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Managing Carrot Rust Fly

In Search of Alternatives for a Tough Customer

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The State of Washington is the number one producer of processing carrots in the United States and the fourth largest producer of fresh market carrots (Washington Agricultural Statistics Service 2001). This accounts for 33% of the processed carrots and almost 4% of the fresh carrots produced in the nation. Carrot production generated $29.8 million dollars for Washington State in 2000 (Sorensen 2000). The leading carrot-producing counties are Benton and Franklin in the eastern part of the state and Cowlitz and Skagit west of the Cascade Mountains. As of 2000 Washington had 5000 acres of processing carrots and 3000 acres of fresh market carrots (Sorensen 2000). Approximately 2% of the carrots grown in Washington were grown organically (Sorensen 2000).

About the Pest

Arguably the most important pest of carrots, particularly on the western side of the state, is the carrot rust fly (*Psila rosae* Fabricius) (Figure 1, a and b). The rust fly adult is about 6-8 mm long with a shiny black thorax and abdomen, a reddish-brown head, and yellow legs. The adult female lays its eggs in the soil at the base of the carrot. Six to ten days later the larva hatches and feeds on the carrot root, rendering the carrots impossible to market. Carrot rust flies obtain

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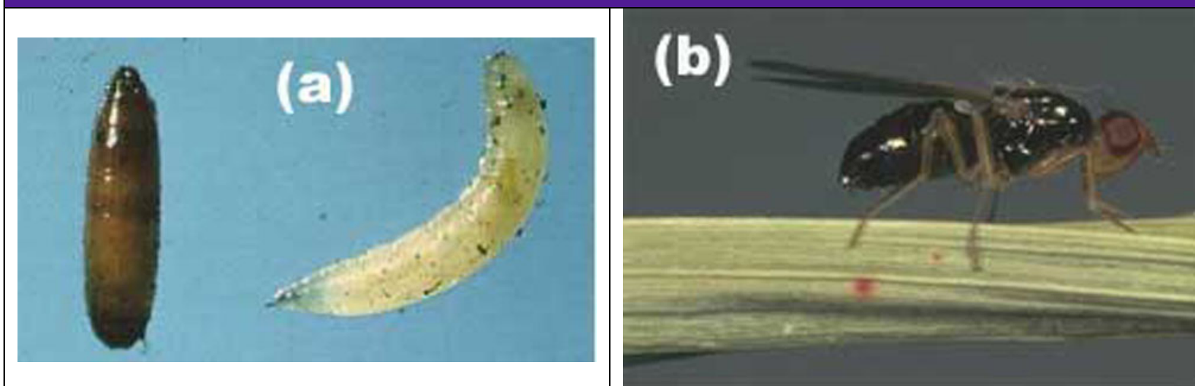
their common name from the rust colored frass (excrement) they deposit in the superficial feeding tunnels on the carrot.

FIGURE 1



Pupa and larva of the carrot rust fly. | **Adult carrot rust fly at rest.**

In Washington State there are generally three generations of the fly per year, with the third generation causing the greatest economic damage (Antonelli and Getzin 1997).

Managing CRF

The host range of the carrot rust fly (CRF) extends to 107 different plant species, all in the same family as the carrot. Many of the host species are also grown for food, including celery, parsnips, celeriac, parsley, and dill (Degen, Stadler and Ellis, 1999). Many fresh market carrot producers grow the other host plants as well, which confounds management of the fly. Inability to manage rust fly populations in a cost-effective manner has driven some farmers out of carrot production.

Insecticides have limited effectiveness against CRF, due to the behavioral patterns of the pest (Dufault and Coaker 1987). The rust fly adult spends most of its time in the periphery of the fields, flying into the field to lay eggs at the base of the carrot, and then leaving the field. After hatching, the larva moves down into the soil to feed on the carrot and eventually pupates in the soil. When the adult emerges from the pupal case, it flies to the periphery of the field. This behavioral pattern leaves only limited opportunities for control with insecticides.

Numerous pyrethroids and organophosphates have been tested to control CRF populations. In general, pyrethroids do not appear to be effective against eggs and larvae, but do reduce adult populations with continual broadcast spraying. This strategy has a large impact on non-target invertebrates and promotes overspraying. Some organophosphates (OPs) have been shown to be quite effective against the larval stage. In the Pacific Northwest, the recommended pesticide for control of CRF is Diazinon 50W applied at 2 lbs ai/A at planting as a seed furrow drench

(DeAngelis et al. 2000). This will protect the crop for the first generation of rust flies, but additional side dress applications will be needed when the second generation emerges in early July.

