

Eggplant Tolerance to Halosulfuron Applied through Drip Irrigation

Theodore Webster and

U.S. Department of Agriculture, Agricultural Research Service, Crop Protection and Management Research Unit, 115 Coastal Way, Tifton, GA 31794

A. Culpepper

University of Georgia, Department of Crop and Soil Science, P.O. Box 748, Tifton, GA 31793-0748

Additional index words. chemigation, *Cyperus esculentus*, *Cyperus rotundus*, eggplant, methyl bromide alternative, plasticulture, purple nutsedge, *Solanum melongena*, yellow nutsedge

Abstract. Halosulfuron is an alternative to methyl bromide for managing nutsedges (*Cyperus* spp.) in several vegetable crops. Field studies were conducted to evaluate eggplant growth and yield when halosulfuron was applied through drip-irrigation before transplant at four rates (0, 26, 39, or 52 g·ha⁻¹ a.i.) or following transplant (26 g·ha⁻¹ applied 1, 2, or 3 weeks after transplant) in spring and fall crops in 2002 and 2003. Inverse linear relationships were observed between rate of halosulfuron and eggplant growth and rate of halosulfuron and eggplant yield. Halosulfuron at 52 g·ha⁻¹ reduced eggplant growth (crop height and canopy width) 19% to 22%. Eggplant fruit biomass at the first harvest was reduced 37% to 63% by halosulfuron applied before transplant. Eggplant was capable of recovering from the initial injury and there was no effect of halosulfuron rate on fruit biomass at the final harvest. Total season fruit biomass was reduced ≤4% from halosulfuron at 39 g·ha⁻¹, while halosulfuron at 52 g·ha⁻¹ reduced fruit biomass 33%. Delay in application of halosulfuron to 3 weeks after transplant (WAT) resulted in ≤7% reduction in fruit biomass and number for the entire season. When halosulfuron was applied 1 WAT, fruit biomass at the first two harvests was reduced >33%, however total season harvest from this treatment was >99% of the yield from the nontreated control. This preliminary study indicates that halosulfuron injected through drip tape may have the potential to assist in the replacement of methyl bromide for nutsedge management in eggplant. However, there are many issues that must be addressed and studied before adopting this practice in eggplant.

Methyl bromide has been used since the early 1900s and has become a critical component of pest management in large-scale commercial production of many vegetable crops, including eggplant (Ragsdale and Wheeler, 1995). Methyl bromide effectively manages soilborne plant pathogens, insects, nematodes, and weeds. However, methyl bromide has been identified as an ozone depleting substance and its use is scheduled to be abolished in most agricultural production (U.S. EPA, 2002). About 85% of methyl bromide used in the U.S. is applied for preplant soil fumigation (Julian et al. 1998). The loss of methyl bromide is estimated to cause \$12 million loss in eggplant production (Ragsdale and Wheeler, 1995) and has created a significant challenge for growers to manage previously suppressed pests (Duniway, 2002; Martin, 2003). The natural pest resistance found in wild eggplant species may allow breeding programs to improve pest (e.g., insect, nematode, and plant pathogen) tolerance in cultivated eggplant varieties (Kashyap et al., 2003), however weeds will continue to be a significant issue.

Polyethylene mulch is an effective barrier for controlling most weeds in vegetable crops, with two exceptions. First, weeds can become a problem in the holes that are punched in the mulch to transplant the crop (Schonbeck, 1998). Second, there are two weed species that are capable of piercing the polyethylene mulch barrier, purple nutsedge and yellow nutsedge. While polyethylene mulch will suppress nutsedge growth (Chase et al., 1998; Majek and Neary, 1991; Patterson, 1998; Webster, 2005), enough shoots are capable of penetrating the mulch barrier and affecting crop yield. In polyethylene mulch systems in the southern U.S., yellow nutsedge (*Cyperus esculentus*) and purple nutsedge (*Cyperus rotundus*) are among the most troublesome weeds of vegetable crops (Webster, 2002; Webster and MacDonald, 2001). Nutsedges will compete with crops for water, light, and nutrients, with potential to reduce vegetable crop yields >50%

(Gilreath and Santos, 2004; Motis et al., 2004; Motis et al., 2003) and can cause mechanical damage to fruit.

