FINAL REPORT
WTFRC Project #AE-01-47 **WSU Project # 6093**

Project title: Enhancing biological control of leafrollers through ground cover management and augmentation of alternate hosts for leafroller parasites.

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Objectives:
1. Determine the effects of cover crops in an apple orchard on the biological control of leafrollers, aphids and on other components of the arthropod community.
2. Determine the effects of cover crops on apple tree vigor, fruit size and fruit quality.

Significant findings:
- There was no difference in the level of leafroller parasitism between cover crop treatments. There was no establishment of *Xenotemna* as an alternate leafroller host in alfalfa due to high levels of general predator activity in this treatment. Low levels of parasitism by *Apanteles* sp. were noted in both cover crops, and natural infestations of *Colpoclypeus florus* were detected in both treatments without seeding but at low levels and only in the fall.
- Assessments of leafroller parasitism in 2001 in a nearby organic orchard suggested that treatments of Sevin for fruit thinning were highly detrimental to leafroller biological control in the WVC orchard.
- Leafroller densities increased from low levels in 1999 to very high levels following three years of NO chemical control. Fruit injury was high and there was no difference between plots.
- There were no significant advantages or disadvantages associated with an alfalfa cover crop compared to a grass cover crop relative to most pests. Predatory mites seemed higher and pest mites lower in alfalfa treatments, but spider mites were not a serious problem in either treatment.
- Lygus densities were high in the alfalfa cover crop compared to the grass, but this did not translate into higher injury levels to fruit.
- Horticulturally, there seemed to be no adverse effects from the alfalfa cover crop on tree growth, yields or fruit quality.

Methods:
Cover crop and biological control: Two cover crops were established in one-half acre replicated plots at the Wenatchee Valley College orchard. The cover crops were alfalfa and a standard orchard grass. A non-pest leafroller species, for example, *Xenotemna pallorana*, that can be propagated in the laboratory was introduced into both cover crop. Establishment of the non-pest leafroller species was determined through sampling cover crop plants. Aphid species known to support parasites of the apple aphid were introduced into both cover crops and establishment verified through sampling of cover crop plants.

Mating disruption was used for codling moth control, and leafroller control was maintained only with biological control. Non-pest leafrollers were seeded into the cover crop at regular intervals throughout the summer as a potential alternate host for parasites. Sentinel OBLR larvae were used to determine the establishment of *C. florus* and the activity of other parasites. Sentinel OBLR larvae were placed on trees throughout the different cover crop plots and on trees between the plots, collected after a period of exposure and evaluated for parasitism by *C. florus*. Parasitism of the non-pest leafroller was determined by sampling larvae of this species in the ground cover. The naturally occurring PLR populations in each plot were monitored on a regular interval to determine the level of parasitism in each ground cover treatment.

Population densities and species composition of aphids that establish on the alfalfa and grass cover crops were evaluated by sampling cover crop plants at regular intervals throughout the season. The relative percent parasitism of cover crop and apple tree aphid populations was evaluated by random samples along transects from throughout the cover crop and trees within cover crop treatments and on trees outside the cover crop treatment areas. Kinds of parasites attacking aphids in trees were determined through rearing sub-samples of aphids in the laboratory.

Other pest and beneficial arthropods occurring on the cover crops and in the orchard were monitored with standard methods developed in the SARE project. The level of fruit injury from codling moth, leafroller and other potential fruit pests were determined at harvest. Cover crops were maintained for three years to determine the long-term stability of leafroller biological control in orchards with different cover crop.

Cover crop and horticultural effects: The impact of a cover crop such as alfalfa on apple tree growth and fruit quality was evaluated by comparing shoot growth, yield, fruit size and fruit quality. Shoot growth assessments were taken at the end of the summer growth period from trees pre-selected in spring. Fruit size and quality were determined by collecting samples from pre-selected trees in each cover crop at harvest and making standard measurements. Yield was determined by measuring the number of fruit (bins) collected from each cover crop plot at harvest over time. All horticultural practices were maintained the same on trees within each cover crop plot.

Soil fertility and tree nutrition: Levels of nitrogen, and possibly other minor elements, were evaluated at regular intervals in different cover crop plots using standardized methods. Leaf nutrient levels were evaluated twice each year using standard methods to determine differences between cover crop plots.

