FINAL REPORT
WTFRC Project #: ARS-Wapato Organization Project # ARS-YARL

Project Title: Biological control of leafrollers through habitat modification
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OBJECTIVES:

1) **Establish new and expand existing rose gardens and establish *Ancylis* and *C. florus***
2) **Measure parasitism of and damage by leafrollers at different distances along transects from rose plantings into apple orchards.**
3) **Monitor the seasonal phenology and stability of alternate host populations in rose gardens and associated parasitism of SLR by *C. florus* and other parasitoids**
4) **Conduct field-day demonstrations for establishing and maintaining rose plantings and widely disseminate information from project to grower community**

SIGNIFICANT FINDINGS

- **High parasitism by *C. florus* in spring and summer was observed at orchards near gardens that harbored significant numbers of Ancylis and C. florus.**
- **The strawberries *Fragraria virginiana* collected at various localities under pine trees in the Cascade Mountains and the commercial *Fragraria* var. Quinault were excellent supplements to the gardens composed of *Rosa woodsii***
- **Ancylis did not establish or quickly went extinct at some gardens due to unknown factors that may include intense predation or pesticide spray drift.**
- **Re-infestation of gardens with *Ancylis* at several sites resulted in successful establishment and subsequent high parasitism of leafrollers in spring and summer by *C. florus***
- **In orchards adjacent to productive gardens parasitism by *C. florus* accounted for up to 95% of spring and summer parasitism. In orchards adjacent to poor gardens (few Ancylis) tachinids dominated parasitism but parasitism is usually lower, especially in spring. In the Royal slope, Frenchman hills the close relative of *Colpoclypeus, Sympiesis* spp., is often dominant in summer.**

Budget: This proposal was funded for 2 of proposed 3 years; subsequent matching funds were received from Western SARE for $105,000 over 3 years (2005-2007).

2003	2004	WTFRC Total
52,400	51,700	104,100

Objective 1. Establish and expand gardens

Since the inception of this work in 2001, eighteen growers and the PI's lab group have planted 35 gardens of multi-floral rose and strawberries (34 single gardens plus 50 small gardens around one 500 acre orchard) throughout the major pome fruit centers of the Pacific Northwest. Four new gardens were planted in 2005 and six older gardens were re-infested with *Ancylis.* The objective of having many gardens over a wide geographic range is to test that this habitat manipulation is robust to geographic variation in climate and other biological and physical factors. At each garden we have attempted to establish the Strawberry leafroller, *Ancylis comptana*, document the use of this host by the parasite *Colpoclypeus florus* and to determine the impact of the availability of this alternate and overwintering host on the parasitism of pest leafrollers in targeted orchards in spring and summer. The positions of the 35 gardens are shown in Figure 1**.**