Unlike similar vegetable cropping systems (e.g., tomato, cucumber, and cantaloupe), acceptable long-term alternatives to methyl bromide for nutsedge management in eggplant have not been identified. Halosulfuron (Trade name Sandea, Gowan Co., Yuma, Ariz.) has been identified as a potential herbicide for use in several cucurbit crops (Batts et al., 2001; Brown and Masiunas, 2002; Haar et al., 2002; Johnson and Mullinix, 2002; Webster and Culpepper, 2005; Webster et al., 2003) and solanaceous crops (Buker et al., 2004; Grichar et al., 2003; Haar et al., 2002). Halosulfuron controls purple and yellow nutsedge (Blum et al., 2000; Derr et al., 1996; Vencill et al., 1995), impedes tuber production (Lowe et al., 2000; Nelson and Renner, 2002; Warren and Coble, 1999), reduces tuber viability (Molin et al., 1999), prevents shoot regrowth (Earl et al., 2004) and reduces nutsedge competitiveness (Ferrell et al., 2004). While halosulfuron effectively controls both nutsedge species, crop tolerance limits adoption of this tactic for a broad range of vegetable crops. For example, previous research has indicated that foliar applications of halosulfuron at 26 g·ha⁻¹ reduced eggplant growth >51% at 12 d after treatment (Flanders and Culpepper 2002).

Application of pesticides through drip irrigation (chemigation) has demonstrated effective pest management of insects (Leib et al. 2000), plant pathogens (Gullino et al., 2002; Webster et al., 2001), nematodes (Wang and Yates, 1999; Webster et al., 2001), and weeds (Dowler et al., 1997; Fennimore et al., 2003). Halosulfuron applied through drip irrigation may provide an alternative means of using this herbicide to target nutsedge, while minimizing the impact on the crop. The objectives of this field study were to evaluate eggplant growth and yield response to halosulfuron 1) applied at three rates through drip irrigation before crop transplant and 2) applied through drip irrigation at three intervals following crop transplant.

Materials and Methods

Field studies were conducted in Tifton, Ga., in Spring and Fall 2002 and 2003 (four site-years). The study area had been out of crop production for 5 years and most recently contained centipedegrass (*Eremochloa ophiuroides* Munro) sod. Nutsedge population densities were low (<0.5 shoots/m²). The soil was a Tifton loamy sand (fine-loamy, kaolinitic, thermic Plinthic Kandiodults) having 86%

Table 1. Eggplant height and number of leaves at each of the application times in spring and fall crops in 2002 and 2003.

Crop season	Application time					
	1 week after transplant		2 weeks after transplant		3 weeks after transplant	
	Plant ht (cm)	Leaves (no.)	Plant ht (cm)	Leaves (no.)	Plant ht (cm)	Leaves (no.)
Spring 2002	15.0	2–4	15.8	3–6	19.3	4–6
Fall 2002	14.8	2–4	16.4	3–6	20.0	5–8
Spring 2003	16.6	2–3	16.6	4–5	18.5	6–9
Fall 2003	14.4	4–5	17.4	4–6	17.8	9–15

Received for publication 11 Mar. 2005. Accepted for publication 14 May 2005. Mention of a trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the USDA and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

sand, 7% silt, 7% clay (USDA–NRCS–Soil-Survey Division, 2001), 0.8 to 1.0% organic matter and pH of 6.3 to 6.5. Raised beds (15 cm tall) were formed in one operation (Blue Line Superbedder 4000, Kennco Mfg., Inc.) and polyethylene mulch and drip tape applied in a separate operation (Blue Line Plastic Mulch Layer 3000, Kennco Mfg., Inc.). Black low density polyethylene mulch (thickness of 32 μm) and drip tape (T-Tape: output of 250 LPH/100 m at 0.55 Bar, tubing wall 0.2 mm thick, emitters spaced 20 cm apart) were laid in plots (1.8 \times 6.1 m), with a bed top of 0.76 m. Treatments were arranged as a randomized complete block design with four replications. To minimize the effect of nematodes and plant pathogens on crop growth, each bed was treated with Inline, a mixture of 133 $\text{kg}\cdot\text{ha}^{-1}$ a.i. 1,3-dichloropropene and 75 $\text{kg}\cdot\text{ha}^{-1}$ a.i. chloropicrin. This mixture was injected through the drip irrigation system (1500 ppm injected over 6 h, followed by flushing of the lines for 1 h) 15 to 23 d before crop transplanting. The test was managed uniformly for fertility and pests following University of Georgia Extension recommendations (Granberry, 1990). At planting, all plots received 168 $\text{kg}\cdot\text{ha}^{-1}$ of 10N–16P–0K. Throughout the growing season, plots were drip irrigated 3 to 5 times a week (based on need) and each week received 22 $\text{kg}\cdot\text{ha}^{-1}$ of 7N–0P–5.8K liquid fertilizer injected through the drip irrigation system.

