Cover Crop and Herbicide Combinations for Weed Control in Polyethylene-mulched Bell Pepper

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SUMMARY. Field trials were conducted in 2006 and 2007 to evaluate the performance of 'Caliente' mustard cover crop and herbicide combinations for weed control in polyethylene-mulched bell pepper (*Capsicum annuum*). 'Caliente' mustard is a blend of brown mustard (*Brassica juncea*) and white mustard (*Sinapis alba*). Herbicide treatments included 1/2× and 1× rates of two pre-emergence (PRE) and two postdirected (PD) herbicides. PRE herbicides were applied 1 week before transplanting, whereas PD herbicides were applied at 4 to 5 weeks after transplanting. 'Caliente' mustard did not supplement weed control or improve bell pepper yield in herbicide-treated plots. There was a significant herbicide selection by application rate interaction for large crabgrass (*Digitaria sanguinalis*) control and bell pepper yield, but only the main effect of herbicide selection and application rate affected the control of purple nutsedge (*Cyperus rotundus*), yellow nutsedge (*Cyperus esculentus*), and palmer amaranth (*Amaranthus palmeri*). Bell pepper injury was not more than 9% from all herbicides and application rates. Except for large crabgrass, control of all weed species improved by increasing the application rate from 1/2× to 1×. S-metolachlor PRE provided more broad-spectrum weed control than other herbicides. Halosulfuron applied PRE or PD was selective to purple nutsedge and yellow nutsedge, whereas trifloxysulfuron performed better than halosulfuron on palmer amaranth and large crabgrass. Plots treated with the 1× rate of S-metolachlor or trifloxysulfuron produced the highest marketable bell pepper yield among the herbicide treatments, but no herbicide treatment allowed for marketable yield equivalent to the weed-free treatment.

Bell pepper is an important fresh-market vegetable crop in the southern United States [U.S. Department of Agriculture (USDA), 2008]. Weeds are the major limiting factor in bell pepper production, competing for resources and harboring harmful crop pests (Frank et al., 1988). Purple nutsedge, yellow nutsedge, palmer amaranth, and large crabgrass are among the major weed problems in vegetable-growing areas of

the southern United States (Webster, 2002). Methyl bromide, a preplant soil fumigant, has been widely used under polyethylene mulch for effective weed control in vegetable production, including bell pepper (Duniway, 2002). However, because of its ozone-depleting potential, methyl bromide is being phased out from the U.S. agricultural industry (U.S. Environmental Protection Agency, 2008). The loss of methyl bromide may complicate weed management in bell pepper, thereby negatively impacting production. Therefore, an effective alternative of methyl bromide is urgently needed. A number of potential methyl bromide alternatives

are available in vegetable production. However, no single alternative is a stand-alone replacement for methyl bromide (Noling, 2002). Thus, research efforts are needed to develop an integrated weed management program by combining two or more alternatives that can provide effective weed control in bell pepper.

One potential nonchemical tactic is the inclusion of cover crops belonging to the mustard family (Brassicaceae) in bell pepper production systems. The weed suppressiveness of plants of the mustard family is attributed to rapid early-season biomass accumulation and groundcover, thereby physically suppressing seed germination and growth of new weed seedlings (Beckie et al., 2008; Eberlein et al., 1998). Additionally, maceration of mustard family plant tissue releases a number of allelopathic compounds, including isothiocyanates (Fahay et al., 2001). Isothiocyanates are biologically active compounds that prevent or delay weed emergence (Brown and Morra, 1995; Haramoto and Gallandt, 2005; Vaughn and Boydston, 1997). Thus, growing mustard family cover crops before a commercial crop may reduce early-season weed competition. Norsworthy and Meehan (2005) found that the competitiveness of bell pepper can be increased over yellow nutsedge by amending soil with wild radish (*Raphanus raphanistrum*). Likewise, soil amended with rapeseed (*Brassica napus*) reduced weed density and biomass up to 85% and 96%, respectively, in the following potato (*Solanum tuberosum*) crop (Boydston and Hang, 1995). 'Caliente' mustard has the capacity to produce a high amount of glucosinolates, the precursor of isothiocyanates, which makes it a promising cover crop for weed suppression (Norsworthy et al., 2005).