Results and discussion:
During the spring of 1999, a 5th leaf Fuji apple (BC#2/M9, 800 TPA) orchard block at the WVC Grady Auvil Teaching and Demonstration Orchard was divided into six plots (for two treatments, alfalfa and grass, with three replications each). Each plot exceeded one acre in size and a core area for sampling in the center of each plot, approximately .25 acre in size, was delineated. A “star” configuration with a transect from the border of each plot to the approximate center was designated as the “sample area.” Thirty trees were selected within the star configuration and numbered 1-30. The orchard is farmed utilizing pheromone-based mating disruption for codling moth. Other than one delayed dormant superior oil treatment, no pesticides were applied.

Overview of progress and observations:

Leafrollers: During 1999, no pandemis larvae were detected in samples and hence no parasitism were observed. In 2000 a total of 29 of 900 buds (3%) examined was infested with pandemis leafroller larvae, and parasitism by *Apanteles* occurred in 12.5% of the larvae. In 2001 levels increased to 43% infested buds in both treatments, and parasitism by *Apanteles* was 5% in the grass treatment and 2.1% in the alfalfa treatment. During early May (petal fall stage), 100 leafroller-infested shoot tips were collected from each plot, and leafrollers were reared in the laboratory. During 1999 no parasitism was observed. In 2000 Pandemis leafroller parasitism by *Apanteles* was 3.3% in the alfalfa treatment and 5.0% in the grass treatment. In 2001, leafroller parasitism by *Apanteles* was 11% in alfalfa and 7% in the grass treatment.

Shoots high in the tree canopy were inspected (300 shoots per plot) to determine leafroller infestation levels from mid-May through late August. In 2000 infestation of leafrollers was 7% for both treatments in early spring but increased to an infestation level of 90% for both treatments by mid-July. Leafroller infestation appeared two months earlier in 2000 than in 1999, and leafroller counts were five times higher than in 1999. In 2001 early spring infestation was 42% for both treatments and increased to dense infestations of 95% by mid-July.

Sentinel leafroller larvae (OBLR) were placed in plots to assess the occurrence of parasites. In 1999, 2000 and 2001 a Braconid, *Apanteles sp.,* and Tachinids were detected in all plots from July through mid-September. Total parasitism of sentinel OBLR reached levels as high as 80% in 1999 and 86% in 2000. The presence of *Apanteles* was detected in both treatments and much earlier in 2000 than in 1999 when it was observed in alfalfa treatments only. *Colpoclypeus florus* was observed in both treatments from early September through early October in both years. During 1999 *C. florus* was detected only in the alfalfa treatment. This parasitoid occurred naturally in the orchard without seeding. In 2001 the sample trees in an organic block were included as part of this study in order to determine differences between parasitism by *C. florus* in untreated trees and the experimental plots where a spring application of Sevin had been used. Parasitism of sentinel OBLR by *C. florus* (33%) was observed in the organic block beginning in late August and increased to 89% by mid-September. Parasitism by *C. florus* in the grass treatment occurred by early September but remained below 5%. In the alfalfa treatment, parasitism by *C. florus* occurred by late August and reached 90% by early September. Tachinids were detected in all plots from early July through late August. Parasitism by *Apanteles* was detected 30 days earlier than in 2000; however, the percent parasitism remained the same with no differences between treatments.

During the summer of 2000, *Xenotemna pallorana* were released in the alfalfa cover crop on a weekly basis in an attempt to establish a host population for *C. florus*. Although *Xenotemna* was an adequate host for *C. florus* under laboratory conditions and preliminary field studies, we could not establish populations in the orchard. This was most likely due to high levels of natural mortality in the orchard by large numbers of general predators.

During the 2001 season the strawberry leafroller (*Ancylis comptana fragaria*) was substituted for *Xenotemna* as a possible host for *C. florus.* A colony of strawberry leafroller was established on 400 Quinault strawberry plants in the greenhouse and seeded with early instar *C. florus* larvae. When the larvae reached a mature stage, the plants were moved to the orchard and placed in the tree rows. Endemic pandemis larvae were collected every 10 days and brought to the lab for rearing out in order to determine if *C. florus* will move into the tree canopy to parasitize pandemis. One plot of each grass and alfalfa treatment served as the control. The first pandemis samples collected (early and mid-August) following the seeding of *C. florus* in the orchard indicated 0% parasitism by *C. florus*. One hundred percent of leafrollers collected were parasitized by either *Apanteles* or Tachinids. By late

August and early September, only 6% of parasitism was by *C. florus* in both treatments. No parasitism by *C. florus* occurred in the control plots. Spring 2002 pandemis sampling will determine if *C. florus* was able to overwinter on the strawberry leafroller host and whether the parasitoid moves into the tree canopy in early spring. Additional research with the strawberry leafroller as an alternate host for *C. florus* is planned but under a different project directed by Tom Unruh and funded by IFAFS/RAMP.

