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SPECIES SPECTRUM, SEVERITY AND PERSISTENCE OF PESTICIDE SIDE-EFFECTS ON U.K. ARABLE SPRINGTAIL POPULATIONS

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SUMMARY :
This paper examines the impact of current pesticide use on epigeal Collembola (springtails) using results from a long-term (6-year) comparison of farming systems (Ministry of Agriculture "SCARAB" project) and from short-term field studies. Organophosphorus insecticides changed the species composition of collembolan communities, with a wider spectrum of species affected adversely by chlorpyrifos than by dimethoate. Epigeal Collembola took longer than predatory arthropods to recover from effects of chlorpyrifos but were not adversely affected by pirimicarb or cypermethrin. Variation in pesticide effects between species, chemicals and geographical locations is discussed in the context of monitoring pesticide side-effects.

Key-words : Collembola, pesticides, side-effects, persistence, bioindicators.

RÉSUMÉ : EFFETS NON INTENTIONNELS DES PESTICIDES SUR LES POPULATIONS DE COLLEMBOLES DANS LES CHAMPS CULTIVÉS EN ANGLETERRE.
On a étudié l'effet de pesticides, utilisés communément, sur les populations de Collemboles vivant dans les couches superficielles du sol. Les résultats ont été obtenus à la suite d'une étude comparative portant sur 6 années consécutives (projet "SCARAB" du Ministère britannique de l'Agriculture) et, d'autre part, à la suite d'études à court terme. Les organophosphorés, à large spectre d'action, ont modifié la composition des communautés de Collemboles, un plus grand nombre d'espèces étant affectées par le chlorpyrifos plutôt que par le diméthoate. La persistance des effets sur les Collemboles épigés était plus longue que sur la faune auxiliaire. Aucun effet n'a été constasté suite aux applications de pyrimicarbe ou de cyperméthrine. La variation des effets selon les espèces, les produits chimiques appliqués et leur localisation, est analysée dans le cadre d'une gestion des effets secondaires des pesticides.

Mots-clés : Collemboles, faune auxiliaire, pesticides, chlorpyrifos, diméthoate, cyperméthrine, pyrimicarbe.

INTRODUCTION

Collembola (springtails) are among the most numerous and widespread arthropods in agricultural land. Populations of the "lucerne-flea" (*Sminthurus viridis* L.), for instance, are distributed globally across several zoogeographical regions (MACLAGAN, 1932) and densities of this species in suction samples from wheat may exceed 1000 m^{-2} (VICKERMAN, 1992). Collembola are easily sampled in the field using suction sampling or pitfall trapping for epigeal (surface dwelling) species and by extracting edaphic (subterranean) species from soil cores (BERBIERS *et al.* 1989). This paper focuses on epigeal species, which are preyed upon by other arthropods and could be at risk of direct exposure to sprayed pesticide applications, particularly if little or no crop cover is present at the time of spraying (WILES & FRAMPTON, 1996).

During the last two decades there have been numerous published studies of pesticide side effects on arthropods in arable land but the majority (>80%) have focused on predatory taxa, with less emphasis (*c.* 30 % of studies) on Collembola, despite evidence for their susceptibility to a number of pesticides which are currently in use (FRAMPTON, 1994). Even fewer field studies (<10%) recorded responses of individual collembolan species to pesticides, so there is little available information on the spectrum of susceptible species in an arable community. This paper utilises results from a long-term pesticide systems comparison (the SCARAB project) and a one-season replicated-field experiment to examine the responses of the arable collembolan community to current pesticide usage in the U.K. Particular emphasis is given to inter-species variation in vulnerability and recovery ability.