The treated area for each plot included the width of the raised bed (0.76 m) by the length of the raised bed (6.1 m), for a total of 4.64 m^2 . All treatments were applied to moist soil in the raised beds. Treatments in the first test included halosulfuron at 0, 26, 39, and 52 $\text{g}\cdot\text{ha}^{-1}$ a.i. applied through drip irrigation 1 to 6 d before crop transplanting. In the second test, 26 $\text{g}\cdot\text{ha}^{-1}$ of halosulfuron was applied through the drip irrigation at 1, 2, and 3 weeks after transplanting (WAT). Eggplant height and number of leaves per plant at each of the post-transplant treatment times is found in Table 1. Halosulfuron treatments were mixed with 2.1 L of water and injected into the drip irrigation system over 1 h using a pump that delivered 35 $\text{mL}\cdot\text{min}^{-1}$. ‘Santana’ eggplant were hand-transplanted in a single row on each bed with a between plant spacing of 46 cm on 9 Apr. 2002, 14 Aug. 2002, 23 Apr. 2003, and 25 Aug. 2003.

Height and canopy width of four eggplant plants per plot were measured at 34 to 38 DAP. Eggplant fruit were hand-harvested 4 to 6 times, beginning 49 to 70 d after transplanting and continuing for 28 to 39 d. Only fruit that were consistent with U.S. grading standards for Fancy and No. 1 eggplant were considered marketable fruit and included in data analysis (Granberry, 1990; Sargent, 1998; USDA–AMS, 1997). Yield data were grouped and analyzed in three categories to evaluate 1) the effect of treatments in delaying fruit maturity (initial harvest and second harvest), 2) recovery of the plant from early-season treatment-related injury (final harvest), and 3) overall effect of treatments on fruiting (cumulative crop yield). For each harvest, fruit biomass data were transformed as a percent of the nontreated control. Data were subjected

to analysis of variance. Dependent variables (crop height and yield) and halosulfuron rate and time of application were fit to a linear regression models. Differences among slope estimates of linear regression were evaluated using a *t* test.

Results and Discussion

Pretransplant applications of halosulfuron. Halosulfuron slowed early-season eggplant growth and caused foliar chlorosis. However

new leaves in the terminal were actively growing by 3 WAT. An inverse linear relationship was observed between rates of halosulfuron applied pre-transplant and both crop height and crop canopy width (Fig. 1). The greatest reductions (19 to 22% reduction) in crop height and canopy width occurred at 52 g/ha halosulfuron. No detectable differences were observed between the slope of the regression for crop height and canopy width ($t = 0.13$). Previous research indicated that when applied over the crop, halosulfuron at 52 $\text{g}\cdot\text{ha}^{-1}$ injured eggplant

