Insect pest and natural enemy populations in paired organic and conventional apple orchards in the Yakima Valley, Washington

ALAN KNIGHT

USDA, ARS, 3706 W. NOB HILL BLVD, YAKIMA, WA 98902

ABSTRACT

Insect pest and natural enemy populations were evaluated during the 1990 growing season in five paired certified organic and conventional apple orchards in the Yakima Valley, Washington. Each orchard-pair was managed by one grower and had similar conditions of location, extent, cultivars, and tree density. Organic orchards had not been treated with synthetic insecticides for 1-2 years before this study. Fruit injury from codling moth and population densities of phytophagous mites, sucking bugs, rosy apple and green aphids, leafminers, leafhoppers, and selected natural enemies were monitored throughout the season. Damage from codling moth was over 3% in three of the five organic orchards. Densities of phytophagous mites were high in one conventional orchard at the end of the season. Organic orchards had significantly higher populations of sucking bugs at bloom than did conventional orchards. There was no significant difference between orchard types in the densities of rosy apple aphid colonies per tree, but colonies in conventional orchards had significantly more aphids and significantly less parasitism than in organic orchards. The population density of green aphids was higher in conventional than organic orchards during the second half of the season. There was little difference in numbers of adult leafhoppers caught on sticky traps between orchard types, but captures of a leafhopper egg parasite were significantly higher in organic than in conventional orchards throughout the season. Immature leafminer populations were significantly higher and parasitism of leafminer was significantly lower in conventional than organic orchards after July. Parasitism of codling moth was not found in any orchard.

Key words: Codling moth, organic, apple, pest management, aphid, mite, leafhopper, leafminer, egg parasite

INTRODUCTION

Increased public awareness and changes in societal attitudes towards pesticides (Ott *et al.* 1991) and increased consumer support for IPM practices (Hollingsworth *et al.* 1993) are forcing a reconsideration of existing pest management programs in apple production (Prokopy & Croft 1994). The focus of this movement is to develop alternatives to broadspectrum neuroactive insecticides for the major pests in each region. In the western U.S., codling moth, *Cydia pomonella* (L.) is the key insect pest in apples and conventionally-managed orchards rely on a series of 'cover sprays' against this pest during the season (Washington State Cooperative Extension Service 1992). Organophosphate insecticides have been used almost exclusively to manage codling moth during the last 35 years, and resistance has recently been documented (Varela *et al.* 1993, Knight *et al.* 1994). The frequent use of organophosphate insecticides in apple also contributes to outbreaks of secondary pests (Prokopy & Croft 1994), such as mites, sucking bugs, aphids, leafhoppers, and leafminers. The mean number of insecticide sprays applied in Washington apple orchards is eight per season (Beers & Brunner 1991). Biological control plays a limited role in managing populations of pests in sprayed orchards, except for instances where natural enemies have developed insecticide resistance (e.g., predatory mites [Hoyt 1969]).

The level of biological control of insect pests which can be established in commercial apple orchards can probably best be viewed by examining populations in certified-organic orchards. Organic orchards cannot be treated with organophosphate, carbamate, pyrethroid, or other synthetic insecticides (Washington State Department of Agriculture 1992). Instead, growers must rely on a short list of materials which includes botanicals, microbials, minerals, natural oils, and soaps. These materials are thought not to be as disruptive of natural enemies as synthetic insecticides. The organic certification program in Washington state began in 1988 with 11 growers having a total of 40 ha of pome fruits. This peaked in 1990 with 100 growers and 800 ha (M. McEvoy, personal communication). The size of the program has stabilized at ca. 0.5% of the total apple production in Washington (350 ha). Little information has been gathered on the success of organic apple pest management during this brief period. The objective of my study was to compare insect and mite pests and natural enemy population densities in paired organic and conventional apple orchards in the Yakima Valley of Washington.

MATERIALS AND METHODS

Study sites. In 1990, five apple growers with both organic and conventional orchards in the Yakima Valley were included in this study. Each organic orchard was paired with another orchard treated conventionally with synthetic insecticides. Orchard-pairs were matched for their similarity in area, cultivar, and planting density. The orchards were primarily 'Delicious' interplanted with 'Golden Delicious' at a density of 450-600 trees per ha and ranged in size from 4-16 ha.