METHODS

The SCARAB project (1990-1996)

The U.K. Ministry of Agriculture, Fisheries and Food (MAFF) SCARAB project ("Seeking Confirmation About Results At Boxworth") aims to determine whether adverse effects of pesticides on cereal arthropods during the 1980s at Boxworth farm in Eastern England (GREIG-SMITH *et al.* 1992) would occur in other crops, at different sites and with different pesticide inputs. SCARAB has three sites in England and seven fields (8 to 34 ha) in total. The sites differ in their crop rotations, reflecting regional variations in farming practice (COOPER, 1990). Each of the fields was divided in half in autumn 1990 to allow a comparison of conventional ("current farm practice", CFP) and low input ("reduced input approach", RIA) pesticide systems. For each crop the CFP regime has mimicked actual pesticide use by responding to the results of pesticide usage surveys (e.g. GARTHWAITE *et al.* 1995) whereas RIA has avoided pesticide use where practicable. The contrasting CFP and RIA pesticide regimes were in force for six years (autumn 1990-1996), during which time arthropod populations were monitored continuously using suction samples and pitfall traps to determine the relative effects of the two regimes. Full details of the SCARAB crop rotations and differences between the CFP and RIA pesticide inputs are given in FRAMPTON & ÇILGI (1996). Results presented in this paper refer specifically to one of the seven SCARAB fields ("Field 5") where, under a grass-wheat rotation, the most adverse effects of CFP pesticide use occurred.

Replicated-field study (1994)

The SCARAB project was set up to explore the overall impact of pesticide regimes so it was not always possible to isolate effects of individual chemicals other than those with substantial effects (organophosphorus insecticides). To aid interpretation of the SCARAB project results, a one-season field experiment was conducted to investigate in detail the relative effects on Collembola of the insecticides chlorpyrifos, cypermethrin and pirimicarb. Four contiguous fields of winter wheat cv. Hereward, (2.4 to 3.3 ha), were used as blocks in a randomised-plot experiment in which each of the three chemicals plus an unsprayed control were randomly allocated to four plots (*c.* 0.7 ha) within each field. The chemicals were applied by tractor-sprayer on 24 June 1994 (growth stages 61 to 69) as commercially available products according to label recommendations against aphids (cypermethrin, pirimicarb) and wheat blossom midge (chlorpyrifos). Full details of the products, active ingredients, application rates, spray equipment and meteorological conditions are given in a report on bioassay work conducted in one of the four study fields (WILES & FRAMPTON, 1996). Collembola were sampled 35 d pre- and 10 d post-treatment using five Ryobi suction samples taken from the centre of each plot, according to the procedure of MACLEOD *et al.* (1994) for predatory arthropods.

RESULTS

SCARAB Project

The most adverse effects of CFP pesticide use in the SCARAB project occurred in a field under a grass and wheat rotation (FRAMPTON & ÇILGI, 1996). Following use of chlorpyrifos in this field in 1991, epigeal Collembola were more severely affected than the predatory taxa Staphylinidae, Linyphiidae and Carabidae, both in terms of the number of species affected and the time taken for recovery (Fig. 1). Among the Collembola there was marked inter-species variation in recovery times, with population reductions in *Lepidocyrtus* spp. (*L. cyaneus* Tullberg + *L. violaceus* Lubbock) and *Sminthurus viridis* (L.) persisting for several years (Fig. 2). The similarity of collembolan communities was decreased by all organophosphorus insecticide applications, more so by chlorpyrifos than by dimethoate (Fig. 3).

Fig. 1. Species spectrum of effects (□) (number of species adversely affected) and minimum recovery time (■) (time for first species to recover) following use of chlorpyrifos in grass, January 1991 (SCARAB project Field 5).

