Weed Management Effects on Insects and Diseases of Cabbage and Snapbean

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SUMMARY. Field studies were conducted to determine insect and plant pathogen management effects on weed competitiveness and crop yield and to evaluate weed management impacts on insect pests, diseases, and crop yield. At similar densities, redroot pigweed (*Amaranthus retroflexus* L.) reduced snapbean (*Phaseolus vulgaris* L.) and cabbage (*Brassica oleracea* L. var *capitata*) yield more than that of common purslane (*Portulaca oleracea* L.), a low growing weed. In 1995, diamondback moth [*Plutella xylostella* (L.)] was greater on cabbage growing in plots with purslane than in plots of cabbage growing without weeds. Imported cabbageworm [*Pieris rapae* (L.)] was greater on cabbage growing in plots with either purslane or pigweed than when growing alone. However, the amount of feeding damage to cabbage was similar across treatments. Disease incidence was low, but fungicide treatments made redroot pigweed more competitive with snapbean, reducing yield in 1995.

Pest management systems for vegetable crops are usually developed for an individual pest category (i.e., weeds, insect pests, or plant pathogens) without assessing their impact on other categories of pests. Weeds, plant pathogens, and insect pests interact with each other and the crop in ways that can be detrimental, neutral, or beneficial to crop production. Crops and pests should be regarded as members of an interacting, mutually interdependent agroecosystem. Pest management programs, therefore, must integrate pest control tactics to achieve optimal management.

Redroot pigweed (*Amaranthus retroflexus* L.) and common purslane (*Portulaca oleracea* L.) are present in most vegetable production fields in the midwestern United States. Both species are C-4 plants that are most competitive during periods of warm temperatures, high light levels, and limited water availability (Kraybill and Martin, 1996; Legere and Schreiber, 1989; Shurtleff and Coble, 1985; Weaver and McWilliams, 1980). They are especially competitive with late plantings of cabbage (*Brassica oleracea* L. var *capitata*) and snapbean (*Phaseolus vulgaris* L.), two C-3 crops.

Common purslane and redroot pigweed may also directly affect insect and plant pathogen populations in crops by serving as alternate hosts for crop pests. For example, both species are alternate hosts of cucumber mosaic virus (Friess and Maillet, 1996; Weaver and McWilliams, 1980), and redroot pigweed is a host of *Fusarium oxysporum* Schleih Tend.: Fr. and *Rhizoctonia solani* Kühn (Weaver and McWilliams, 1980). Weeds may be preferred by insect herbivores as a food source more than crops. For example, young larvae of the cutworm [*Spodoptera latifascia* (Walker)] preferred *Amaranthus* species and purslane over sorghum [*Sorghum bicolor* (L.) Moench] or maize (*Zea mays* L.) (Portillo et al., 1996).

Weeds may affect quality of crop plants as hosts for other pests and interfere with pesticide applications. In previous research, we found that weed competition reduced cabbage size, which may have made the crop less able to support large populations of diamondback moth (DBM) and cabbage looper (CL) [*Trichoplusia ni* (Hübner)] or made it difficult for females to locate plants, thus reducing the number of eggs laid (Bottenberg et al., 1996). Crop growth in weedy fields can be delayed, which may alter the coincidence between pathogen presence and susceptible growth stages of the host (Altman and Campbell, 1977). Weeds shade and reduce air movement around the crop, thereby increasing humidity (Altman and Campbell, 1977) and favoring plant pathogens that require moist leaf surfaces for their development.

Herbicides used in weed management can affect insects and plant pathogens. Trifluralin [2,6-dinitro-*N,N'*-dipropyl-4-(trifluoromethyl) benzenamine], applied to the soil before planting snapbean, increased seedling death due to *Rhizoctonia solani*, but when applied before planting cabbage it lowered the incidence of clubroot (*Plasmodiophora brassicae*) (Altman and Campbell, 1977). Increased populations of some phloem-feeding insects have been found after applications of sublethal doses of herbicides because these insects obtain a higher nutritional value from their food when a plant is stressed (Kjœr and Elmegaard, 1996). Crop plants treated with herbicides may have reduced wax formation or changes in metabolism, making them more susceptible to plant pathogens (Altman and Campbell, 1977). Weeds killed by herbicides, such as glyphosate [*N*-(phosphonomethyl)glycine], may serve as a food source, increasing the inoculum of pathogenic fungi, which subsequently cause poor crop emergence (Pittaway, 1995).