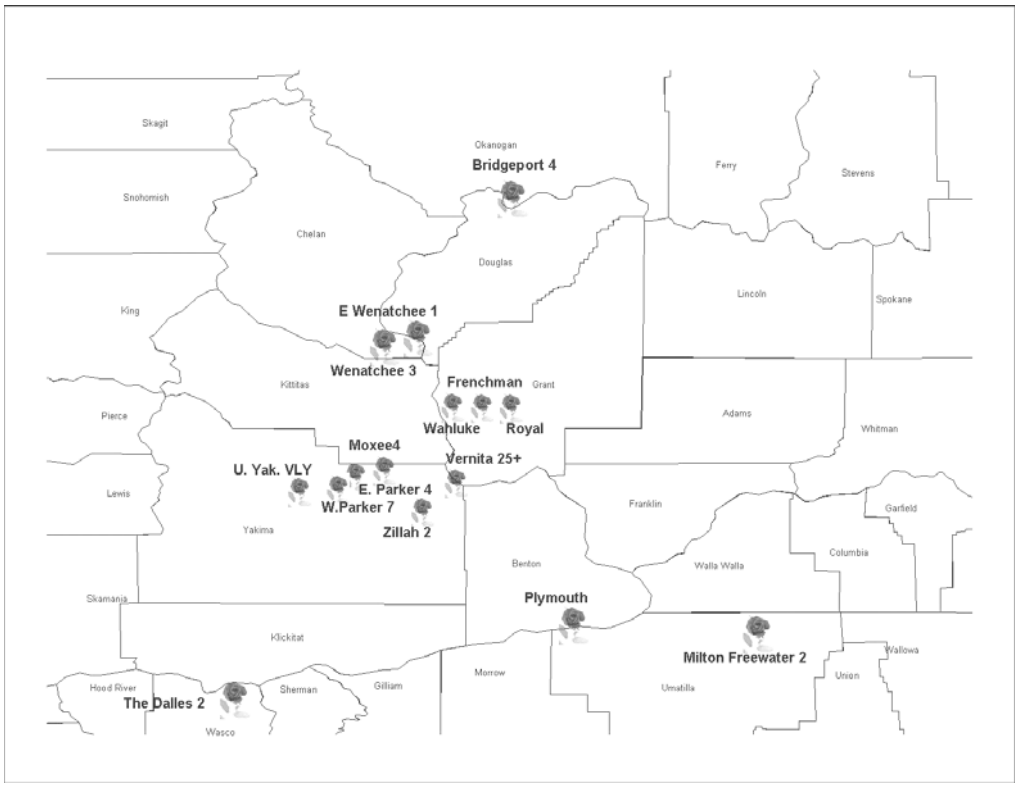

Figure 1. Locations of gardens of the multi-floral rose, *Rosa woodsii,* planted adjacent to pome fruit and cherry orchards in Central Washington and North-Central Oregon are depicted. Gardens were planted at Wahluke, Plymouth, Upper Yakima Valley, and one in Zillah in 2005. In all cases these gardens were established by growers; we provided consultation on placement, help in planting in some cases, and infested them with *Ancylis*, and monitored parasitism in the orchards nearby.

To assess the value of strawberries in the gardens we conducted common garden experiments begun in 2002 and assessed in 2004. We planted 19 accessions of strawberries including 3 species and multiple varieties including commercial hybrids in 5 gardens. Similarly we planted 11 sources of Rosa spp. including *Rosa woodsii* and *Rosa nutkana*. We found locally collected *Fragraria virginiana* (from the Cascade Mountains under pine trees) ranked highest in cover and spreading followed closely by several accession of the *F. chiloensis*. The commercial variety Quinalt followed by the wild Cascade species ranked highest in producing/supporting *Ancylis* through the season. However, at many of our gardens strawberry appears to be slowly disappearing because of the combined pressures of encroaching over-story of the roses and weed

growth. At all gardens roses have prospered once they make it through the first year and an adequate water supply continues.

Objective 2. Evaluate parasitism

We monitored parasitism by *C. florus* and other parasitoids in orchards next to gardens using sentinel leafroller larvae which since 2003 we put directly onto tree branches (4th instar OBLR produced in the laboratory; 25 larvae/ branch, 10-20 branches/site, 3 sites/orchard) using a barrier of steel wool to prevent migration throughout the tree. Larvae are deployed at 3 specific times: in spring and summer (when pest leafrollers are in susceptible larval stages) and in fall (when parasitism of sentinel leafrollers indicates that *C. florus* are seeking overwintering hosts).

