Distribution and Abundance of Soil Fauna in Principal Cotton Growing Valleys of NSW — Key Findings and Conclusions

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Background

Soil fauna have generally remained an 'unseen' resource to Australian cotton growers. No studies have investigated the effects of cotton farming practices and insecticides on beneficial soil fauna since the 1970's (Bishop and Blood, 1977 & 1980; Room, 1979). This study (Lytton–Hitchins, 1998) was a baseline biodiversity survey of the principal soil faunal groups found in irrigated cotton fields of north western New South Wales. Field work was conducted on commercial cotton farms located in the Macquarie, lower Namoi, and Gwydir valleys. The various growers and agronomists involved were practitioners of innovative and 'best management' practices. Fields sampled differed in (i) the age of cotton production and (ii) the crop protection practices used to control insect pests. Some field experiments were conducted using whole cotton fields that were unreplicated, whilst others used large replicated plots within whole fields on commercial cotton farms. At the Australian Cotton Research Institute (ACRI), a small field with replicate plots of Envirofeast® cotton and lucerne was also sampled. Standardised experimental designs were devised and sampling equipment constructed. Surface–active species were collected using pitfall traps, visual ground searching, and hand collection. Pitfall trapping periods were usually aligned with irrigation cycles. Extensive field observations were included to determine species–specific behavioural patterns, identify key refugia, and collect species that might avoid pitfall traps. Soil cores were used to sample soil fauna in rhizosphere soil to a depth of 150 mm. Springtails, soil–dwelling beetles, ants, and earwigs were considered in detail, and identified to species or morphological–species. Beetles and earwigs were assigned 'reported' feeding habits, and ants and springtails allocated to functional groups.

Results and Discussion

More species of soil fauna were found in furrow–irrigated cotton fields than was previously recognised. A total of 196 species of beetles, ants, earwigs and springtails were identified. Within these four groups, seasonal catches in individual fields were dominated by one to three species. Approximately 20 species were therefore consistently common on the soil surface in any given cotton field. Four species and one genera of springtails were recorded for the first time in Australia. Larvae of the Green Carab Beetle, *Calosoma schayeri*, was also collected for the first time in any Australian field crop. Very little is known about the biology and ecology of any of the soil fauna species identified in this study.

Generalist predators and litter transformers were the dominant ecological groups found on the soil surface. Among the predators, earwigs, beetles (carabids and staphylinids), and wolf spiders were generally nocturnal.

For the soil–dwelling beetles, the most common feeding habit groups were generalist predators, fungivores and scavengers. For springtails and ants, the most commonly represented functional group(s) were hemiedaphic (i.e. fauna that move between the soil surface and upper 150 mm of the soil profile) fungal feeders; and generalised myrmicines (*Pheidole* spp.), dominant dolicherines (*Iridomyrmex vicinus* spp. group), and opportunists (*Rhytidoponera metallica* group), respectively. Species from all three ant functional groups are collected in cotton foliage using suction samplers. Earthworms, both natives and introduced species, and Meat Ants were entirely absent from the commercial cotton fields sampled during this study.

Irrigation and effective rain was a primary factor influencing the seasonal daily catch rates (DCR's) of several soil fauna groups. For example, the highest DCR's of surface–active springtails coincided with irrigations or effective rain. Surface soil moisture was also important for earwigs, but DCR's were often smaller during trapping periods that included, or closely followed, the application of irrigation water. DCR's of total earwigs peaked during January, and peaks and troughs appeared to correspond well with average air temperatures. However, significant declines in DCR's of ants followed heavy rains and/or excessive waterlogging. Foraging activities of *I. vicinus* group workers ceased when the application of irrigation water coincided with larvae being present in their nests.

