Weed Control in Sweet Bell Pepper Using Sequential Postdirected Applications of Pelargonic Acid

Charles L. Webber III^{1,3}, Merritt J. Taylor², and James W. Shrefler²

ADDITIONAL INDEX WORDS. *Amaranthus spinosus*, *Capsicum annuum*, crop injury, crop yield, cutleaf groundcherry, *Cyperus esculentus*, *Digitaria ischaemum*, *Physalis angulata*, phytotoxicity, smooth crabgrass, spiny amaranth, yellow nutsedge

SUMMARY. Pepper (*Capsicum annuum*) producers would benefit from additional herbicide options that are safe to the crop and provide effective weed control. Research was conducted in southeastern Oklahoma (Atoka County, Lane, OK) during 2010 and 2011 to determine the impact of pelargonic acid on weed control efficacy, crop injury, and pepper yields. The experiment included pelargonic acid applied unshielded postdirected at 5, 10, and 15 lb/acre, plus an untreated weedy control and an untreated weed-free control. ‘Jupiter’ sweet bell pepper, a tobacco mosaic virus-resistant sweet pepper with a 70-day maturity, was transplanted into single rows on 3-ft centered raised beds with 18 inches between plants (9680 plants/acre) on 28 May 2010 and 27 May 2011, respectively. Weeds included smooth crabgrass (*Digitaria ischaemum*), cutleaf groundcherry (*Physalis angulata*), spiny amaranth (*Amaranthus spinosus*), and yellow nutsedge (*Cyperus esculentus*). Pelargonic acid was applied postdirected each year in mid-June and then reapplied 8 days later. The 15-lb/acre pelargonic acid treatment resulted in the maximum smooth crabgrass control (56%) and broadleaf weed control (66%) at 1 day after the initial spray treatment (DAIT), and 33% yellow nutsedge control at 3 DAIT. Pelargonic acid at 15 lb/acre provided equal or slightly greater smooth crabgrass and broadleaf (cutleaf groundcherry and spiny amaranth) control compared with the 10-lb/acre application, and consistently greater control than the 5-lb/acre rate and the weedy control. Pelargonic acid was less effective at controlling yellow nutsedge than smooth crabgrass and broadleaf weeds. As the rate of pelargonic acid increased from 5 to 15 lb/acre, yellow nutsedge control also increased significantly for all observation dates. Increasing the pelargonic acid application rate increased the crop injury rating. The maximum crop injury occurred for each application rate at 1 DAIT with 7%, 8.0%, and 13.8% injury for pelargonic acid rates 5, 10, and 15 lb/acre, respectively. There was little or no new crop injury after the second postdirected application of pelargonic acid and crop injury following 3 DAIT for application rates was 2% or less. Only the 15-lb/acre pelargonic acid application produced greater fruit per hectare (4784 fruit/ha) and yields (58.65 kg·ha⁻¹) than the weedy control (1196 fruit/ha and 19.59 kg·ha⁻¹). The weed-free yields (7176 fruit/ha, 178.11 kg·ha⁻¹, and 24.82 g/fruit) were significantly greater than all pelargonic acid treatments and the weedy control. Pelargonic acid provided unsatisfactory weed control for all rates and did not significantly benefit from the sequential applications. The authors suggest the pelargonic acid be applied to smaller weeds to increase the weed control to acceptable levels (>80%).

As an important fresh-market vegetable crop in the United States, bell pepper domestic consumption (11 lb/person) continues to increase (Wells et al., 2013). The increasing gap between domestic production and U.S. demand provides an opportunity for increased domestic bell pepper production (Wells et al., 2013). There is also an increasing demand by consumers for more naturally produced vegetable crops (Webber et al., 2014). Therefore, producers growing bell peppers for markets that desire the use of more naturally occurring herbicides need alternatives that effectively provide season-long weed

control. Although corn gluten meal has shown promise as an early season preemergent herbicide in vegetable production, any uncontrolled weeds can cause serious yield reductions (Webber et al., 2010). In general,

there are limited options for control of annual broadleaf weeds in summer vegetables, and both organic and conventional producers would benefit from appropriate herbicides that effectively provide postemergent weed control (Kemble et al., 2013). Previous research with postemergence nonsynthetic contact herbicides in noncrop situations determined that these herbicides must be applied to very young or small weeds if acceptable weed control is expected (Webber et al., 2012a). A potential solution to this would be to increase weed control efficacy on larger weeds and decrease crop injury by using multiple or sequential postdirected herbicide applications (herbicides postdirected sprayed at the base of the crop rather than over-the-top).