Parasitism was measured at 21 orchards one or more times in 2004 (not shown) and at 142 sites in 27 orchards in 2005 (see below). Attempts to measure parasitism in Arrowhead (Okanagon) and The Dalles generally failed because of very poor recovery of deployed insects. In Arrowhead we ascribe this to a combination of overhead sprinklers and pesticide use. Parasitism results are depicted in 3 ways: first is the season-long pattern of parasitism across all sites; second is the proportion of parasitism due to *C. florus* across all sites and all dates through mid August represented as a plot of *C. florus* versus total parasitism; third is the pattern of parasitism seen at 9 sites where parasitism was monitored in spring, summer, and fall. Figure 2 plots season-long parasitism in 2005 showing that parasitism increases significantly throughought the season and that *C. florus* dominates the parasitism through most of the year, with two parasitic flies (Tachinidae) accounting for most of the remaining parasitism. Figure 3 plots spring and summer parasitsm by *C. florus* against total parasitsm. It shows that overall *C. florus* is responsible for 70% of all parasitism despite many sites/dates where most parasitism was due to tachinid flies.

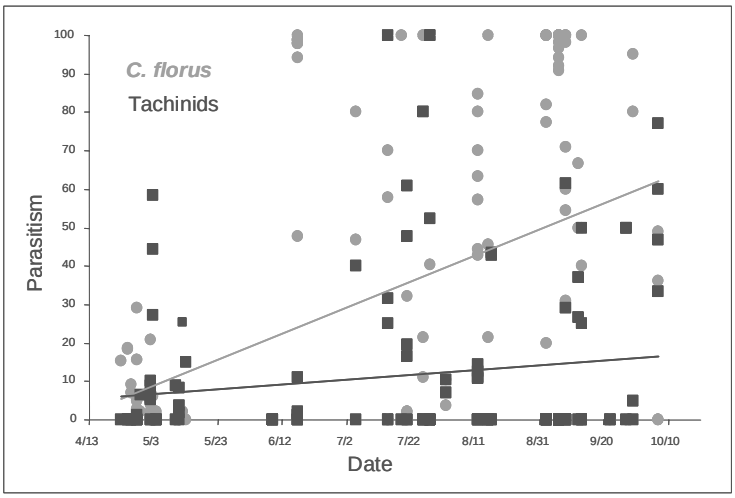

Figure 2. 2005 season-long parasitism by *C. florus* (light circles) and tachinid flies (dark squares) plotted against collection date of sentinel OBLR deployed 2-3 weeks before. Pest leafrollers are not present in orchards at the appropriate stage for *C. florus* or Tachinid attack after late August; parasitism by *C. florus* of sentinel leafrollers late in summer and especially in fall represents a measure of it seeking hosts on which to overwinter. The overwintering hosts of the tachinids are unknown.

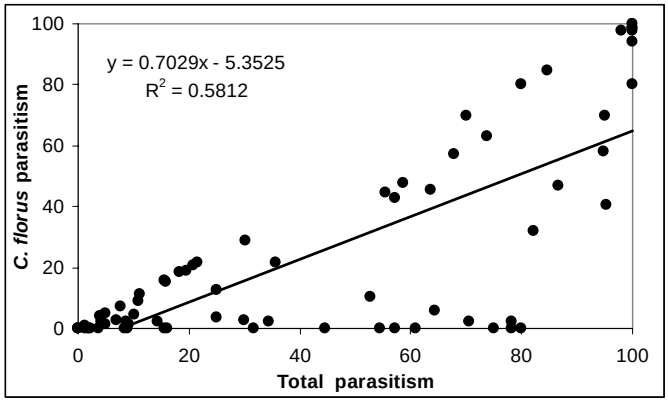

Figure 3. The percentage of parasitism due to *C. florus* is plotted against total percent parasitism for collection dates from early May until mid August. There are two patterns of parasitism: at some sites and dates tachinid flies dominate parasitism and that due to C. florus is low (points close to x axis); at other sites and dates parasitism is dominated by C. florus (points close to the fitted line). Overall, *C. florus* accounts for roughly 70% of all

parasitism.

Parasitism of our experimentally depoyed sentinel hosts remained very high in late summer into fall (after mid-late August), when suitable stages of pest leafrollers are not found in or near orchards. This parasitism of fall deployed sentinels is coincident with *C. florus* parasitism of *Ancylis* leafrollers in the gardens. The overwintering hosts and biology of the tachinid flies remains unknown but their abundance after mid-August also suggests they may be subject to manipulation if a suitable overwintering host and habitat were found. Figure 4 provides some detail on seasonal pattern of parasitism at 9 sites where we were able to measure parasitism at spring, summer and fall periods.