Despite the current insecticide recommendations for CRF control, diazinon has drawbacks including limited effectiveness and uncertainty about human health and environmental effects. In British Columbia, one particularly small field that was sprayed seven times during a single growing season still reported substantial CRF damage (Judd et al. 1985). The grower had been routinely spraying fourteen times, but the seven times represented an adult monitoring-based spray program. In addition to a possible lack of efficacy, diazinon poses a hazard to applicators and has been linked to numerous bird kills. Some studies have shown salmon's normal olfactory responses to be altered by low concentrations of diazinon in water (Turner 2002). Urban uses of diazinon will be completely phased out before 2004 and the uncertain availability of diazinon for agricultural uses suggests that alternative control strategies must be developed.

Non-Chemical Controls

For organic farmers the recommended cultural control is to use row covers or to rotate the carrot crop every other year. Both of these tactics work well when done properly, but they have drawbacks. Row covers can be highly effective but are labor intensive, particularly if fields require continuous cultivation. They work as a physical barrier, excluding the pest insect from feeding or laying eggs on the crop. Their effectiveness is dependent on the covers being undamaged and anchored in the ground properly, creating an impervious barrier. All this takes time and labor, plus there is an additional expense of replacing the covers every 2 to 3 years. Covers are made of polyester or polypropylene and are subject to UV radiation damage, which makes the material brittle and easily ripped. Examples of floating row covers are Reemay, Agronet, and Argyl P17.

Because the CRF is a weak flier and will not infest fields from a long distance, crop rotation can be a highly effective strategy against this pest. It is recommended that carrots be rotated into a different field every other year. To be effective, the new carrot field must be situated at a sufficient distance (ca. 1000 meters) from the old field to discourage relocation of the CRF. This makes rotation impractical for small acreage farmers.

CRF Theories and Behaviors

Carrots produce the phenolic compound chlorogenic acid when stressed by environmental conditions, such as low temperatures, or by insect damage. Cole (1985) was able to show that CRF is attracted to chlorogenic acid, which helps explain why fields used for multiple years to grow carrots become very attractive to the CRF. Cole et al. (1988) were able to develop a model to predict susceptibility to CRF attack based on levels of chlorogenic acid present. Gurein et al. (1984) showed that olfactory and contact chemostimuli are involved in selection of the carrot host for an oviposition site.

Numerous studies have shown that intercropping carrots with a cover crop reduces CRF damage (Miles, et al. 1996; Ramert 1993; Ramert and Ekbom 1996; Theunissen and Schelling 2000). How cover crops help reduce pest pressure is not well understood. There are two competing theories, (a) increase in natural enemies due to increase in suitable habitat and (b) the resource concentration hypothesis, which states that in a monoculture the available resources are easier to locate and exploit than in a polyculture. Sheehan (1986) argued that intercropping with a cover crop works via the latter hypothesis because increasing the number of generalist predators would not necessarily make them more effective in reducing a specific targeted pest population. Because the CRF female uses both visual and olfactory cues to locate an appropriate host for egg laying, a fragrant cover crop may confound the olfactory cue.

Based on the available data, Ramert (1993) concluded that the following criteria should be met to get the most effective reduction in pest populations using intercropping systems.

Target pest(s) should be oligophagous (i.e., tending to feed on a limited range of plants).

The intersown crop should not be a host plant for the target pest(s).

The intercrop should disturb the behavior of the pest causing a reduction in the pest population in that field

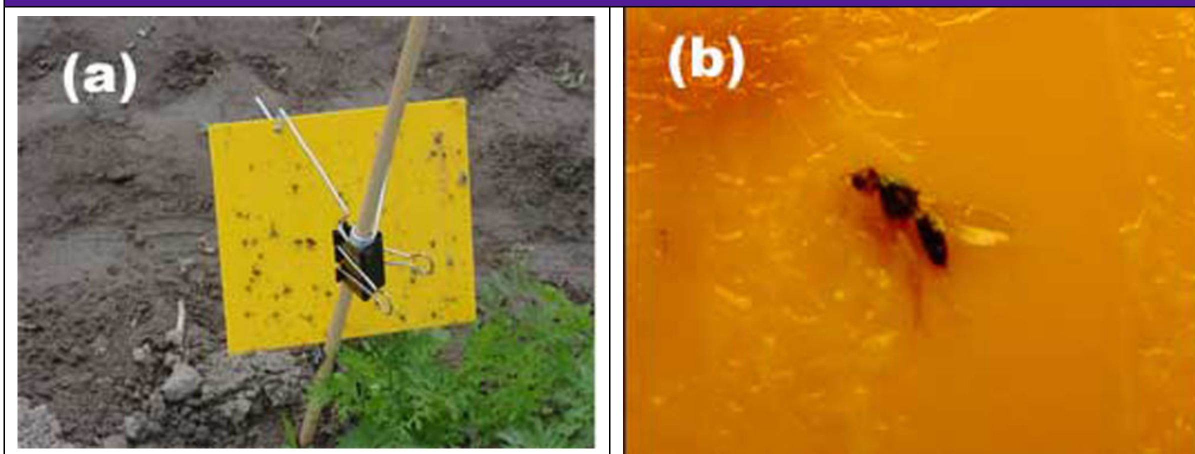
The intercrop should not reduce the cash crop yield to the point of negating the positive impact of the reduced pest pressure.