Spray practices. Conventional orchards received an average of 3.7 sprays of azinphosmethyl (Guthion 50W, Miles Chem., Kansas City, MO) directed at codling moth. In contrast, organic orchards were treated with either ryania (Ryan 50, Dunhill Chem., Riverside, CA), granulosis virus (provided by Dr. L. Falcon, Univ. of California, Berkeley), *Bacillus thuringiensis* Berliner (Dipel 2X, Abbott Labs, N. Chicago, IL), or cryolite (Kryocide 96, Penwalt Chem., Bryan, TX) alone or in various combinations (a mean of 14 sprays of these materials was applied per orchard). Secondary pests in conventional orchards were treated with a mean of 2.5 sprays of carbamate and organophosphate insecticides at standard rates (Washington State University Cooperative Extension Service 1992). These included: phosphamidon (Swat 8E, Ciba Geigy, Greensboro, NC), carbaryl (Sevin XLR, Union Carbide, NY, NY), and oxamyl (Vydate 2L, E. I. Dupont de Nemours & Co., Wilmington, DE). Growers applied in organic orchards a mean of 2.0 sprays for secondary pests at standard rates; including soap, pyrethrum, and rotenone (Integrated Fertility Management 1990).

Pests and Natural Enemies. Population densities of various pest and beneficial arthropods were monitored in each orchard. These included: the phytophagous mites, *Tetranychus urticae* Koch and *Panonychus ulmi* (Koch) and the predatory mite, *Typhlodromus occidentalis* (Nesbitt); the sucking bug, *Campylomma verbasci* (Meyer); rosy apple aphid, *Dysaphis plantaginea* Passerini, a complex of green aphids, *Aphis pomi* DeGeer, *Rhopalosiphum fitchii* (Sanderson), and *Aphis spiraecola* Patch, aphid parasitism, and generalist aphid predators; white apple leafhopper, *Typhlocyba pomaria* McAtee and a mymarid egg parasitoid, *Anagrus* sp.; western tentiform leafminer, *Phyllonorycter mespilella* (Hubner) and levels of leafminer parasitism; and fruit injury by codling moth.

Sampling. Sampling was done on 11 and 24 May, 8 and 20 June, 6 and 31 July, 16 and 27 August, and 10 September. Fruit injury was determined 2-3 July and 27-28 August. Scouts walked transects within each orchard and arbitrarily chose the trees, shoots, and leaves to sample. Mites were sampled by collecting 16 leaves from each of ten trees at each orchard. Leaves were washed in 800 ml of a 50:50 solution of water (with 1 g detergent added) and 25% ETOH for 30 s. The liquid was poured through a fine sieve into a petri plate, and mites were counted under a dissecting microscope. *C. verbasci* nymphs were washed similarly from five blossom clusters collected from each of ten trees per orchard on 23 April. Rosy apple aphids were sampled by counting the number of infested shoots observed per 3 min from 10 trees in each orchard on 2-3 July. Ten colonies were collected and the number of living and parasitized aphids and the number of generalist predators within each colony were recorded. Green aphids were sampled by counting the number of aphids on the most infested leaf per shoot from five shoots on each of 10 trees in each orchard. The total number of generalist predators per shoot was also recorded. Adult white apple leafhopper and *Anagrus* sp. adults were sampled with sticky yellow cards (Trece Inc., Salinas, CA). Five traps were placed at 2.0 m in the tree canopy and were retrieved after 7 d. Data were expressed as the mean number of adults caught per day per trap for each orchard. The number of immature leafminers per 10 leaves was counted from 20 trees in each orchard by selecting the third leaf down the shoot from the leaf visually selected. Levels of parasitism were assessed for each generation by dissecting 50 mines from each orchard. Host feeding was included as a part of total parasitism (Barrett & Brunner 1990). Fruit injury was determined mid-season and at harvest by inspecting fruit along 40 transects, 20 apples from five consecutive trees (4,000 apples per orchard). Fruit injury for each orchard was weighted by the percentage of the total number of trees of each cultivar. Corrugated cardboard bands were placed around forty trees in each orchard on 10 June and 15 August to determine parasitism of codling moth larvae. Diapausing larvae were kept at 2°C for 120 d and then reared at 22°C until the completion of moth and parasitoid emergence. Differences in the mean population counts of pests and natural enemies between organic and conventional orchards were analyzed using a paired sample t-test for each date.

RESULTS

Pest and Natural Enemies. Phytophagous mite populations were low and populations of predatory mites were high in all orchards during the season (Fig. 1A and 1B). However, on the last sample date, phytophagous mite populations (*T. urticae*) increased in one conventional orchard to high levels, more than 20 mites per leaf (Fig. 1A).

Population densities of *C. verbasci* during bloom were significantly higher in organic than in conventional orchards (mean ± SE = 2.0 ± 0.5 and 0.1 ± 0.01 nymphs per five blossom clusters, respectively). Fruit injury at harvest from *C. verbasci* was detected only in one orchard (2.8% of fruit).