Several farm management factors had an impact on species diversity and relative abundance of soil fauna; including the age, size, tillage regime, and rotation sequence of each cotton field; availability of surface residues and food; and management tactics used to control insect pests. Soil cracks and crevices were the most important within–field refugia for soil–dwelling beetles and earwigs. Lucerne strips in Envirofeast® cotton at ACRI appeared to benefit some predatory ants, spiders, springtails and crickets, but were poorly colonised by predatory soil–dwelling beetles and earwigs. In addition to soil water potential, springtail numbers appeared to be affected by the availability of moistened surface residues, soil predator numbers, and insecticide usage. For example, seasonal DCR's of springtails were small in Envirofeast® cotton that had the largest DCR's of ants and earwigs across all cotton fields sampled. Springtails therefore appeared food limited, and might serve as an important food source for soil predators during stages I and II. Conversely, springtail DCR's across all seasons peaked in sprayed fields with long cotton histories and low soil predator numbers. Sprayed and unsprayed fields, both large and small, with long histories of irrigated cotton, generally supported smaller total numbers of soil–dwelling beetle species. Unsprayed, Ist–

season cotton had the greatest species diversity of soil–dwelling beetles, whilst all individual cotton fields were dominated by species with body lengths < 5 mm.

Most predatory species did not colonise irrigated cotton until stage II.

Furrow–irrigated cotton fields with large DCR's of ants during stage I were: (1) well drained, (2) usually small in size, (3) often linked to grassy field margins or lucerne strips, (4) maintained with minimum tillage, and (5) either managed with only 'soft option' foliar sprays, or without soil and foliar insecticides. The smallest DCR's and lowest species diversity of ants occurred in large fields that either (i) had long histories of conventionally sprayed cotton or (ii) were excessively waterlogged.

The Common Brown Earwig, *L. truncata*, was more abundant during stages I and II in old fields than in newly developed ones. It appeared (1) less affected by field size, insecticide usage, rotation sequence, and tillage than springtails, ants and ground beetles; and (2) tolerant to even the most extreme cotton management practices.

Insecticide usage is a key management factor influencing species diversity and abundance of non–target invertebrates like soil fauna in cotton agroecosystems. Repeated endosulfan sprays appeared to cause no detectable reduction in DCR's of several groups of soil fauna at Doreen during stages I and II of 1995–96. Consistent treatment differences for springtails, soil–dwelling beetles, and ants in sprayed and unsprayed cotton were generally confined to stage III. Predatory beetles (Figure 1) and ants (Figure 2) appeared to be the most adversely affected by stage III insecticides. Most groups of springtails, soil–dwelling beetles, and ants did not recover, either between consecutive pyrethroid, carbamate, and organophosphate sprays, or by the final sampling. During stage III, the Green Carab Beetle, *C. schayeri,* comprised 45% of the generalist predators collected in unsprayed, Ist–season cotton; but was entirely absent in sprayed cotton, irrespective of age. The practice of simultaneously treating several large fields on individual cotton farms with broad spectrum insecticides presents major problems for most non–target invertebrates like the soil fauna.

Conclusions

(1) There are more species of soil fauna associated with the ground floor of furrow–irrigated cotton fields than was previously recognised. Abundances can exhibit marked seasonal fluctuations.

(1) Surface–active soil fauna found in furrow–irrigated cotton are strongly influenced by abiotic factors.