Insect or disease management can also affect weed populations. Insects or plant pathogens attacking a weed may reduce its competitiveness with the crop. Common purslane infected with cucumber mosaic virus had a lower competitive ability than healthy plants (Friess and Maillet, 1996). Insecti-

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cides or fungicides may control insects or plant pathogens that attack the weed, increasing its competitiveness (Brust, 1994). For example, organophosphate insecticides killed the weevil [*Trichapion lativentre*] responsible for controlling sesbania [*Sesbania punicea* (Cav.) Benth] (Hoffmann and Moran, 1995).

Cabbage and snapbean are two widely grown crops with differing pest complexes and production systems, where pest interactions may cause difficulties in pest management. The objectives of our study were to determine insect and disease management effects on weed competitiveness and evaluate weed management impacts on insect pests and plant pathogens.

Materials and methods

The study was conducted in 1994 and 1995 at the University of Illinois Vegetable Crop Research Farm, Champaign. The soil was a Flanagan silt loam (fine montimorrillontic, mesic, Aquic Arguidoll; pH 6.3 to 6.6 and organic matter 3.1% to 3.3%). The research site was moldboard plowed and disked in the fall and harrowed in the spring before planting.

There were separate experiments for snapbean and cabbage. Each experiment was a split-plot design with weed-free treatments replicated four times and weed treatments replicated eight times. Weed management systems were used as the whole plots and pesticide treatments were used as the subplots. The subplots contained either three rows of cabbage or four rows of snapbean. Subplot size was 10 × 15 ft (3 × 4.6 m).

'Market Prize' cabbage plants were grown in the greenhouse for 6 weeks and then were mechanically transplanted 1.5 ft (45 cm) apart in 3-ft (0.9-m) wide rows. 'Mustang' snapbean was seeded 3 inches (7 cm) apart in 2.5-ft (75-cm) wide rows. The crops were planted between 30 May and 10 June in both years. Plant populations were 8860 plants/acre (21,900 plants/ha) for cabbage and 75,300 plants/acre (186,000 plants/ha) for snapbean.

Weed treatments were 1) no weeds, 2) common purslane only, or 3) redroot pigweed only. Common purslane and redroot pigweed were seeded at 300 seed/ft of row (1000 seed/m of row) ≈1 week after planting the crop. The weed seed were shallowly incorporated by lightly raking the soil surface. Germination from the existing weed seed bank also contributed to weed populations. Napropamide [*N*,*N*-diethyl-2-(1-naphthalenyloxy) propanamide] at (a.i.) 1.0 lb/acre (1.1 $kg \cdot ha^{-1}$) was applied to all plots ≈3 weeks after crop planting, when the crop and weeds had established. Napropamide has been shown to provide acceptable preemergence control of redroot pigweed and common purslane but does not effect emerged weeds or cabbage (Hoyt et al., 1996) Our previous research has shown that napropamide does not affect snapbean. All other weeds that emerged except common purslane or redroot pigweed were removed by hand. Redroot pigweed and common purslane were thinned to 0.6 plants/ft^2 (6 plants/m^2) ≈3 weeks after emergence. Intraspecific competition can cause weed death leading to a reduction in final weed densities (Orwick and Schreiber, 1979). Therefore, weed densities were determined at the end of the season. Also, at crop harvest, the height and dry weight of five randomly chosen weeds per plot were determined.