Densities of rosy apple aphid colonies per tree did not differ between organic and conventional orchards (Fig. 2A). However, the number of living aphids per colony in early July was significantly higher in conventional orchards. In addition, within individual colonies, significantly higher number of parasitized aphids were found in the organic orchards (Fig. 2B). Predator densities in aphid colonies did not differ between orchard types.

Densities of green aphids were low in organic orchards all season (Fig. 3). Densities were much higher in conventional than in organic orchards during July and August and on two dates these differences were significant. Few generalist predators (primarily immature coccinellids, syrphids, and chrysopids) were found on shoots infested with aphids (i.e., less than 0.1 predators per shoot in the organic orchards) but these data are not included here.

Few differences were seen in populations of white apple leafhopper between organic and conventional orchards during the season (Fig. 4A). In contrast, density of the egg parasitoid, *Anagrus* sp., was substantially higher in organic orchards in five of the seven samples (Fig. 4B).

Table 1

Summary of fruit injury by codling moth in mid-summer (2-3 July) and just before harvest (27-28 August) in organic and conventional apple orchards, 1990.

	Percentage fruit injury			
	Mid-summer		At Harvest	
Orchard	Organic	Conventional	Organic	Conventional
Y1	4.00	0.28	32.48	0.78
Y2	10.18	0.15	21.33	0.23
Y3	0.28	0.13	0.83	0.20
Y4	0.13	0.20	3.65	0.90
Y5	0.23	0.03	0.28	0.05
Mean	2.96	0.16	11.70	0.43
SE	1.95	0.04	6.50	0.17

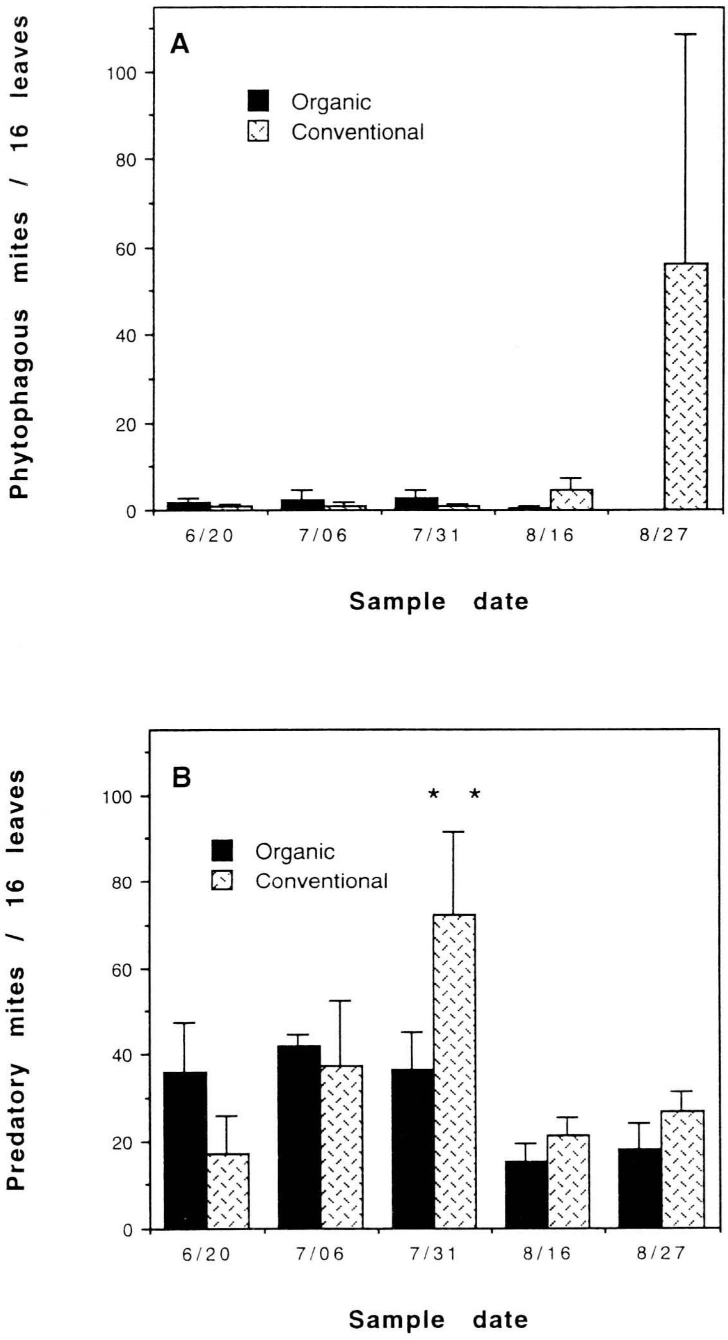
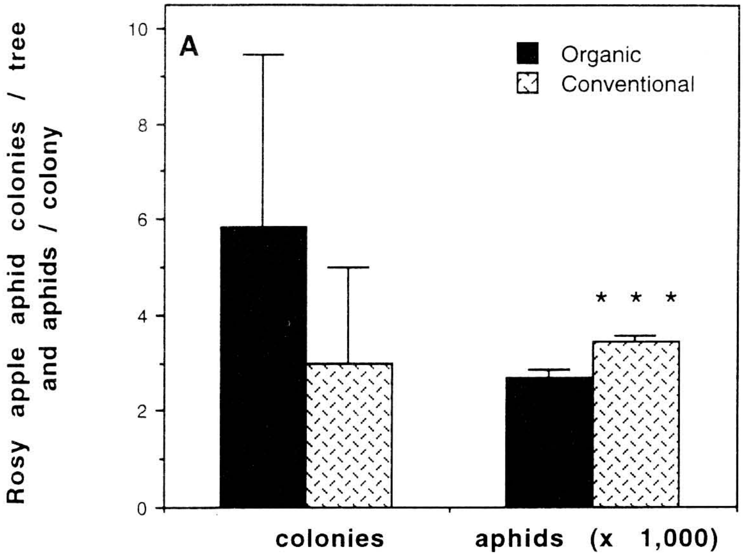