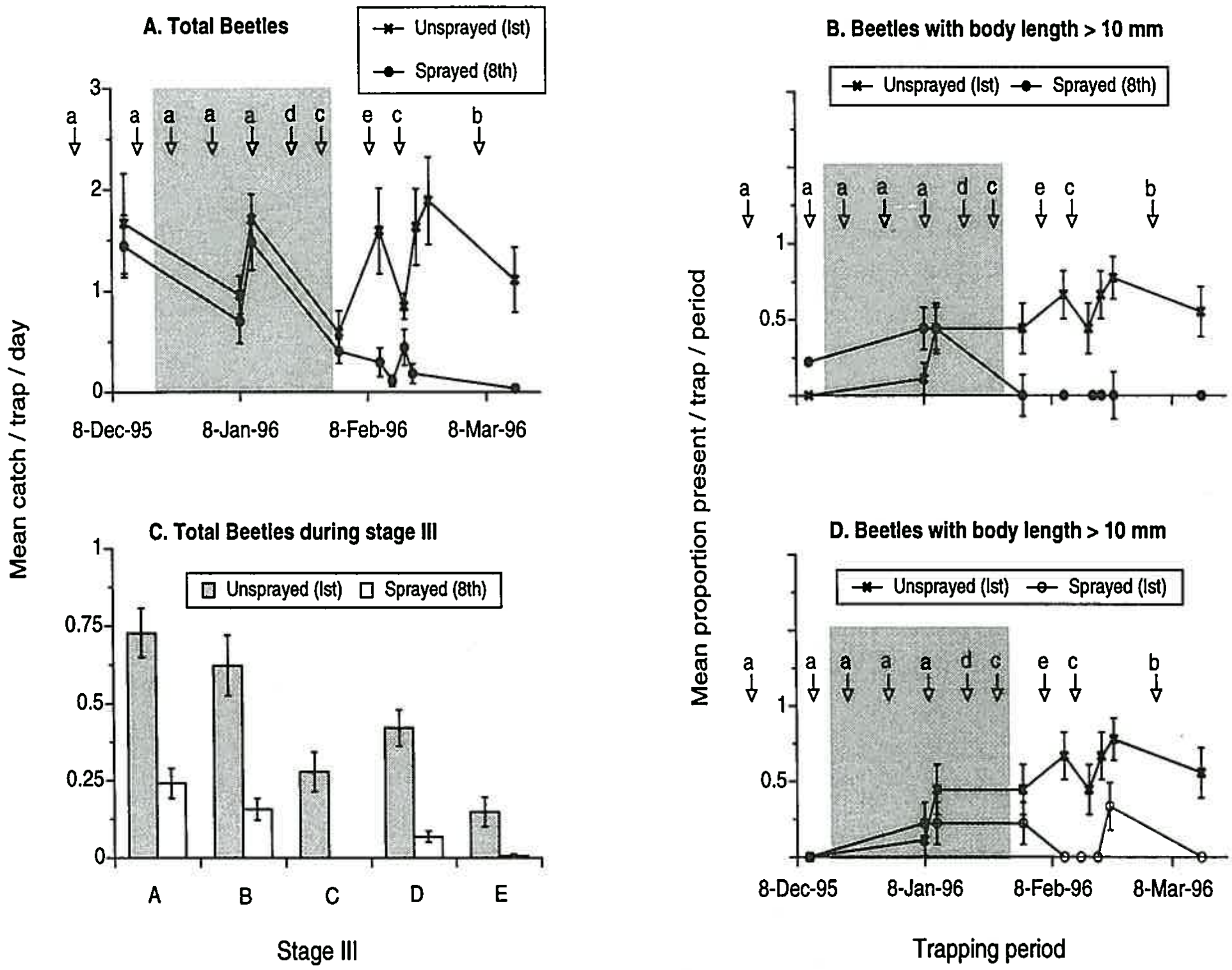

Figure 1: Effects of insecticides and field age on the seasonal daily catch rates of beetles at Doreen during 1995–96. Graphs A and C show the mean seasonal daily catch rates of total beetles and beetle groups, A–E, in unsprayed, Ist–season and sprayed, 8th–season cotton. Graph B shows the proportion of traps containing beetles with body length > 10 mm in unsprayed, Ist–season and sprayed, 8th–season cotton; whilst graph D shows beetles with the same body length in unsprayed, Ist–season and sprayed, Ist–season cotton.

Groups A–E in graph C = beetles < 5 mm in length (A), generalist predators (B), *Calosoma schayeri* (C), fungivores (D) and scavengers (E).

Insecticide codes: a = Endosulfan (Organochlorine); b = Profenofos (Organophosphate); c = Thiodicarb (Carbamate); d = Deltamethrin (Pyrethroid); and e = Bifenthrin–Dimethoate (Pyrethroid).

Shading in graphs indicates stage II.

