Developing integrated control tactics for cole crop pests

Final report, 13 February 2008

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Background: Broccoli and other cole crops are attacked by numerous insect pests, whether the crops are grown on commercial farms or in home gardens. The key pest is a complex of three species of caterpillars: imported cabbageworm, diamondback moth, and cabbage looper, but other pests such as flea beetles, aphids, cabbage maggot, and harlequin bug can also be important. Although most commercial farmers use conventional insecticides for caterpillar management, most market gardeners prefer to not use conventional insecticides, yet alternative tactics are not well demonstrated or understood. All three species of caterpillars have several parasitoid wasp species that attack them, but these natural enemies are often killed by insecticides. This project was done to evaluate reduced-risk chemicals that are acceptable to market gardeners, and to see if some chemicals can be successfully combined with biological and mechanical tactics to form a truly integrated management program.

Objectives: 1) Determine whether or not parasitism of cabbageworm can be significantly increased by provision of a flowering border that can provide nectar to native parasitoid wasps. 2) Compare caterpillar control by microbial insecticides, conventional insecticides, row covers, and hand-picking, all in conjunction with a flowering border for enhanced biological control. 3) Evaluate predator augmentation for suppression of caterpillar and aphid pests.

Methods:

All trials were conducted at OSU's Waterman Agricultural and Natural Resources Laboratory in Columbus. The crop used in all trials was broccoli ('Flash Hybrid', W. Atlee Burpee & Co., Warminster PA). The flowering border crop used was sweet alyssum ('Carpet of Snow', W. Atlee Burpee & Co.). Both broccoli and sweet alyssum were seeded in 200-cell plug trays on 1 March 2007, and transplanted in late April. Density of the three caterpillar species was converted to Larval Units by multiplying the number of small (<13 mm) imported cabbageworm larvae by 0.1, multiplying the number of large (≥13 mm) imported cabbageworm larvae by 0.67, multiplying the number of diamondback larvae by 0.1, multiplying the number of small (<13 mm) cabbage looper larvae by 0.67, and multiplying the number of large (>13 mm) cabbage looper larvae by 1.0, then summing those components. Data were subjected to analysis of variance (ANOVA) and mean comparisons were made by least significant difference (LSD) tests in the SAS 9.1 microcomputer statistics program.

A field trial was conducted on parasitoid enhancement by provision of a flowering border of sweet alyssum. A randomized complete block design was used with two treatments and four blocked replicates. The two treatments were broccoli with flowering borders and broccoli without flowering borders. Within a blocked replicate, the two treatments were separated by 50 meters of soybeans to avoid potential movement of parasitoids between treatments, and blocks were separated by 300 meters. There were 12 plants per plot, arranged as three rows of four broccoli plants each. Plants were 60 cm apart within rows, and rows were 90 cm apart. The with-flower plots had one row of sweet alyssum on each of two sides, with sweet alyssum planted 15 cm apart within the row. Plots were established on 23 April by transplanting. No insecticides were used. Four whole plants per plot were inspected once per week to determine the species, number, and size of larvae. During each of four weeks in June, all pupae and all larvae that were close to full-grown size were collected from all 12 plants per plot and taken to the lab where they were held for two weeks to determine whether or not they were parasitized. Broccoli heads were harvested and evaluated for caterpillar contamination on 27 June for early-maturing plants and on 5 July for late-maturing plants.

A second field trial was conducted to evaluate efficacy of insecticides and mechanical controls for caterpillar and flea beetle control, all in the presence of a flowering border that was used to enhance parasitoid activity. A randomized complete block design was used with ten treatments and four blocked replicates. Treatments were sprays of BT (Bonide's Thuricide, 2.5 ml in 473 ml water), spinosad (Fertilome's Borer Bagworm Spray, 7.5 ml in 473 ml water), methoxyfenozide (Dow AgroScience's Intrepid, 0.7 ml in 473 ml water), azadirachtin (Gowan's Aza-Direct, 2.9 ml in 473 ml water), esfenvalerate (Ortho's Bug-B-Gon Max, ready-to-use), and pyrethrins + PBO (Spectracide's BugStop, 7.5 ml per 473 ml water), as well as BT dust (Fertilome's Dipel Dust), row covers, hand-picking, and an untreated check. Each plot was three adjacent broccoli plants spaced 60 cm apart. There was one row of sweet alyssum between adjacent treatment rows, and all rows were 90 cm apart. Sweet alyssum was planted 30 cm apart within rows. Plots were established on 20 April by transplanting. Row covers ('Super-Light Insect Barrier', Gardens Alive! Inc., Lawrenceburg IN) used were a 90 cm by 180 cm piece per 3-plant plot for the first two weeks, then a 180 cm by 300 cm piece per 3-plant plot for the remainder of the trial. Row covers were anchored by metal garden staples. Plots were scouted once per week for caterpillars as well as flea beetles and other pests. One plant per plot was scouted during the first two weeks. All three plants per plot were scouted during the next three weeks. One plant per plot was counted during the final three weeks, and insects found in the head were recorded separately than insects found on leaves. In the hand-picking treatment, insects were removed during each scouting as soon as insects were counted. Row cover plots were not scouted, based on experience the previous year that frequent disruption of the covers led to tearing of the covers and pest invasion. Insecticide treatments were applied seven times from late April until mid-June. Spray treatments were applied by hand with 1-liter spray bottles. Broccoli heads were harvested and evaluated for caterpillar contamination on 20 June.