Figure 1. Seasonal population densities of (A) phytophagous mites and (B) predatory mites (B) per sample of sixteen leaves per tree from five paired organic and conventional orchards, 1990. '**' denotes a significant difference, $p < 0.05$.



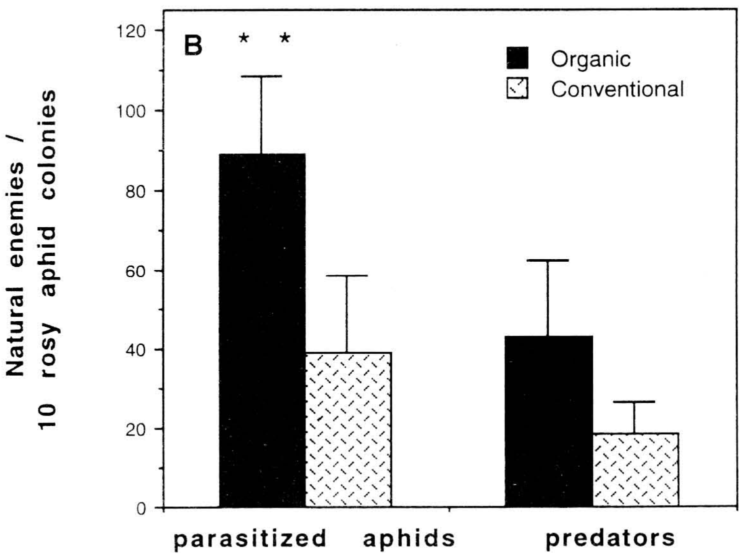


Figure 2. Number of rosy apple aphid colonies per tree and aphids per colony (A) and the number of parasitized aphids and generalist predators per colony (B) from five paired organic and conventional orchards, 2-3 July, 1990. '**' and '***' denotes a significant difference, $p < 0.05$ and < 0.01, respectively.

Densities of leafminers increased steadily during the season in all orchards but averaged less than 1.5 mines per leaf by the third generation (Fig. 5A). During August and September significantly more mines were found in the conventional than organic orchards. Percent parasitism of leafminer larvae was significantly higher in the organic than in the conventional orchards in both the second and third generations (Fig. 5B).

Large numbers of codling moth were recovered from the cardboard bands placed in organic orchards from the summer and overwintering generations (103 and 532 adults emerged, respectively), but no parasitoids were collected. Similarly, no parasitoids were collected from the sample of overwintering codling moth from conventional orchards (108 adults emerged).

Following the first flight of codling moth the organic orchards Y1 and Y2 had high levels of fruit injury (Table 1). Both of these orchards were adjacent to small unsprayed apple blocks treated unsuccessfully with an experimental sex pheromone membrane dispenser. At harvest, levels of fruit injury from codling moth exceeded 20% in orchards Y1 and Y2. In addition, the organic orchard Y4 suffered nearly 4% fruit injury at harvest. In contrast, both organic orchards Y3 and Y5 which were situated within 1 km of each other and were fairly isolated from other apple orchards, had less than 1% fruit injury at harvest. Fruit injury in all five conventional orchards was less than 1% before harvest (Table 1).