It became apparent that cover crops did not appreciable enhance leafroller parasitism. This is likely due in great part to the use of Sevin as a fruit-thinning agent in both treatments. Sevin is known to be highly toxic to *C. florus* (Brunner et al. 2001), but its impact on other parasitoids is not as well understood.

Western tentiform leafminer and parasitism: In late June leaves were sampled for western tentiform leafminer (WTLM) to determine the density of this pest and to assess levels of parasitism. No leafminers were observed during the summer of 2001. In 2000, WTLM appeared 1.5 months earlier than in 1999, and parasitism by *Pnigalio flavipes* increased from 15% (1999) in both treatments, to over 70% in 2000. The average number of mines per leaf increased from <2 (1999) to 3-4 mines per leaf in 2000 but then declined again in 2001 to non-detectable levels in both treatments.

White apple leafhopper: White apple leafhopper (WALH) density was determined by counting the number of nymphs on leaves (150-leaf sample per plot). Counts taken mid-June and early August revealed densities of <1 WALH per leaf. WALH counts made in August 2001 were five times greater in the grass compared to the alfalfa treatment, whereas in 2000 WALH counts were higher in the alfalfa treatment.

Mites: Mites were sampled at biweekly intervals from early June through early September. Fifty-leaf samples were collected from each replicate on each sample date, brushed in the laboratory and counted under magnification. The active stages and eggs of phytophagous and predaceous mite species were recorded. In 1999 and 2000 spider mites were higher in the grass compared to the alfalfa treatment while predatory mites were higher in the alfalfa treatment. In 2001 spider mites appeared first in late July, one month later than in 2000; predatory mites were three times higher in the grass compared to the alfalfa treatment by the late August peak, and no *Zetzellia mali* were observed.

Campylomma, lygus, thrips and stink bug: Another measure of arthropod presence and density within each cover crop treatment was made by four limb tap samples during the months of May and June. Campylomma densities were very low in 1999, increased by six times in 2000 although no fruit injury was noted, and were near zero in 2001, again with no fruit injury detected. Thrips densities decreased slightly from 2000 with no difference between treatments. In the three years of the study there were no lygus or stinkbug detected on beat trays nor was there any fruit injury noted by these pests. However, lygus was present and detected in sweep net sampling of the orchard cover crop. Beneficial insects observed included ladybeetle larvae and adults, parasitic wasps, arachnids, lacewing nymphs and adults, syrphid flies and deraeocoris.

Apple grain aphid (AGA), green apple aphid (GAA) and rosy apple aphid (RAA): Aphid density was determined by counting aphid-infested leaves on five shoots in 30 trees per replicate. Shoots were examined for aphid infestation from late May through early August. By mid-July of 2001, densities of more than five infested leaves per shoot reached a peak of 66% in alfalfa and 45% in grass treatments, the same trend as in 2000 but with three times higher populations in both treatments. Aphid densities subsided to less than 1% by mid-August 2001 for both treatments. An abundance of lady beetles, damsel bugs, syrphid flies and brown and green lacewing was present from late May onward.

In 2001, active RAA colonies were initially observed in late June at peak densities for the season (7% infested shoots where >5 leaves per shoot were infested). RAA densities were two times higher in alfalfa than in grass. RAA infestations were below 3% by late July and declined to 0% by early August, representing no change in RAA populations from 2000 counts. While RAA aphid densities seemed to be consistently higher in the alfalfa treatment, there was no impact on tree health or crop yield.

Aphid predator counts: Aphid predator counts were done from mid-July through mid-August. Aphid predators were more abundant in the alfalfa treatment with numbers peaking in early August of 2001. Predators observed include Damsel bug, deraeocoris, lacewings, ladybeetles, lygus, spiders, syrphid flies and minute pirate bug.

Overwintering arthropods: Overwintering arthropods were trapped inside one-inch wide cardboard strips wrapped around the trunk near the crown on each of 30 sample trees per plot during early September. Bands were collected in late October and various species counted. For 1999, the overwintering beneficial insect population was three times higher in the alfalfa treatments than in grass treatments. Pest arthropods collected were noctuids, lygus, Lygaeidae, winged green apple aphid, leafhopper and Arctiidae. Beneficial arthropods included Aphididae, Heerobiidae, Chalcidoidea, green lacewing, Stethorus, Deraeocoris sp., Nabid nymph, and Syrphidae. Miscellaneous arthropods included Collembola, weevil, Carabidae, Hymenoptera and Acarina. Total 1999 arthropod counts averaged 9.7 in grass treatments and 38.7 in alfalfa treatments. Data in 2000 indicated an increase of overwintering arthropods with no difference between treatments. Data from 2001 are not yet available.