Chemical weed control options in pepper include pre-emergence (PRE) and post-emergence (POST) herbicides. Registered PRE residual herbicides

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.3048	ft	m	3.2808
9.3540	gal/acre	L·ha ⁻¹	0.1069
2.54	inch(es)	cm	0.3937
1.1209	lb/acre	kg·ha ⁻¹	0.8922
0.0254	mil	mm	39.3701
6.8948	psi	kPa	0.1450

for in-row weed control include ben-sulide, trifluralin, clomazone, napropamide, and oxyfluorfen (Smith and Daugovich, 2008; Stall, 2007). Although these herbicides are effective against many annual grasses and certain broadleaf weeds, control of purple nutsedge, yellow nutsedge, and palmer amaranth is marginal. Other factors that limit the use of these herbicides include rotation restrictions, moisture requirement for herbicide activation, and the required interval between application and transplanting. Registered POST herbicide options for in-row weed control include only graminicides such as sethoxydim and clethodim (Stall, 2007). Thus, it would be beneficial to evaluate other herbicides that may provide effective control of purple nutsedge, yellow nutsedge, and palmer amaranth without injuring bell pepper.

S-metolachlor is a chloroacetamide herbicide that has been granted third-party registration for pre- and post-transplant weed control in bell pepper (Culpepper, 2003; Stall, 2007). In polyethylene-mulched bell pepper, the pretransplant application includes a nonincorporated spray of S-metolachlor on preformed beds before laying plastic mulch. The post-transplant application is PD in bell pepper row middles between the parallel mulch rows. S-metolachlor provides effective control of annual grasses, palmer amaranth, and yellow nutsedge, but inconsistent control of purple nutsedge (Clewis et al., 2008; Obrigawitch et al., 1980; Syngenta Crop Protection, 2007a). Halosulfuron, a sulfonylurea herbicide, provides excellent soil and foliar control of purple nutsedge and yellow nutsedge (Grichar et al., 2003; Umeda and Towers, 2006). However, its use is restricted only to row middles, and herbicide contact with plastic should be avoided (Gowan Co., 2007). Trifloxysulfuron, another sulfonylurea herbicide, provides effective control of many weed species, including purple nutsedge, yellow nutsedge, palmer amaranth, and large crabgrass (Clewis et al., 2008; Culpepper and Stall 2003; Hudetz et al., 2000; Syngenta Crop Protection, 2007b). At present, trifloxysulfuron is not labeled for use in U.S. bell pepper production.

Because of weed control efficacy, these herbicides may serve as a viable

weed management option in bell pepper. However, sensitivity of bell pepper may limit the use of full rates of these herbicides. Unfortunately, adequate weed control using low rates is doubtful (Sullivan and Bouw 1997). Thus, herbicides may need to be supplemented with other weed control strategies to obtain acceptable weed control without causing crop injury. Malik et al. (2008) suggested that herbicide rates be reduced in sweet corn (*Zea mays*) when using a spring-grown, mustard family cover crop. The objective of this research was to evaluate weed control and bell pepper response to a 'Caliente' mustard with and without PRE and PD herbicides at reduced ($1/2\times$) and full ($1\times$) application rates in a polyethylene-mulched production system.

Materials and methods

Experiments were conducted in 2006 at Clemson, SC, and in 2007 at Fayetteville, AR. The predominant soil type at both sites was a silt loam (fine-loamy, mixed, active, nonacid) with 1.5% to 1.7% organic matter and a pH of 6.1. The test sites at Clemson and Fayetteville were infested with purple nutsedge and yellow nutsedge, respectively. Palmer amaranth and large crabgrass (Azlin Seed Co., Leland, MS) were manually broadcast-seeded at both test sites.

The experimental design was a randomized complete block with four replications. The treatment design was a three-factor factorial, consisting of cover crops, herbicides, and application rates. Treatment factors included two levels of cover crops: 'Caliente' mustard and fallow; four levels of herbicides: two PRE and two PD herbicides; and two levels of application rates: $1/2\times$ and $1\times$. Herbicides used for PRE application were S-metolachlor (Dual Magnum 7.62 EC; Syngenta Crop Protection, Greensboro, NC) and halosulfuron (Sanda 75 DG; Gowan Co., Yuma, AZ), whereas trifloxysulfuron (Envoke 75 DG; Syngenta Crop Protection) and halosulfuron were applied PD. The $1\times$ rates for S-metolachlor, halosulfuron, and trifloxysulfuron were 1.4, 0.024, and 0.007 lb/acre, respectively. Weedy and weed-free control treatments were included for each cover crop treatment ('Caliente' mustard and fallow). The experimental

procedures were the same for both years unless specifically mentioned.