There were two pesticide treatments: 1) applications with insecticides or fungicides and 2) untreated. In 1994 for cabbage, the microbial insecticide *Bacillus thuringiensis* (Bt) (Dipel 2X) was applied at 0.9 lb/acre (1 $kg \cdot ha^{-1}$) with cygon at 0.5 lb/acre (0.6 $kg \cdot ha^{-1}$) on 12 July to control lepidopteran pests, based on established threshold levels. On 20 July, Bt alone was applied. In 1995, Bt alone was applied on 20 and 28 July and 14 Aug. A foliar spray of two fungicides [iprodione (3-(3,5-dichlorophenyl)-*N*-(1-methylethyl)- 2,4-dioxo-1-imidazolidine carboxamide) and chlorothalonil (tetrachloroisophthalonitrile)] was applied to snapbean to control white mold [*Sclerotinia sclerotiorum* (Lib.) deBary], grey mold (*Botrytis cinerea* Pers.:Fr.), rust [*Uromyces appediculatus* (Pers: Pers) Unger], anthracnose [*Colletotrichum lindemnthianum* (Sacc. & Magnus) Lams.-Scrib.], and other foliar pathogens. Chlorothalonil (Bravo 720) at (a.i.) 1.5 lb/acre (1.7 $kg \cdot ha^{-1}$) was applied on a 7-d interval. Iprodione (Rovral 4F) at 0.75 lb/acre (0.84 $kg \cdot ha^{-1}$) was applied once at 10% bloom and once at full bloom. All pesticides were applied with a small plot sprayer mounted on a tractor.

Insect pest populations were monitored in cabbage but not the snapbean experiment because of labor limitations. It is our experience that, in central Illinois, insect pests are a major constraint in cabbage but not snapbean production. In 1994, insect counts were made only in the untreated plots. Five plants per plot from the center rows were cut at the ground level on 7 to 11 July and four plants per plot on 3 to 4 Aug. and transported to the laboratory. Leaf-feeding insects and selected natural enemies were counted. In 1995, counts were made in the treated and untreated plots. On 18 and 31 July, six plants per plot were destructively sampled for insect counts as described for 1994. The insects counted were the lepidopteran pests DBM, ICW, CL, and aphids [primarily *Myzus persicae* (Sulzer) and *Lipaphis erysimi* (Kaltenbach)]. Eggs, larvae, and pupae were counted separately. DBM pupae and aphids were recorded as parasitized if a parasitoid cocoon or aphid mummy, respectively, were present. No attempt was made to

Table 1. Yields of snapbean and cabbage with different weed and pesticide treatments.

Weeds[z]	Pesticide[y]	Snapbean 1994	Snapbean 1995	Cabbage 1994	Cabbage 1995
		tons/acre			
None	No	0.82	1.77 a[x]	15.6 a	12.1 abc
Purslane	No	0.94	1.46 ab	9.77 bc	11.7 cd
Pigweed	No	0.77	1.31 b	8.21 c	9.77 d
None	Yes	1.09	1.44 ab	12.6 ab	13.0 a
Purslane	Yes	0.92	1.45 ab	7.23 c	12.4 ab
Pigweed	Yes	0.81	0.91 c	8.50 bc	11.0 bcd

[z]The weed species were common purslane (*Portulaca oleracea* L.) and redroot pigweed (*Amaranthus retroflexus* L.).
[y]A combination of the fungicides iprodione and chlorothalonil were applied to the snapbean plots. The microbial insecticide *Bacillus thuringiensis* was applied to the cabbage plots.
[x]Means within columns were separated using a protected LSD (0.05).

Table 2. Height, densities, and dry weight of common purslane and redroot pigweed in plots treated or untreated with pesticides in 1994.

		Snapbean			Cabbage		
Weeds[z]	Pesticide[y]	Ht (cm)	Density (plants/m^2)	Wt (g·m^{-2})	Ht (cm)	Density (plants/m^2)	Wt (g·m^{-2})
Purslane	No	16 b[x]	2.5	145 b	19 b	2.1	180 b
Pigweed	No	49 a	1.2	223 a	27 a	1.6	310 a
Purslane	Yes	21 b	2.4	128 b	20 b	2.2	143 b
Pigweed	Yes	52 a	1.0	221 a	29 a	1.6	314 a

[z]The weed species were common purslane (*Portulaca oleracea* L.) and redroot pigweed (*Amaranthus retroflexus* L.).
[y]A combination of the fungicides iprodione and chlorothalonil were applied to the snapbean plots. The microbial insecticide *Bacillus thuringensis* was applied to the cabbage plots.
[x]Means within columns were separated using a protected LSD (0.05).

identify the species of parasitoids.