In several gardens *Ancylis* failed to establish or were extirpated by pesticide drift or unknown cause (possibly intensive predation). Six such gardens were reinfested with *Ancylis* in 2005. Still to be analyzed are samples from 12 rose gardens taken in late November-December designed to provide estimates of *Ancylis* abundance and parasitism by *C. florus* that help us generate expectations for parasitism in the orchards in the coming spring . These samples will be analyzed through February and results, redictions, and tests of predictions will be reported next year.

More importantly, *Ancylis* abundance in gardens was low in the winter of 2004-2005 (not shown) and this presaged lower spring parasitism by *C. florus* than in previous years. This resulted in modest parasitism in spring as seen in Figure 4. Low spring parasitism was observed at older sites (UP7, Moxee) as well as newer sites (DJM, Ostensen). Fortunately during the 2005 year *Ancylis* populations and *C. florus* populations rebounded resulting in strong parasitism in summer and exceptionally highparasitism in fall. We expect much higher spring parasitism at all sites (excpt those where it is already very high such as UP3). A significant exception to spring parasitism leading to higer summer parasitism was observed at several sites (e.g. UP4 in Figure 4) and these are reliable associated with spray patterns.

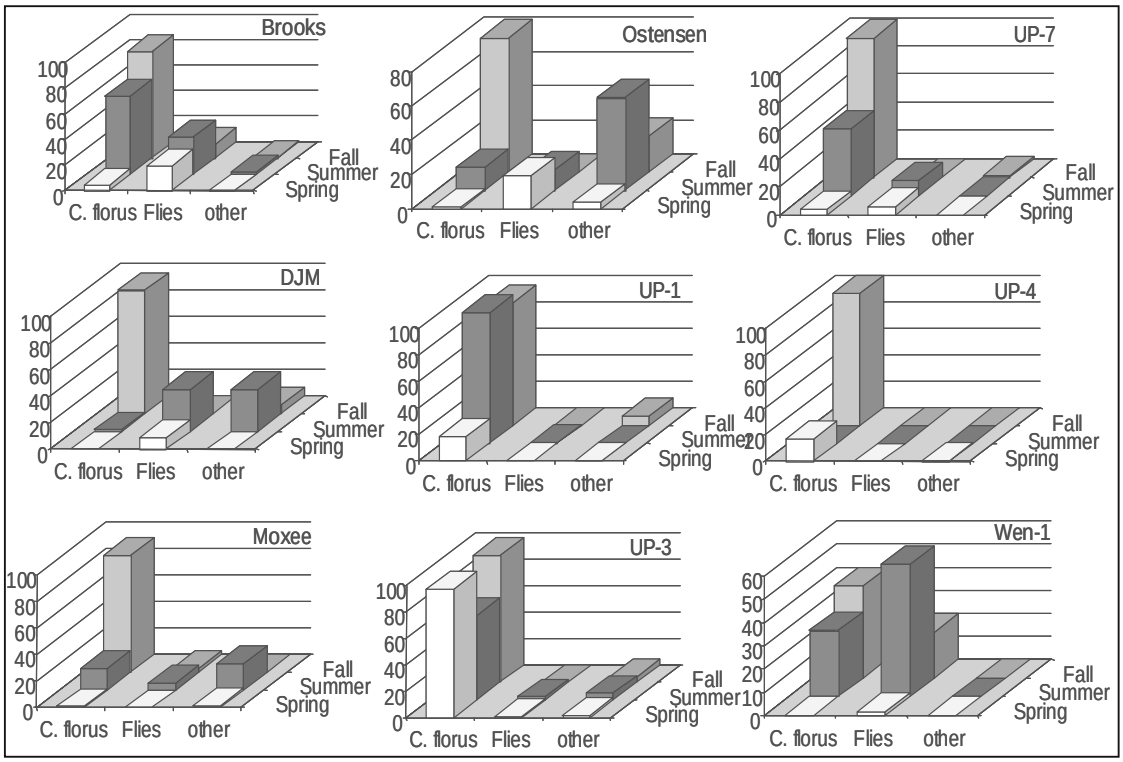

Figure 4. Pattern of parasitism by *C. florus*, tachinids and other wasps in 9 sites in 2005.

Objective 3. Monitor abundance and parasitism of *Ancylis* in rose gardens