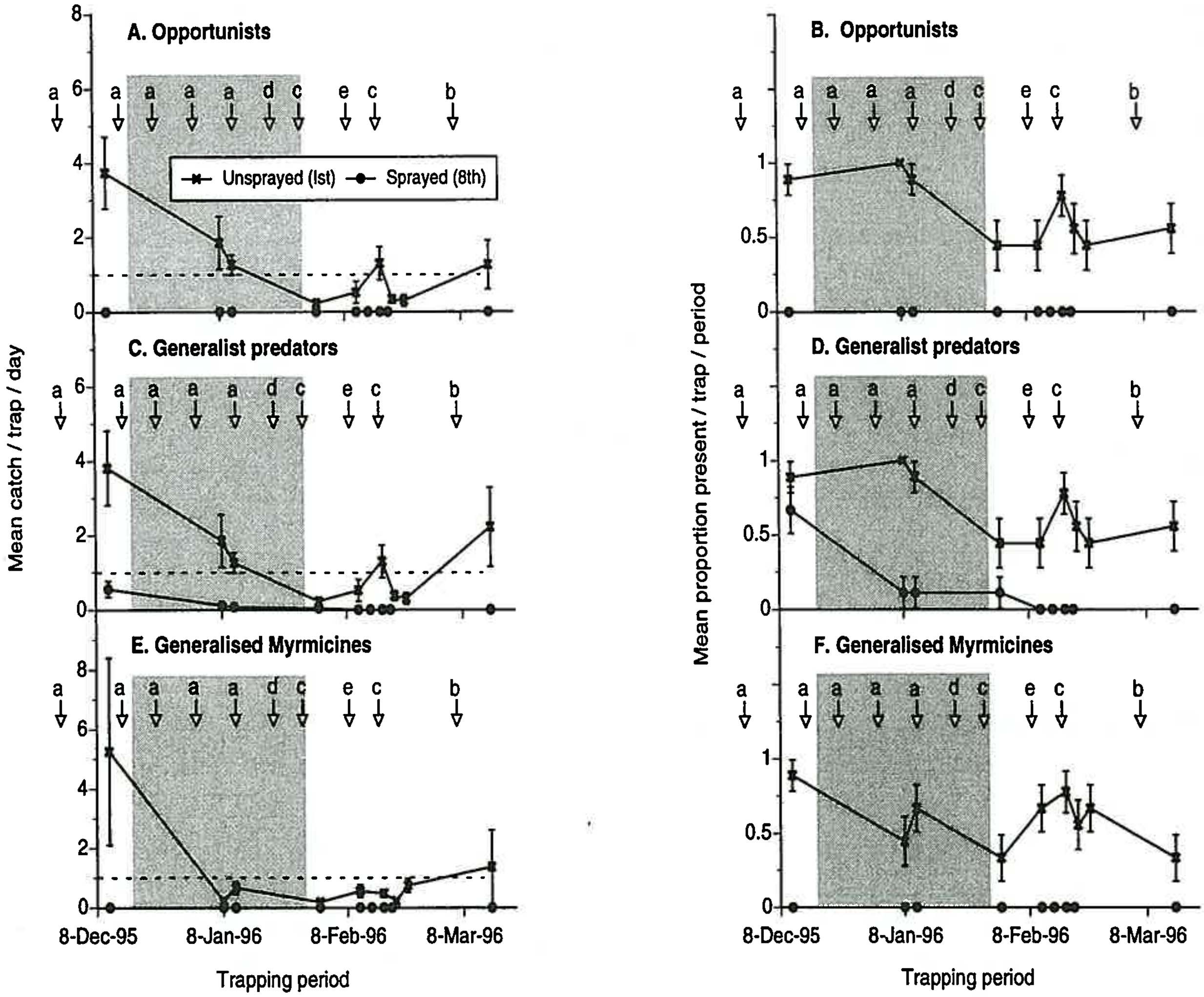

Figure 2: Mean daily catch rates and proportion of traps containing ants using pitfall traps in unsprayed, Ist–season (✖) and sprayed, 8th–season (●) cotton at Doreen during 1995–96.

Insecticide codes: a = Endosulfan (Organochlorine); b = Profenofos (Organophosphate); c = Thiodicarb (Carbamate); d = Deltamethrin (Pyrethroid); and e = Bifenthrin–Dimethoate (Pyrethroid).

Shading in graphs indicates stage II.

(3) Springtails appear to be food limited for a significant proportion of the growing season in most cotton fields. However, because they are one of the most abundant groups of surface–active fauna they may serve as an important prey source for soil predators.

(4) Ants and larger predatory soil–dwelling beetles were the groups most adversely affected by current agronomic and crop protection practices.

(5) Obtaining reliable density estimates of soil fauna in commercial cotton fields proved to be extremely difficult and laborious.

(6) The nocturnal habits of many predatory soil fauna found in irrigated cotton fields have resulted in their potential contribution to the suppression of insect pests being unnoticed in most current IPM research activities. The impact of these fauna on insects pests found in cotton is not known. Quantification of the impact of potentially important soil predators on key insect pests, and development of commercially 'user–friendly' sampling systems are necessary if they are to be included in IPM systems.