The incidences of black rot, bacterial soft rot, and alternaria leaf spot on cabbage and anthracnose and white mold and gray mold on snapbean were determined by counting all infected plants in the center row of each plot at crop harvest.

In 1994, at maturity we harvested a 15-ft (4.6-m) section from the center row of cabbage. In 1995, 10 cabbage plants randomly chosen from the center row were harvested. The heads plus the four wrapper leaves were weighed and rated for insect damage according to the method described in Bottenberg et al. (1997), using a scale of 1 to 6, where 1 = no insect feeding damage and 6 = severe damage. In snapbean, hand harvesting simulated the once-over harvesting method used for the processing crop. A 6.5-ft (2-m) section from each of the two center rows was harvested and total pod weight was determined. Any insect-feeding damage to the pods was also rated using a scale similar to that used for cabbage.

SAS's general linear model procedure (SAS Institute, Cary, N.C.) was used for analyses of variance (ANOVA). When necessary, data were log or square-root transformed to satisfy the additivity and homogeneity of variance requirements of ANOVA.

Results and discussion

Pesticide treatment did not affect the yield of the weed-free controls in either crop (Table 1). There were no effects of weed or pesticide treatments on snapbean yields in 1994. In 1995, redroot pigweed reduced snapbean yield compared to the weed-free control. The reduced snapbean yield from redroot pigweed competition was greater in the fungicide-treated plots (37%) than in the untreated plots (26%), even though disease incidence in the snapbean was negligible. Common purslane did not affect snapbean yield.

In 1994, cabbage yields were affected by weed management system but not by insecticide treatment (Table 1). Head weights in the weed-free control treatment were 33% to 47% greater than those in the weedy treatments (Table 1). There were no differences in cabbage yield between the common purslane and redroot pigweed treatments. In 1995, differences between weed management systems in cabbage were less pronounced than in the previous year. Redroot pigweed reduced head weights compared to the weed-free treatments, ranging from 15% to 19% in the untreated and treated plots, respectively. In common purslane treatments, plots with cabbage treated with insecticide yielded more than untreated plots. Plant pathogens were not a problem in either year, probably due to our use of pathogen-free seed and a site where cabbage had not been previously grown.

Redroot pigweed was taller and produced more dry matter than common purslane, but neither measurement was affected by pesticide treatment (Table 2). Final weed densities in 1994 ranged from 0.09 to 0.24 plants/ft^2 (1.0 to 2.5 plants/m^2) but they were not different between treatments. Weed densities and biomass production were lower in 1995 than 1994; however, a similar trend was observed (data not shown). One reason for smaller purslane plants at crop harvest in 1994 was that they were defoliated in late season by an unknown foliar pathogen. The incidence of defoliation did not differ between the fungicide and no-fungicide treatments. The tall growth of redroot pigweed allowed it to shade the crops, resulting in greater yield reductions than with common purslane. McGiffen et al. (1992) also found that when eastern black nightshade (*Solanum ptycanthum* Dun.) was taller than tomato (*Lycopersicon esculentum* Mill.) crop yield was reduced.

In 1994, DBM and ICW larvae were not affected by weed management system. However, on 6 July, aphids were more numerous in the

Table 3. Effects of weed treatments (with no insecticide) on aphids and larvae of diamondback moth (DBM) and imported cabbageworm (ICW), 1994.

	July 6				July 28			
	DBM[y]	ICW	Aphids	Mummified[z]	DBM	ICW	Aphids	Mummified
Weeds[y]	(no./plant)			(%)	(no./plant)			(%)
None	19.0[x]	0.05	359a	15	10.6	2.31	158	43
Purslane	9.3	0.28	199b	17	7.8	2.65	179	45
Pigweed	11.1	0.18	215b	14	6.6	1.53	204	49

[z]Mummified = percent of aphids that were mummified at the time of sampling.
[y]The weed species were common purslane (*Portulaca oleracea* L.) and redroot pigweed (*Amaranthus retroflexus* L.).
[x]Means within columns were separated using a protected LSD (0.05).