Nutrition and leaf analysis: Pre-bloom ammonium nitrate 34-0-0 was applied to all treatment plots at .175 lbs. per tree or 45-50 lbs. of actual N per acre. No other fertilizers were applied. Leaf analysis in July of 2001 indicated that nitrogen levels in both treatments were 2.9%, which is slightly higher than 1999 and 2000 levels and exceeds optimum N ranges. Zinc levels in both treatments were 13 ppm in 2001, and this represents no change from 1999 and 2000 zinc levels.

Cover crop N content and biomass: During July, biomass samples were collected by clipping three 1-meter diameter areas at six inches above ground from each treatment plot. Composite samples were analyzed for total nitrogen. Cascade Analytical results for 2001 in the alfalfa treatment showed 5% total nitrogen, an excess N value which is slightly higher than in 2000. The nitrogen value for the grass treatment was 2.7%, which represents no change from 2000 N values.

Cover crop composition: During the second year of this project, various weeds invaded the primary cover crops of alfalfa and grass. In an attempt to reestablish a more homogenous cover, reseeding of the alfalfa and grass plots was done in early spring of 2001 and a broadleaf herbicide (2-4 D) was applied. By the end of the third year, both grass and alfalfa were well established and dominated the cover. Analysis of the resulting cover composition was done by recording species observed within 10 randomly chosen 1-meter areas per plot. By mid-July alfalfa and grass composed nearly 90% of the cover in their respective treatments.

Trunk growth measurements: During April of 1999, 10 groups of five trees per treatment plot were chosen based on uniform characteristics. Trunk circumference measurements were taken at 20 cm above the graft union. In early spring of 2000, a large percentage of those trees was removed due to winter damage. New trees were selected, and measurements were taken during April of 2000 and April of 2001. An average 2.2 cm growth was measured for the trees in both treatments.

Shoot growth assessment (vigor): The impact of grass vs. alfalfa treatments on apple tree growth is being evaluated by shoot growth assessments taken at the end of the grand growth period. Ten trees per plot were preselected, and one uniformly representative branch was chosen on each of the 10 trees. Shoots were measured and (cm) growth recorded for three shoot-type classifications: true terminal shoots, true lateral shoots and bourse shoots. Terminal shoot growth was greatest (14.3 cm) in the grass treatment, lateral shoot growth the same (6.3-6.9) for both treatments, and bourse shoot growth greater (10.1 cm) in the alfalfa treatment.

Fruit insect damage and horticultural effects - cull analysis: Data for 2001 have not yet been summarized.

Soils: General soil fertility is assessed each April and September. To assess soil, chemical and colloidal properties, samples will be subject to a complete nutrient analysis (N, P, K, S, Mg, Ca, Mn, B, Zn, Mo, Cu, Fe) and measure of pH and OM%. Separate samples were taken from the drive row and the tree row at a 12-inch depth using a 10-core composite for each treatment plot. Early spring 2001 soil N values were deficient in the alfalfa treatment and at optimum levels in the grass treatment. September 2001 soil N values remained the same for both treatments.

Budget:
Enhancing biological control of leafrollers through ground cover management and augmentation of alternate hosts for leafroller parasites.
Jay F. Brunner
Project duration: 3 years
Current year: 2001
Original budget request: $23,300

Year	**Year 1 (1999)**	**Year 2 (2000)**	**Year 3 (2001)**	**Total 1999-01**
Total	$ 23,300	$ 26,202	$ 10,820	**$ 60,322**

Current year breakdown

Item	**Year 1 (1999)**	**Year 2 (2000)**	**Year 3 (2001)**	**Total 1999-01**
Salaries	0	18,540	7,500	26,040
Benefits (%)	0	5,562	1,820	7,382
Wages	15,000	0	0	15,000
Benefits (%)	2,400	0	0	2,400
Equipment	0	0	0	0
Supplies	5,000	1,000	1,000	7,000
Travel	900	1,100	500	2,500
Miscellaneous	0	0	0	0
Total	$ 23,300	$ 26,202	$ 10,820	**$ 60,322**