DISCUSSION

This study shows that densities of pests other than codling moth and *C. verbasci* are similar in organic and conventional orchards or are lower in organic than conventional orchards in the Yakima Valley. The elimination of broad-spectrum insecticides from organic orchards appeared to allow higher levels of natural enemies to develop than in conventional orchards. However, codling moth was not controlled biologically in either orchard type. In contrast, there were low levels of parasitism in abandoned apple orchards (3.4% of the overwintering larvae) and crabapple plantings (7.0% of summer generation and 8.7% of overwintering larvae) in Yakima. All the parasitoids collected were the braconid *Ascogaster quadridentatus* Wesmael or its hyperparasitoid *Perilampus* sp.

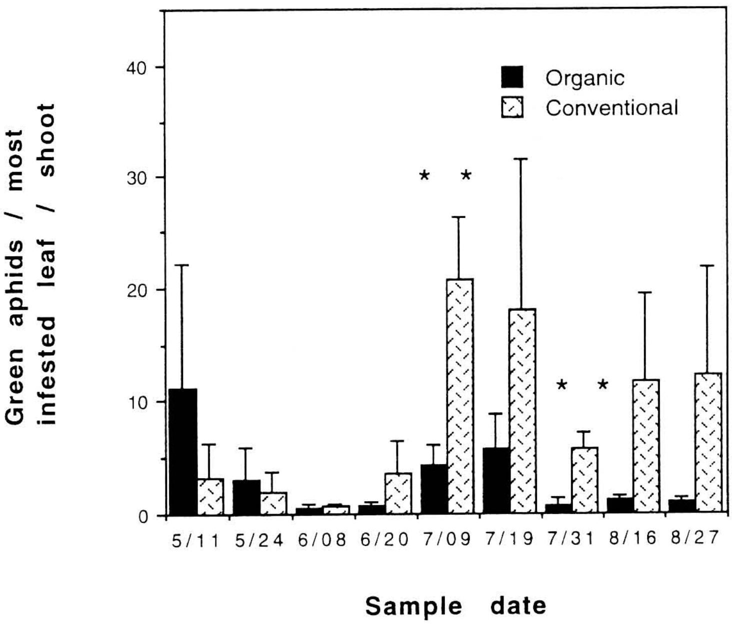


Figure 3. Seasonal population densities of green aphids per most infested shoot per tree from five paired organic and conventional orchards, 1990. '**' denotes a significant difference, $p < 0.05$.

