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Edited by
D.M. Glen
M.P. Greaves
H.M. Anderson
IACR-Long Ashton Research Station, University of Bristol, UK

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17 Ecological Aspects of SCARAB and TALISMAN Studies

M. HANCOCK[1], G.K. FRAMPTON[2], T. ÇILGI[2], S.E. JONES[3] AND D.B. JOHNSON[3]

[1]ADAS Boxworth, Boxworth, Cambs, UK
[2]Department of Biology, University of Southampton, UK
[3]School of Biological Sciences, University of Wales, UK

17.1 INTRODUCTION

In 1981, the Boxworth Project (funded by the Ministry of Agriculture, Fisheries and Food) started at ADAS Boxworth with three objectives including that of examining and comparing the environmental side-effects of contrasting pesticide regimes (Greig-Smith *et al.*, 1992). The experiment was prompted by the increasing concern about effects that pesticides could be having on the environment, raised most prominently by the Royal Commission on Environmental Pollution (1979). There was some previous evidence that non-target invertebrates were adversely affected, but more evidence was needed from a long-term, systematic and realistic study in a representative arable environment.

By the end of the Project, in 1988, it had been established that the intensive use of permitted pesticides in wheat crops adversely affected the populations of many invertebrate species. Monitoring showed long-term decreases in catches of many important polyphagous predatory species in the intensively treated area, the major impact coming from the application of insecticides and molluscicides during the winter. Some species, such as the lucerne flea (*Sminthurus viridis*), were not detected in the intensively treated area after the first year of the experiment (Vickerman, 1992). Compared with the lower input treatments, populations of other species also decreased but populations of a few species, such as the carabid beetle *Trechus quadristriatus*, increased in the intensively treated area in several years. There was some indication that the control exerted by predators on crop pests such as aphids was reduced by the intensive pesticide regime (Burn, 1992). Full details of the design and results of the Boxworth Project are given in Greig-Smith *et al.* (1992).

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In 1990, two new 6-year experiments, again funded by the Ministry of Agriculture, Fisheries and Food, were started by ADAS to answer some of the questions raised by the results of the Boxworth Project (Cooper, 1990). These were: (1) were the side-effects of pesticides (especially insecticides) on invertebrates apparent in other locations and under other arable rotations, and (2) what were the economic and environmental effects of reducing pesticide use? In addition, the opportunity was taken to examine the effects of pesticides on soil microbial biomass. SCARAB (Seeking Confirmation About Results At Boxworth) was designed to answer the first question, and is primarily concerned with environmental effects. TALISMAN (Towards A Lower Input System Minimizing Agrochemicals and Nitrogen), was designed to answer the second question, and is concerned primarily with economic effects.

17.2 MATERIALS AND METHODS

17.2.1 SCARAB

17.2.1.1 Sites

SCARAB is sited at the ADAS Research Centres at Drayton (clay soil) in Warwickshire; Gleadthorpe (sandy soil) in Nottinghamshire; and High Mowthorpe (silty clay loam soil over chalk) in North Yorkshire.

17.2.1.2 Treatments and Design

There are two treatment factors: pesticide regime and rotation. Two pesticide regimes are compared in each rotation. The intention in the current farm practice (CFP) regime was to apply a pesticide programme typical of an informed, commercial farmer and thus it is a combination of insurance and reactive treatments. It is less extreme than the intensive (Full Insurance) regime used in the Boxworth Project (Greig-Smith *et al.*, 1992; Frampton & Çilgi, 1993a). The reduced input approach (RIA) regime contrasts with CFP in that no insecticides are used unless the continuity of the experiment is threatened, and the use of fungicides and herbicides is minimal and only as necessary to avoid more than 10% loss of yield or crop value.

The two pesticide regimes have been compared in a total of eight sets of paired areas at the three sites. Each pair is located in a single field and remains there throughout the experiment. The field is usually divided equally between the pair, one half of the field being treated according to the RIA regime and the other according to the CFP regime. Assessments were made in a study area within each CFP and RIA area, leaving a buffer zone of 36 m between the pair of study areas in a field.

The six-course rotations consist of cereal, cereal, break crop 1, cereal, cereal, break crop 2. At High Mowthorpe, one of the four cereal crops is spring-sown, as are one or two of the four cereals (depending on the rotation) at Gleadthorpe. The break crops were chosen to be typical of farms on the soil type in that area. At Drayton, a grass ley is used as the break crop; at Gleadthorpe, sugarbeet and potatoes or beans; and at High Mowthorpe, oilseed rape and spring beans.

17.2.1.3 Assessments

Monitoring of crop development, weed distribution, pest and disease levels, and assessment of yield have been done by ADAS research consultants. Researchers from the Central Science Laboratory are studying the effects of treatments on earthworm populations at each site; this work is not covered in this chapter.

Invertebrates present in the study areas have been sampled using pitfall traps and Dietrick suction samplers (D-vacs). Pitfall traps have been operated in each study area throughout every other week during the year, except between harvest and drilling, or during autumn cultivations (spring-sown crops). The traps were arranged in four transects parallel with the field boundary, one in the boundary and the other three at 10 m, 75 m and 150 m into the field. Any pitfall trap in the CFP part of a field was at least 84 m from the nearest trap in the adjacent RIA area. D-vac samples were taken in each study area on about 18 occasions each year, especially from April to October when samples were collected once every 14 days. There was at least 110 m between a D-vac sampling location in CFP and one in RIA. All sampling has been done by ADAS staff. Catches of invertebrates have been identified, assigned to species, and the results interpreted by researchers at Southampton University.