The test sites were cultivated twice with a disk-harrow and field cultivator before planting the cover crop in mid-March of each year. During land preparation, 36 lb/acre of nitrogen (N) was incorporated into the soil as a starter fertilizer for the cover crop. 'Caliente' mustard (Weaver Seed, Crantree, OR) was seeded in 15-ft-long plots at 17 lb/acre using a 10-row drill with 7-inch row spacing. Simultaneously, a fallow treatment with no cover crop was also established. Plots were broadcast with 36 lb/acre N and 27 lb/acre of sulfur (S) at 3 weeks after 'Caliente' mustard emergence and irrigated per crop requirements. At the midflowering stage (nearly 9 weeks after planting), 'Caliente' mustard was flail mowed and immediately incorporated into the soil to a 4-inch depth using a roto-tiller. Following incorporation, 6-inch-high planting beds were prepared in each plot. Planting beds were 15 ft long and 3 ft wide at the base, with a 6-ft spacing between centers of parallel beds.

PRE herbicide treatments were applied to the top of the beds, and the beds were immediately covered with a black low-density polyethylene mulch (1 mil thick; Robert Marvel Plastic Mulch, Annville, PA). As beds were covered, a single drip line was placed beneath the mulch for irrigation and fertigation purposes. Two rows of 'Heritage' bell pepper (4-week-old seedlings) were transplanted by hand 1 week after laying the plastic mulch at a 12- $\times$ 12-inch spacing, for a total of 20 plants per plot. PD herbicides were applied at 4 weeks after transplanting (WATP) and directed to the base of about 11-inch-tall pepper plants in 2006 and at 5 WATP to about 12-inch-tall pepper plants in 2007. Herbicides were applied PD rather than over-the-top to minimize injury to the sensitive pepper plants. The average weed sizes at PD herbicide application in 2006 were 7, 9, and 4 inches for purple nutsedge, palmer amaranth, and large crabgrass, respectively. In 2007, yellow nutsedge, palmer amaranth, and large crabgrass were 10, 12, and 5 inches tall, respectively. Herbicides were applied using a carbon dioxide-purified backpack sprayer (R&D Sprayers, Opelousas, LA) calibrated

to deliver 20 gal/acre of water at 40 psi. PRE herbicides were applied with a two-nozzle (19-inch spacing) boom, equipped with 11002 XR flat-fan nozzles (Teejet spray nozzle; Spraying Systems Co., Wheaton, IL), and PD herbicides were applied with a single OC-02 off-center nozzle (Teejet spray nozzle) by making one pass on either side of the beds. A non-ionic surfactant (Induce 90% active agent; Helena Chemical Co., Memphis, TN) was added at 0.25% (v/v) to both PD herbicides before application. Weeds were removed from hand-weeded plots once weekly. The area between the polyethylene-mulched beds was kept free of weeds through hand weeding and application of 0.5 lb/acre paraquat (Gramoxone Inteon 2 EC; Syngenta Crop Protection) using a hooded sprayer. Drip irrigation, fertilization, and plant protection measures were according to standard crop management practices (Sanders, 2004).

Data were collected on weed control, crop injury, and fruit yield. Crop injury for bell pepper and weed control for individual weed species were evaluated every other week from 2 WATP through 8 WATP for PRE treatments and at 6 and 8 to 9 WATP for PD treatments. Crop injury and weed control were rated visually on a scale of 0 to 100, where 0 equals no crop injury or weed suppression and 100 equals crop death or total weed control. Ratings were based on chlorosis and necrosis of plant tissues and stunting and stand loss of plants. Fully grown pepper fruits were hand-harvested three times in 2006 and five times in 2007. At the final harvest, all fruits were gathered regardless of size or maturity. Harvested bell pepper fruits were categorized into different grades according to U.S. grading standards and were weighed separately for each grade category (USDA, 2005).

