PROJECT SUMMARY
CALIFORNIA LETTUCE RESEARCH BOARD
April 1, 2008 to March 31, 2009

Supporting aphid predators by planting intercrops with alternative prey

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Summary

Growers that use beneficial insects to help control the lettuce aphid (*Nasonovia ribis-nigri*) and other pest aphids have focused their attention on syrphid flies, also known as hover flies. Syrphid fly larvae consume dozens of aphids as they develop. To attract syrphids into lettuce fields, growers have used intercroppings of flowering plants such as sweet alyssum. Flowers provide food to adult syrphid flies, but not to syrphid larvae. Therefore, syrphid populations can increase only when aphids are present. It may be possible to increase local syrphid populations before pest aphids arrive by providing an alternative source of aphid prey. Our long-range goal is to assess the feasibility of using intercrops and alternative prey to enhance infield syrphid populations.

Four intercrop plant species were grown in plots embedded in fields of commercial organic romaine lettuce. The intercrops and the crop were sampled for aphids, syrphid flies, and other insects. The intercrops were compared in terms of (i) their ability to provide non-pest aphids as an alternative food source to syrphid flies, and (ii) their impact on pest aphids in the adjacent lettuce crop.

We found one intercrop—barley—that hosted alternative aphids and fostered syrphid fly development. We expected the syrphids that were ovipositing and developing in the barley to help control pest aphids in the adjacent crop; however, we did not detect this effect. We can see two reasons for this outcome: (1) Syrphids are highly mobile. After syrphids used the habitat plants, we expected them to move just a few meters, to the immediately adjacent crop. Instead, they may have moved greater distances, to locations beyond our plots. (2) Syrphids use the pest aphids as a food source, too. We expected syrphids emanating from the habitat plants to provide additional pest control, no matter how much syrphid activity was occuring in the crop. In fact, the habitat-sourced pest control must be much greater than the crop-sourced pest control; otherwise, we cannot detect it. Barley intercroppings will improve pest control only in situations where there are relatively few pest aphids in the crop and relatively many aphids in the barley.

Our research provided new evidence that syrphid flies help control lettuce aphids. We saw fewer aphids per plant at harvest in fields that had more syrphid eggs and larvae during the crop cycle. Given that barley supports syrphid flies and that syrphids provide aphid control, it stands to reason that barley plantings can improve lettuce aphid control, especially (and perhaps only) at times when the non-pest aphids on barley outnumber the pest aphids in the lettuce crop. However, this cultural practice remains innovative and experimental.

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Supporting aphid predators through intercrops with alternative prey

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Objective:

Test the ability of intercrops bearing non-pest aphids to increase syrphid populations and reduce aphid populations in lettuce fields.

Procedures

In lettuce-growing regions where the lettuce aphid is a key pest problem, organic growers commonly plant flowers within their fields. Their purpose is to provide nectar to syrphid flies, which help control the lettuce aphid. The research presented here tested whether syrphid-based aphid control could be further improved by providing syrphid flies with alternative, non-pest aphids as an additional food source. The experiment was conducted in romaine lettuce fields managed by a commercial organic lettuce grower near Hollister, California. In each of six fields, one bed was dedicated to the experiment and divided into 5 plots. Each plot was the width of the bed (60 inches) and 40 meters in length, and each plot was planted to one of five intercrop plant treatments (see table). Three intercrop plants—vetch, bell beans, and barley—were expected to provide alternative, non-pest aphids to syrphid flies. These intercrops were compared with two controls: sweet alyssum, which provided nectar, and romaine lettuce, which provided no additional resources.

Intercrop plant treatments	
1	Common vetch, *Vicia sativa*
2	Bell beans, *Vicia faba*
3	Spring barley, *Hordeum vulgare* cv. UC 603
4	Sweet alyssum, *Lobularia maritima*
5	Romaine lettuce, *Lactuca sativa*

Plots were separated by 2-5 m of bare soil. The treatments were replicated once per experimental block; six experimental blocks were planted in different fields and on different dates from March to July, 2009. Intercrops were planted in five seed lines occupying the central 45 inches of the 60 inch bed. The romaine plots were planted with the variety that was used in the field, which varied among blocks.