A New Study

In 2002, we began a two-year study to monitor carrot rust fly activity and to determine the effectiveness of between-row cover crops in reducing CRF damage without impacting yield. We concentrated on cover crops that (a) were well suited to our test plots, (b) would add nutritive value to the soil, and (c) had exhibited some successes in CRF reduction (e.g., various clovers, especially crimson clover, showed promise in other research). We did not experiment with odiferous crops such as garlic and onions for the purpose of blocking CRF olfactory cues.

Our monitoring program used yellow sticky traps (Figure 2) to track, and eventually aid in predicting, adult rust fly activity in the field. We set the traps at a 45-degree angle, which is supposed to increase their attractiveness to the rust fly while reducing the number of beneficial insects attracted to them (Collier and Finch 1990). Adult CRF populations were monitored on a weekly basis at two Washington State University sites (the Puyallup Research and Extension Center, the Vancouver Research and Extension Unit) and on three farms in western Washington. Figure 3, the trap data from one of the farms, illustrates results typical of those we obtained.

FIGURE 2

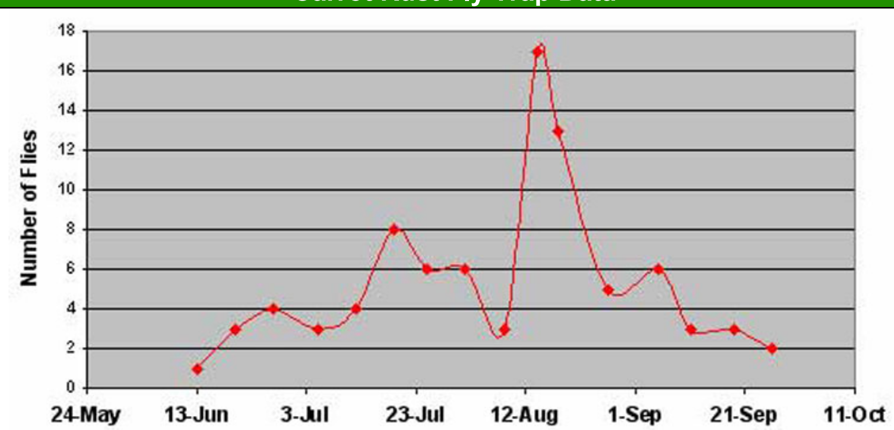


Yellow sticky trap as displayed in the field to catch carrot rust fly.

Close-up of carrot rust fly stuck to the trap.

FIGURE 3

Carrot Rust Fly Trap Data



The number of carrot rust flies trapped on yellow sticky traps at Terry's Berries, an organic Community Supported Agriculture (CSA) farm in Tacoma, WA. Traps were checked weekly.

The other objective of this experiment was to determine whether a cover crop interplanted between carrot rows could reduce the damage caused by the rust fly without reducing carrot yields. Cover crops have been used effectively to reduce CRF damage, with mixed results on its impact on carrot yield (Miles et al. 1996, Ramert 1993, Ramert and Ekbom 1996, Theunissen and Schelling 2000). Cover crops offer the additional benefits of adding nutrients to the field, helping to conserve water, and increasing habitat for beneficial insects.

Cover crop field experiments were carried out at the WSU Puyallup and Vancouver sites. Five different cover crops treatments were compared for their ability to reduce CRF damage and their impact on carrot development and yield. We compared harbinger medic (*Medicago littoralis*), crimson clover (*Trifolium incarnatum*), subterranean clover (*Trifolium subterraneum*), white clover (*Trifolium repens*), and common vetch (*Vicia sativa*) to a control plot with no cover crop. The results from the Puyallup site are shown in Table 1.