(7) Current 'best management practices' being adopted within the Australian cotton industry to effectively control insect pests and weeds, and conserve soil moisture, may need modification in the future should effective management of soil biota be desirable.

Future directions

Feeding preferences and frequencies of almost all fauna considered in this study are yet to be investigated. For the most abundant groups of predatory fauna, an important first step therefore is to establish 'who eats what?' during each stage of the cotton growing season. Historically, progress in our understanding of predator–prey interactions in the field has been slow, because many predators are small, often hidden, nocturnal, interact with their prey for very brief periods, and leave behind little evidence of their attack. However, it is fortunate that direct observational studies (slow, time consuming and disruptive) conducted in the field, glasshouse and laboratory can now be complemented with state–of–the–art qualitative techniques. Such post–mortem techniques are rapid, cost effective, and allow predation to occur naturally in the field. Enzyme–linked immunoassays (ELISA) are one such opportunity that would allow researchers in Australian cotton to use pest– and stage–specifc monoclonal antibodies (MAbs) (Hagler & Naranjo, 1996) to qualitatively define the feeding habits of common insects (soil and climbing) found in cotton. If required, this kind of research could be conducted on a valley by valley basis.

Little is known of the 'absolute' population densities of beneficial soil fauna. Most of the techniques employed in this baseline study were only partially quantitative. Effective sampling systems (reliable, user friendly, cost effective) must therefore be developed if we are to better understand the potential role of soil fauna in sustainable cotton production. Within–field and within–season variability in population densities and rates of colonisation need to be quantified. Complementary day–night and dawn–dusk sampling (e.g. suction, beat–bucket, and drop cloth) of the crop canopy is required (e.g. for climbing ants, earwigs, spiders, staphylinids, carabids and other beetle families). Novel techniques are needed to obtain reliable estimates of ground densities. The relative efficiencies of techniques (e.g. baited pitfall traps, light traps, direct counts / unit of raised bed) must be assessed within defined unit areas (e.g. within large field enclosures).

Accurate identification of beneficials is one of the first essential skills to be learnt by entomologists and pest managers working in IPM systems. More comprehensive and user–friendly systems of taxa identification are required. Spiders are one group in need of particular attention. User friendly–pictorial keys for identification of key soil – and plant–based predators and relevant ecological information would be logical additions to current versions of entomoLOGIC®. Such information could also be made available on the recently developed 'hand–held devices' (e.g. palm pilot® and palm PC's®) for use by pest managers in the field. Specialised identification resources are required for use in research laboratories, since many technicians in rural–based research institutes begin with little, if any, training in entomology.

In closing, this study found a wide diversity of soil fauna in furrow–irrigated fields of NSW, that are abundant at certain times in the growing season and have not previously been reported. The majority of these soil fauna were affected by insecticide usage, cultivation, and irrigation. The role of soil fauna with regards to the sustainability of irrigated cotton production is unclear. Most fauna found were allocated to 'reported' feeding habits or functional groups. Little is known about their biology and ecology. Similarly, the impact of predacious groups of soil fauna on key insects pests found in Australian cotton is yet to be investigated.

References

Bishop, A.L., and Blood, P.R. (1977). A record of beneficial arthropods and insect diseases in southeast Queensland cotton. *PANS (Pest Artic. News Summ.)*, **23**: 384–6.

Bishop, A.L., and Blood, P.R.B. (1980). Arthropod ground strata composition of the cotton ecosystem in south–eastern Queensland, and the effect of some control strategies. *Aust. J. Zool.*, **28**: 693–97.

Hagler, J.R., and Naranjo, S.E. (1996). Using gut content immunoassays to evaluate predacious biological control agents: a case study pp. 383–399. *In* W.O.C. Symondson and J.E. Liddell (eds.). *The ecology of agricultural pests– Biochemical approaches*. The systematics Association Special Volume Series 53. Chapman & Hall, London, UK.

Lytton–Hitchins, J.A. (Submitted March 1998). *Seasonal abundance and diversity of soil fauna in the principal cotton growing valleys of NSW*. Ph.D. thesis (University of Sydney).

Room, P.M. (1979). Parasites and predators of *Heliothis* spp. (Lepidoptera: Noctuidae) in cotton in the Namoi valley, New South Wales. *J. Aust. ent. Soc.*, **18**: 223–8.

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