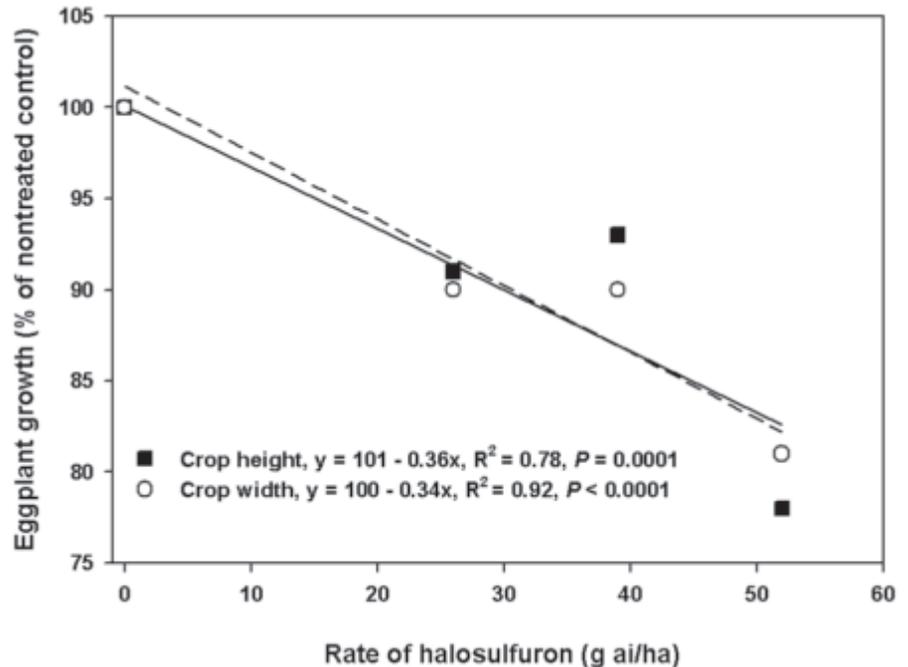


Fig. 1. Crop plant height (dashed regression line) and canopy width (solid regression line) measured 34 to 39 d after transplant when four rates of halosulfuron were applied to eggplant before transplant.

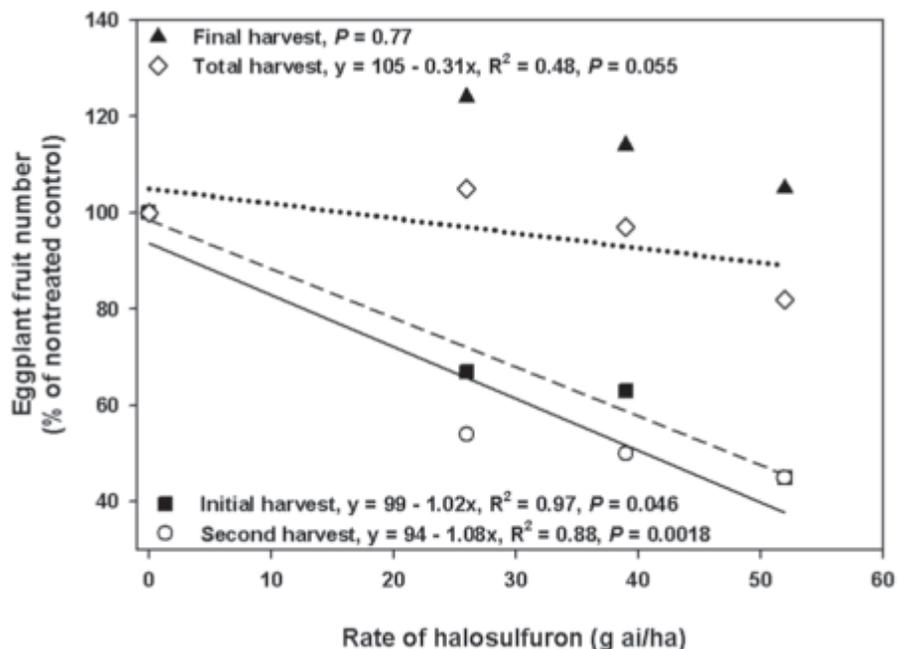


Fig. 2. Eggplant fruit number at the initial, second, final, and total season harvests when four halosulfuron rates were applied to eggplant before transplant. Inverse linear relationships were observed between eggplant fruit number and halosulfuron rate for initial harvest (dashed line), second harvest (solid line), and total harvest (dotted line) ($P < 0.055$). No apparent effect of halosulfuron rate on eggplant fruit number was observed for final harvest ($P = 0.77$), therefore there is no regression for these data.

66%, while a precision postdirected application (directed to the bottom 25% of the plant) injured eggplant 29% (Flanders and Culpepper, 2002). Similar results were observed when halosulfuron was applied to bell pepper, with the least amount of crop injury (19%) from soil applied applications, intermediate crop injury

(36%) from precision-directed applications, and greatest crop injury (63%) from topical applications (Culpepper, 2002).

