Spider Management in Agroecosystems: Habitat Manipulation

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ABSTRACT / Based on the literature and on work conducted in Israel, the management of spider populations through habitat manipulation was found to be very helpful in controlling pest insects in various crops. Spiders were found to be reduced or eliminated by nonselective insecticides, although some resistance has been noted

In some ecological situations, spiders can contribute to prey reduction and regulation. In each ecosystem the impact of spiders follows two pathways. These are the predatory pressure of the whole group of spiders on the entomocoenosis, and the pressure of particular spider species on some species of phytophagous insects (Luczak 1979). The results obtained by American, Japanese, and Polish arachnologists in crop fields, and by Canadian and Israeli arachnologists in orchards, provide evidence that spiders can be used as the natural enemies of pests in several key crops. It is known that, under crop conditions, spiders are important enemies of aphids, mites, and lepidoptera larvae and eggs.

Spider Predation in the Agroecosystem

By preventing reproduction of single insect species, spiders, along with other general predators, largely account for maintaining biocoenotic stability in ecosystems (Riechert 1974, Huffaker 1975). Spiders are not always generally polyphagous; some are rather specialized and oligophagous (Dabrowska-Prot and Luczak 1968).

Numerical analyses of spider predation are found in a few publications (Turnbull 1960a, b, Kajak 1965, 1971, Luczak and Dabrowska-Prot 1966, Haynes and Sisojevic 1966, Dabrowska-Prot and Luczak 1968, Moulder and others 1970). A few attempts have been made to determine indirect benefits from predation by spiders, namely their effects on the biomass and survival of plants infested with pests.

The effect of spider predation on grasshoppers was estimated from measurements of the yield of grass consumed by these insects (Kajak and others 1968). The authors found that the average losses in plant material were lower in the presence of spiders. Horner (1972) introduced the jumping spider *Metaphidippus galathea* (Walckenaer) into potted barley plants infested with the aphid *Schizaphis graminum* (Rodani). Spider predation on aphids resulted in a prolongation of the life of the plants by more than 10 days, though it did not stop the ultimate destruction of the plants.

Observations in potato fields (Kajak 1965) revealed that a spider capturing two aphids a day early in spring is more effective than a spider capuring 50 aphids a day during the outbreak period. Spiders have been found to be predators of eggs and larvae of *Heliothis* spp. and other lepidoptera in cotton and soybeans in the United States (Whitcomb and others 1963, Bell and Whitcomb 1964, Smith and Stadelbacher 1978, McDaniel and Sterling 1979, Buschman and others 1977, Room 1980). A direct numerical relationship was established recently between two spider species and *Heliothis* spp. in Queensland (Bishop and Blood 1981). Kayashima (1960) found that the spider *Misumena tricuspidata* (Fab.) is an effective natural enemy of cabbage pests. Oliver 1964) discovered 19 spider species in the cocoon of the pest *Hyphantria cunea* (Drury). Dippenaar-Schoeman (1979) showed that some spiders helped control mites in strawberries.

In Japan (Kiritani 1979) and the Philippines (IRRI 1976), it was demonstrated that spiders have an important role as predators in rice fields. Spiders have been introduced into rice fields in the People's Republic of China as biological control agents of rice pests (Nyffeler and Benz 1980). Sasaba and others (1973) tested food preferences and metabolism of *Lycosa pseudoannulata* (Boes. and Strand). The rice pests, *Nephotettix cincticeps* Uhler and *Nilaparvata lugens* Stal., accounted for about 80% of the diet of these spiders. The same spider was studied by Kawahara and others (1974) with reference to the colonization of rice, developmental biology, and predation. The predation by species of spiders occuring in rice fields was analyzed in detail by Kiritani and others (1972). The species involved were *Lycosa pseudoannulata, Tetragnatha* sp., *Oedothorax insecticeps* Boes. and Strand, and *Enplognatha japonica* Boes. and Strand. The densities of these spiders were estimated under natural conditions and then the populations were experimentally increased. The authors estimated the mortality of the pests caused by the spiders at various developmental stages in the pests' life cycle. They also reported data on the feeding behavior in spiders. They found that pests are mainly captured by immature stages of the wolf spider *Lycosa*