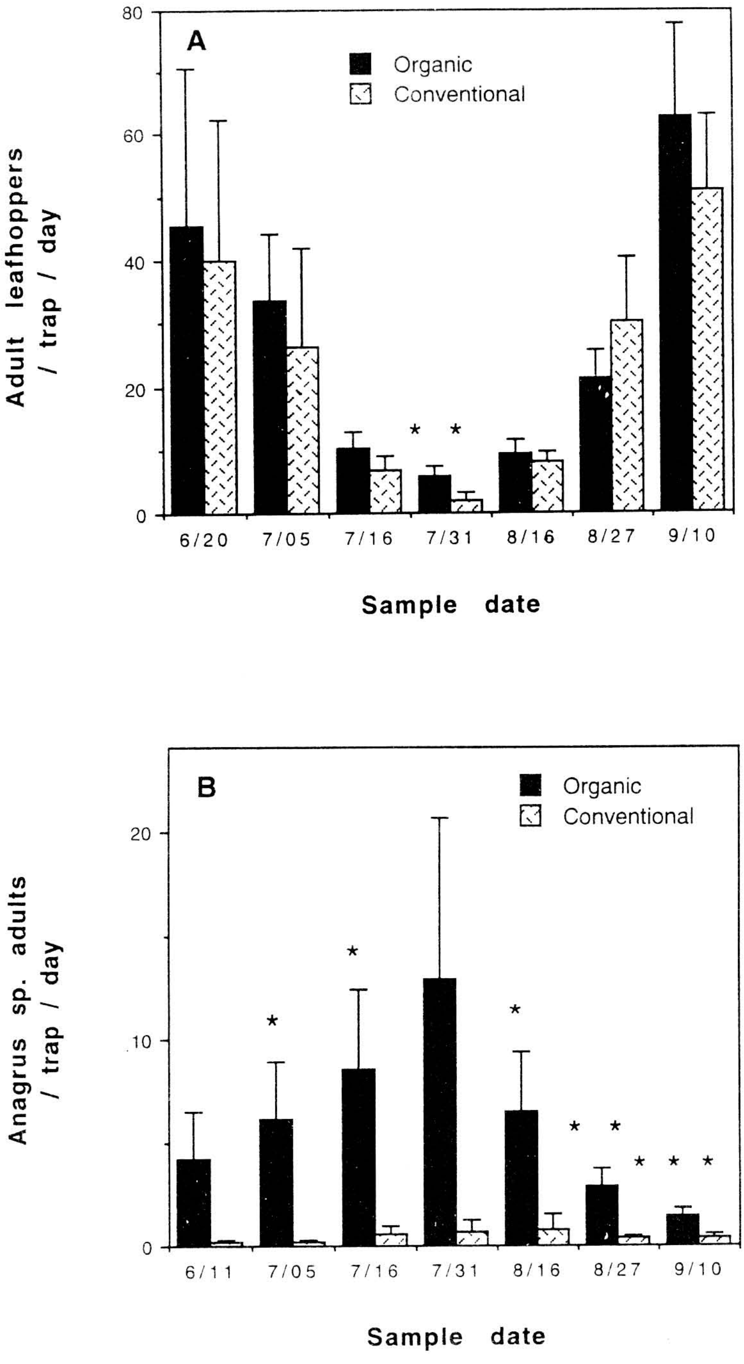


Figure 4. Seasonal population density of adult leafhoppers per trap per day (A), and adult *Anagrus* sp. per trap per day (B) from five paired organic and conventional orchards, 1990. '*', '**', and '***' denotes a significant difference of $p < 0.10$, < 0.05, and < 0.01, respectively.

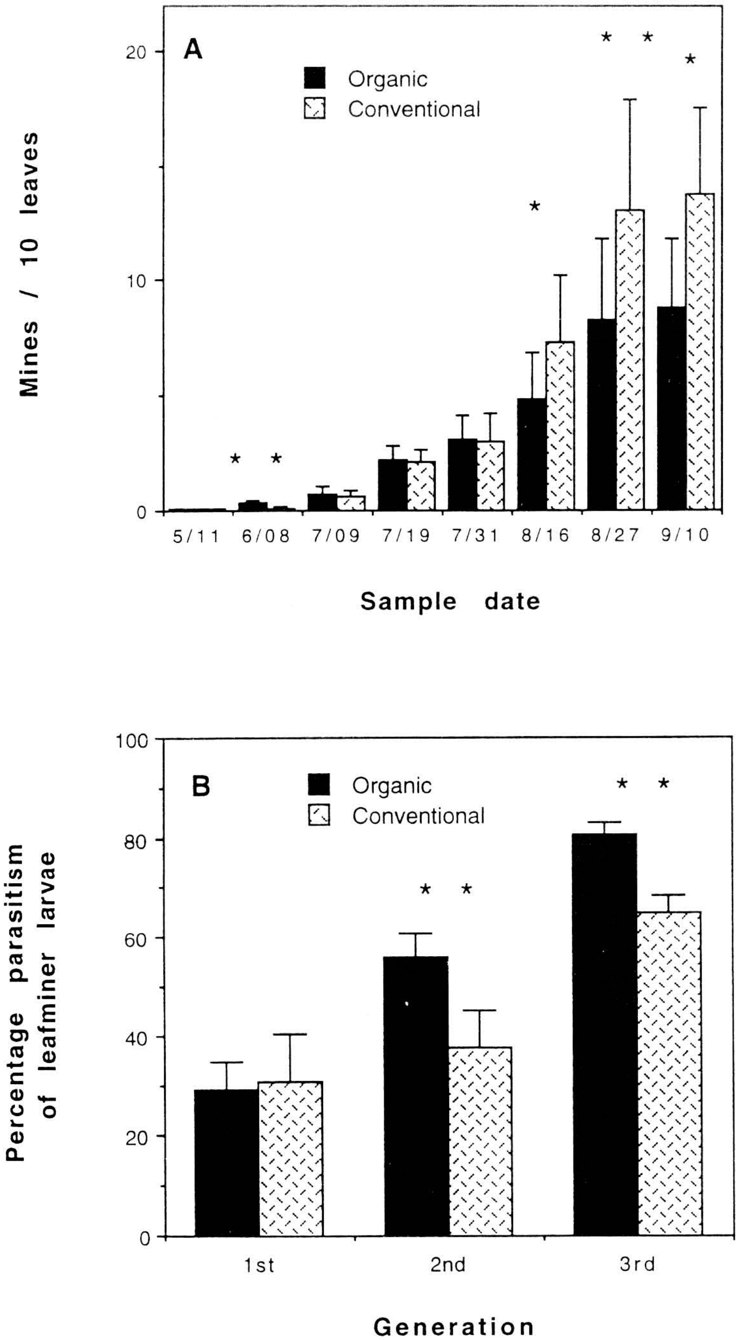


Figure 5. Seasonal population densities of western tentiform leafminer per 10 leaves per tree (A) and percent parasitism per generation (B) in organic and conventional orchards, 1990. '*' and '**' denotes $p < 0.10$ and < 0.05, respectively.

