31

The MAFF SCARAB project: seven years of pesticide side-effects research on arthropods

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INTRODUCTION

One of the key results from the Ministry of Agriculture, Fisheries and Food (MAFF) Boxworth project (1981–1988), a farm-scale comparison of pesticide input systems in winter wheat (Greig-Smith *et al.*, 1992), was the vulnerability of some arthropod taxa to repeated and prophylactic use of pesticides under a high input 'full insurance' regime (Burn, 1992; Vickerman, 1992). Catches of small Carabidae such as *Bembidion* and *Notiophilus* spp. and Collembola such as *Sminthurus viridis* L. were markedly and persistently depleted in the high input regime soon after it was initiated. However, the siting of the study on one cereal farm precluded extrapolation of the results to other arable scenarios at different geographical locations. This chapter presents some results from the MAFF SCARAB (Seeking Confirmation About Results At Boxworth) study (1990–1996), which used a different experimental approach to investigate the relevance of the pesticide effects seen at Boxworth to a wider variety of arable farming situations with different pesticide demands.

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MATERIAL AND METHODS

Sites

The SCARAB project comprised seven study fields located at three MAFF Agricultural Development and Advisory Service (ADAS) Research Centres in central and northern England (Frampton and Çilgi, 1996). Results from three of the study fields are given to permit comparisons of data from each site. The fields were: Field 5 (8 ha, Drayton, Warwickshire, 52.2°N 1.8°W); Near Kingston (8 ha, Gleadthorpe, Nottinghamshire, 53.2°N 1.1°W); and Bugdale (19 ha, High Mowthorpe, North Yorkshire, 54.1°N 0.6°W). Respective soil types were calcareous clay, stony sand and calcareous loam. The arable rotation of each Research Centre typified the farming practice of the locality, with cropping as shown later in Figures 31.2 and 31.3. All fields received a conventional pesticide regime during 1990 ('current farm practice', CFP). Then, from autumn 1990 to autumn 1996, pesticides were applied as half-field treatments, one half of each field receiving CFP inputs and the other a 'reduced input approach' (RIA) of pesticide use.

Pesticide regimes

MAFF pesticide usage surveys (e.g. Garthwaite *et al.*, 1995) were used to ensure that the CFP pesticide regime mimicked conventional practice for each crop. The RIA regime contrasted strongly with the CFP by avoiding use of insecticides in all crops and years. Fungicide and herbicide use was also reduced in RIA compared with CFP where possible, though this was more easily achieved in cereals and grass than in root break crops (Frampton and Çilgi, 1996). Management of the two halves of each study field differed only in their pesticide regimes, all other husbandry activities (tillage, harvesting and fertilization) being perfomed on a whole-field basis.

Arthropod sampling

Abundance and species richness of arthropods was estimated using suction sampling (D-vac) (Dietrick, 1961). Four D-vac samples (total 1.84 m^2) were taken at matched locations in each field-half, between 25 m and 125 m from a common field boundary as described in Frampton (1997b). Except during adverse weather and periods of cultivation, samples were collected in all months and over 150 taxa were identified and recorded. For brevity, results are presented here for predatory Coleoptera (Carabidae, Staphylinidae) Coccinellidae and Cantharidae and epigeic Collembola on three summer sampling occasions in each year.

RESULTS

Pesticides

During the period 1990–1996, on average the RIA inputs of herbicides, fungicides and insecticides were, respectively, 48%, 53% and 100% lower than CFP inputs. A summary of the overall pesticide inputs in each field is shown in Figure 31.1. The high use of herbicides in Near Kingston field mainly reflects the high herbicide demands of a sugar beet crop grown in 1996.