For each plot, insects were monitored both in the intercrop and in the adjacent lettuce crop. Sampling occured three times: at 5 weeks before harvest, at 3 weeks before harvest, and 1 week before harvest. Plant material was brought back to the laboratory, stored at approximately 36 °F, then washed in a five gallon bucket. Insects were collected by funneling the wash water through a nylon mesh filter, then counted with the aid of a dissecting microscope and stored in 70% alcohol. We counted aphids, syrphid eggs and larvae, and other pest and beneficial insects.

The intercrop was sampled by clipping plant material from three 30 x 23 cm rectangles, distributed evenly along the 40 m length of the plot, into a plastic bag. After washing and counting, we calculated the number of insects/m^2. Values were summed across the three sample dates and $\log_{10}$-transformed for analysis. ANOVAs included intercrop species as a fixed effect and block as a random effect; means were separated by Tukey tests.

The lettuce crop was sampled by collecting a total of 24 lettuce plants: at each of three distances (1, 3, and 5 beds away from the intercrop) we collected 8 heads of lettuce. The 8 lettuces from each distance were first pooled into a single sample; after our analysis showed no effect of distance, the samples from the three distances were pooled again. Thus, the mean numbers of insects/plant were calculated from 24 plants. Counts of syrphid larvae and lettuce aphids were analyzed by repeated measures MANOVAs with intercrop species, sample date, and experimental block in the model.

Experimental intercrop plots of bell beans (in the foreground, lower right), romaine, vetch, alyssum, and barley (in the distance). Insects were sampled from both the intercrop and the romaine crop to see which intercrops could act as a source of syrphid flies and improve lettuce aphid control.

<table>
<tr><td colspan="2">Romaine plants growing adjacent to the intercrop were collected into plastic bags.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">The plant material was washed over a fine mesh filter, and the insects were then sorted and counted.</td></tr>
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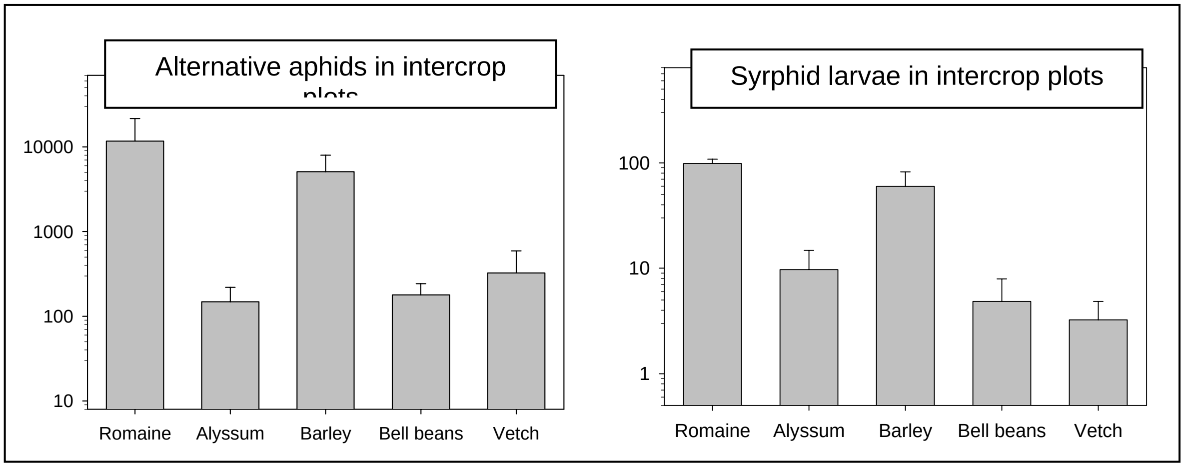
Results and Discussion:

Did the intercrop plants attract non-pest aphids?

Did the intercrop plants support syrphid flies?

Bell beans and vetch failed to provide alternative aphids. Barley, however, supported substantial populations of alternative aphids (primarily the corn leaf aphid, *Rhopalosiphum maidis*); the alternative aphids on barley were nearly as abundant as the pest aphids on the romaine. The syrphid flies did not colonize the alyssum, bell beans, and vetch, where there were few aphids; but syrphid flies did colonize the barley. Syrphid larvae were almost as abundant in barley as in romaine, and syrphid pupae were observed in the barley, indicating that the alternative aphids on barley are acceptable to ovipositing females and are an adequate food source for syrphid development. (ANOVA output in table below.)

In 2007, we compared 9 potential intercrops and found that barley hosted non-pest aphids and syrphid larvae throughout the growing season, whereas bell beans and vetch each hosted non-pest aphids and syrphid larvae at certain times of year. Together, the results from 2007 and 2008 indicate that barley is the most promising intercrop for non-pest aphids.



