Purslane in untreated soil (foreground) has suffered much more sawfly damage than that in insecticide-treated soil (background).

unprotected plants. Moreover, preliminary results show that plants under sawfly attack produced seeds about 16 percent smaller with lower germination than protected plants.

The effect of the soil systemic insecticides in the 1979 study was to prohibit severe damage to purslane by the sawfly. A small-scale laboratory test conducted in 1981 showed that purslane leaves from plants grown in field plots treated with Aldicarb at 2 pounds active ingredient per acre were toxic to feeding adults of the leafmining weevil. Mortality was 100 percent when five weevils were allowed to feed for 48 hours on leaf clusters from insecticide-treated plants; no mortality occurred when five weevils fed on leaves from untreated plants. Illinois researchers have shown that carbaryl and malathion are highly toxic to the sawfly in the laboratory. These tests indicate that insecticides may interfere with the establishment of natural enemies on purslane in cropping systems where insecticide perturbations are commonplace.

Conclusion

Although it did not appear to us that the purslane sawfly or portulaca leafmining weevil actually killed any of the plants in the U.C. Davis plots, we are, nevertheless, encouraged that these insects seem capable of sufficiently stressing the weed to reduce its competitiveness and seed production. Further research is needed, however, to explore the possibility of integrating the two purslane-feeding insects into the weed management programs of crops where purslane is a problem. In this context we may be able to enhance the impact of the biological control agents by minimizing or altering cultural practices such as cultivation and pesticide use that adversely affect the survival of both insects. Also, as more data are generated on the reproductive biology and the predators and parasitoids of the sawfly and the weevil, as well as their competitive interactions, we should be able to better understand if the insects possess the attributes necessary for a good biological control agent.

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Mites: a primary food source for two predators in San Joaquin Valley cotton

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Most published predation studies have been concerned with the more common predators in the cotton field "food web"—the complex of pest and beneficial insects—and assume that major pest species are the principal prey. We believe that in California cotton, and perhaps in most cotton-growing areas, predators feed on a complex of primary and secondary pests, such as aphids, thrips, whiteflies, and mites. Indeed, the "secondary pests" may be an essential food source for the major predators.

Important elements of the cotton field food web are the predators the big-eyed bugs, *Geocoris* spp., and minute-pirate bug, *Orius tristicolor* White, as well as a complex of spider mites, *Tetranychus* spp., and *Thrips* spp. Secondary pest species need to be evaluated for their potential to serve as food sources for predacious arthropods. Under our scheme, these groups would be considered "secondary beneficial arthropods" because of their potential to provide food for beneficial arthropods, which may then increase in numbers and prey upon primary pests.

Our objective in this study was to sample cotton plants to determine the relative abundance of the various arthropods and to establish their role as primary food sources for major predacious arthropods.

Field trials

Our studies were conducted on 'Acala SJ-2' cotton at the U.S. Department of Agriculture Cotton Research Station, in California's San Joaquin Valley. Four schedules of nitrogen fertilization plus insecticide/acaricide application were used to create differences in numbers of arthropod predators and prey (see table). The experimental plots received weed control and irrigation treatments normal for the Shafter station. Each plot was 40 rows, or 133 feet (40 meters), wide and 200 feet (60 meters) long. The entire plot received a particular treatment.

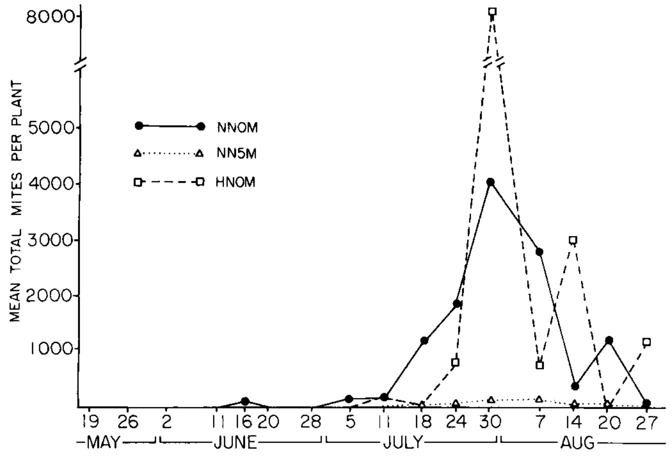

Fig. 1 Mites from plants subjected to various treatments (see table).