Factors regulating the population of *C. verbasci* in apple are poorly known (Thistlewood *et al.* 1990). Fewer *C. verbasci* nymphs were found during bloom in organic than in conventional apple orchards in British Columbia (McBrien *et al.*, in press). However, these orchards had been organic for 10-15 yrs and were not sprayed during the season with ryania.

To manage codling moth in 1990, organic apple growers had to choose between a number of relatively ineffective materials. Typically, organic growers in Washington used weekly sprays of ryania, Bt, and virus, often in combination. The cost of pest management for organic growers compared with a conventional program of azinphosmethyl was 5- to 10-fold higher (Knight, unpublished data), yet despite these costs, many growers suffered economic levels of fruit injury. In a spray trial conducted in 1991, fruit injury during the second generation of codling moth was reduced only 81, 47, and 16% with six weekly applications of ryania, virus, and Bt compared with an unsprayed check, respectively (Knight, unpublished data). Inspection of these injuries plus those collected from four commercial orchards treated with combinations of these materials, found that on 65-80% of these apples, codling moth larvae had created only shallow tunnels. The absence of feeding by codling moth larvae prior to entering the fruit makes stomach poisons such as Bt (Andermatti *et al.* 1988) and virus (Falcon *et al.* 1968) largely ineffective in producing clean fruit, although these materials can potentially be used to reduce populations in later generations (Wearing 1990). Ryania acts as both a contact and stomach poison and was used commonly in the 1950's in seasonal spray programs (Patterson & MacLellan 1954). However, orchards must be sprayed 6-12 times per season and repeated applications of ryania can cause severe phytotoxicity on some cultivars (Knight, unpublished data).

Because of their inability to control codling moth in 1990, two organic growers dropped out of the program. In 1991, a pheromone dispenser system (Isomate-C, Pacific Biocontrol, Davis, CA) was registered for mating disruption of codling moth and its adoption by organic growers during the past three years has been high (> 90% in 1993, M. McEvoy, personal communication). A survey of fifteen organic growers, who adopted mating disruption, found that their use of ryania, Bt, and virus declined by 80% from 1990 to 1993 (Knight, unpublished data). The benefit of using mating disruption for organic growers can be seen by comparing levels of fruit injury in the two organic orchards Y3 and Y5 in 1991. Orchard Y3 adopted mating disruption and had less than 0.4% fruit injury. In contrast, the organic orchard Y5 continued to use virus and Bt and suffered ca. 40% fruit injury from codling moth. Subsequentially, the grower dropped out of the program (Knight, unpublished data).

Mating disruption has worked well in apple orchards with low population densities of codling moth (Gut & Brunner 1991, Howell 1992). Yet, in a three year survey of seven paired conventional and pheromone-treated orchards in the Yakima Valley, the use of insecticides for secondary pests declined only 20% and levels of biological control of secondary pests did not increase with the adoption of mating disruption (Knight, in press). In particular, some apple growers suffered economic losses to leafrollers in orchards treated with mating disruption (Howell 1992, Brunner *et al.* 1992) and use of organophosphate insecticides for the summer generation of leafroller has become widespread. Interestingly, leafrollers were not observed in orchards in this study in 1990. In the following year, however, 12% fruit injury from the leafroller, *Pandemis pyrusana* Kearfott, occurred in one orchard. During the following two years, the grower used Bt for both the overwintering and summer generation and fruit injury was less than 0.3% (Knight, unpublished data).

Knight (in press) concluded that natural enemies cannot reduce pest populations in apple orchards sprayed with broad-spectrum insecticides nor can they respond quickly to pest outbreaks in small, isolated pheromone-treated orchards surrounded by sprayed orchards. Creating a sustained role for biological control in tree fruit pest management may require area-wide reduction in the use of broad-spectrum insecticides.

In the eastern U.S., Prokopy *et al.* (1990) suggested that apple orchardists adopt a transitional approach towards the use of fewer insecticides and enhanced biological control. In transitional second-stage IPM, orchards would not be treated with synthetic insecticides after petal-fall except along borders. Adoption of a similar approach in the western U.S. orchards might have to rely on mating disruption to manage codling moth, with Bt possibly mating disruption for leafroller. Other pests would either be managed early in the season or later with selective insecticides and growers would rely more on biological control. Continued study of pest and natural enemy populations in organic orchards using mating disruption for codling moth may provide more evidence for the success of this approach.