As discussed under objective 2, abundance of *Ancylis* in gardens is critical to the success of this habitat manipulation. In some gardens, despite repeated attempts to colonize it, the leafroller has not established. In other gardens, it is very abundant every year. Figure 5 depicts the abundance of *Ancylis* across years for 3 gardens and the parasitism of these *Ancylis*. Please note that *Ancylis* density (in fallen leaves) is presented on a logarithmic scale and varies between 13/m^2 to over 3000/m^2! Despite high variability, in most years, parasitism of *Ancylis* by *C. florus* exceeded 30%. It is also important to note that strawberries are also planted and established in most gardens. They contribute significantly to the abundance of *Ancylis* (roughly 75% of Ancylis overwinter in strawberry opposed to the rose) but C. florus much prefers to parasitize *Ancylis* in roses. We discovered that this preference is unrelated to the plant species but the height of the strawberries versus the rose. Specifically when strawberry plants are elevated to be the same height as rose plants, the use of the Ancylis hosts in the strawberries goes up. This is depicted in Figure 6. Overall, these results suggest that strawberries add stability to the garden system, providing abundant Ancylis to go up and also infest the roses, while at the same time protecting some subset of Anclis from overexploitation by parasitoids.

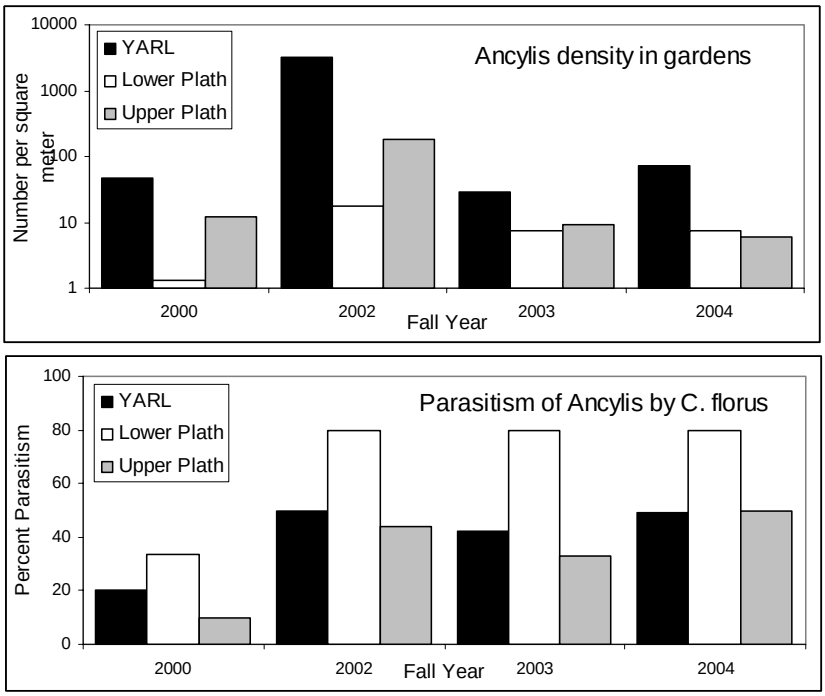

Figure 5. Highly variable Ancylis density in gardens (logarithmic scale of abundance) in upper panel and the more consistent pattern of parasitism by C. florus across four years.