Scythe[®] (Dow AgroSciences, Indianapolis, IN) is a fatty acid based, nonselective, synthetic contact herbicide consisting of 57% pelargonic acid and other related fatty acids. Pelargonic acid is naturally occurring in many plants and animals and present in many foods (U.S. Environmental Protection Agency, 2004). Pelargonic acid injures and kills plants by destroying the cell membranes, causing rapid desiccation of plant tissues (Webber et al., 2014). Chloroplast bleaching is seen within a short time after application (Senseman, 2007). The primary impact is the immediate decrease in intercellular pH with a resulting loss of cell membrane integrity (Senseman, 2007). Although pelargonic acid is not listed as a “certified organic” herbicide, it is seen as a more natural type herbicide for use in sustainable crop production (Webber and Shrefler, 2007).

Previous field studies determined that pelargonic acid applied at 5, 10.8, and 16.7 lb/acre as Scythe[®] at 3%, 6.5%, and 10% (v/v) at 100 gal/acre was effective as a broadcast postemergence contact herbicide when

Units			
To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
0.3048	ft	m	3.2808
3.7854	gal	L	0.2642
9.3540	gal/acre	L·ha ⁻¹	0.1069
2.54	inch(es)	cm	0.3937
0.4536	lb	kg	2.2046
1.1209	lb/acre	kg·ha ⁻¹	0.8922
28.3495	oz	g	0.0353

applied to small annual weeds (Webber and Shrefler, 2007). Webber et al. (2012b) determined that the application volume could be reduced from 100 to 40 gal/acre in postdirected applications in spring transplanted onion (*Allium cepa*) and still maintain good weed control with pelargonic acid applied at 5, 10, and 15 lb/acre. Unfortunately, crop injury and significant reduction in onion yields were observed with pelargonic acid application rates compared with the weed-free control.

Pelargonic acid in commercial formulations has potential as a nonselective postemergent contact herbicide for weeds in vegetable crops if application method and rate can be customized to individual crops to maintain weed control efficacy without reducing yields due to crop injury (Webber and Shrefler, 2007; Webber et al., 2005, 2012a, 2014). Research was conducted to determine the impact of sequential post-directed applications of pelargonic acid on weed control efficacy, crop injury, and yields in bell pepper.

Materials and methods

The experiments were conducted in 2010 and 2011 at the Oklahoma State University, Lane Agricultural Center, Lane, OK (lat. 34°17'N, long. 95°57'W) on a Bernow fine-loamy, siliceous, thermic Glossic Paleudalf soil. Before planting, the soil was fertilized and prepared following Oklahoma

Cooperative Extension Service recommendations (Motes et al., 1994). The experiment was a randomized complete block design with five treatments and four replications repeated across 2010 and 2011. 'Jupiter' sweet bell pepper, a tobacco mosaic virus-resistant sweet pepper with a 70-d maturity, were transplanted into single rows on 3-ft centered raised beds with 18 inches between plants (9680 plants/acre) on 28 May 2010 and 27 May 2011, respectively. Plots consisted of four 36-inch rows in plots 12 ft wide by 30 ft long. Soil moisture was maintained during the experiment by rainfall supplemented with overhead irrigation for a combined total of 55 cm of water from planting to harvest each year. All other required cultural practices, including insect and disease control, were completed according to Oklahoma State University recommendations (Motes et al., 1994).

Weed control treatments consisted of sequential applications of pelargonic acid applied at 5, 10, and 15 lb/acre, an untreated weedy control, and an untreated weed-free control. Weed-free plots were maintained by hand hoeing. Pelargonic acid was postdirected applied without shields [40 gal/acre, 0.4 gal/min (XR8004VS nozzle; Spraying Systems, Wheaton, IL)] to the base of the pepper plants on 16 June 2010 and 2011, 19 and 20 d after transplanting (DAT), respectively, and then reapplied 8 d later (24 June 2010 and 2011). No pepper flowers were present during either application. Although 'Jupiter' sweet bell pepper typically grows 60 to 90 cm tall, the lower leaves were inadvertently sprayed during both applications. At the time of initial applications, smooth crabgrass was 8 to 10 cm tall, cutleaf groundcherry was 5 cm tall, spiny amaranth was 8 to 10 cm tall, and yellow nutsedge was 10 to 15 cm tall. Smooth crabgrass represented 60% of the weed cover, while cutleaf groundcherry and spiny amaranth represented 35% and 3% of weed cover, respectively. Yellow nutsedge represented less than 2% of the weed cover.