Table 4. Effect of different weed treatments with or without insect control (Bt) on diamondback moth (DBM), imported cabbageworm (ICW), and cabbage looper larvae (CL) on cabbage on 31 July and insect damage score at harvest, 1995.

Weed[z]	Insecticide	DBM	ICW	CL	Damage score[y]
			no./plant		
None	No	8.0 bc[x]	1.75 b	7.9 ab	6.00 a
Purslane	No	16.3 a	2.71 a	10.2 a	5.88 a
Pigweed	No	11.8 ab	2.71 a	8.8 a	5.96 a
None	Yes	5.2 c	0.17 c	3.9 c	5.70 ab
Purslane	Yes	3.8 c	0.42 c	5.8 bc	5.46 b
Pigweed	Yes	2.8 c	0.13 c	3.9 c	5.35 b

[z]The weed species were common purslane (*Portulaca oleracea* L.) and redroot pigweed (*Amaranthus retroflexus* L.).
[y]Insect damage was rated on a scale of 1 to 6, where a score of 1 represents no insect feeding damage and 6 represents severe damage. Data were square-root transformed for analysis. The nontransformed data is presented in the table.
[x]Means within columns were separated using a protected LSD (0.05).

weed-free treatments than in treatments with weeds (Table 3). This difference was insignificant on 28 July. Aphid parasitization rates were similar in weedy and weed-free treatments, and they increased from 14% to 17% on 6 July to 43% to 49% on 28 July. On 18 and 31 July 1995, DBM, ICW and CL larvae were affected by weed management system, insecticide treatment, or both. Since the trends were similar, only the 31 July data is shown (Table 4). The Bt treatment reduced the number of caterpillars. In the untreated plots, cabbage in common purslane and redroot pigweed treatments had more ICW than cabbage in weed-free treatments. Populations of DBM were greater in purslane plots than in weed-free plots. In the treated plots, numbers of caterpillars were similar in the different weed management systems. In 1995, parasitization rates and aphid populations were not affected (data not shown). The amount of larval feeding damage to cabbage leaves, as indicated by damage scores, were reduced by Bt in the common purslane and redroot pigweed treatments but not in the weed-free treatments (Table 4). Damage levels were not commercially acceptable with any of the treatments, probably because rains during weeks of 1 and 7 Aug. prevented timely application of insecticides.

Interactions between weed, plant pathogen, and insect management appear to be environmental, pest, and crop dependent, occurring in one year but not in the other. For example, although disease incidence was low, fungicide treatments made redroot pigweed more competitive with snapbean, reducing yield in 1995 but not 1994. In 1995, common purslane in cabbage plots treated with Bt insecticide was less competitive than purslane in untreated plots. We are uncertain of the cause of this reduced competitiveness, but this suggests that even systems using microbial pesticides such as Bt may affect weed competitiveness.

Redroot pigweed and common purslane had varied effects on insect populations in cabbage. Early in the 1994 growing season, aphid populations were lower in the weedy treatments compared to the weed-free plots. Numbers of these insects were too low to analyze in 1995. DBM and ICW, however, were greater in the weedy treatments in 1995. In our study neither common purslane nor redroot pigweed appeared to increase activity of insect parasitoids. Therefore, leaving weeds in a field for this purpose is not warranted by our study. More extensive studies and information will be necessary before cabbage or snapbean growers can predict interactions between pest categories and the methods used to manage them.

This research and previous experiments (McGiffen et al., 1992) indicate that, in the midwestern United States, weeds such as redroot pigweed, which overtop the crop, reduce yield more than weeds such as common purslane growing below the crop canopy. Managing weeds after cabbage and snapbean establishment should be aimed primarily at preventing weeds from overtopping the crop.

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