Data were analyzed separately for each rating, but results of rating at 4 and 8 to 9 WATP are presented. Data were first checked for homogeneous variances using studentized residual plots, and arcsine square-root transformation of injury and weed control data were performed whenever required. Weed-free and weedy control treatments were not included in the injury and weed control analysis, but yield data were included for both control treatments. Data for bell

pepper injury and palmer amaranth and large crabgrass control were subjected to analysis of variance with a full factorial treatment structure for year, cover crop, herbicides, and application rate. Replications (nested within a year) were treated as a random factor, whereas year, cover crop, herbicides, and application rates were treated as fixed factors. Purple nutsedge and yellow nutsedge control data were analyzed in a similar way, but separately by years. Type III statistics were used to test all possible effects of fixed factors, and treatment means were separated by Fisher's least significant difference at $\alpha = 0.05$ (SAS Institute, Cary, NC). There was no significant year by treatment interaction ($P > 0.05$) for bell pepper injury and palmer amaranth and large crabgrass control; therefore, data were pooled over years for these variables. However, purple nutsedge and yellow nutsedge control data are presented separately for each year because of the difference in species.

Results and discussion

BELL PEPPER INJURY. Bell pepper tolerance was evaluated based on the level of tissue chlorosis and necrosis and plant stunting. Bell pepper was unaffected by cover crop treatment, with no visual injury at any rating (data not shown). Similarly, in a previous study, no deleterious effect (<5% injury) was observed on bell pepper transplanted to brown mustard-amended plots (Norsworthy et al., 2007). Although main effects of herbicide selection and application rates were significant, the bell pepper injury levels were no more than 9% for all herbicides and application rates at all ratings (data not shown). Injury from PRE herbicides diminished after 2 WATP. Halosulfuron was most injurious of the PRE herbicides, but plants recovered later with $\leq 3\%$ injury at 6 WATP. Injury with all PD herbicides was negligible ($\leq 2\%$) at all ratings. This is most likely because these herbicides were directed to the base of the bell pepper plants, which minimized the herbicide contact with plant foliage, thereby causing negligible symptoms. Norsworthy et al. (2005) also suggested that halosulfuron be applied PD in chile pepper (*C. annuum*) to minimize crop injury.

WEED CONTROL. There was no significant main effect of 'Caliente'

mustard cover crop or any interaction of 'Caliente' mustard with other treatment factors for control of any weed species tested; therefore, data were averaged over cover crop treatments (data not shown). These results suggest no advantage of using 'Caliente' mustard cover crop with herbicides for weed control in polyethylene-mulched bell pepper. The poor weed control from 'Caliente' mustard may be associated with the low amount of isothiocyanate production (Fennimore and Doohan, 2008). Previous studies incorporating mustard family cover crops with herbicides produced diverse results, with some showing an additive effect of mustard family cover crop on weed suppression from herbicides, but others showing little or no benefit of mustard family cover crops (Geary et al., 2008; Malik et al., 2008; Norsworthy et al., 2005). These differences could be attributed to the variation in glucosinolate production capacity of different species of the mustard family. Moreover, the amount of glucosinolate production and glucosinolate to isothiocyanates conversion efficiency, which are highly dependent on soil and environmental conditions and management practices, governs the release of isothiocyanates from mustard family tissues into soil (Haramoto and Gallandt, 2004; Norsworthy et al., 2005).

Weed species responded differently to herbicide treatments, possibly because of differential selectivity from herbicides and rates. Purple nutsedge, yellow nutsedge, and palmer amaranth were influenced by the main effects of herbicide selection and application rates, whereas large crabgrass was affected by the interaction of the above parameters at all ratings. In general, PRE herbicides were more effective early in the season (4 WATP), and weed control declined late in the season (8 to 9 WATP) (Tables 1 and 2). Among PRE herbicides, S-metolachlor provided broad-spectrum weed control compared with halosulfuron, whose activity was limited to purple nutsedge and yellow nutsedge (Tables 1 and 2). Our results are supported by the previous research and the label recommendations for these herbicides (Clewes et al., 2007; Gowan Co., 2007; Santos et al., 2008; Syngenta Crop Protection, 2007a).

Table 1. Main effect of herbicide selection and application rate on purple nutsedge, yellow nutsedge, and palmer amaranth control at 4 and 8 to 9 weeks after transplanting bell pepper, averaged over cover crop ('Caliente' mustard and fallow) treatments.

Treatment	Timing ^y	Weed control (%) ^z											
		Purple nutsedge				Yellow nutsedge				Palmer amaranth			
		4 WATP		8 WATP		4 WATP		9 WATP		4 WATP		8–9 WATP	
Herbicide main effect ^x													
S-metolachlor	PRE	54	B	36	C	60	B	52	C	69	A	58	A
Halosulfuron	PRE	64	A	53	B	69	A	60	B	30	B	26	D
Halosulfuron	PD	—		69	A	—		77	A	—		33	C
Trifloxysulfuron	PD	—		42	C	—		57	BC	—		49	B
Rate main effect ^{w,v}													
1/2×	—	52	b	43	b	55	b	55	b	41	b	35	b
1×	—	66	a	57	a	74	a	68	a	58	a	48	a

^zPurple nutsedge control data for 2006; yellow nutsedge control data for 2007; palmer amaranth control data averaged over 2006 and 2007; WATP = weeks after transplanting.