ACKNOWLEDGEMENTS

I thank Ronah Grigg and numerous summer field assistants at the USDA-ARS Laboratory, Yakima, WA who helped collect the data, and the growers for their cooperation. I acknowledge the information on the organic certification program provided by Miles McEvoy, Washington State Department of Agriculture, Olympia, WA, and the critical comments of an earlier draft provided by Larry Hull, Penn State University, Biglerville, PA, and Dave Horton, USDA-ARS, Yakima, WA.

REFERENCES

Andermatt, M., E. Mani, Th. Wildbolz, and P. Lethey. 1988. Susceptibility of *Cydia pomonella* to *Bacillus thuringiensis* under laboratory and field conditions. Entomol. Exp. Appl. 49: 291-295.

Barrett, B. A. and J. F. Brunner. 1990. Types of parasitoid-induced mortality, host stage preferences, and sex ratios exhibited by *Pnigalio flavipes* (Hymenoptera: Eulophidae) using *Phyllonorycter elmaella* (Lepidoptera: Gracillariidae) as a host. Environ. Entomol. 19: 803-807.

Beers, E. H. and J. F. Brunner. 1991. Washington state apple and pear pesticide use survey 1989-90. Final report to USDA/NPIAP.

Brunner, J. F., L. J. Gut, and A. L. Knight. 1992. Transition of apple and pear orchards to a pheromone-based pest management system. Proc. WA Hort. Assoc. 88: 169-175.

Falcon, L. A., W. R. Kane, and R. S. Bethell. 1968. Preliminary evaluation of a granulosis virus for control of the codling moth. J. Econ. Entomol. 61: 1208-1213.

Gut, L. J. and J. F. Brunner. 1991. Mating disruption as a control for codling moth in Washington. Proc. WA Hort. Assoc. 87: 199-201.

Hollingsworth, C. S., M. J. Paschall, N. L. Cohen, and W. M. Coli. 1993. Support in New England for certification and labelling of produce grown using integrated pest management. Amer. J. Altern. Agric. 8: 78-84.

Howell, J. F. 1992. Two years of commercial use of Isomate-C to disrupt mating for control of codling moth. Proc. WA Hort. Assoc. 88: 176-181.

Hoyt, S. C. 1969. Integrated chemical control of insects and biological control of mites on apple in Washington. J. Econ. Entomol. 62: 74-86.

Integrated Fertility Management. 1990. *Products and services for natural agriculture.* Vol. 7. 47 pp.

Knight, A. L. 1994. Grower adoption of mating disruption for codling moth in Yakima Valley, Washington. J. Econ. Entomol., in press.

Knight, A. L., J. F. Brunner, and D. Alston. 1994. Survey of azinphosmethyl resistance in codling moth in Washington and Utah. J. Econ. Entomol. 87: 285-292.

McBrien, H. L., G. J. R. Judd, and J. H. Borden. *Campylomma verbasci* (Heteroptera: Miridae): pheromone-based seasonal flight patterns and prediction of nymphal densities in apple orchards. J. Econ. Entomol., in press.

Ott, S. L., C. L. Huang, and S. K. Misra. 1991. Consumers' perception of risk from pesticide residues and demands for certification of residue-free produce. pp. 175-188 In: J. A. Caswell (ed.) *Economics of food safety.* Elsevier, New York.

Patterson, N. A. and C. R. MacLellan. 1954. Control of codling moth and other orchard pests with ryania. Annu. Rep. Entomol. Soc Ontario. pp. 25-32.

Prokopy, R. J., M. Christie, S. A. Johnson, and M. T. O'Brien. 1990. Transitional step toward second-stage integrated management of arthropod pests of apple in Massachusetts orchards. J. Econ. Entomol. 83: 2405-2410.

Prokopy, R. J. and B. A. Croft. 1994. Tree fruit pest management. In R. L. Metcalf and W. H. Luckman (eds.) *Introduction to pest management.* John Wiley & Sons, NY.

Thistlewood, H. M. A., J. H. Borden, and R. D. McMullen. 1990. Seasonal abundance of the mullein bug *Campylomma verbasci* (Meyer) (Heteroptera: Miridae). Can. Entomol. 122: 1045-1058.

Varela, L. G., S. C. Welter, V. P. Jones, J. F. Brunner, and H. Riedl. 1993. Monitoring and characterization of insecticide resistance in codling moth (Lepidoptera: Tortricidae) in four western states. J. Econ. Entomol. 86: 1-10.

Washington State Department of Agriculture. 1992. Organic food production. Chapter 15.86. pp. 158-160.

Washington State University Cooperative Extension Service. 1992. Spray guide for tree fruits in eastern Washington. Washington State Univ. Bull. 0419. 156 pp.

Wearing, C. H. 1990. Granulosis virus control of codling moth in Nelson. Proc. N. Z. Weed and Pest Control Conf. 43: 317-321.