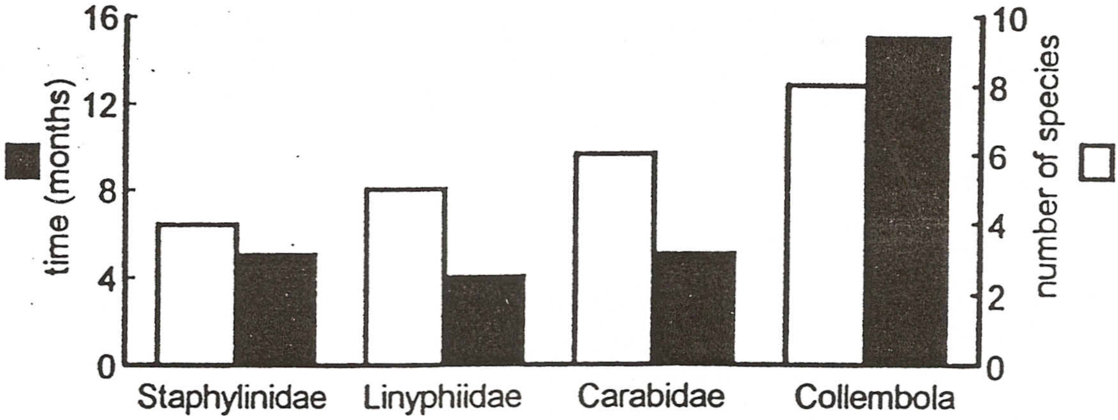
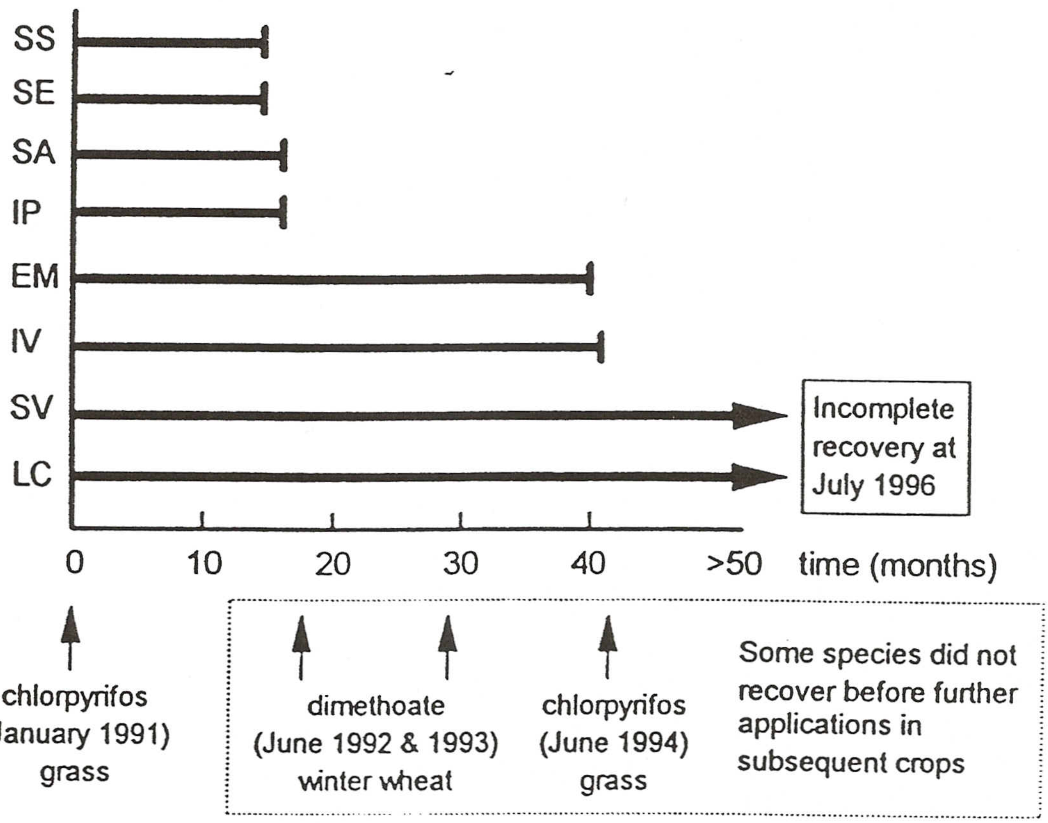


Fig. 2. Recovery times of Collembola after use of chlorpyrifos in a grass and wheat rotation in January 1991 (SCARAB project Field 5).



SS = *Sminthurides signatus*; SE = *Sminthurinus elegans*; SA = *S. aureus*; IP = *Isotomurus palustris*; EM = *Entomobrya multifasciata*; IV = *Isotoma viridis*; SV = *Sminthurus viridis*; LC = [*Lepidocyrtus cyaneus* + *L. violaceus*].