^yPRE = pre-emergence, PD = postdirected.

^xMain effect of herbicide selection averaged over application rates. Herbicide means within a column followed by the same uppercase letter are not different based on Fisher's protected least significant difference (LSD) at $\alpha = 0.05$.

^wMain effect of rate averaged over herbicides. Rate means within a column followed by the same lowercase letter are not different based on LSD at $\alpha = 0.05$.

^vRate: 1/2× = S-metolachlor PRE (0.7 lb/acre), halosulfuron PRE/PD (0.012 lb/acre), and trifloxysulfuron PD (0.0035 lb/acre); 1× = S-metolachlor PRE (1.4 lb/acre), halosulfuron PRE/PD (0.024 lb/acre), and trifloxysulfuron PD (0.0035 lb/acre); 1 lb/acre = 1.1209 kg·ha⁻¹.

Table 2. Interaction of herbicide selection and application rate on large crabgrass control at 4 and 8 to 9 weeks after transplanting bell pepper, averaged over cover crop treatments ('Caliente' mustard and fallow) and years (2006 and 2007).

Herbicide	Timing ^y	Rate (lb/acre) ^x	Large crabgrass control (%) ^z			
			4 WATP		8–9 WATP	
S-metolachlor	PRE	0.7	58	b	48	b
		1.4	74	a	61	a
Halosulfuron	PRE	0.012	17	c	5	e
		0.024	21	c	8	e
Halosulfuron	PD	0.012	—		1	e
		0.024	—		4	e
Trifloxysulfuron	PD	0.0035	—		21	d
		0.007	—		33	c

^zTreatment means within a column followed by the same letter are not different based on Fisher's protected least significant difference at $\alpha = 0.05$; WATP = weeks after transplanting.

^yPRE = pre-emergence, PD = postdirected.

^x1 lb/acre = 1.1209 kg·ha⁻¹.

Weed control levels were not acceptable among PD treatments, although trifloxysulfuron had a broader spectrum of activity than halosulfuron (Tables 1 and 2). The poor performance of trifloxysulfuron can be partly explained by the herbicide selectivity and partly by the weed size-dependent activity. A previous study has shown marginal activity of trifloxysulfuron on large crabgrass (Richardson et al., 2007), and efficacy of trifloxysulfuron decreased considerably with increased size of yellow nutsedge, redroot pigweed (*Amaranthus retroflexus*), and other broad-leaf weeds (Singh and Singh, 2004). Similar to the PRE application, halosulfuron applied PD was selective to nutsedge species, with relatively poor control of palmer amaranth and no

control of large crabgrass. Our results are in accordance with previous reports that halosulfuron applied POST performed poorly against palmer amaranth and large crabgrass (Kammler et al., 2008; Norsworthy and Meister, 2007).

Control of all weed species was significantly improved 12% to 19% by increasing herbicide rates from 1/2× to 1× (Table 1), except for large crabgrass at 8 to 9 WATP for which control was unaffected by rates of halosulfuron PRE or PD (Table 2). This could be explained by the lack of activity of halosulfuron on large crabgrass, as discussed above.

BELL PEPPER YIELD. There was no main effect or interaction of 'Caliente' mustard cover crop on bell pepper yield; therefore, yields were averaged

over cover crop treatments for herbicide selection and application rate. The interaction of herbicide selection and application rate was significant for most fruit categories and for marketable fruit yield (Table 3). The maximum marketable bell pepper yield (28,330 lb/acre) was in weed-free plots, of which 59% was contributed by the U.S. No. 1 fruit category. Conversely, nontreated plots produced the minimum marketable yield (13,250 lb/acre), with a reduction of 53% over weed-free plots.