The size and composition of soil microflora have been assessed in CFP and RIA plots at High Mowthorpe and Gleadthorpe over a 4-year period by researchers at the University of Wales, Bangor. Soil samples were taken following each pesticide application. Since 1992, sampling has also been carried out before the pesticide application. On each occasion, six samples (about 1 kg weight from 2 to 10 cm depth) were taken in an oblong grid pattern at 10 m intervals from each plot. After sieving (6.7 mm), the following chemical and microbiological parameters were measured: pH and soil moisture content; total soil fungal biomass (Sundman & Sivela, 1977); and total soil microbial biomass. The latter was quantified using the fumigation–extraction method of Vance *et al.* (1991), followed by biomass estimation either by dissolved organic carbon analysis (Wu *et al.*, 1990) or by ninhydrin assay (Amato & Ladd, 1988; Joergensen & Brookes, 1990). Periodically, supplementary analyses were implemented as follows: organic carbon (Kalembasa & Jenkinson, 1973); soil organic nitrogen and microbial biomass nitrogen (Jackson, 1958); vital fungal biomass (Soderstrom, 1977); indirect (agar plate) counting of bacteria and fungi (Duah-Yentumi & Johnson, 1986; Williamson & Johnson, 1990a); and soil mineralization rates in carbon-amended and non-amended soil (modified from Williamson & Johnson, 1990b).

Data from all assessments were subjected to analysis of variance where appropriate and significance tests. The design of the experiment is not orthodox in that it lacks true replication of treatments, which is inevitable given the large-scale plots necessary for this type of study (see Greig-Smith *et al.*, 1992).

17.2.2 TALISMAN

17.2.2.1 Sites

There were four TALISMAN sites, one at each of the three research centres hosting SCARAB and one at ADAS Boxworth Research Centre, where the soil type is a heavy clay loam (Hanslope Series). Unforeseen soil problems led to the early termination of the site at Gleadthorpe after the 1991/92 season.

17.2.2.2 Treatments and design

The experiment is arranged in one field at each site as a replicated block design with the blocks parallel to the field boundary and with rotation and input level (agrochemicals and nitrogen) as the main treatments. Main plots are each about 24 × 24 m. Plots in the block nearest the field boundary are not divided, but those in all other blocks have pesticide sub-treatment plots (each 3 × 3 m) so that the effect of a particular class of pesticide (e.g. fungicide) on crop performance can be measured.

At each site, standard and alternative rotations are tested under current commercial practice (CCP) and low input approach (LIA) regimes. Both rotations are six-course with the standard rotation typical of the area and soil type. The alternative rotation was designed to indicate whether or not the rotation could be manipulated to improve economic performance in a low input regime. The standard rotation at Boxworth and Drayton consists of winter oilseed rape, winter wheat, winter wheat, winter beans, winter wheat, winter wheat, and is the same at High Mowthorpe except that the second cereal crop following winter beans is winter barley. The alternative rotations at the three sites differ considerably: at Boxworth, linseed, winter wheat, spring wheat, spring beans, winter wheat, spring wheat; at Drayton, spring beans, triticale, triticale, spring oats, triticale, triticale; and at High Mowthorpe, spring beans, winter wheat, spring barley, linseed, winter wheat, spring barley. At Drayton and High Mowthorpe, each rotation is represented twice with one duplicate starting in 1990 at break crop 1 and the other at break crop 2 in the cropping sequence. At Boxworth, only the standard rotation is duplicated.

The CCP regime follows the pesticide use expected of an informed farmer and the nitrogen requirements as determined by Fertiplan, the ADAS commercial fertilizer recommendation programme. The objective in the LIA regime is to use 50% of the nitrogen applied to the corresponding CCP sub-treatment and not to use pesticides at all. However, if it is estimated that the crop value lost by not applying a particular pesticide treatment exceeds 10%, up to 50% of the recommended dose of that pesticide can be applied. In extreme conditions that threaten the continuation of the experiment there is provision for a full recommended dose to be applied. Further details of the design, etc., are given in Perks & Lane (1990).

17.2.2.3 Assessments

Weed, pest and disease incidence, invertebrates and crop performance have been assessed by ADAS. Changes in weed seed levels in the soil and soil-dwelling nematode populations have been monitored by researchers at the Scottish Crop Research Institute, Invergowrie; these studies are not covered in this chapter.

Invertebrate populations were monitored in the block nearest the field boundary by using pitfall traps and D-vacs. The plots were relatively small for invertebrate monitoring and ideally should be much larger. Therefore, monitoring was aimed at detecting changes relating to short-term pesticide effects. Four pitfall traps were placed along the length of the centre line of each plot. They were emptied every 7 days or, when a pesticide was applied, immediately before and 4–7 days after the application. The contents of the four traps were bulked together to give one plot catch that was identified and assigned to species for the more abundant beetles, spiders and known indicator species or species of interest. In the absence of a pesticide application, the catch from every other week was identified. To support the interpretation of pitfall trap monitoring, samples were taken with a D-vac from every plot in the block once every 2 weeks from the first week in April until harvest.

17.3 RESULTS AND DISCUSSION

17.3.1 SCARAB

17.3.1.1 Invertebrates

The principal aim of SCARAB is to identify any long-term effects of pesticide applications by comparing CFP and RIA areas of each field. As the experiment has been designed to run over 6 years, the summary of results presented here should be regarded as preliminary.