Fig. 3. Similarity of epigeal Collembola communities in suction samples from conventional and no-insecticide pesticide regimes in the SCARAB project grass-wheat rotation (Field 5).

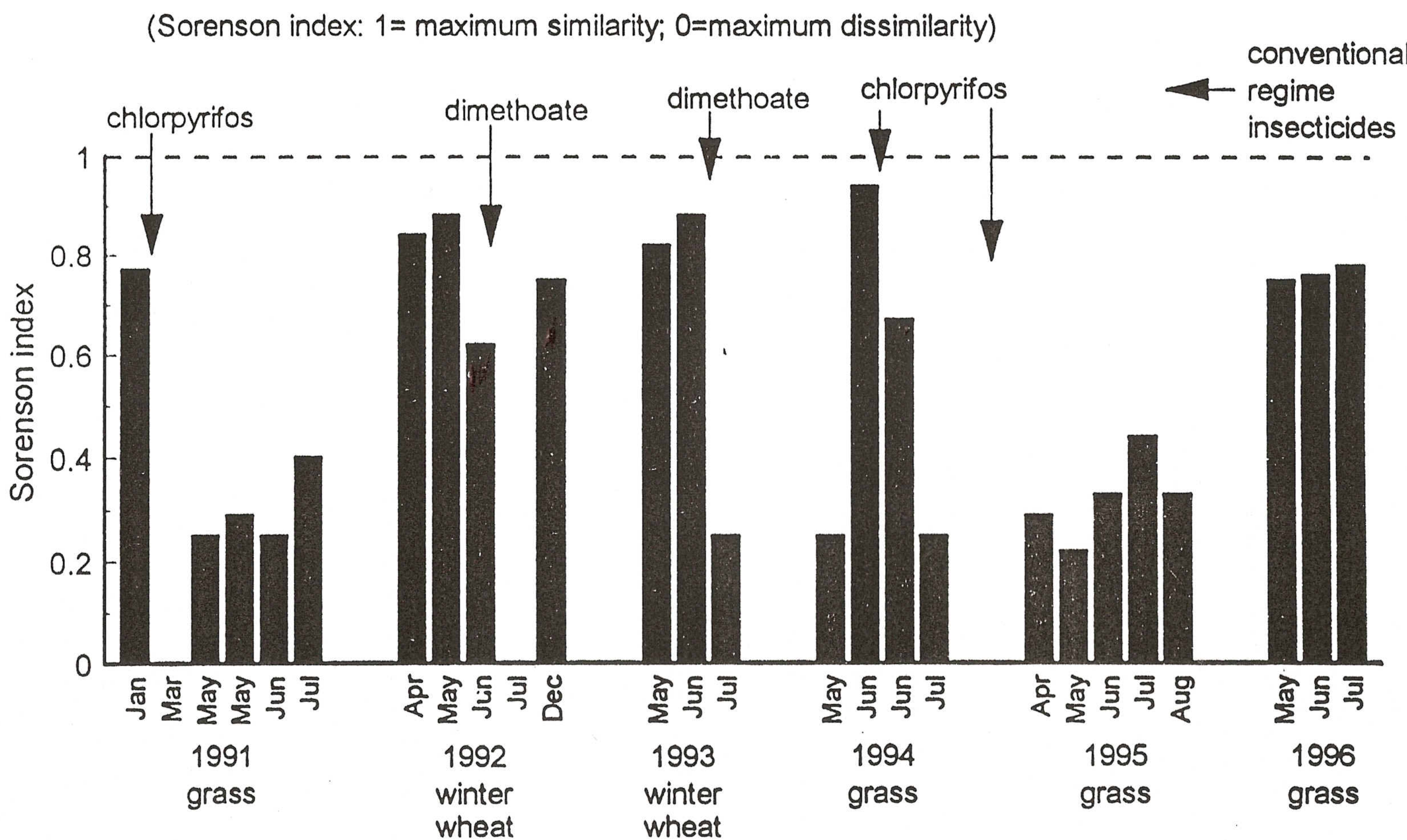


Table 1. Impact of June 1994 insecticide applications on epigeal Collembola in a contiguous-field study in winter wheat. Repeated measures analysis of variance with factors treatment, field, time (35 days pre- and 10 days post-treatment). Symbols denote significant ($P<0.05$) population increase (+) or decrease (-) relative to unsprayed controls. Parentheses [ ] indicate a significant ($P<0.05$) field-by-treatment interaction where the population change was consistent in three out of four fields. Where no symbol is given, either population change did not differ significantly from controls ($P>0.05$) or, if significant ($P<0.05$), the direction of change was inconsistent between fields.