Bell pepper is a poor competitor with weeds, and depending on weed density and species, yield losses of 46%, 73%, 74%, and 94% in bell pepper from large crabgrass, purple nutsedge, yellow nutsedge, and palmer amaranth, respectively, have been reported for polyethylene-mulched production system (Morales-Payan et al., 1998; Motis et al., 2003; Norsworthy et al., 2008). All herbicides at the 1× rate significantly improved the marketable fruit yield compared with weedy plots, but failed to maintain marketable yield equivalent to the weed-free treatment (Table 3). Only S-metolachlor-treated plots produced the fancy fruit yield equivalent to the weed-free plots. Although plots treated with S-metolachlor and trifloxysulfuron at the 1× rate produced total (sum of marketable and culls fruits) fruit yield similar to weed-free plots (data not shown), they had a higher proportion of culls or nonmarketable fruit yield than did the weed-free plots (Table 3). Among herbicide treatments, S-metolachlor

Table 3. Interaction of herbicide selection and application rate on fruit yield of bell pepper, averaged over cover crop treatments ('Caliente' mustard and fallow) and years (2006 and 2007).^z

Herbicide	Timing ^y	Rate (lb/acre) ^x	Bell pepper fruit yield (lb/acre) ^w									
			U.S. Fancy		U.S. No. 1		U.S. No. 2		Marketable		Culls	
S-metolachlor	PRE	0.7	4,020	c	11,220	cd	3,740	bc	18,980	d	2,460	b
		1.4	7,520	ab	14,080	b	4,320	b	25,920	b	2,600	b
Halosulfuron	PRE	0.012	3,040	de	7,770	e	3,230	bc	14,040	ef	3,580	a
		0.024	4,700	c	10,750	cd	4,990	ab	20,440	d	3,200	ab
Halosulfuron	PD	0.012	2,230	e	11,350	c	4,970	ab	18,550	d	2,760	b
		0.024	4,650	c	11,410	c	5,890	a	21,950	cd	2,440	b
Trifloxysulfuron	PD	0.0035	3,790	cd	9,590	d	2,540	c	15,920	e	3,200	ab
		0.007	6,800	b	12,220	c	4,910	ab	23,930	bc	3,640	a
Weed-free control	Season	—	7,740	a	16,610	a	3,980	b	28,330	a	1,550	c
Weedy control	Season	—	3,060	de	7,330	e	2,860	c	13,250	f	3,010	ab

^zTreatment means within a column followed by the same letter are not different based on Fisher's protected least significant difference (LSD) at $\alpha = 0.05$ except for U.S. No. 2 and culls fruit yield, which are based on LSD at $\alpha = 0.05$.

^yPRE = pre-emergence; PD = postdirected.

^x1 lb/acre = 1.1209 kg-ha⁻¹.

^wBell pepper fruit yield = fresh weight of bell pepper fruits per category; marketable yield = U.S. fancy + U.S. No. 1 + U.S. No. 2 fruit weights; culls include the nonmarketable fruits.

PRE and trifloxysulfuron PD at the 1× rate had the highest fancy and marketable fruit yield.

The bell pepper yield among herbicides treatments seems to be related to the efficacy of herbicides against a diverse weed flora present in the field. Bell pepper treated with S-metolachlor at the 1× rate had the highest marketable yield because of broad spectrum control of purple nutsedge, yellow nutsedge, palmer amaranth, and large crabgrass. In contrast, PRE- or PD-applied halosulfuron even at the 1× rate did not control palmer amaranth and large crabgrass, and therefore, fruit yield was lowest among herbicide treatments. Trifloxysulfuron at the 1× rate provided comparatively better control of palmer amaranth and large crabgrass than halosulfuron, and also had some activity on nutsedge species; hence, marketable fruit yield was equivalent to S-metolachlor. The increased weed control associated with increased application rates improved the marketable yield of bell pepper for most of the herbicides. However, because the weed control levels were lower than weed-free plots and did not persist all season, none of the herbicide-treated plots produced marketable yield equivalent to weed-free plots.

Overall, no benefit of combining 'Caliente' mustard cover crop with herbicides was observed for improving the weed control from herbicides or increasing marketable yield in polyethylene-mulched bell pepper. Bell pepper had a fair level of tolerance to PRE-applied S-metolachlor and

halosulfuron at the tested rates, and injury was minimized from PD-applied trifloxysulfuron and halosulfuron by directing the spray application. However, none of the herbicides tested in the present study were sufficient to provide acceptable season-long weed control and marketable yield in bell pepper. Therefore, to provide prolonged broad-spectrum weed control, and in turn marketable yield, a combination of PRE-applied S-metolachlor followed by a weed size-dependent PD application of trifloxysulfuron could be a viable option in polyethylene-mulched bell pepper.

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