Baseline studies in the fields before the experiment detected many predatory species including, in the pitfall traps, a total of 41 ground beetle (Carabidae) species, 42 rove beetle (Staphylinidae) species, 55 spider (Araneae) species, including 38 money spider (Linyphiidae) species and nine wolf spider (Lycosidae) species, and seven harvestmen (Opiliones) species. Differences between fields at the same site in invertebrate species diversity and abundance were detected at Gleadthorpe and Drayton, but not at High Mowthorpe. These differences may have been associated with differences in cropping and, in one case, the recent use of aldicarb, a soil-applied insecticide/ nematicide. Variability in abundance and diversity within some fields was also detected. Such differences between and within fields have to be considered when interpreting results from the treatment years.

Considerable differences in pesticide exposure have been generated between the CFP and RIA study areas. In the 16 crops grown up to harvest 1992, a total of 34 herbicide, 34 fungicide and 15 insecticide applications were applied to the SCARAB fields; the CFP areas were treated with full rate applications and the RIA areas with half rates of herbicides and fungicides. No insecticides were applied to RIA areas but each CFP area was treated at least twice with an insecticide during this period.

So far, trends in CFP and RIA catches have indicated that, as in the Boxworth Project, insecticide treatments affected the populations of some non-target invertebrate species. For example, chlorpyrifos (an organophosphorus insecticide) was applied at Drayton to a fifth grass ley crop in January 1991. For about 3 months after this application no carabid (ground) beetles were trapped in the CFP area (Figure 17.1). The catches of carabid beetles were usually less in the CFP area than those in the RIA area over the following 12 months, even though no more applications of an insecticide were made. In the summer of the next year, a second organophosphorus insecticide, dimethoate, was applied to the winter wheat crop following the grass ley. Catches of carabid beetles in the CFP area were larger than in the RIA area for about 4 weeks after this foliar application (Figure 17.1).

The contrasting effects of these two insecticide applications illustrate the need for careful interpretation of pitfall trap results based on knowledge of the life cycles and behaviour of the species concerned and of the limitations of the trapping technique. The commonest carabid species in this field at Drayton was *Trechus quadristriatus*. The pattern of pitfall trap catches for this species (Figure 17.2) was similar to that for all carabids. *Trechus quadristriatus* adults are very dispersive and it is not surprising that effects of the insecticide on this species were short-lived. Mechanisms of pesticide effects on this species were discussed by Frampton & Çilgi (1993b). In contrast, although the carabid beetle *Bembidion obtusum* (Figure 17.3) and several species of springtail (Collembola) were not trapped in the CFP area until

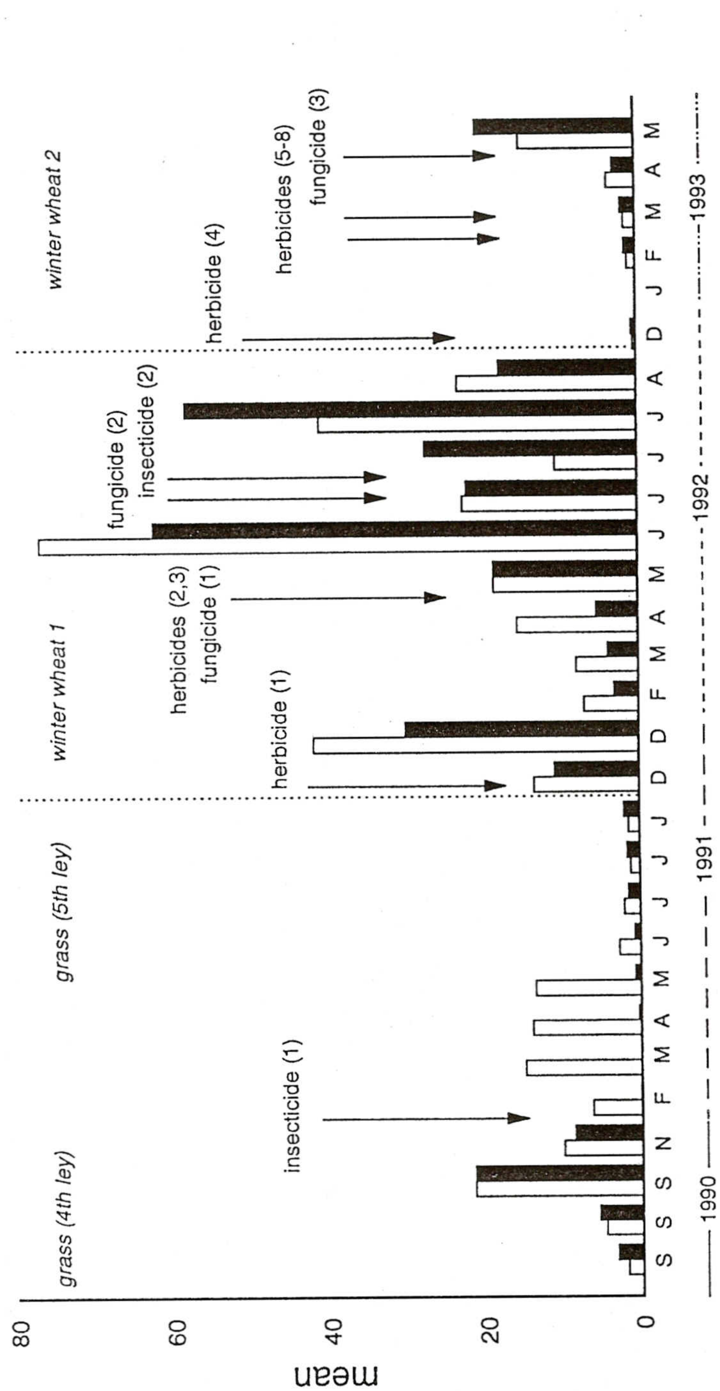


Figure 17.1. Geometric mean of log-transformed Carabidae catch per pitfall trap in the RIA (□) and CFP (■) areas of field 5. Fungicides and herbicides were applied at full rate to the CFP area of the field and at half rate to the RIA area; insecticides were applied only to the CFP area