Fruit development and maturity were delayed by halosulfuron applied pre-transplant. Treatments had a similar effect on fruit number and fruit biomass at the initial two harvests.

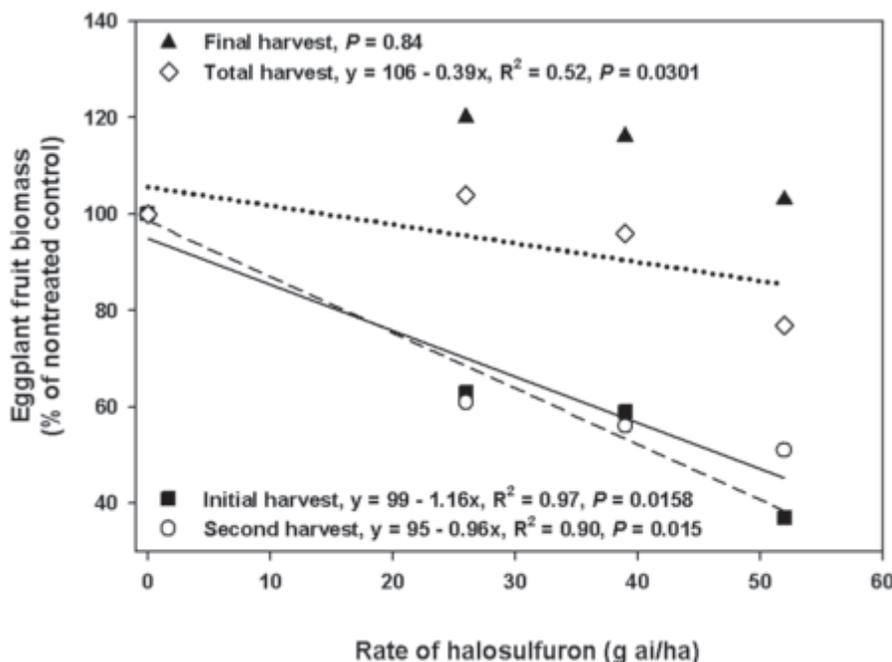


Fig. 3. Eggplant fruit biomass at the first, second, final, and total season harvest when four halosulfuron rates were applied through drip irrigation to eggplant before transplant. Inverse linear relationships were observed between eggplant fruit biomass and halosulfuron rate for initial harvest (dashed line), second harvest (solid line), and total harvest (dotted line) ($P < 0.0301$). No apparent effect of halosulfuron rate on eggplant fruit number for final harvest ($P = 0.84$) was observed, therefore there is no regression for these data.