Arthropods

Summer catches of predatory Coleoptera (Figure 31.2) and epigeic (surface-dwelling) Collembola (Figure 31.3) varied considerably between sites and years. Differences in the number of predatory Coleoptera species trapped in each of the pesticide regimes changed markedly on consecutive sampling occasions in some years (Figure 31.2) whereas the spatial variation in Collembola species was generally more stable within a season, except after some insecticide applications (Figure 31.3). Apart from the winter cereals crops of 1994 and 1995, diversity of epigeic Collembola was relatively low at the Gleadthorpe site (Figure 31.3b) but no other consistent effects of cropping or site were evident. Following sprayed organophosphorus insecticide applications (chlorpyrifos, dimethoate, triazophos) the number of predatory Coleoptera species trapped was lower in the sprayed (CFP) regime on 8 of the 10 occasions when sampling was preceded by an application in the same season (Figure 31.2). Catches of Collembola species showed a similar pattern but the lower numbers of species trapped in the CFP regime after use of chlorpyrifos at Gleadthorpe and Drayton persisted throughout the

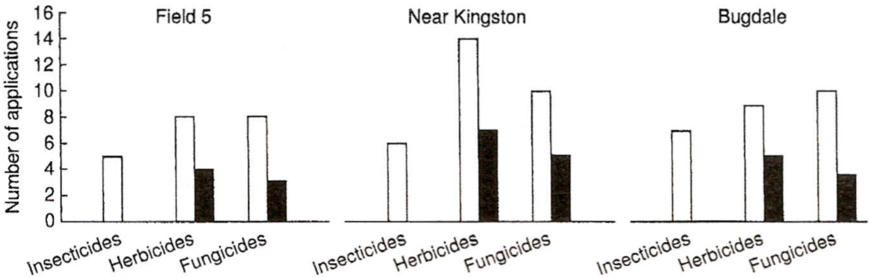

Figure 31.1 Number of current farm practice (■) and reduced input approach (□) full-rate pesticide applications made on three sites between autumn 1990 and autumn 1996.