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pseudoannulata, and by adults of smaller spider species. Spiders consumed 4.4 to 60.3% of nymphs and 8.2 to 24.4% of adult *Nephotettix cincticeps* in the study rice fields. Spiders were noted as predators of lepidoptera larvae on banana in Costa Rica (Harrison 1963), on apple in Canada (Dondale 1956 and 1958), on citrus in California (Carroll 1980), and on apple in Israel (Mansour and others 1980a). It has been shown that larval aggregation of *Spodoptera* spp. was disturbed by spiders (Yamanaka and others 1972, Mansour and others 1981).

Composition of Spider Fauna in Crop Fields

The spider fauna in cotton fields have been examined by Whitcomb and others (1963), Whitcomb and Bell (1964), Aguilar (1968), and Leigh and Hunter (1969). Soybean spider fauna were examined by LeSar and Unzicker (1978), and alfalfa spider fauna have been studied by Howell and Pienkowski (1971), Wheeler (1973), and Yeargan and Dondale (1974). Baily and Chada (1968) studied spider populations in grain sorghums. Other studies have been made on row and pasture crop spiders in the United States and in other countries.

The spider fauna in paddy fields in Japan, Korea, Taiwan, and Thailand have been investigated. About 16 species of spiders are recorded as preying on Brown Planthopper (BPH) (Chiu 1979). In India, about 20 species of spiders were observed preying on BPH (Samal and Misra 1975).

Spiders often constitute a large part of the predatory arthropod fauna of orchards and prey on such pests as aphids, mites, and moths (Dondale and others 1979). Surveys of spider populations in apple orchards were carried out by Chant (1956) in England, Dondale (1956, 1958) in Nova Scotia, Specht and Dondale (1960) in New Jersey, Hukusima and Kondo (1962) in Japan, Legner and Otman (1964) in Wisconsin, Dondale (1966) and MacLellan (1973) in Australia, Hagley (1974) in Ontario, Dondale and others (1979) in Quebec, Mansour and others (1980) in Israel, and McCaffrey and Horsburgh (1980) in central Virginia. Putnam (1967) reported on the spiders in peach orchards in Ontario, Muma (1975) on the spiders in citrus in Florida, and Carroll (1980) on the spiders in citrus in southern California.

Effects of Agroecosystem Management on Spider Populations

The effects of cultural practices, such as plowing, harrowing, and harvest, on invertebrate animals living in crop fields can radically alter population sizes and compositions. Harvest, for example, is a period of mass destruction and migration of insects and spiders to the nearest undisturbed vegetation (Whitcomb and Bell 1964). Some detailed results on the effects of mowing on particular spider families and species are reported by Howell and Pienkowski (1971). Immature thomisids and salticids decreased, but species of other families of mainly ground-dwelling spiders, e.g. *Pachygnatha tristriata* C. L. Koch and species of the family Lycosidae, were not affected and maintained their numbers during four days after mowing. Linyphiids increased in numbers during four days after mowing, apparently because the mowed field attracted many potential prey insects; their numbers soon returned to the level found before mowing.

Only a few papers are concerned with the effects of pesticides on spiders. The effect of pesticides on eight cotton pest species and associated predators, including spiders, was discussed by Whitcomb and Bell (1964). The authors emphasize the role of proper pesticide timing, the importance of a strictly local application, and the need for selective pesticides. Spiders were less susceptible to organophosphates and carbamates than to chlorinated hydrocarbons. Also, spiders were less susceptible to insecticides than some insect predators such as the coccinellids, *Geocoris* sp. and *Nabis* sp. Repeated treatments eliminated spiders as well, however (Laster and Brazzel 1968).