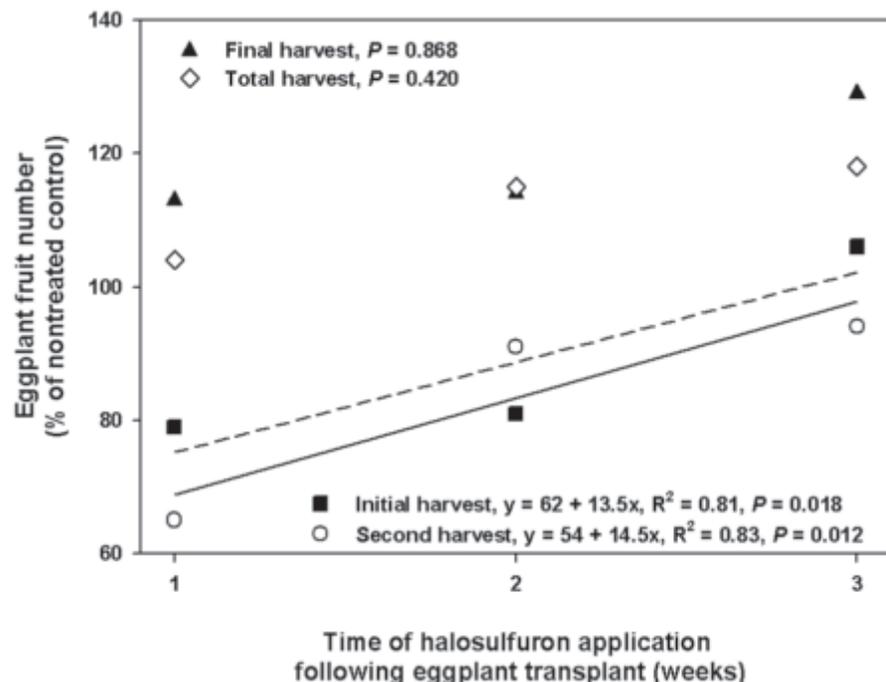


Fig. 4. Eggplant fruit number at the first, second, and final harvest and cumulative season harvest when 26 g·ha⁻¹ halosulfuron was applied through drip irrigation 1, 2, and 3 weeks following eggplant transplant. Linear relationships were observed between eggplant fruit number and delay halosulfuron application following transplant for initial harvest (dashed line) and second harvest (solid line) ($P < 0.018$). There was no apparent effect of delay in halosulfuron application on eggplant fruit number for final harvest ($P = 0.77$) or total harvest ($P = 0.42$), therefore there are no regression for these data.

Inverse linear relationships were observed between fruit number and rate of halosulfuron at the first harvest and second harvest (Fig. 2). Regression slopes of fruit biomass and rate of halosulfuron were similar ($t = 0.20$) at the first two harvests. Fruit numbers at the first two harvests were reduced 33% to 55% by halosulfuron. The initial two harvests collectively represented 52% of the total season fruit number harvested in the nontreated control.

Fruit biomass was related to halosulfuron in an inverse linear manner at the first harvest and was reduced 37% to 63% by halosulfuron (Fig. 3). Culpepper (2002) reported that bell pepper yield from the initial harvest was reduced 6% to 41% by halosulfuron at 26, 39, and 52 g·ha⁻¹. The second eggplant harvest was similarly affected by halosulfuron rate with reductions in fruit biomass ranging from 39% to 49% (Fig. 3). Fruit biomass from the first two harvests accounted for 56% of the total season harvest in the nontreated control. As with fruit number, the slopes of the regressions for the first two harvest dates were similar for fruit biomass ($t = 0.75$).

At the final harvest, no detectable relationship was observed between fruit number and halosulfuron rate ($P = 0.77$, Fig. 2) or fruit biomass and halosulfuron rate ($P = 0.84$, Fig. 3). While there was significant early season injury, eggplant growth recovered and crop yield was similar among all halosulfuron treatments and the nontreated control. Halosulfuron application resulted in fruit numbers of 105% to 124% of the nontreated control (Fig. 2), while fruit biomass was 103% to 120% of the nontreated control at the final harvest (Fig. 3). The final harvest accounted for 29% of the number of fruit and 26% of the fruit biomass.

When all harvests were summed for the season, inverse linear relationship were observed between fruit number and halosulfuron rate and fruit biomass and halosulfuron rate (Figs. 2 and 3). Reduction in total yield (fruit number and biomass) from halosulfuron was $\leq 4\%$ when halosulfuron was applied at 39 g·ha⁻¹, while halosulfuron at 52 g·ha⁻¹ reduced fruit number 18% and fruit biomass 33%. Previous research indicated that halosulfuron (26, 39, and 52 g·ha⁻¹) applied to the soil surface before transplanting bell pepper did not reduce total season fruit biomass relative to the nontreated control (Culpepper, 2002).

Use of halosulfuron as a pretransplant application will delay eggplant development and maturity. While eggplant yields over the course of the season did recover to levels similar to the nontreated control when halosulfuron was applied at ≤ 39 g·ha⁻¹, the delay in fruit maturity could be a significant factor influencing the utility of this application. In many fresh market commodities, earliness of crop maturity is a crucial factor in determining profitability.

Post-transplant applications of halosulfuron. Differences in plant height ($P = 0.268$) and plant canopy width ($P = 0.562$) could not be detected among halosulfuron treatments applied following eggplant transplant. Maximum reduction in plant height (6%) and canopy width (5%) occurred in the earliest treatment following crop transplant (1 WAT) (data not shown).