A third field trial was conducted to evaluate whether a release of lacewing eggs and lady beetle larvae could adequately suppress caterpillars on broccoli. A randomized complete block design was used with two treatments and four replicates. The two treatments were predator release and no predator release. Plots were established on 23 April by transplanting. Each plot was four adjacent plants, spaced 60 cm apart. Rows were 150 cm apart, with a 150 cm alley between adjacent plots. No insecticides were used. All four plants per plot were scouted once per week. Once aphids were detected in most plots, lacewing eggs on cards were purchased from Rincon-Vitova Insectaries Inc. (Ventura, CA). Each card was 1.9 cm by 3.8 cm, and held approximately 167 lacewing eggs. Lacewing eggs were released on 11 May in late afternoon by placing one card on top of a leaf in the middle canopy on each plant in the lacewing plots. Lady beetle larvae were collected from a local apple orchard and released on 9 June, using two larvae per plant on the middle two plants per plot and one larva per plant on the end two plants per plot. Broccoli heads were harvested and evaluated for caterpillar contamination on 5 July.

Results:

In the flowering border trial, parasitization of diamondback was high in both treatments during the four week period evaluated, and there was no significant difference between treatments (Table 1). Parasitization of imported cabbageworm was lower but also not significantly different between treatments (Table 2). The parasitoids recovered were ichneumonids, braconids, and chalcids. Caterpillars were detected during scouting but the average number of larval units per plant did not differ significantly between treatments (Table 3). At harvest, the number of caterpillars found in the head, the head weight, and head diameter did not differ between treatments (Table 4). Harvested heads were small due to droughty conditions.

Table 1. Percentage of diamondback moth parasitized on broccoli in flowering border trial.

Treatment	*% of DBM parasitized before collection on each date*				
	9 June	*13 June*	*20 June*	*27 June*	*all samples*
With flowering border	41% (N=38)	52% (N=27)	52% (N=42)	78% (N=34)	59% (N=141)
No flower border	36% (N=19)	27% (N=17)	52% (N=26)	90% (N=13)	52% (N=75)
Probability value from ANOVA (trtmt effect)	*0.42*	*0.39*	*0.99*	*0.99*	*0.51*

Table 2. Percentage of imported cabbageworm parasitized on broccoli in flowering border trial.

Treatment	*% of ICW parasitized before collection on each date*				
	9 June	*13 June*	*20 June*	*27 June*	*all samples*
With flowering border	0% (N=2)	0% (N=1)	6% (N=15)	67% (N=7)	20% (N=25)
No flowering border	0% (N=5)	0% (N=6)	0% (N=8)	25% (N=3)	2% (N=22)
P value (trtmt effect)	-	-	*0.42*	*0.33*	*0.19*

Table 3. Caterpillar pest density on broccoli, detected by scouting in flowering border trial.

Treatment	*Number of larval units per broccoli plant on 8 sampling dates*							
	4/30	*5/7*	*5/21*	*5/31*	*6/8*	*6/15*	*6/20*	*6/27*
With flowering border	0	0	0.01	0.24	0.17	0.16	0.51	0.69
No flowering border	0	0	0	0.06	0.28	0.09	0.31	0.59
P value (trtmt effect)	-	-	*0.39*	*0.10*	*0.72*	*0.47*	*0.12*	*0.81*

Table 4. Caterpillar infestation and yield at harvest in broccoli flowering border trial.

Treatment	*Larval units per harvested head*	*Weight of broccoli head harvested (grams)*	*Diameter of broccoli head harvested (cm)*
With flowering border	0.034	199	10.3
No flowering border	0.059	241	10.6
P value (trtmt effect)	*0.72*	*0.47*	*0.86*

In the integrated control trial, the number of larval units per head differed significantly among treatments, with the most larval units in the hand-pick treatment and the least in row cover, esfenvalerate, methoxyfenozide, spinosad, and B.t. dust treatments (Table 5). The weight of harvested broccoli heads was significantly higher in the row cover treatment than in all other treatments (Table 5). The number of larval units per plant differed significantly among treatments on two dates: on 30 May when infestation was higher in azadirachtin than other treatments, and on 6 June when esfenvalerate and spinosad were significantly less infested than untreated, azadirachtin, hand-picking, or pyrehrins + PBO. The ranking of treatments according to larval units found during weekly scouting was similar (Table 6).

Table 5. Caterpillar infestation and yield at harvest in broccoli integrated control trial.