Weed control and crop phytotoxicity ratings were collected at 1, 3, 7, 9, 11, 16, 21, and 28 DAIT (17 June to 13 July 2010 and 2011). Weed control ratings represent the percent weed control for a treatment compared with the weedy control. A visual rating system of 0% to 100% was

used, 0% representing no weed control and 100% representing complete weed control. The visual ratings were focused on the percentage groundcover that the weed control produced. For crop response to the treatments, a 0% to 100% visual rating system was used in which 0% represented no crop injury (necrosis) and 100% represented crop death. The visual ratings were based on visual damage to the crop leaves. Weed control and crop injury data were converted using an arcsine transformation to facilitate statistical analysis and mean separation to normalize data within the parameters suggested by Ahrens et al. (1990). Marketable pepper fruit were harvested on 12 Aug. 2010 (76 DAP) and 11 Aug. 2011 (76 DAP). Marketable fruit was determined by using U.S. Department of Agriculture standards (USDA, 2005). Only mature, green, unblemished fruit that were at least 2.5 inches long and 2.5 inches in diameter were determined to be marketable, which could include U.S. Fancy, U.S. No. 1, and U.S. No. 2 (USDA, 2005). All fruit in these three grades were combined to provide a total marketable yield in pounds per plot and total marketable yield (kilograms per hectare). All data (weed control ratings, crop injury and fruit yields) were subjected to analysis of variance (SAS version 9.2; SAS Institute, Cary, NC) and mean separation using least significant difference with $P = 0.05$.

Results and discussion

There were no significant year-by-treatment interactions for weed ratings (Tables 1–3), crop injury ratings (Table 4), or yield data (Table 5); therefore, the data presented are averaged across 2010 and 2011.

WEED CONTROL. Control of smooth crabgrass, 56% (Table 1), and broadleaf weeds (cutleaf groundcherry and spiny amaranth), 66% (Table 2), peaked with the 15-lb/acre application rate at 1 DAIT, while yellow nutsedge peaked at 3 DAIT with 33% control (Table 3). Smooth crabgrass control decreased for all application rates from initial weed control ratings at 1 DAIT until 9 DAIT (Table 1), 1 d after the sequential application, where smooth crabgrass control peaked a second time and then tended to decrease through the remainder of the weed control ratings. In general, the broadleaf weed control ratings follow the same trend

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¹Sugarcane Research Unit, Agricultural Research Service, U.S. Department of Agriculture, 5883 USDA Road, Houma, LA 70360

²Division of Agriculture Sciences and Natural Resources, Oklahoma State University, Cooperative Extension Service, 1901 S. 9th Street, Durant, OK 74702

³Corresponding author. E-mail: Webber@ars.usda.gov.

Table 1. Smooth crabgrass control as a result of sequential postdirected applications of pelargonic acid (PA) applied at 5, 10, and 15 lb/acre in bell pepper averaged across years in 2010 and 2011, at Lane, OK.

Weed control treatment	Days after initial treatment							
	1	3	7	9 ^a	11	16	21	28
	Smooth crabgrass control (%)							
PA 5 lb/acre ^y	26 c ^x	13 c	13 c	16 c	17 c	10 c	3 d	3 d
PA 10 lb/acre	38 bc	26 c	23 b	36 b	37 b	27 b	14 c	14 c
PA 15 lb/acre	56 b	49 b	43 b	49 b	47 b	39 b	24 b	20 b
Weedy control ^w	0 d	0 d	0 d	0 d	0 e	0 d	0 d	0 d
Weed-free ^v	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a

^aThe second postdirected application was applied at 8 d after the initial treatment (DAIT). The 9, 11, 16, 21, and 28 DAIT also represent 1, 3, 8, 13, and 20 d after the sequential treatment, respectively.

^yPA was postdirected applied without shields to the base of the bell pepper plants on 16 June 2010 and 2011, 19 d after transplanting (DAT) and 20 DAT, respectively, and then reapplied 8 d later (24 June 2010 and 2011); 1 lb/acre = 1.1209 kg·ha⁻¹.