Spiders living in regions where pesticides have been used for a long time showed some resistance to insecticides. For example, *Oxyopes salticus* Hentz, a known predator on pests of the genus *Heliothis*, was resistant to methyl parathion, while completely vulnerable to toxaphene with DDT admixture (Redmond and Brazzel 1968). In Israel it was found that specimens of the spider *Chiracanthium mildei* L. Koch that came from a sprayed citrus grove had much more resistance to Malathion than did spiders of the same species from an unsprayed apple orchard. Raatikainen and Huhta (1968) found that the herbicide MCPA affected spiders indirectly by destroying their habitat.

Studies on Spider Predation in Israel

Studies on spider predation in Israel have included ongoing work with citrus, avocados, and cotton. Recent sudies on spiders in avocados have been especially productive. Earlier work on spiders in apple orchards will serve as an example of such investigations.

The larva of the Egyptian cotton worm, *Spodoptera littoralis* (Boisd.), attacks many crops and is perhaps the major pest of Israeli agriculture (Bar-Daroma 1967). During the last few years, great efforts have been made in Israel to control *S. littoralis* by biological means, so far without success.

On untreated apple trees in the experimental orchard of the research station at Newe Ya'ar, *S. littoralis* has never been

Table 1. Fate of *Spodoptera littoralis* egg masses attached to apple foliage (cv. Orleans) in an untreated orchard at Newe Ya'ar, 1970–72

			5 days after exposure														
			Damage to egg mass					Number of larvae on infested leaf					Damage to infested leaf				
Egg masses			0[a]	1	2	3	4	0[a]	1	2	3	4	0[a]	1	2	3	4
Exposed																	
Total	1970	110	12	0	2	10	86	92	7	6	1	4	98	5	2	1	4
	1971	25	0	0	2	3	20	23	2	0	0	0	23	1	1	0	0
	1972	120	25	1	1	3	90	102	5	5	2	7	93	20	4	2	1
Enclosed in bag																	
Total	1970	55	55	0	0	0	0	0	0	6	2	47	0	0	1	4	50
	1971	25	25	0	0	0	0	0	0	0	0	25	0	0	0	0	23
	1972	100	100	0	0	0	0	0	6	7	18	69	0	4	4	18	74
Ringed with glue																	
Total	1970	55	46	0	0	1	8	2	2	0	0	51	53	2	0	0	0
	1971	25	25	0	0	0	0	0	0	0	0	25	18	7	0	0	0
	1972	100	100	0	0	0	0	11	2	3	19	65	86	12	2	0	0

0[a] – No damage to egg mass; no larvae present; no signs of feeding on leaf.
4 – Egg mass totally destroyed; all hatched larvae present; entire area of leaf nibbled by larvae.

much of a problem, whereas in commercial orchards in the same region it has become a serious pest. This fact led to the hypothesis that natural agents in the untreated orchard prevent the larvae from developing and causing damage. An experiment was designed to test this hypothesis (Mansour and others 1980).

Egg masses of *S. littoralis* were laid by females upon pieces of paper in the laboratory. Each egg mass consisted of 200 to 400 eggs. These egg masses were attached with pins to the underside of the leaves on unsprayed apple trees and were exposed as follows: 1) fully exposed, unprotected; 2) enclosed by bags of Egyptian cotton cloth to prevent access of natural enemies; and 3) surrounded by a ring of Oesteco® insect glue to snare potential enemies. To indicate the fate of these egg masses, the following parameters were examined and evaluated on a scale of 0–4: a) Damage to egg mass—a measure of the disappearance of eggs and/or hatched larvae (0 = no damage—egg mass intact, 4 = egg mass totally destroyed); b) Number of larvae—a measure of the number of larvae on the leaf (0 = no larvae present, 4 = all larvae present); c) Damage to leaf—a measure of the feeding of the larvae on the leaf to which the egg mass was attached (0 = no feeding damage, 4 = entire leaf surface nibbled by hatched larvae). Daily observations indicated that spiders were preying upon the exposed young larvae (Table 1). Larvae hatched from exposed egg masses caused minimal damage to the leaves. On the other hand, egg masses enclosed in cloth bags were not harmed and yielded many larvae that caused severe damage to the leaves.