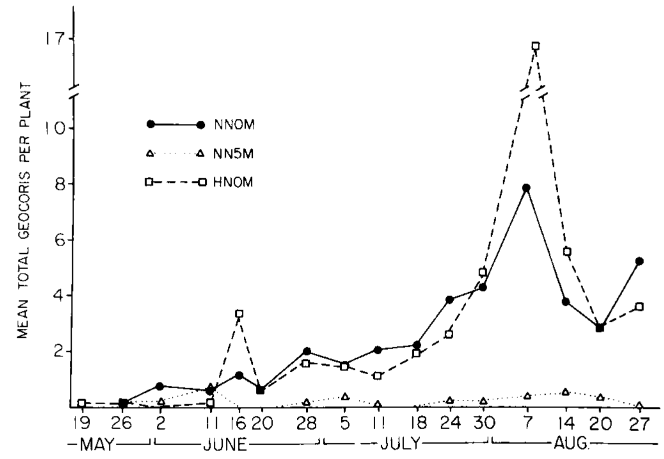

Fig. 2 Big-eyed bugs from plants subjected to various treatments.

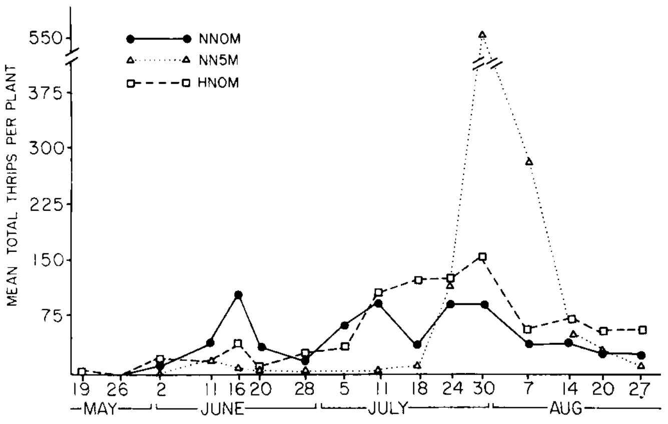

Fig. 3 Thrips from plants subjected to various treatments.

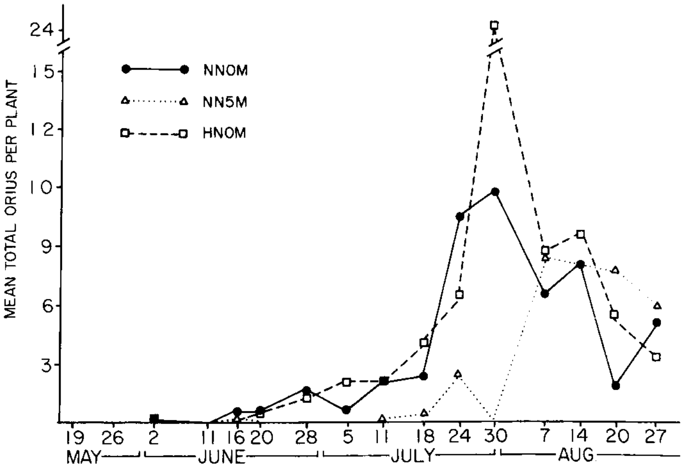

Fig. 4 Pirate bugs from plants subjected to various treatments.

Arthropods (insects, mites, and spiders) were collected from each treatment area by a system of bagging individual plants. Bagged plants were then taken to a laboratory for recovery, then processed through a berlese funnel, after which arthropods were counted. Ten plants per treatment were sampled each week, and thus each data point for arthropods represents a mean value from 10 samples.

Predators and food sources

Predators collected consistently at levels of one or more per plant were the big-eyed bug, *Geocoris pallens* Ståhl, and minute-pirate bug, *Orius tristicolor*. A complex of mites, principally *Tetranychus urticae* (Koch) and *T. turkestani* Ugarov & Nikolski, and the western flower thrips, *Frankliniella occidentalis* Pergande, were the only prey collected consistently at levels of five or more per plant.