^xValues in a column followed by the same letter are not significantly different at $P \leq 0.05$ least significant difference.

^wThe weeds in the weedy control were untreated and allowed to grow as a comparison with the other treatments.

^vThe weed-free treatment involved the removal of all weeds by hand-weeding.

Table 2. Broadleaf (cutleaf groundcherry and spiny amaranth) weed control as a result of sequential postdirected applications of pelargonic acid (PA) applied at 5, 10, and 15 lb/acre in bell pepper averaged across years in 2010 and 2011 at Lane, OK.

Weed control treatment	Days after initial treatment							
	1	3	7	9 ^a	11	16	21	28
	Broadleaf control (%)							
PA 5 lb/acre ^y	23 d ^x	18 d	16 d	29 c	24 c	19 d	16 d	12 c
PA 10 lb/acre	44 c	32 c	32 b	48 b	44 b	41 c	29 c	26 b
PA 15 lb/acre	66 b	64 b	58 b	53 b	53 b	54 b	40 b	36 b
Weedy control ^w	0 e	0 e	0 e	0 d	0 d	0 e	0 e	0 e
Weed-free ^v	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a

^aThe second postdirected application was applied at 8 d after the initial treatment (DAIT). The 9, 11, 16, 21, and 28 DAIT also represent 1, 3, 8, 13, and 20 d after the sequential treatment, respectively.

^yPA was postdirected applied without shields to the base of the bell pepper plants on 16 June 2010 and 2011, 19 d after transplanting (DAT) and 20 DAT, respectively, and then reapplied 8 d later (24 June 2010 and 2011); 1 lb/acre = 1.1209 kg·ha⁻¹.

^xValues in a column followed by the same letter are not significantly different at $P \leq 0.05$ least significant difference.

^wThe weeds in the weedy control were untreated and allowed to grow as a comparison with the other treatments.

^vThe weed-free treatment involved the removal of all weeds by hand-weeding.

Table 3. Yellow nutsedge control as a result of sequential postdirected applications of pelargonic acid (PA) applied at 5, 10, and 15 lb/acre in bell pepper averaged across years in 2010 and 2011 at Lane, OK.

Weed control treatment	Days after initial treatment							
	1	3	7	9 ^a	11	16	21	28
	Yellow nutsedge control (%)							
PA 5 lb/acre ^y	3 c ^x	10 c	8 cd	2 d	2 cd	1 c	1 c	1 c
PA 10 lb/acre	15 b	9 c	8 c	10 c	6 c	5 c	4 bc	3 b
PA 15 lb/acre	31 b	33 b	26 b	22 b	28 b	25 b	6 b	6 b
Weedy control ^w	0 c	0 c	0 d	0 d	0 d	0 c	0 c	0 c
Weed-free ^v	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a

^aThe second postdirected application was applied at 8 d after the initial treatment (DAIT). The 9, 11, 16, 21, and 28 DAIT also represent 1, 3, 8, 13, and 20 d after the sequential treatment, respectively.

^yPA was postdirected applied without shields to the base of the bell pepper plants on 16 June 2010 and 2011, 19 d after transplanting (DAT) and 20 DAT, respectively, and then reapplied 8 d later (24 June 2010 and 2011); 1 lb/acre = 1.1209 kg·ha⁻¹.

^xValues in a column followed by the same letter are not significantly different at $P \leq 0.05$ least significant difference.

^wThe weeds in the weedy control were untreated and allowed to grow as a comparison with the other treatments.

^vThe weed-free treatment involved the removal of all weeds by hand-weeding.

as the smooth crabgrass weed control ratings, with the exception that the 5- and 10-lb/acre applications reached their greatest control at 9 DAIT, 1 d after the sequential treatment (Table 2). Yellow nutsedge had the greatest inconsistencies among the different application rates and rating times (Table 3). The 5-lb/acre rate peaked at 3 DAIT (10%) and decreased from that

point until the end of the ratings. The 10-lb/acre rate followed the typical trend of peaking at 1 DAIT (15%), decreasing at the 3 (9%) and 7 (8%) DAIT ratings, and producing a second peak at 9 DAIT (10%). The 15-lb/acre rate tended to follow the 10-lb/acre trend but with a slight delay, first peaking at 3 DAIT (33%), decreasing through the 9 DAIT rating

(22%), and producing a second peak at 11 DAIT (28%). Pelargonic acid provided unsatisfactory weed control for all pelargonic acid rates and did not significantly benefit from the sequential applications (Tables 1, 2, and 3). Although Webber et al. (2014) showed good (>80%) control of the same grass (smooth crabgrass, 8 to 15 cm tall) and broadleaf (cutleaf groundcherry

Table 4. Bell pepper injury as a result of sequential postdirected applications of pelargonic acid (PA) applied at 5, 10, and 15 lb/acre averaged across years in 2010 and 2011 at Lane, OK.