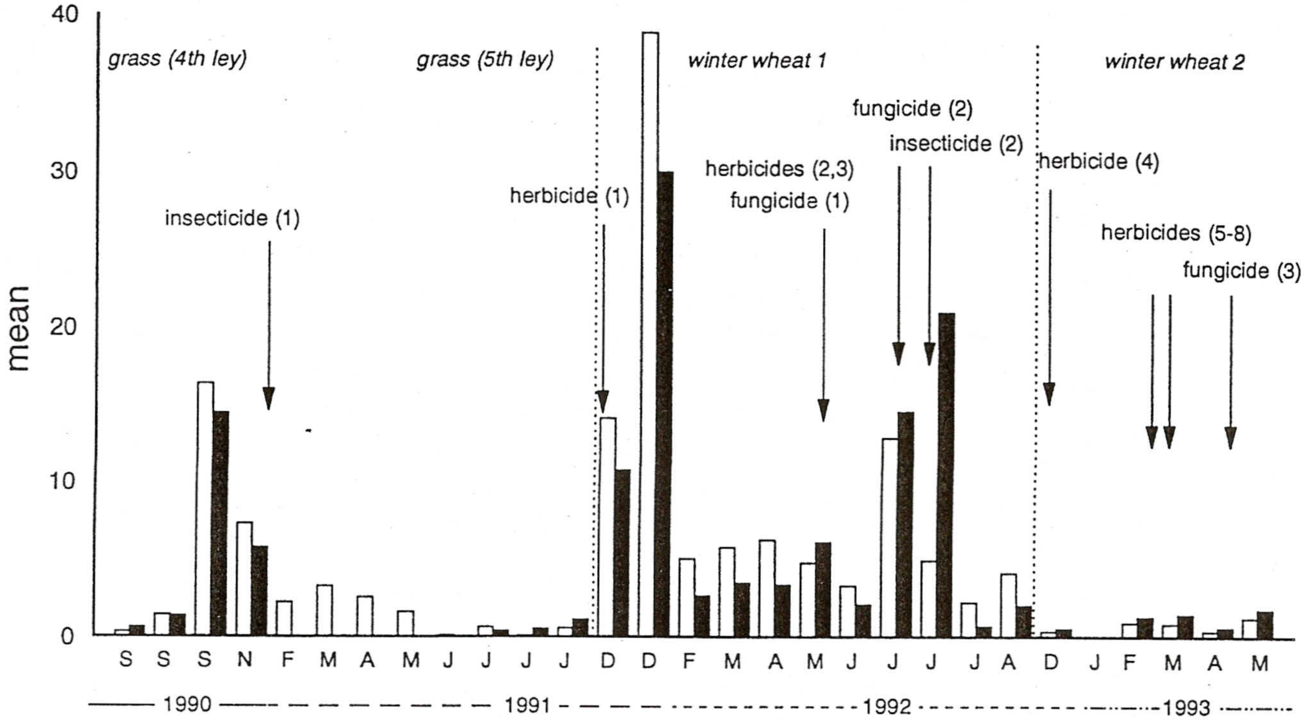


Figure 17.2. Geometric mean of log-transformed *Trechus quadristriatus* catch per pitfall trap in the RIA (□) and CFP (■) areas of field 5. Fungicides and herbicides were applied at full rate to the CFP area of the field and at half rate to the RIA area; insecticides were applied only to the CFP area