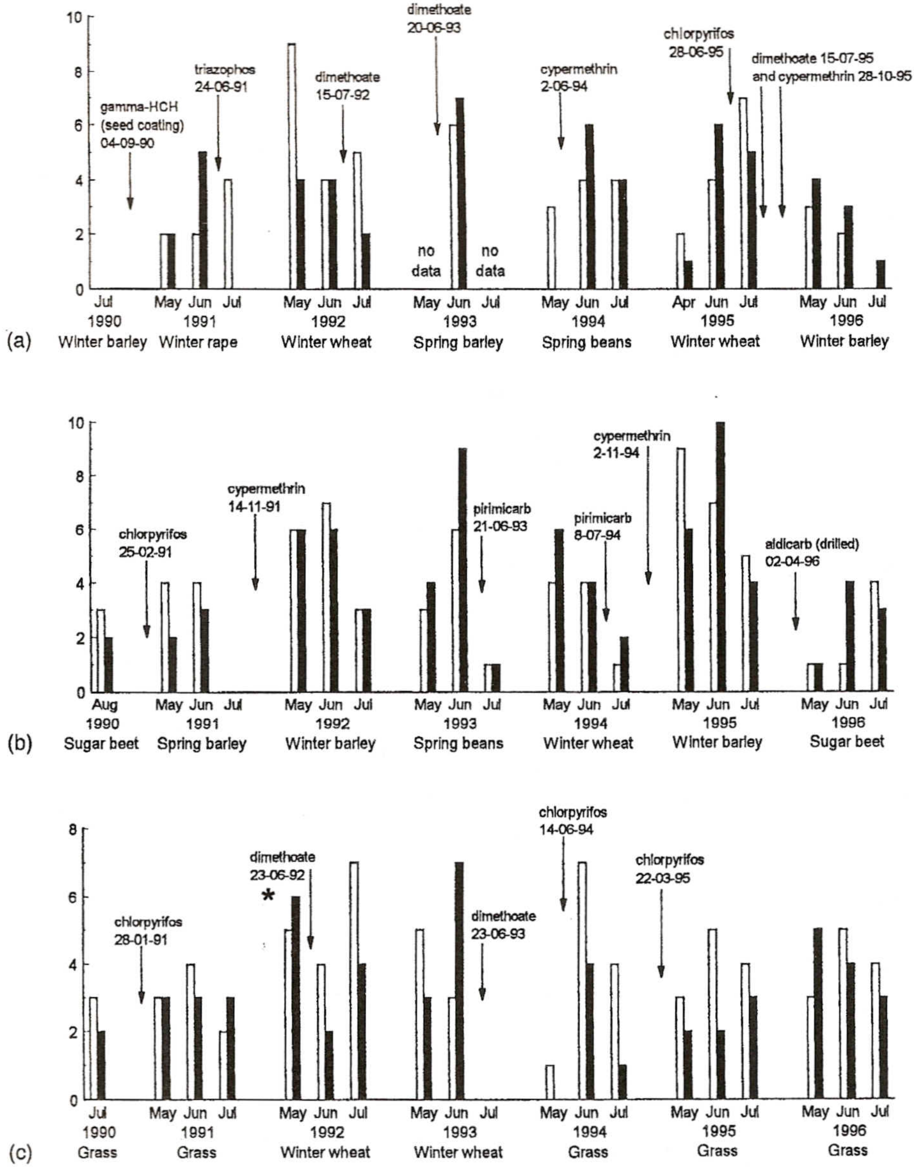

Figure 31.2 Number of predatory Coleoptera species in four suction samples (1.84 m^2) from current farm practice (CFP) (■) and reduced input approach (RIA) (□) pesticide regimes of three rotations. Insecticides were applied only under the CFP regime. Minimum time interval between sampling and a previous insecticide application = 5 days, except * (= 1 day). **(a)** Bugdale field, High Mowthorpe; **(b)** Near Kingston field, Gleadthorpe; **(c)** Field 5, Drayton.