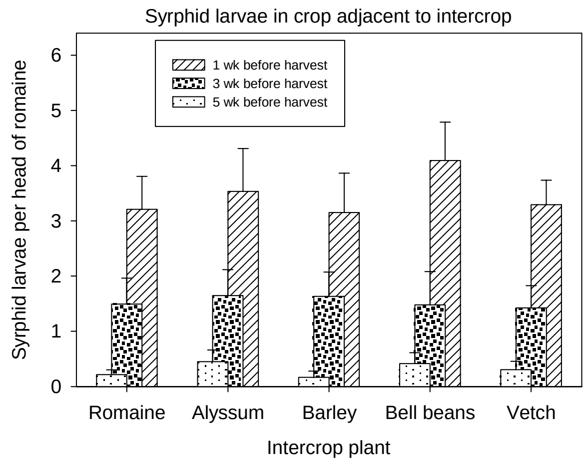
Did the intercrop plants promote any other pest insects or beneficial insects?

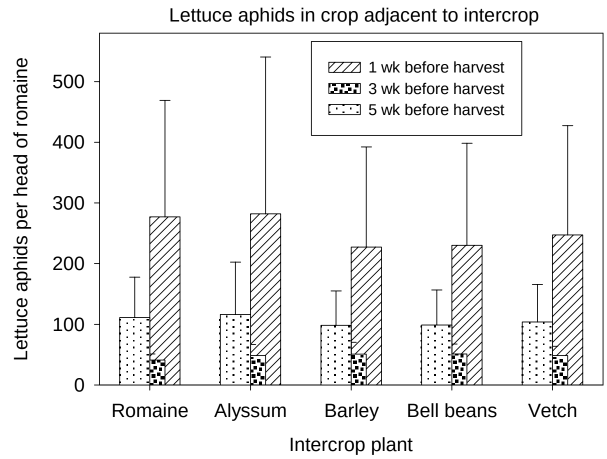
ANOVAs suggested that thrips and the predatory bug *Orius* sp. were more common in some intercrop plants than others; however, means were not sufficiently different to be distinguished statistically. (See table for ANOVA output; data are not shown.)

Did the crop next to the intercrop plants have more syrphid larvae?
Did the crop next to the intercrop plants have fewer aphids?

The two intercrop plants with additional resources turned out to be alyssum and barley (providing nectar and aphids), so we expected to see relatively more syrphids in the romaine growing next to alyssum and barley. Instead, the number of syrphid larvae per head of romaine was about the same, no matter which intercrop plant it was next to. Finally, similar numbers of syrphid larvae generated levels of pest control: the romaine plants growing next to the intercrop plants (and the romaine control) had similar numbers of lettuce aphids. (ANOVA output in table below.)

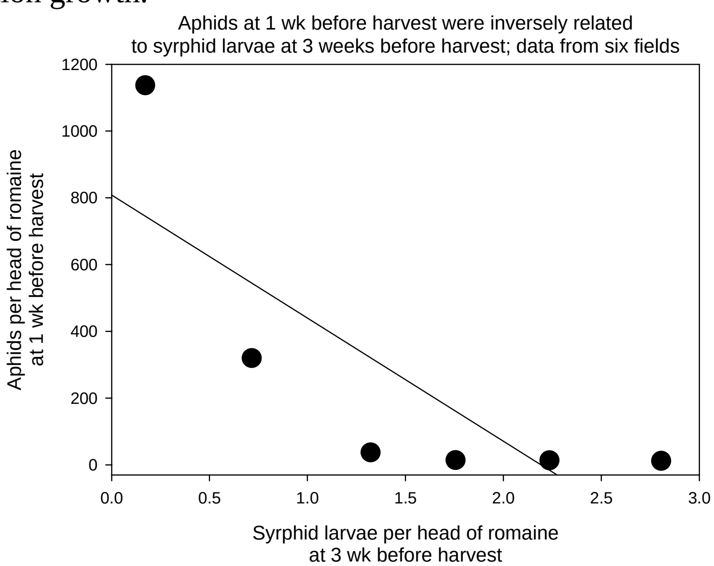
We can imagine three possible explanations for this unexpected result. First, the intercrop plants might influence lettuce aphid control, but the effect may be subtle compared to other factors that influence syrphid and aphid populations. In particular, field location and planting date accounted for much of the variation in insect numbers. Second, the syrphids could have been using the intercrop plants and then flying beyond the immediately adjacent crop plants. In this case, any benefits coming from the intercrop plants were getting spread across an area greater than our plots. Third, when lettuce aphids were present in the romaine, the romaine was acting as a source of syrphids. The syrphid activity generated by the crop itself could have overshadowed the additional activity generated by the intercrops.