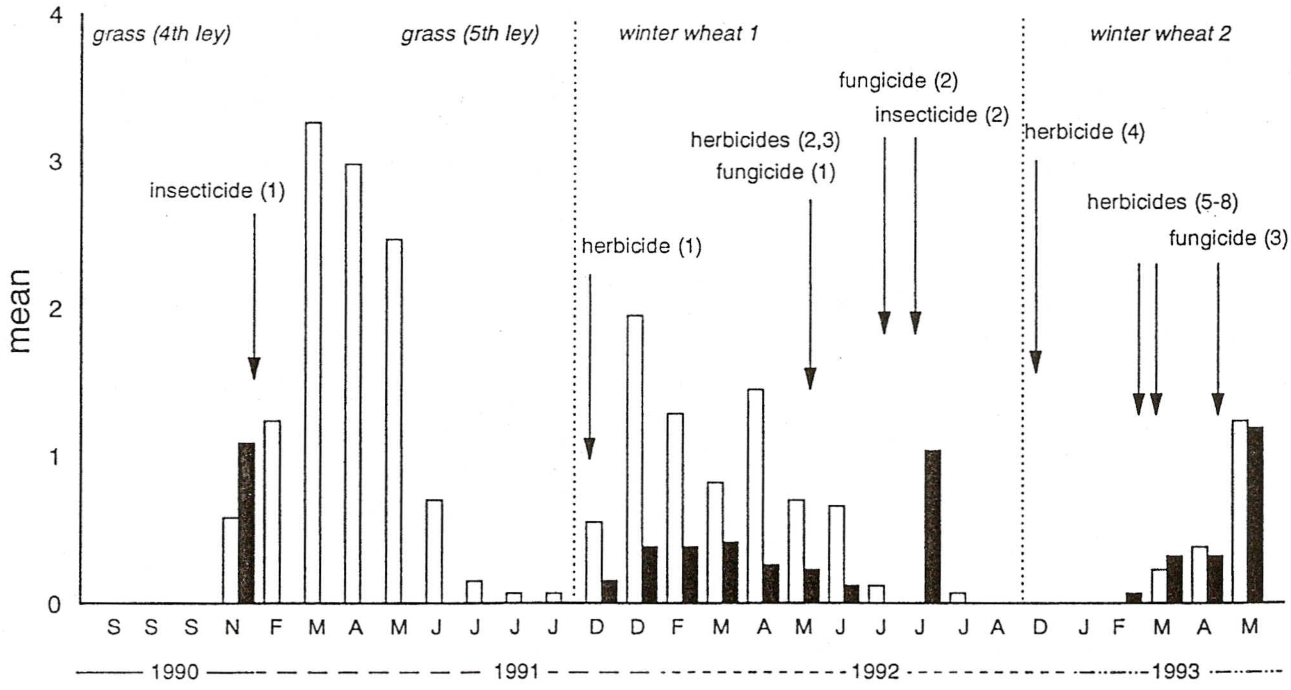


Figure 17.3. Geometric mean of log-transformed *Bembidion obtusum* catch per pitfall trap in the RIA (□) and CFP (■) areas of field 5. Fungicides and herbicides were applied at full rate to the CFP area of the field and at half rate to the RIA area; insecticides were applied only to the CFP area

many months after the application of chlorpyrifos, the catch patterns suggested that there was a real effect of the pesticide on the, relatively small, numbers of this species. The differences in persistence of effect between the beetle species may be explained by their behaviour. Larvae of *Trechus quadristriatus* live underground during the winter where they are relatively protected against pesticides. *Bembidion obtusum* remain as adults on the soil surface during this time and are relatively vulnerable to pesticides. If a large proportion of adults are killed, the next population of larvae is likely to be relatively small. The size of the following generation may also be adversely affected. Hence, the effect of a pesticide on a species with the life cycle of *Bembidion obtusum* may be more persistent than on a species like *Trechus quadristriatus*.

There was some evidence, from another Drayton field, that some non-target invertebrates were affected by an application of deltamethrin (a synthetic pyrethroid) made in the late autumn of 1991 and again in 1992 to winter cereals to prevent the occurrence of barley yellow dwarf virus. Trap catches of some beetle species, particularly *Bembidion,* and of the spider genus *Oedothorax* (Figure 17.4) were reduced after application.

However, there were few, if any, detectable differences in trap catches of non-target invertebrates following some other insecticide applications. For example, trap catches were less adversely affected by a spray of chlorpyrifos to the CFP area of winter wheat at Gleadthorpe than at Drayton. The contrast between Drayton and Gleadthorpe might be explained by differences in timing or faunal composition; species that are potentially susceptible to pesticides because of their life cycle were scarce in the field at Gleadthorpe. In other instances, it has not been possible, yet, to determine if fewer specimens were caught in CFP as a result of a pesticide or because the species had declined naturally in the field.

Preliminary results of invertebrate monitoring in SCARAB mirror those of the Boxworth Project, with severe effects of pesticide use on some ground beetles and springtails, even though the two studies differ in pesticide inputs, in crops, in soil type and in the size of the treated areas. Details of results from the first year were given in Frampton & Çilgi (1992). Evidence from both the Boxworth Project and SCARAB suggests that some ground beetle species may be good indicators of non-target pesticide effects, but SCARAB has shown that difference in species composition on different farms have to be taken into account when assessing non-target effects.

17.3.1.2 Soil Microbial Biomass

A summary of results is presented here, with major trends and findings highlighted. At High Mowthorpe, biomass parameters have fluctuated more in CFP areas than in RIA areas. Changes in the soil fungal biomass, the largest population component, seem to have been the major factor under-