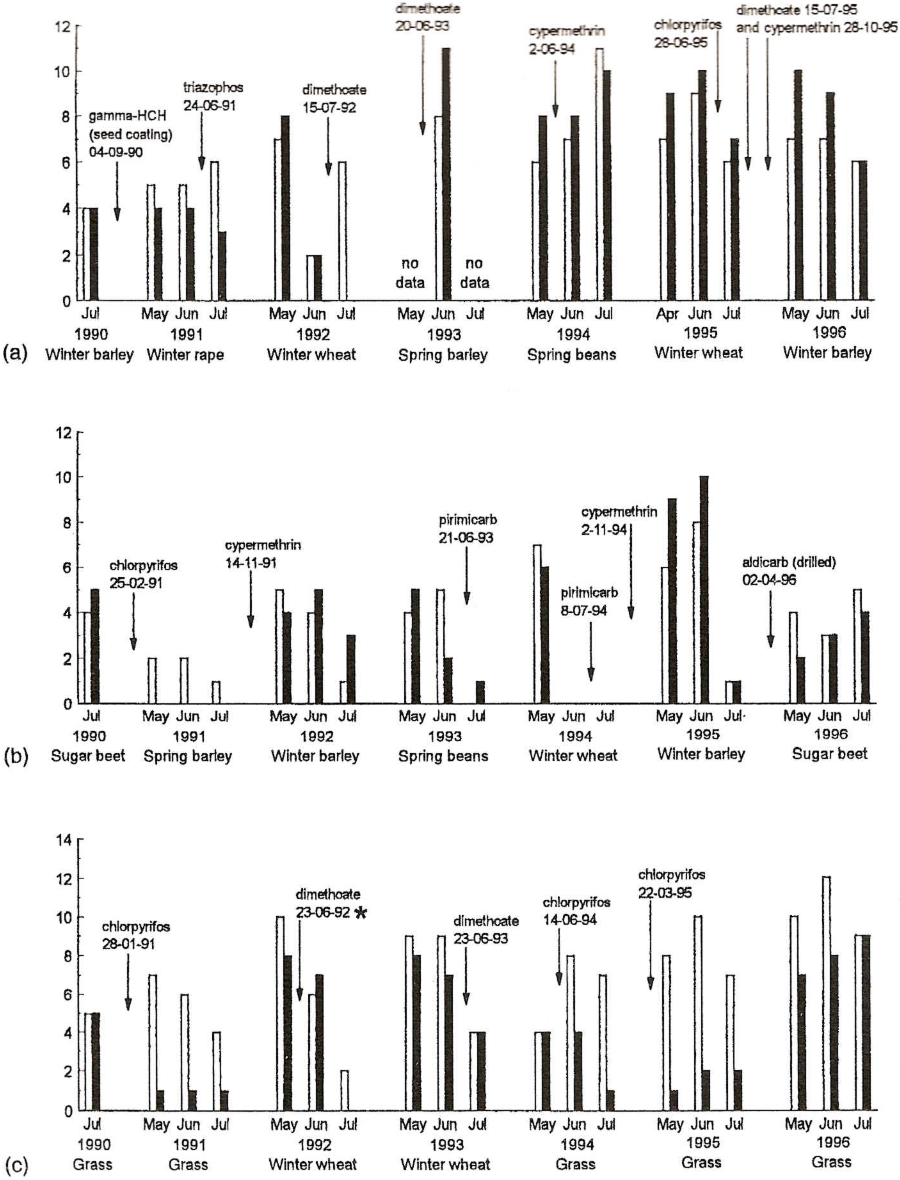

Figure 31.3 Number of abundant ($n > 3$) Collembola species in four suction samples (1.84 m^2) from current farm practice (CFP) (■) and reduced input approach (RIA) (□) pesticide regimes of three rotations. Minimum time interval between sampling and a previous insecticide application = 5 days, except *(= 1 day). **(a)** Bugdale field, High Mowthorpe; **(b)** Near Kingston field, Gleadthorpe; **(c)** Field 5, Drayton.

summer (Figure 31.3). There were no consistent patterns in the total numbers of Collembola and predatory Coleoptera species trapped after use of the synthetic pyrethroid, cypermethrin.

DISCUSSION

The results presented here focus on predatory Coleoptera, Collembola and insecticides in three fields and so represent a subset of the full SCARAB project data. The design of SCARAB, lacking orthodox replication, is amenable to multivariate methods of data analysis (e.g. as in Siepel and Van de Bund, 1988; Sanderson, 1994). For present purposes, confidence that changes in species richness shown in Figures 31.2 and 31.3 reflect actual effects of insecticides is based on: the timing of the changes in relation to pesticide applications; the magnitude of the changes; their persistence; and, for Collembola, the relative parity of CFP and RIA catches in the 'pre-treatment' year (1990). Other farming system studies (examples in Frampton, 1997b) have used similar criteria to infer negative or positive pesticide effects in unreplicated experimental designs.

The primary aim of SCARAB was to investigate the overall environmental consequences of using conventional and reduced-input regimes rather than effects of individual pesticides, but results consistent with negative effects of particular broad-spectrum insecticides have occurred. Some of the spatial variation in the arthropod catches shown in Figures 31.2 and 31.3 perhaps also reflects effects of fungicide and herbicide use, which differed between the regimes (Figure 31.1). For instance, the lower CFP number of Collembola species trapped in spring beans in 1993 (Figure 31.3b) would be consistent with a negative effect of the fungicide benomyl (e.g. Krogh, 1991) which was applied in May as a greater quantity of active ingredient under CFP than RIA. Effects of some pesticides would have been too subtle to detect against the perturbations caused by broad-spectrum insecticides, particularly if they were indirect or cumulative and thereby not coinciding clearly with specific applications. The environmental importance of such use of pesticides should be clarified when the full data set, which includes other fields with less intensive use of broad-spectrum insecticides, is analysed. Confidence in the interpretation of individual non-replicated observations, such as the use of benomyl described above, should also be improved as the full analysis will include a greater number of representative pesticide-field-crop combinations. Present results indicate that the most obvious negative effects of pesticide use were related to organophosphorus insecticides, but even within this class of pesticide there was spatial and temporal variation, with effects of chlorpyrifos on numbers of Collembola species more pronounced than those of dimethoate at two of the sites (Figure 31.3b,c).