Did the syrphid larvae in the crop help control the lettuce aphids?

In the romaine crop, the population dynamics of the syrphid larvae and lettuce aphids appeared to be independent of which intercrop was nearby. When we examine the insect populations in the crop without regard to the intercrop treatments, we see negative relationships between syrphid numbers on early sample dates and aphid numbers at later sample dates. For example, fields that had relatively high numbers of syrphid larvae at 3 weeks before harvest were more likely to have small numbers of aphids just prior to harvest (linear regression: aphids at harvest=809-(368)(syrphid larvae at 3 wk before harvest), r^2=0.64, P=0.06)). These relationships between sample dates bolster our conviction that syrphid larvae help suppress lettuce aphid population growth.



What are the practical applications of this study?

Evidence from this study and others shows that it should be worthwhile to encourage syrphid populations in a field of lettuce. Flower plantings are presumed to promote syrphid activity; however, we have yet to determine whether alternative aphids provide any additional boost. Barley succeeds at providing alternative aphids that are used by syrphids and can promote their reproduction. For growers considering this approach, we recommend barley over bell beans, vetch, and the other intercrops we screened. Although barley fosters syrphid reproduction and syrphids suppress aphid numbers, we were unable to prove that barley improves aphid pest control in the adjacent crop. Thus, the strategy of planting intercrops with alternative aphids remains innovative and experimental. Growers and researchers wishing to further test this approach should modify their efforts to account for the following considerations:

(i) pest control benefits may develop only when the intercrop outperforms the crop as a nursery for syrphids—that is, when alternative aphids in the intercrop are much more abundant than pest aphids in the crop.

(ii) pest control benefits of the intercrop may be observed only at the large spatial scales at which syrphids move. So far as we know, flight range has not been measured for any syrphid species; such information would be useful.

Summary of the intercrop experiment

Exptl. Block	Wet date	Sample dates in 2008			Harvest
1	March 24	May 6	May 21	May 30	June 9
2	April 9	May 15	May 30	June 18	June 25
3	April 25	June 1	June 18	July 2	July 3
4	May 26	June 26	July 9	July 28	not harvested due to aphids
5	July 11	Aug. 12	Aug. 26	Sept. 5	Sept. 8
6	July 29	Sept. 5	Sept. 18	Oct. 3	Oct. 11

Results of ANOVAs testing for effects of intercrop species on $\log_{10}$-transformed counts of aphids and syrphid larvae found in the intercrop

	Response variable	Source of variation	d.f.	Test statistic and value	P
Intercrops (cumulative across 3 sample dates)	Aphids	Intercrop plant species	4	F=7.4	<0.01
		Block	-	t=1.9	0.09
	Syrphids	Intercrop plant species	4	F=13.9	<0.01
		Block	-	t=0.7	0.62
	Thrips	Intercrop plant species	4	F=2.8	0.05
		Block	-	t=2.8	0.01
	Orius	Intercrop plant species	4	F=24.8	<0.01
		Block	-	t=3.2	<0.01

Results of ANOVAs testing for effects of intercrop species on counts/head of aphids and syrphid larvae in the adjacent romaine lettuce.

Sample date	Response variable	Source of variation	d.f.	Test statistic and value	P
5 weeks before harvest	Aphids	Intercrop plant species	4	F=0.1	0.97
		Block	5	F=77.7	<0.01
	Syrphids	Intercrop plant species	4	F=2.2	0.11
		Block	5	F=16.9	<0.01
3 weeks before harvest	Aphids	Intercrop plant species	4	F=0.4	0.84
		Block	5	F=19.4	<0.01
	Syrphids	Intercrop plant species	4	F=0.1	0.99
		Block	5	F=9.1	<0.01
1 week before harvest	Aphids	Intercrop plant species	4	F=1.7	0.19
		Block	5	F=343.4	<0.01
	Syrphids	Intercrop plant species	4	F=0.7	0.62
		Block	5	F=5.6	<0.01