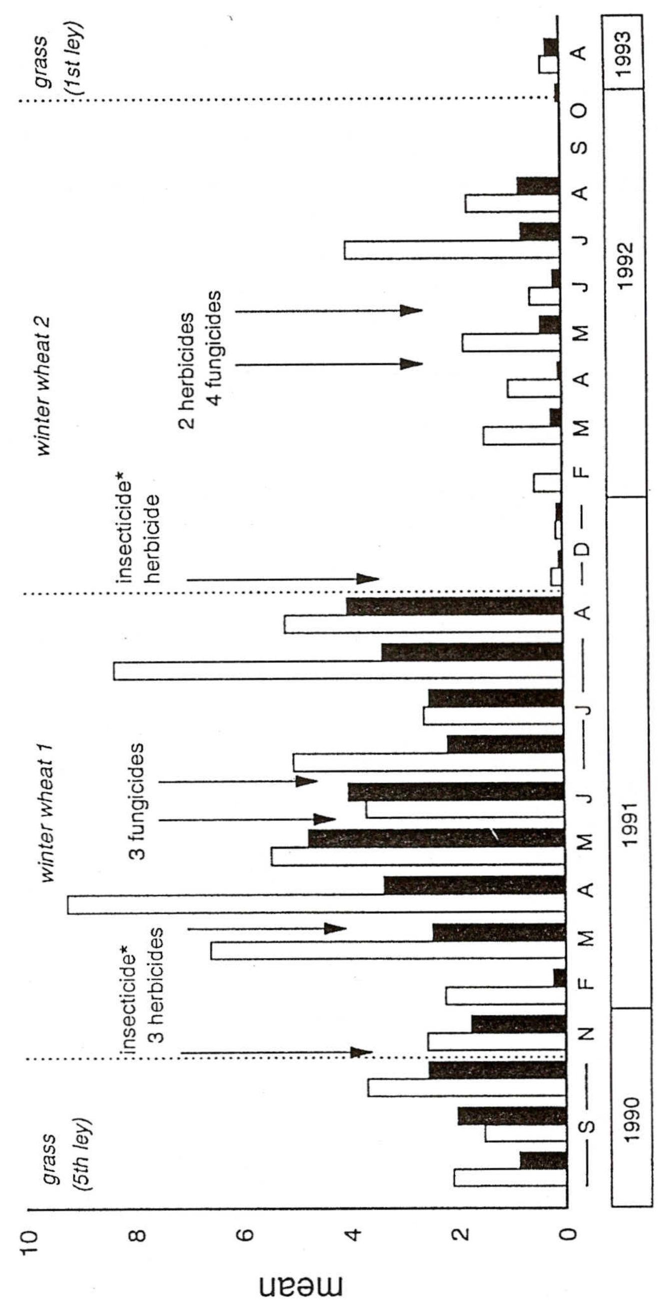
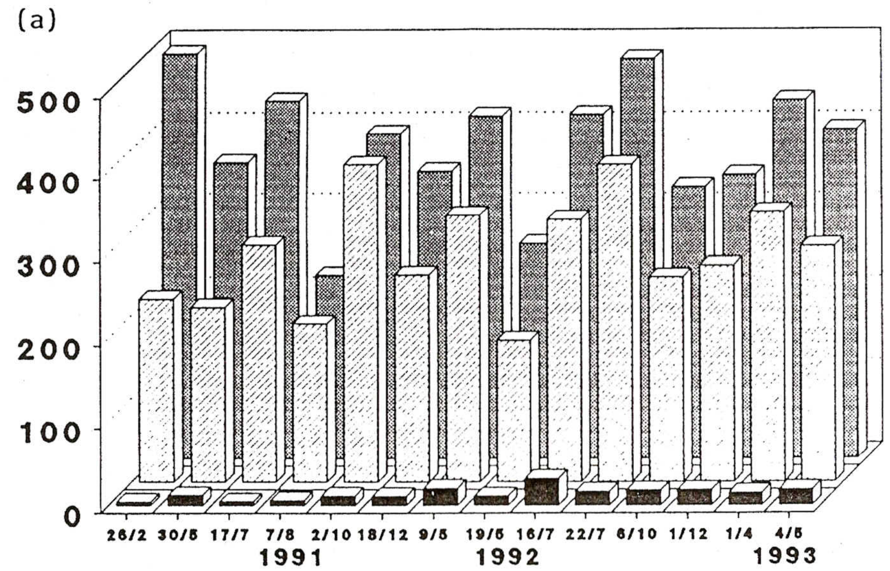


Figure 17.4. Geometric mean of log-transformed *Oedothoras* spp. catch per pitfall trap in the RIA (□) and CFP (■) areas of field 1. Fungicides and herbicides were applied at full rate to the CFP area of the field and at half rate to the RIA area; insecticides were applied only to the CFP area. *Deltamethrin



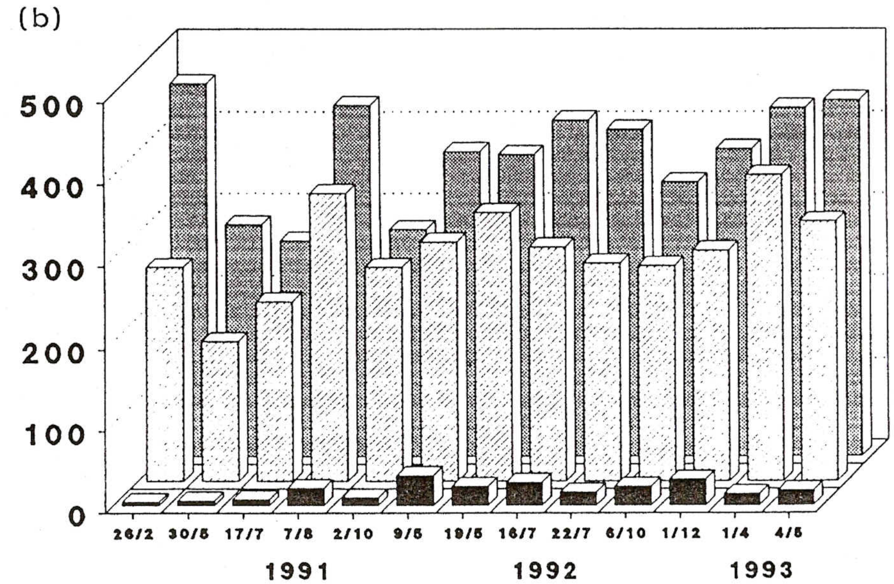


Figure 17.5. Total, fungal and vital biomass, High Mowthorpe. (a) CFP site. Pesticide regime: commercial dosage of insecticides, herbicides and fungicides. (b) RIA site. Pesticide regime: half commercial rate of herbicides and fungicides; no insecticides. Vital fungi (■); total fungi (▨); total biomass (□)

going flux (Figure 17.5). A similar pattern has emerged at Gleadthorpe from 1992 onwards (data not shown). At Gleadthorpe, drought and minor differences between CFP and RIA pesticide regimes in 1991 made interpretation of the results more difficult and a definite microbial response to pesticide treatment was detected only after data had been collected for 3 years. This illustrates the need for such studies to be long-term.