Numbers of big-eyed bugs, of which more than 90 percent were immatures, were very closely associated with the numbers of mites (fig. 1, 2). The plot (HNOM) with the highest

Treatments used to create differences in pest and beneficial arthropod abundance in cotton field study

Designation	Treatment*	Actual rates	Application dates
NNOM	Normal nitrogen	80 lb (21% nitrate nitrogen + 10% phosphorus)	21 June
	0 miticides/insecticides	—	—
NN5M	Normal nitrogen	(——as in NNOM——)	
	5 miticide applications, dicofol (Kelthane)	4 qt	19 May 12, 18 June 10 July 8 Aug.
	Propargite	2 pt	8 Aug. only
	4 insecticide applications, acephate (Orthene)	1 lb	19 May 12, 18, 28 June
HNOM	High nitrogen	160 lb (21% nitrate nitrogen + 10% phosphorus)	21 June
	0 miticides/insecticides	—	—
HN5M	High nitrogen	(——as in HNOM——)	
	5 miticide applications	(——as in NN5M——)	
	4 insecticide applications	(——as in NN5M——)	

*Insecticides/miticides were applied to plants by a standard high-clearance ground rig.

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numbers of mites (more than 8,000 per plant) also had exceptionally high numbers of big-eyed bugs (more than 17 per plant). A separate plot, NN0M, with approximately half as many mites as in HN0M, also contained about 50 percent fewer big-eyed bugs.

In the miticide-treated plot NN5M, where mites were at very low levels (1 to 2 percent of those in HN0M and NN0M), less than one big-eyed bug per plant was found. These low levels were sustained for two months after the last application of insecticide on 28 June. Considering this two-month interval and the known short residual effect of the insecticide used, it is likely that the low levels of big-eyed bugs were sustained because of a lack of mites and not because of any direct effect from the chemical.

These low levels in NN5M were sustained despite a rapidly increasing thrips population in plants treated with pesticides (fig. 3). But the thrips population was not as readily available to the big-eyed bugs as were the mites for several reasons. Mites were found aggregated on the underneath surfaces of leaves on the upper halves of plants, and big-eyed bugs were most frequently found in the same areas. Thrips were mostly congregated inside flowers. Of the total thrips in the population, at least one-third were adults, highly mobile, and not as vulnerable to attack as were the relatively stationary mites. At the end of July, plants were at or nearing their peak of vegetative growth. The large size of the plants and increased foliar surface area greatly increased the predator's searching requirements.

Minute-pirate bugs also were most closely associated with high numbers of mites (fig. 1, 4). Unusually high numbers of pirate bugs (more than 24 per plant, 73 percent nymphs) were collected from plants where mites were most abundant (more than 8,000 per plant). At lower mite levels, pirate bugs (79 percent nymphs) were reduced correspondingly. A major difference from the pattern found with big-eyed bugs was the increase of numbers of pirate bugs (78 to 95 percent nymphs) later in the season, closely associated with high numbers of thrips, from plants with low numbers of mites.

Thrips were consistently the single most abundant species from plant emergence through the end of June. Thrips feeding on plants has frequently resulted in their classification as pests and in subsequent insecticide applications. We found thrips, particularly in May-June, actively feeding on mite eggs wherever mites were congregated. Thrips may be considered beneficial also in that they provide an essential food source for predaceous arthropods, especially for pirate bugs. When flowers became available, most thrips were found in those structures, and population trends in July-August were most closely associated with flowering patterns, not with mites.

Mites as food source

Mites were by a large extent the most numerous of all arthropods found on cotton in July-August. Beyond an as-yet undefined level, mites can cause cotton yield reductions, but it is also obvious that they are a primary food source for the predatory big-eyed and minute-pirate bugs. Our findings indicate that guidelines for the assessment of mites on cotton should consider their essential role as primary food sources at all population levels, as well as their potential for yield reduction.

The value of an adequate food base for predaceous arthropods as provided by mites is relevant for the development of economic thresholds not only for mites, but also for pests that may occur later in the season. Enhancement of a predaceous potential was reflected in the higher levels of big-eyed bugs (8 to 17 times) and of pirate bugs (4 to 8 times) found on untreated plants with abundant food, than on insecticide-treated plants with a much lower food (mite) level. The increased potential for regulation of pest numbers through higher numbers of predators was especially significant, because the higher numbers were present over an extended period, including July-August. In the San Joaquin Valley, an increase in predation potential during this period is highly beneficial, because lygus bugs and lepidopterous worms also occur on cotton at this time.

This study indicates that broader guidelines should be used in developing economic thresholds for cotton pests. Data are especially needed on seasonal interactions among plant fruiting patterns and various densities of known age groups of potential pests, their natural enemies, and their arthropod food sources.

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