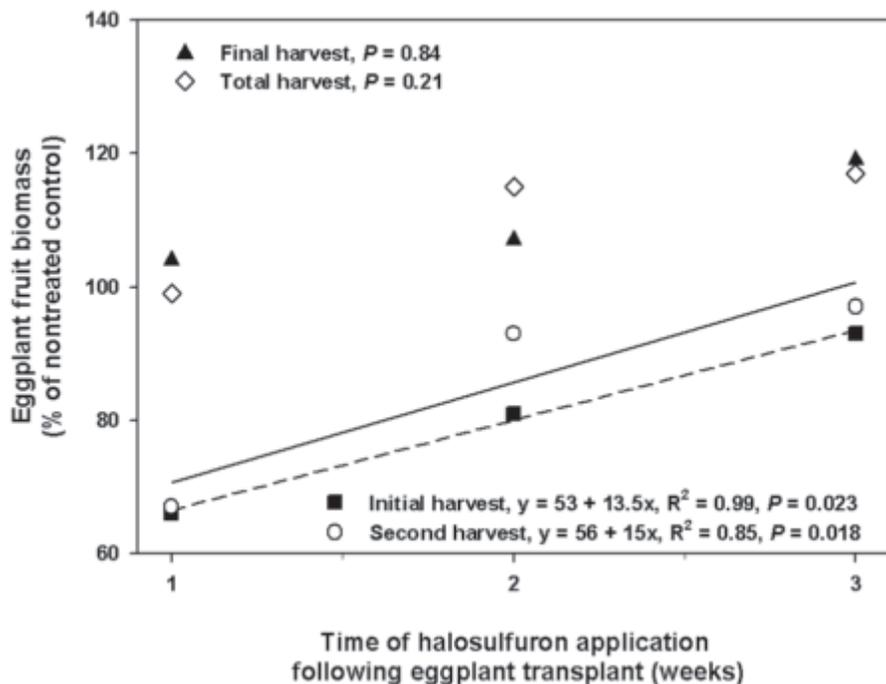


Fig. 5. Eggplant fruit biomass at the first, second, and final harvest and cumulative season harvest when 26 g·ha⁻¹ halosulfuron was applied through drip irrigation 1, 2, and 3 weeks following eggplant transplant. Linear relationships were observed between eggplant fruit biomass and delay halosulfuron application following transplant for initial harvest (dashed line) and second harvest (solid line) ($P < 0.023$). There was no apparent effect of delay in halosulfuron application on eggplant fruit biomass for final harvest ($P = 0.84$) or total harvest ($P = 0.21$), therefore there are no regression for these data.

Linear relationships were observed between delay in time of halosulfuron application following eggplant transplant and fruit number at the first and second harvest (Fig. 4). The slopes of the regression for each harvest were similar ($t \leq 1.1$). When halosulfuron was applied 1 WAT, fruit number in the first and second harvest was reduced 21% and 35%, respectively, relative to the nontreated control. Halosulfuron applied 2 WAT reduced fruit number 18% and 9% at the first harvest and second harvests, respectively. When halosulfuron application was delayed until 3 WAT, reductions in fruit numbers were $\leq 6\%$ for the entire season. No detectable differences in fruit number among treatments were observed for the final harvest and the cumulative season harvest total ($P > 0.420$). Fruit numbers from all post-transplant halosulfuron applications were $\geq 104\%$ of the nontreated control at the final harvest and cumulative season total.

Post-transplant application of halosulfuron reduced eggplant fruit biomass at the initial two harvests (Fig. 5). Linear relationships were observed between fruit biomass and delay in halosulfuron application time. Fruit biomass at the first two harvests was reduced $\geq 33\%$ when halosulfuron was applied 1 WAT, however the cumulative season harvest from this treatment was $\geq 99\%$ of the nontreated control. Halosulfuron applied 2 WAT reduced fruit number at the first harvest 19% relative to the nontreated control, but cumulative harvest at the end of the season yielded 115% of the nontreated control. When applied 3 WAT, eggplant fruit numbers were reduced $\leq 7\%$ at all harvest times. No differences were observed in fruit biomass at the final harvest and cumulative

season harvest among halosulfuron application times ($P \geq 0.211$).