Weed control treatment	Days after initial treatment							
	1	3	7	9 ^a	11	16	21	28
	Crop injury (%)							
PA 5 lb/acre ^y	7.0 b ^x	2.5 b	1.0 ab	1.5 a	1.0 bc	0.0 b	0.0 b	0 a
PA 10 lb/acre	8.0 b	2.0 b	1.0 b	2.0 a	1.0 b	1.0 a	1.0 a	0 a
PA 15 lb/acre	13.8 a	6.5 a	1.8 a	1.5 a	2.0 a	1.8 a	1.0 a	0 a
Weedy control ^w	0.0 c	0.0 c	0.0 c	0.0 b	0.0 c	0.0 b	0.0 b	0 a
Weed-free ^v	0.0 c	0.0 c	0.0 c	0.0 b	0.0 c	0.0 b	0.0 b	0 a

^aThe second postdirected application was applied at 8 d after the initial treatment (DAIT). The 9, 11, 16, 21, and 28 DAIT also represent 1, 3, 8, 13, and 20 d after the sequential treatment, respectively.

^yPelargonic acid was postdirected applied without shields to the base of the bell pepper plants on 16 June 2010 and 2011, 19 d after transplanting (DAT) and 20 DAT, respectively, and then reapplied 8 d later (24 June 2010 and 2011); 1 lb/acre = 1.1209 kg·ha⁻¹.

^xValues in a column followed by the same letter are not significantly different at $P \leq 0.05$ least significant difference.

^wThe weeds in the weedy control were untreated and allowed to grow as a comparison with the other treatments.

^vThe weed-free treatment involved the removal of all weeds by hand-weeding.

Table 5. Impact of sequential postdirected applications of pelargonic acid (PA) applied at 5, 10, and 15 lb/acre on marketable bell pepper fruit number and yield averaged across years in 2010 and 2011 at Lane, OK.

Weed control treatment	Fruit production (fruit/ha) ^z	Yield (kg·ha ⁻¹) ^y	Avg fruit wt (g/fruit) ^x
PA 5 lb/acre ^w	598 d ^v	12.54 c	20.97 b
PA 10 lb/acre	1,196 c	13.76 c	11.51 d
PA 15 lb/acre	4,784 b	58.65 b	12.26 d
Weedy control ^u	1,196 c	19.59 c	16.38 c
Weed-free ^t	7,176 a	178.11 a	24.82 a

^zMarketable fruit consisted of only mature, green unblemished fruit at least 2.5 inches (6.35 cm) long and 2.5 inches (6.35 cm) in diameter of 'Jupiter' sweet bell peppers, a tobacco mosaic virus-resistant sweet pepper with a 70-d maturity, harvested on 12 Aug. 2010 and 11 Aug. 2011 at Lane, OK; 1 fruit/ha = 2.4711 fruit/acre.

^yPepper yields represent the combined weight of marketable pepper fruit harvested (U.S. Fancy, U.S. No. 1, and U.S. No. 2) during a single season ending harvest; 1 kg·ha⁻¹ = 0.8922 lb/acre.

^x1 g = 0.0353 oz.

^wPA was postdirected applied without shields to the base of the bell pepper plants on 16 June 2010 and 2011, 19 d after transplanting (DAT) and 20 DAT, respectively, and then reapplied 8 d later (24 June 2010 and 2011); 1 lb/acre = 1.1209 kg·ha⁻¹.

^vValues in a column followed by the same letter are not significantly different at $P \leq 0.05$ least significant difference.

^uThe weeds in the weedy control were untreated and allowed to grow as a comparison with the other treatments.

^tThe weed-free treatment involved the removal of all weeds by hand-weeding.

at 5 to 8 cm tall and spiny amaranth at 5 to 8 cm tall) weed species in yellow squash (*Cucurbita pepo*), we suggest the pelargonic acid be applied to smaller weeds to increase the weed control to acceptable levels (80% to 90%).