Species	Treatment		
	chlorpyrifos	cypermethrin	pirimicarb
Isotoma notabilis Schäffer	-	+	
Isotomurus palustris (Müller)	[-]		
Entomobrya multifasciata (Tullberg)	-	[+]	
Heteromurus nitidus (Templeton)	-		
Lepidocyrtus spp.	[-]		
Orchesella villosa (Geoffroy)	[-]		
TOTAL ARTHROPLEONA	-		
Sphaeridia pumilis (Krausbauer)	-	[+]	
other Sminthurididae		+	+
Sminthurinus aureus (Lubbock)	-	+	
Sminthurinus elegans (Fitch)	[-]		+
TOTAL SYMPHYPLEONA	-	+	
TOTAL COLLEMBOLA	-		

Replicated -field study

Chlorpyrifos consistently adversely affected collembolan populations in relation to unsprayed controls whereas cypermethrin and, to a lesser extent pirimicarb, apparently had a positive effect on populations (Table 1). In a number of cases the effect of a chemical was not consistent across all four fields, as indicated by significant ($P<0.05$) field-by-treatment interactions (Table 1).

DISCUSSION

Results from the SCARAB project indicate that epigeal Collembola were more vulnerable than predatory arthropods to organophosphorus insecticides. This could have implications for the choice of indicator taxa selected for pesticide side-effects testing. The most rapidly-recovering collembolan species, *Sminthurides signatus* and *Sminthurinus elegans* (Fig. 2), took longer to recover from the effects of chlorpyrifos than did all species of Staphylinidae and Linyphiidae. Reasons for the wide range of recovery times among Collembola (Fig. 2) are not known but could include variation among species in (1) life histories (e.g. timing of reproduction, number of generations), (2) habitat preferences (e.g. foliage or soil), or (3) dispersal ability.These aspects of collembolan ecology warrant further investigation. In view of the marked changes in the similarity of collembolan communities after use of organophosphorus insecticides (Fig. 3) it is surprising that substantial knock-on effects on predatory arthropods were not seen in the SCARAB project. Reasons for the lack of indirect effects on predators could be either that polyphagous species switched to alternative sources of prey, or that the spatial scale of the study was insufficient to allow detection of pesticide effects on predatory species which are probably able to disperse more quickly than Collembola. The latter explanation clearly has implications for interpreting results of pesticide studies in which small plot sizes could lead to underestimation of pesticide effects on mobile species.

The replicated-field study demonstrated non-toxicity of pirimicarb to Collembola in the field, confirming the results of residual bioassay experiments which were conducted in one of the study fields (WILES & FRAMPTON, 1996). The reason for consistent increases in Collembola populations after use of cypermethrin requires further investigation but could reflect harmful effects of the insecticide on Linyphiidae, which prey upon Collembola. Field-to-field variation in effects of pesticides (Table 1) could in part be explained by heterogeneity in the distribution of species, with some vulnerable species being absent from some of the fields. Such spatial variation implies that results of a single-field pesticide experiment would depend strongly upon which field was chosen for the experiment. In this respect, multi-field experiments would be preferable to single-field studies.

In conclusion, the results presented in this paper show (1) the susceptibility of epigeal Collembola communities to organophosphorus insecticide use; (2) the lack of adverse effects of cypermethrin and pirimicarb on Collembola; (3) a need for further investigation of collembolan ecology to allow high vulnerability and poor recovery to be explained; and (4) that serious consideration should be given to the spatial scale of pesticide experiments, whose results may be atypical if too few fields are included.

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