Spider populations were monitored year-round in both untreated and pesticide-treated apple orchards situated two miles apart. The population level in the unsprayed orchard was considerably higher than in the sprayed orchard (Figure 1). In the unsprayed orchard, spider populations increased sharply from the beginning of April to a peak in mid-August. A second peak was observed in October, after which the population decreased sharply at the onset of winter.

In the sprayed orchard, the spider population was evidently affected by pesticide treatments, and was often eliminated altogether. However, when the interval between the applications was long enough (as between applications 8 and 9), the spiders reappeared in the orchard.

Sixteen species belonging to seven families were recorded in the unsprayed orchard, as compared with only six species belonging to six families in the sprayed orchard. Oxyopidae appeared only in the commercial (sprayed) orchard, whereas Dictynidae and Lycosidae were found only in the untreated orchard. *Chiracanthium mildei* was found to be the dominant species in the untreated orchard and showed the greatest ability to prey on *S. littoralis* larvae, reaching a total of 250 larvae over five days in the laboratory. This species constituted about one third or more of the overall spider populations and was found to attack several other apple pests, including *Carpocapsa pomonella* (L.), *Zeuzera pyrina* (L.), *Lithocolletis blancardella* (F.); *Tetranchus cinnabarinus* (Boisd.), *T. urticae* (Koch), *Ceratitis capitata* (Weid.), *Empoasca* spp., and Aphidoidea (Mansour and others 1980b).

Is the decline of the spider population in the sprayed orchard due to the direct effect of pesticides on the spiders, or is

Table 2 Fate of *Spodoptera littoralis* egg masses attached to the foliage of apple trees in the presence and absence of spiders

Treatment	Date of exposure (1974)	Total fertile egg masses	5 days after exposure: Damage to egg mass 0[a]	1	2	3	4	Number of larvae on infested leaf 0[a]	1	2	3	4	Damage to infested leaf 0[a]	1	2	3	4
Spiders present	27.8	20	1	0	1	0	18	20	0	0	0	0	17	2	1	0	0
	19.8	27	0	0	0	0	27	27	0	0	0	0	20	7	0	0	0
	Total	47	1	0	1	0	45	47	0	0	0	0	37	9	1	0	0
	%	100	2	0	2	0	96	100	0	0	0	0	79	19	2	0	0
Spiders absent	27.8	20	14	0	0	0	6	6	1	4	5	4	6	0	3	5	6
	19.8	26	21	0	0	0	5	6	3	3	8	6	6	2	3	5	10
	Total	46	35	0	0	0	11	12	4	7	13	10	12	2	6	10	16
	%	100	76	0	0	0	24	26	8	15	28	23	26	4	13	23	34

0[a] – No damage to egg mass; no larvae present; no signs of feeding on leaf.
4 – Egg mass totally destroyed; all hatched larvae present; entire area of leaf nibbled by larvae.

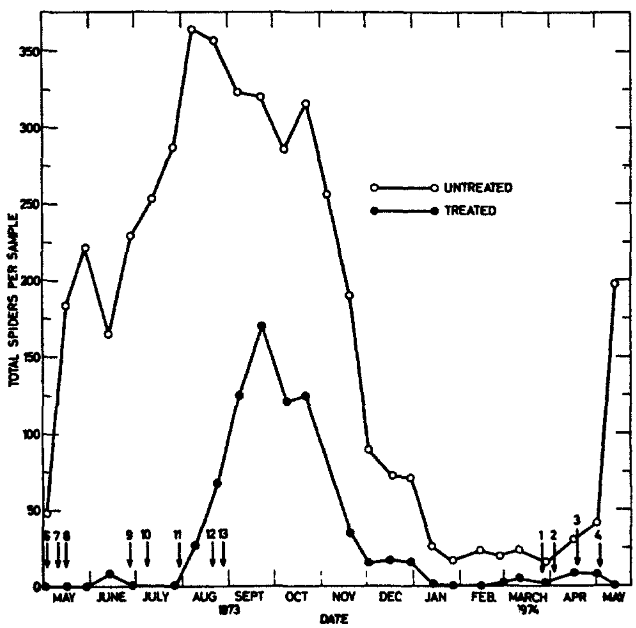

Figure 1. Fluctuation of spider populations in a treated and untreated apple orchard. The numbered arrows denote pesticidal applications in the treated orchard.