There were a number of instances where more species were trapped in the CFP (sprayed) regime than the RIA but with no consistent pattern to give clear support to any positive effects of pesticide use. Statistically significant increases in the abundance of some Collembola species occurred after cypermethrin was sprayed in a replicated-field study in wheat (Frampton, 1997a) but so far no evidence of an effect of cypermethrin has been detected in the SCARAB fields. Given the known broad-spectrum properties of dimethoate, it was unexpected that more species of Collembola and predatory Coleoptera would be trapped in the current farm practice regime after use of dimethoate in spring barley in June 1993 (Figure 31.3a). Abundance of Collembola in CFP catches was 26% higher than in RIA catches and this pattern was also observed for Staphylinidae (36% more abundant in CFP samples), Lathridiidae (53%), Aphididae (26%) and Hymenoptera (33%). These results indicate that a broad-spectrum effect of dimethoate was lacking on this occasion, emphasizing the need for pesticide studies to include a representative range of agricultural, geographical and meteorological conditions for extrapolation of results to be acceptable. In 1992, use of dimethoate in winter wheat was followed by a lower catch of Coleoptera species (Figure 31.2c) but without a decrease in Collembola species (Figure 31.3c). The most likely reason for this result, in which sampling took place one day after the application, is that foliage-dwelling species of predator were exposed to the dimethoate sooner than ground-dwelling Collembola. Another broad-spectrum insecticide application which did not clearly decrease the richness of Collembola species was the use of chlorpyrifos in winter wheat in Bugdale field in 1995 (Figure 31.3a). However, on this occasion both the number of predator species (Figure 31.2a) and the total collembolan abundance, which was 78% lower in CFP than RIA catches in July, were consistent with a negative effect of the insecticide, indicating that species richness alone may be insensitive to some effects of broad-spectrum insecticides.

Despite the limitations of species richness data, it is desirable – when predicting the overall risk to an arthropod community – to ascertain the spectrum of susceptible species and their relative ecological importance. Preliminary results from SCARAB show that there were some specific crop-field-pesticide combinations in which all of the suction sampled (i.e. diurnally active) species of predatory Coleoptera or abundant Collembola species were eliminated, e.g. after use of triazophos in 1991 (Figure 31.2a), chlorpyrifos in 1991 (Figure 31.3b) or dimethoate in 1992 (Figure 31.3a). When determining the range of susceptible species it is important to consider any bias inherent in the sampling method. Pitfall trap catches in grass in 1991 indicated that several species of Carabidae were susceptible to chlorpyrifos (Frampton and Çilgi, 1994) whereas these effects were underestimated by suction samples taken at the same time (Figure 31.2c) because Carabidae formed a very small proportion of the predator catch. In the three SCARAB fields considered here, total elimination of diurnally active predatory Coleoptera or Collembola occurred relatively infrequently but recovery times of some collembolan species subsequently took several years (Frampton, 1997a).

Although the results discussed here are not complete, they illustrate some key points for consideration when conducting pesticide side-effects studies with arthropods:

- Collembola may be suitable for detecting negative effects of organophosphorus pesticide use, as several susceptible species occur in arable crops; currently Coleoptera, but not Collembola, are recommended in field testing procedures with pesticides (e.g. Barrett *et al.*, 1994).
- Extrapolation of pesticide effects from one taxon, geographical location, agricultural or meteorological scenario could be misleading.
- Coleoptera and Collembola are not suitable as indicators of all CFP side-effects, since neither group exhibited consistent negative responses to the synthetic pyrethroid insecticide cypermethrin, which is harmful to other arthropods such as Araneae (e.g. Pullen *et al.*, 1992).

As the occurrence of susceptible species varies spatially and temporally (Frampton, 1997a,b), long-term multi-site studies of pesticide effects are needed to aid interpretation of the results from the many pesticide studies conducted in single fields.

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