PEPPER FOLIAR INJURY. Although the sequential postdirected application of pelargonic acid at 15-lb/acre rate resulted in the greatest weed control, it also produced the greatest crop injury (13.8%) at 1 DAIT (Table 4). Crop injury for all application rates decreased from their peaks at 1 DAIT to their lowest values at 28 DAIT, with only slight numerical increases following the sequential treatments at 9 DAIT (Table 4). In contrast, Webber et al. (2014) reported the greatest injury to yellow squash accrued at 9 DAIT with injury peaks at 1 and 9 DAIT for all applications rates (5, 10, and 15 lb/acre). It appears the differences in crop architecture between bell pepper's initial more erect stance compared with yellow squash's more bushy horizontally spreading canopy may account for less pepper injury from the

pelargonic acid applications. There also may be a greater sensitivity to pelargonic acid for yellow squash compared with bell pepper, or at least, the varieties tested. Further research could determine if there is a crop or variety difference for pelargonic acid sensitivity and the factors effecting crop injury.

PEPPER YIELDS. Pepper plants treated with pelargonic acid at 15 lb/acre yielded greater (4784 fruit/ha and 59 kg·ha⁻¹) than pepper plants treated with pelargonic acid at 5 lb/acre (598 fruit/ha and 12.5 kg·ha⁻¹) and 10 lb/acre (1196 fruit/ha and 13.8 kg·ha⁻¹) (Table 5). The 15-lb/acre rate of pelargonic acid had significantly greater fruit/ha and kg·ha⁻¹ than the weedy control (1196 fruit/ha and 19.6 kg·ha⁻¹), while the 5- and 10-lb/acre rate produced equal or less than the weedy control. The weed-free treatment produced greater yields (7176 fruit/ha and 178.1 kg·ha⁻¹) than any of the pelargonic acid treatments. The weed-free treatment also produced the heaviest average fruit weight (24.8 g/fruit) compared with

the 5-, 10-, and 15-lb/acre treatments (21.0, 11.5, and 12.6 g/fruit, respectively) and the weedy control (16.4 g/fruit) (Table 5). The 5-lb/acre pelargonic acid rate produced 50% less fruit (598 fruit/ha) than the weedy control (1196 fruit/ha) in spite of producing 26%, 23%, and 10% maximum greater grass (1 DAIT), broadleaf (1 DAIT), and nutsedge (3 DAIT) control, respectively (Tables 1–3). This decrease in fruit per hectare with increased weed control with the 5-lb/acre application rate is a clear indication of the detrimental impact of the early herbicide injury (7%) with the postdirected application of pelargonic acid at 5 lb/acre (Table 4). The 10-lb/acre pelargonic acid rate produced the same number of fruit (1196 fruit/ha) than the weedy control (1196 fruit/ha), while providing initial weed control ratings of 38% grass (Table 1), 44% broadleaf (Table 2), and 15% nutsedge (Table 3) control with 8% crop injury (Table 4) at 1 DAIT. It was only when the 15-lb/acre rate provided 56% grass (Table 1), 66% broadleaf (Table 2),

and 31% nutsedge (Table 3) control with 13.8% crop injury (Table 4) did a pelargonic acid application produced greater fruit per hectare (4784 fruit/ha) and yields (58.65 kg·ha⁻¹) than the weedy control (1196 fruit/ha and 19.59 kg·ha⁻¹) (Table 5).

Conclusions

The sequential application of pelargonic acid at 5, 10, and 15 lb/acre produced poor grass (≤56%), broadleaf (≤66%), nutsedge (≤33%) control, and significant crop injury, which resulted in reduced fruit production (fruit per hectare), yields (kilogram per hectare), and fruit weights (grams per fruit). The 15-lb/acre pelargonic acid rate should benefit sustainable crop producers by producing four times the fruit production (fruit per hectare) and 3 times the yield (kilogram per hectare) than the weedy control. The authors suggest that pelargonic acid be applied to smaller weeds to increase the weed control to acceptable levels (80% to 90%). The use of a hooded sprayer may also reduce crop injury without a significantly decrease in weed control. Another option would be the use of a suitable preemergence herbicide to reduce the weed population and height before the postemergence application of pelargonic acid.

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