The effects of individual pesticides on microbial biomass were found to be highly variable within each class (e.g. insecticide, fungicide) of pesticide (Table 17.1). Although a pesticide may have demonstrable effects on soil microbial populations *in vitro*, its effect on microflora *in vivo* may be different and unpredictable because of the influence of a variety of factors. These include the chemistry, the site of action and persistence of the pesticide, the soil type, the movement of pesticide in the soil profile, and the metabolic state of the microbial biomass (Arnold & Briggs, 1990).

Herbicides had variable effects on microbial biomass indicators (Table 17.1). Significant increases in biomass were detected after full-rate applications of bentazone ($P < 0.05$, 23/05/91) and glyphosate ($P < 0.01$, 4/09/91) at High Mowthorpe (Figure 17.5). These herbicides could have indirectly stimulated the microbial biomass by increasing root exudation of crops and

Table 17.1. Biomass action of pesticides used in SCARAB (H = herbicide, F = fungicide, I = insecticide, N = nematicide)

Pesticide	*Type*	*Persistence in soil*	*Biomass action*[1]	*Comments*
Bentazone	H	Low	+[2]	Growth on root exudates (?)
Glyphosate	H	< 60 days	+	Growth on root exudates (?)
Diflufenican	H	15–30 weeks	V	
Isoproturon	H	12–19 days	V	
Metsulfuron-methyl	H	7–30 days	–	Direct effect
Pendimethalin	H	3–4 months	–	Added with insecticide
Chlorothalonil	F	7–15 weeks	+	Indirect action
Propiconazole	F	1–3 months	–	Effects masked by non-uniform sampling
Prochloraz	F	1–3 months	–	Fungal biomass also reduced
Dimethoate	I	2–4 weeks	+	Significant at both locations
Omethoate	I	2–4 weeks	+	Soil-applied
Aldicarb	I/N	1–3 months	?	Drought-stressed biomass
Pirimicarb	I	7–234 days	V	Reduction at High Mowthorpe, not at Gleadthorpe
Cypermethrin	I	3–12 weeks	–	Significant at High Mowthorpe

[1] source: Kidd & James (1991); Cremlyn (1991).
[2] +: biomass consistently higher in CFP than RIA plots.
–: biomass consistently lower in CFP than RIA plots.
V: biomass response variable over sites or locations.

weeds (Cremlyn, 1991). Chakravaty & Chatarpul (1990) recorded similar stimulation of biomass by glyphosate. In contrast, intensive soil sampling around the time of application of metsulfuron-methyl to fields at Gleadthorpe showed significant ($P < 0.05$) inhibitory effects on soil biomass. The herbicide mixture diflufenican + isoproturon had no discernable effect on soil biomass at either location.

Although some of the more modern fungicides are relatively specific in action, other commonly used fungicides are broad-spectrum and will affect non-target soil fungi (Cremlyn, 1991). At High Mowthorpe, the decrease ($P < 0.03$) in microbial biomass following prochloraz treatment (15/05/92) might be predicted to have resulted from a direct fungicidal effect as prochloraz is known to be toxic to soil fungi *in vitro* and in field tests (Nan *et al.*, 1991). However, examples of an initial decline in soil populations followed by growth after fungicide application have been recorded, possibly indicative of the selection of fungicide-resistant strains (Domsch, 1970).

It is known that the normal field use of some insecticides may have some impact on soil micro-organisms (Anderson, 1978). Soil biomass was temporarily significantly reduced ($P < 0.01$) following application of the carbamate pesticide pirimicarb at High Mowthorpe, but not at Gleadthorpe. Sampling before and after the pyrethroid cypermethrin was applied at both locations revealed reductions in soil biomass parameters at all sites (significant at High Mowthorpe, 25/11/92, $P < 0.05$). In contrast, organophosphorus insecticides (dimethoate and omethoate) produced increases in biomass parameters, possibly caused by a temporary reduction of activity of fungal-feeding invertebrates.

The soil biomass studies in SCARAB were prompted by the results of similar studies in the later stages of the Boxworth Project (Jones *et al.*, 1992). Conclusions drawn from the Boxworth work were limited in that no baseline data were available. However, there was evidence that the differential pesticide inputs changed the size and composition of the soil microbial biomass. Soils under the high input regime had lower total and fungal biomass levels than those under the lower input regime. In SCARAB, baseline measurements of biomass have been taken and should improve interpretation of later results. The preliminary results suggest that, as at Boxworth, pesticides have modified soil microbial biomass but the persistence, extent and detail of such changes are not yet evident.

17.3.2 TALISMAN

The summary presented here highlights particular trends or differences in trap catches within each treatment from 1990 to 1992. The interpretation so far has been largely qualitative; a more detailed analysis may be possible when more data are collected. Comparisons with the results of SCARAB will also aid interpretation. In general, trap catches of beetles and/or spiders appeared to have been affected by some pesticide applications at some sites but it has not yet been possible to assess the significance of these effects, either statistically or ecologically.

