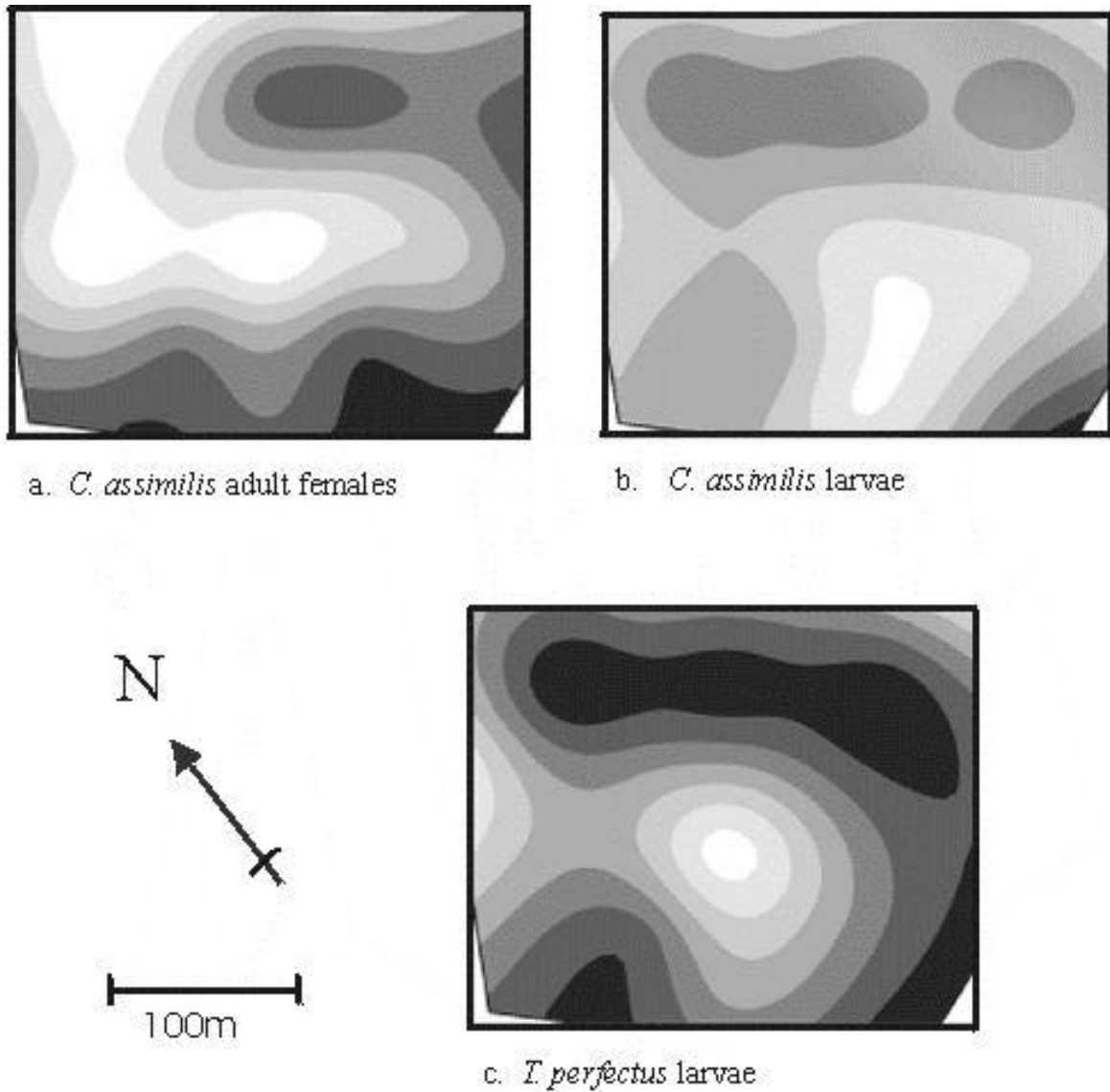


Fig. 1. Distributions of insects interpolated from samples taken at 19 locations in seven density classes with contours equally spaced on a logarithmic scale ($\log_{10} n + 1$). Classes with larger values are represented by darker shades. Maximum and minimum classes, respectively, represent: (a) =15 and <0.6 adult female *C. assimilis* per trap (total for 20 April to 20 June); (b) =70 and =21 *C. assimilis* larvae per 400 pods; (c) >27 and <8 *T. perfectus* larvae per 400 pods.

some inconsistencies in the northern quarter of the crop where adults were most scarce (Figs. 1a & b). Both *C. assimilis* larvae and *Trichomalus perfectus* larvae appeared to be aggregated into regions only c. 0-80 m from crop edges (Figs. 1b & c) and they were also strongly associated ($I_m = 4.82$, $P < 0.003$).

Discussion

The sampling of *Ceutorhynchus assimilis* at regular time intervals from points on a grid across a whole crop and the analysis of these data by SADIE have produced a much more detailed picture of the pattern of crop colonisation by this pest than has hitherto been achieved. A complex pattern was revealed, with invasion on multiple fronts, aggregation throughout colonisation and on different scales, and a simultaneous decline of infestation in all areas of the crop towards the end of flowering. This pattern undoubtedly reflects the interaction of the host location and host selection behaviour of the pest with environmental factors, such as the location of overwintering sites and the direction of the wind. In this crop, the pest invaded on two fronts, at the south-east and the south-west boundaries. To the south-west, the crop was adjacent to woodland, a possible overwintering habitat, and the other field boundaries consisted of hedges with mature trees and herbaceous undergrowth. The movement of *C. assimilis* from overwintering sites towards its host crop is directed by odour-mediated anemotaxis in response to host-plant odour (Evans & Allen-Williams, 1993). Wind direction during the period of immigration was predominantly northerly and this may have contributed to the greater infestation of the southern half of the crop. An understanding of the ways in which environmental factors and behavioural responses determine the distribution patterns of *C. assimilis* could lead to ways of predicting which areas of a crop are most at risk of infestation.

The close spatial association between host and parasitoid distributions shows that the parasitoid was effective both in dispersing throughout the crop and in finding its host within it. Therefore, any post-flowering application of insecticide would have been as likely to kill the parasitoid as the pest. Furthermore, determination of within-field densities of insects for targeting insecticides is not presently a feasible proposition for the grower or advisor and therefore temporal and not spatio-temporal targeting of insecticide treatments against *C. assimilis* must remain the prime strategy for protecting *Trichomalus perfectus* (Alford *et al.*, 1996). However, in the future, advances in our knowledge of the environmental factors and behavioural responses determining the spatial population dynamics 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, stimulo-deterrent diversion (push-pull) strategies (Miller & Cowles, 1990) would incorporate not only spatially targeted insecticides, but also spatially targeted semiochemicals to manipulate the movements and distributions of pest and parasitoid on the crop.

The aggregated nature of the distribution of *C. assimilis* adults in the crop has implications for accurate sampling to support decision making in pest control. Where this insect is as aggregated as in the crop studied, sampling along a single transect into a crop could lead to very inaccurate estimation of population size. This would contribute to the reported unreliability of the method for sampling *C. assimilis* on a transect which is in current use by UK growers (Walters & Lane, 1994), risking the inappropriate use of insecticide. Furthermore, although the distributions of adult female and of larval *C. assimilis* were spatially associated, they were not coincident in all parts of the crop. There is an acknowledged need for the improvement of population assessment methods for this pest and our study suggests that these should be based on more research into, and information on, its spatial population dynamics.

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