TABLE 1

Effect of Cover Crops on Yield at Puyallup Site

Treatments	Marketable Carrot yield (lbs/100 ft. row)
Crimson Clover	285.2
Medic	310.4
Subterranean Clover	294.6
Vetch	316.5
White Clover	245.1

Carrots were intercropped with five different cover crops on certified transitional organic plots at WSU-Puyallup Research and Extension Center. At this site no rust flies were captured by the traps, nor were any rust fly damaged carrots observed. No significant difference between treatments was measured.

We also conducted an on-farm experiment at Terry's Berries organic farm in Tacoma, measuring the effectiveness of row covers and their impact on yields (Table 2).

TABLE 2

Percentage of General and CRF Damage of Harvested Carrots

	13-Jul		19-Jul		30-Jul		16-Aug	
Treatment	**Control**	**Row Cover**	**Control**	**Row Cover**	**Control**	**Row Cover**	**Control**	**Row Cover**
% Total Damage	0.12	0.31	0.18	0.31	0.04	0	0.22	0.28
% CRF Damage	0.09	0.04	0.21	0.08	0.01	0	0.24	0.26

These data were collected at Terry's Berries organic farm in Tacoma, WA, comparing general carrot damage and carrot rust fly specific carrot damage on crops grown with and without row covers. At harvest, carrots were inspected for CRF damage. No significant differences in yields were observed between treatments.

Yield data was collected and the carrots were inspected and graded for CRF damage at the two WSU sites and at Terry's Berries.

Results

At all sites during the experiments, few CRF were captured by the yellow sticky traps (Figure 3). This corresponded with minimal damage to harvested carrots (Table 2). While CRF populations were low this year, we were able to demonstrate that yellow sticky traps can be used to monitor adult fly activity.

Previous studies have demonstrated that cover crops can reduce CRF damage, however it has been unclear whether interplanting cover crops would negatively impact carrot yields. Our data suggests that neither interplanting of cover crops (Table 1) nor using row covers (data not shown) had a negative impact on carrot yields. However, due to the very low population pressure of the CRF this year, we were unable to verify whether cover crops reduced CRF damage. Thus cover crops may be a potentially effective tool for integration into an overall pest management strategy but further studies are required to verify this.

Our work in 2002 laid the foundation for next year's studies, which will include row cover application, intensive monitoring of CRF, and further testing of cover crops. Emphasis in 2003 will be on integration of cover crops and biopesticides.

Conclusions and Next Steps

Pest managers must move away from reliance on the "silver bullet" approaches to controlling pests. Single, overwhelming control tactics generally disrupt both pest and beneficial populations, destabilizing the entire ecosystem within the field, increasing the chance of secondary pest problems and increasing the cost of control. We are trying to develop a biologically based pest management strategy against carrot rust fly populations that utilizes multiple tactics in order to maintain acceptable control of the field population.

This next season, we hope to introduce a biopesticide component to our study. We plan to test application of the fungal pathogens *Beauveria bassiana* and *Metarhizium anisopliae*, entomopathogenic nematodes *Steinernema feltiae* and *Heterorhabditis bacteriophora* and the biochemical pesticide Spinosad. We will apply biopesticide agents at planting and as a side dress when our CRF monitoring data suggest it is necessary.

By combining intensive monitoring, advantageously timed biopesticides, and a cover crop, we hope to achieve an integrated pest management system as effective as diazinon applications, but more sustainable environmentally and economically. As a bonus, the proposed procedures should also enhance soil fertility and increase habitat for natural enemies, the sum total of which may maintain the pest population below an economically damaging level.

David Muehleisen and Marcia Ostrom are with the Washington State University (WSU) Small Farms Program in Puyallup. Andy Bary and Craig Cogger are with the Department of Crop and Soil Science at WSU Puyallup. Carol Miles and Amanda Johnson are with the Department of Horticulture at WSU's Vancouver Research and Extension Center. Terry Carkner owns Terry's Berries, a community supported agriculture (CSA) organic farm in Tacoma. Dave Muehleisen can be reached at (253) 445-4597 or muehleisen@wsu.edu. *This work was supported by a grant from EPA and American Farmland Trust.*

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The work described in this article is just one of many integrated pest management (IPM) efforts underway in Washington State. Several other Washington IPM projects are detailed in the March and April issues of *Agrichemical and Environmental News,* available on the Internet at http://aenews.wsu.edu . For additional information on IPM in Washington State, please consult the following resources:

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