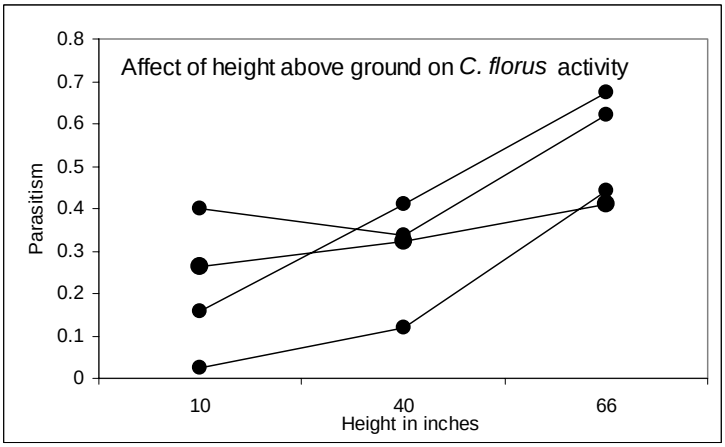

Figure 6. *C. florus* parasitism of *Ancylis* larvae feeding on strawberry plants when plants were deployed at different heights above the ground. Different lines depict replicate vertical transects on the north, east, south and west sides of a rose garden.

Objective 4. Share information

about gardens with growers

To date we have presented our results at the third National Organic Tree Fruit Symposium held in Chelan WA in June 2005, at the Washington Horticultural AssociationConvention in 2001-2005, and from 2001 to 2005, in 2003,4, and 6 at the Western Orchard Pest Management and Disease Conference, and at the WTFRC research reviews yearly since 2001. In addition the work has been covered by the press in the Columbia Basin Journal, ARS magazine, and Western Fruit Grower among others. We have created web pages describing how to implement gardens from how and where to plant and maintain the roses and strawberries, where to find infested roses for transferring *Ancylis* to your own garden, and with overviews of our results for the last 5 seasons. The website is not yet connected but will be so in the coming months. Completion of this website represents an important milestone to be met before the end of 2006 under our WSARE funding.

Many in the grower community are familiar with the concept of using rose gardens to enhance leafroller parasitism based on the above presentations. A measure of this grower awareness are the contacts by growers to consult us on how to establish gardens and our subsequent help in getting the strawberry leafroller established in the gardens they plant. Such was the path taken for the 4 new gardens planted in 2005. We will continue to provide such help, including onsite visits, phone consultations, provision of insects etc. throughout the duration of our SARE funding. Furthermore, we believe the web site will further grower confidence in striking out on their own to create these gardens in the future.

This is a long-term ecological experiment and our work is far from completed. We have several deficiencies under this objective that need to be met. The most important is identifying the cost to growers of creating and maintaining a garden. We know the materials and supplies (black irrigation hose, couplers, ¾ " PVC for risers, 5 sprinkler heads, 20-50 *Rosa woodsii* seedlings, weed cloth, buildozing a clean area to plant, connection to the orchard irrigation) can be less that $200 for a sizable garden, but we need to formalize these estimates and make them available to the grower community.

Conclusions

This remains a work in progress and it should be clear to growers an scientists alike that habitat manipulations are long-term ecological manipulations. Early work, reported to WTFRC in the past has demonstrated the principle that rose habitats can greatly enhance spring and summer parasitism of orchard leafrollers by *C. florus* by providing a nearby overwintering host for this wasp, namely *Ancylis comptana* overwintering as full sized larvae in the rose gardens. The continued work will include studies of dispersal of C> florus from the gardens with Dr. Vince Jones, and continued monitoring of the population trends in gardens planted by my lab and collaborating growers, and finally, continued study of spring and summer parasitism of pest leafrollers in orchards near gardens. Much if this later work wil be supported through 2007 by WSARE but the WTFRC will receive updates.