Treatment	*Larval units per harvested broccoli head*	*Weight of broccoli head harvested (grams)*
row cover	0 C	725 A
esfenvalerate	0 C	195 BC
methoxyfenozide	0 C	246 BC
spinosad	0 C	277 BC
B.t. dust	0 C	317 B
B.t. spray	0.11 BC	270 BC
azadirachtin	0.14 ABC	310 B
pyrethrins + PBO	0.16 ABC	112 C
untreated	0.22 AB	149 BC
hand picking	0.28 A	290 BC
P value from ANOVA (trtmt effect)	*0.0047*	*0.0001*

Table 6. Caterpillar density in broccoli integrated control trial as detected by scouting, listed in order from best to worst by sum of ranked order for each of 8 sampling dates.

Treatment	*Number of larval units per broccoli plant on 8 sampling dates*								*sum of ranks*
	4/30	*5/7*	*5/17*	*5/24*	*5/30*	*6/6*	*6/12*	*6/20*	
esfenvalerate	0	0	0	0	0.02 b	0.02 d	0.08	0.12	61.5
methoxyfenozide	0	0	0	0	0.25 b	0.34 bcd	0.30	0.39	46.5
spinosad	0.02	0.17	0.02	0	0.17 b	0.02 d	0.08	0.20	44.0
B.t. spray	0	0	0	0.08	0.19 b	0.18 cd	0.25	1.40	42.5
pyrethrins + PBO	0	0	0	0.03	0.17 b	0.70 abc	0.45	0.68	41.0
B.t. dust	0	0	0.02	0.01	0.38 b	0.54 abcd	0.28	0.37	38.5
hand picking	0	0	0.01	0.12	0.35 b	0.67 abc	0.45	0.30	35.5
azadirachtin	0	0	0	0.17	1.88 a	0.88 ab	0.52	0.75	25.5
untreated	0	0.08	0.02	0.06	0.53 b	0.92 a	0.50	0.30	25.0
row cover	-	-	-	-	-	-	-	-	-
P value (trtmt effect)	0.46	0.55	0.25	0.69	0.0028	0.0096	0.26	0.10	

In the predator augmentation trial, weekly scouting data showed that the number of caterpillars per plant (Table 7) and the number of aphids per plant (Table 8) did not differ between treatments on any of 8 sampling dates. At harvest, there was no significant treatment effect on the number of caterpillars found in the heads, or the weight or diameter of the broccoli heads harvested (Table 9).

Table 7. Caterpillar infestation in broccoli predator augmentation trial as detected by scouting.

Treatment	*Number of larval units per broccoli plant on 8 sampling dates*							
	4/30	*5/7*	*5/18*	*5/31*	*6/6*	*6/11*	*6/21*	*6/27*
With predator release	0	0	0	0.12	0.09	0.15	1.45	0.08
No predator release	0	0	0	0.11	0.11	0.12	1.15	0.06
P value (trtmt effect)	-	-	-	*0.83*	*0.57*	*0.41*	*0.68*	*0.72*

Table 8. Aphid infestation in broccoli predator augmentation trial as detected by scouting.

Treatment	*Number of aphid colonies per broccoli plant on 8 sampling dates*							
	4/30	*5/7*	*5/18*	*5/31*	*6/6*	*6/11*	*6/21*	*6/27*
With predator release	0.19	0.38	1.19	1.19	0.25	0.60	0.25	0.98
No predator release	0.12	0.44	1.29	0.75	1.38	0	0.50	1.19
P value (trtmt effect)	*0.72*	*0.79*	*0.83*	*0.29*	*0.35*	*0.08*	*0.65*	*0.67*

Table 9. Infestation and yield at harvest in broccoli predator augmentation trial.

Treatment	*Number of caterpillars or pupae per harvested head*	*Weight of broccoli head harvested (grams)*	*Diameter of broccoli head harvested (cm)*
With predator release	0.4	2881	12.6
No predator release	0.2	1808	14.8
P value (trtmt effect)	*0.68*	*0.69*	*0.11*

Discussion & conclusions:

Tactics that seem worthy of further testing are flowering borders of sweet alyssum, row covers, and sprays of methoxyfenozide, spinosad, and B.T., which are reduced-risk insecticides. Sweet alyssum was much more satisfactory than cilantro, Phacelia, or nasturtium used for the same purpose in previous trials, due to sweet alyssum's fast growth, early flowering, and tolerance of cool weather.

The spring crops of broccoli in these trials tended to have few caterpillars during the first three to four weeks after transplanting, then an increase during head formation. It is very challenging to prevent caterpillars from infesting the heads. A possible chemical control program with some of the reduced-risk insecticides would be no sprays before heading, then sprays twice per week after head formation.

Flea beetle damage on cole crops at this site is usually much higher than it was in these trials. Data were recorded on flea beetle density and flea beetle damage ratings, but is not reported here due to negligible density.

Because parasitism of diamondbacks was high in plots with flowering borders and plots without flowering borders, it is possible that the separation of plots by 50 m of soybeans was inadequate to prevent movement of parasitoids between plots; the beneficial effect of the flowers was extended to both treatments.

Predator augmentation had no documented benefit. It is likely that the prey density was too low to support the predators. Release of a small number of locally captured lady beetle larvae seems more likely to work than release of a large number of purchased lacewing eggs. Release of lacewing eggs under hot dry summer conditions is likely to have a low success rate.