In 1990/91, 11 pesticide applications were made in response to the build-up of pests to threatening levels. The results of trapping at Boxworth suggested that a spray of a synthetic pyrethroid adversely affected beetles in oilseed rape, and beetles and money spiders in linseed. At Drayton, catches of mites (Acarina) and springtails were reduced by a pyrethroid applied to oilseed rape. At the same site, there were indications that spiders and beetles were indirectly and adversely affected by the carbamate pirimicarb applied to spring beans. Similar results were obtained at Gleadthorpe for carabid beetles in potatoes and possibly in sugarbeet too, where pirimicarb was applied at full and half rates. At High Mowthorpe, application of pirimicarb to spring beans produced no obvious effects, but the application of an organophosphorus compound, triazophos, seemed to reduce catches of ground beetles.

In the following cropping year, when all rotational treatments were in cereals, trap catches indicated no long-term effects of previous pesticide applications or cropping. Only four pesticide applications were made in response to pest attack. At Boxworth, where no insecticides, nematicides, etc. were applied in 1991/92, there appeared to be some 'edge effects' on catches of several species or groups of invertebrates. Catches of some species were also reduced during periods of low temperatures. Non-pesticidal effects such as these, if real, need to be considered when interpreting the data. At Drayton, catches of carabid beetles and, to a lesser extent, staphylinid (rove) beetles and springtails, were reduced by a spray of deltamethrin applied in December. At Gleadthorpe, dimethoate applied in June may have affected the catch of some invertebrates, especially spiders, but other causal factors could not be ruled out. There were no definite indications that the spray of dimethoate applied at High Mowthorpe in July affected any non-target invertebrates but these were generally at relatively low levels in the traps by then anyway.

The preliminary results of the invertebrate monitoring in TALISMAN are similar to those of SCARAB. Direct and indirect pesticide effects have been indicated for a range of species in several crops. Somewhat surprisingly, it seems possible that the small plot size has not prevented the detection of relatively persistent changes in fauna. More data are required in order to establish the persistence and nature of non-target effects of pesticides.

17.4 SUMMARY AND CONCLUSIONS

The results of the Boxworth Project prompted two 6-year experiments, started in 1990 and funded by the Ministry of Agriculture, Fisheries and Food.

SCARAB has investigated the effects of pesticides on non-target invertebrates at three ADAS research centres and in various crop rotations. Invertebrates were monitored in eight paired study areas, each of which was in a larger treatment area, usually half a field. Pesticides were applied to one treatment area of a pair according to current farm practice. The other treatment area was not treated with any insecticides, molluscicides and nematicides, but other pesticides were applied according to a reduced input approach. Preliminary results indicated that catches of several species of Coleoptera, Collembola and Linyphiidae were considerably reduced following insecticide applications, but the persistence of these effects is not known. Soil microbial biomass has been monitored in each treatment area at two research centres. Responses, mainly of the soil fungal biomass, to some pesticides have been detected but have been highly variable within each class of pesticide. TALISMAN has assessed the economic and, to a lesser extent than SCARAB, environmental effects of reducing inputs to arable rotations at three ADAS research centres. The main treatment factors were rotation and input level. Normal input levels were compared with using half the rate of nitrogen and reduced pesticide rates. No pesticide was applied unless a yield loss of at least 10% was expected from a problem, when up to half the recommended rate was permitted. A full rate was allowed if the continuity of the experiment was threatened. Invertebrates have been monitored in the block of plots nearest the field boundary. So far, pitfall trap catches of Coleoptera, Linyphiidae, Acarina and/or Collembola have been affected by some pyrethroid, carbamate and organophosphate insecticides.

17.5 ACKNOWLEDGEMENTS

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18 Less-intensive Farming and the Environment: an Integrated Farming Systems Approach for UK Arable Crop Production

V.W.L. JORDAN AND J.A. HUTCHEON
Department of Agricultural Sciences, University of Bristol, IACR-Long Ashton Research Station, Bristol, UK

18.1 INTRODUCTION

Strategies to initiate and implement less-intensive approaches to arable crop production systems must be built on a sound base of ecological research and development, and must encompass both existing and new technologies to allow full exploitation of beneficial ecological interactions. Effort should be focused on the need to resolve conflicting requirements for control of pests, diseases and weeds, and on the need to minimize the environmental impact of crop production. Single answers to limited or specific problems are unlikely to offer long-term solutions; only comprehensive, fully integrated and interdisciplinary approaches are likely to meet the challenge to provide less-intensive farming systems which are economically, ecologically and environmentally sound and sustainable in the long term.

The integrated farming systems approach has been identified as a practical option for developing less-intensive arable systems to sustain production, to maintain the competitiveness of farmers and farm income and to safeguard the environment (El Titi *et al.*, 1993; El Titi, Chapter 14), objectives which are all particularly relevant in the current agroeconomic climate. Using data and technology generated from component research within the Institute of Arable Crops Research, this chapter outlines the manipulation and integration of farming practices, within a whole systems approach (the less-intensive farming and the environment or LIFE project), to maintain or enhance the chemical, physical and biological condition of the soil, to increase biodiversity thereby creating benefits to natural regulatory processes, and to reduce the impact of pests, diseases and weeds, thus lowering the requirement for agrochemicals.

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