it largely due to the decimation of their prey? To try to answer this question, six apple trees were chosen at random in the unsprayed orchard. Spiders were carefully eliminated from three of them by repeatedly tapping branches with a stick covered with hard rubber. The arthropods were collected in a silken funnel and, after the spiders were removed, these were replaced on the same trees. Two rings of Oesteco® and Tanglefoot® glues were placed on the trunks of these three trees, to prevent spiders from climbing them. Weeds and drooping branches, which might enable spiders to regain access to the tree, were also eliminated. On the other three experimental trees, the spider fauna was left undisturbed.

Ninety-three egg masses of *S. littoralis*, each containing 300 to 500 eggs, were then attached, fully exposed, to all six experimental trees, as in the preliminary experiments. The fate of the egg masses was evaluated five days after exposure. This experiment was carried out twice in the same season. Wherever spiders were undisturbed, populations of *S. littoralis* were unable to develop (Table 2). Damage to the egg mass was high, whereas damage to the infested leaves was negligible, and no live larvae were observed five days after exposure. On the other hand, on trees from which spiders were eliminated, damage to the egg masses was low and damage to the infested leaves was severe.

When *C. mildei* was exposed to pesticide residues in absorbent nylon bags, it was very quickly and severely affected by Thiodan® (a chlorinated hydrocarbon); all the spiders died within one day after treatment. The effect of Guthion® (an organophosphate insecticide) was slower and less severe. The acaricide compound Plictran® was more detrimental to the spiders than Guthion®, but less so than Thiodan®. Similar results were obtained with topical applications. Besides these laboratory tests, a field experiment was conducted. Here, both Guthion® and Supracide® caused a significant suppression of the spider population. Eighteen days after treatment, the spider population in the control block was four times larger than that in any of the treated blocks (Mansour and others 1981).

Preliminary observations indicated that larval aggregations of *S. littoralis* on apple leaves were disturbed by spiders. The activity of spiders caused the first-instar larvae to disperse in all directions until most of the larvae abandoned the leaves. In later experiments, a significant disturbance effect occurred. In the presence of spiders, an average of 34% of the larvae had abandoned an apple branch and were found on sugarbeet leaves at the bottom of the cages. An average of 64% of the larvae were consumed by the spiders, and only 2% remained on the apple branch. On the other hand, in the absence of spiders, only 1.4% of the larvae left the apple branch. Both the predation and the disturbance effect were affected to some extent by the number of larvae in the colony: the larger the colony, the greater the number of larvae killed or disturbed by the spider (Mansour and others 1981).

Spider Manipulation through Habitat Management

In addition to the possible direct use of spiders as natural enemies of phytophagous insects, the stabilizing effect of polyphagous predators, including spiders, on the ecosystem should be enhanced on a large scale by integrated pest management, and also by the differentiation of crop structure (van Emden and Williams 1974). The stability of agrocoenoses can also be increased by the introduction of spiders into crop fields. Spiders are less resistant to pesticides than many phytophagous insects. Nevertheless, they are more resistant to some pesticides than many species of predatory insects. So far there has been no concerted effort to manage spider populations in agroecosystems. The major objective of any management program would be the increase of the effectiveness of spiders in key crops. To make progress in this area, we need basic data on the biology of spiders found in agricultural situations, their relationships to other spiders and insect predators, their effect on pest populations, and a host of other factors. Both functional and numerical responses should be examined carefully.

Conclusions

It is possible to increase the number of spiders both directly, by introduction of spiders into crop fields, and indirectly, by sowing admixtures of other plants into row and tree crops, by changing the density of crop plants, or by a belt management of crop field borders. The introduction of predators is difficult to carry out, and the protection of predators through the use of selective insecticides thus becomes an important matter for plant protection. Spiders can be effective predators of particular pest species in crops and can help maintain stability in the agroecosystem.

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