These data indicate that halosulfuron may have a potential use in eggplant when applied through drip irrigation following transplant. While there is a potential benefit for halosulfuron in these cropping systems, many unresolved issues need to be addressed before recommending this use of halosulfuron. The foremost concern is nutsedge efficacy from halosulfuron applied through drip irrigation. Halosulfuron is very effective in controlling nutsedge species when applied topically. However, nutsedge efficacy is reduced when halosulfuron is applied to the soil surface relative to topical applications to foliage. Several crops have been shown to be tolerant of surface applications of halosulfuron, including bell pepper, cantaloupe, cucumber, squash, and tomato (Culpepper, 2002; Haar et al., 2002; Johnson and Mullinix, 2005; Stall, 1999; Webster et al., 2003). Of these, only cantaloupe, cucumber, and tomato have acceptable tolerance (and registration) to topical applications of halosulfuron.

Nutsedge efficacy will be related to the ability of halosulfuron to move across the bed. Lateral water movement within a polyethylene mulch covered bed will be influenced by factors such as duration of irrigation, emitter spacing, flow rate, and water pressure (Csinos et al., 2002). Previous research indicated that lateral water movement on a polyethylene mulch covered bed with a single drip irrigation line was 36.1 cm on the emitter and 30.9 cm between emitters that were spaced 30.8 cm apart (Desaeger et al., 2004). Due to the high water solubility of halosulfuron ($K_w = 1630$

mg·L⁻¹ at pH = 7) (Vencill, 2002), movement of halosulfuron away from the drip irrigation may be sufficient to provide the crop with a nutsedge-free area during crop establishment.

Many of the current proposed alternatives to methyl bromide provide effective suppression of nutsedge growth during the early season. However, nutsedge control will often diminish and become indistinguishable from the nontreated control by the conclusion of the growing season (Gilreath et al., 2004; Webster et al., 2001). Due to poor purple nutsedge control from metham and chloropicrin, the addition of herbicides are recommended for pest management systems in Florida tomatoes (Gilreath et al., 2004). The potential role of halosulfuron may be to provide nutsedge suppression following dissipation of the currently used methyl bromide alternative fumigants (i.e., 1,3-dichloropropene, methyl iodide, chloropicrin, metham). Future studies should evaluate the potential benefit of halosulfuron as a component of methyl bromide alternative systems.

Literature Cited

- Batts, R.B., A.S. Culpepper, and K.L. Lewis. 2001. Evaluation of halosulfuron in bareground watermelon culture. Proc. S. Weed Sci. Soc. 54:78.
- Blum, R.R., J. Isgrigg, and F.H. Yelverton. 2000. Purple (*Cyperus rotundus*) and yellow nutsedge (*Cyperus esculentus*) control in bermudagrass (*Cynodon dactylon*) turf. Weed Technol. 14:357-365.
- Brown, D. and J. Masiunas. 2002. Evaluation of herbicides for pumpkin (*Cucurbita* spp.). Weed Technol. 16:282-292.
- Buker, R.S., B. Rathinasabapathi, G. MacDonald, and S.M. Olson. 2004. Physiological basis for differential tolerance of tomato and pepper to rimsulfuron and halosulfuron: site of action study. Weed Sci. 52:201-205.
- Chase, C.A., T.R. Sinclair, D.G. Shilling, J.P. Gilreath, and S.J. Locascio. 1998. Light effects on rhizome morphogenesis in nutsedges (*Cyperus* spp): implications for control by soil solarization. Weed Sci. 46:575-580.
- Csinos, A.S., J.E. Laska, and S. Childers. 2002. Dye injection for predicting pesticide movement in micro-irrigated polyethylene film mulch beds. Pest Mgt. Sci. 58:381-384.
- Culpepper, A.S. 2002. Pepper response to Sandea (halosulfuron) applied under plastic, precision-directed, and topically, p. 49-50. In: W.T. Kelley (ed.). Proc. 2002 Ga. Veg. Conf., Savannah.
- Derr, J.F., R.S. Chandran, and W.D. Ward. 1996. Pre-emergence and post-emergence yellow nutsedge (*Cyperus esculentus*) control with MON 12000 in nursery crops. Weed Technol. 10:95-99.
- Desaeger, J.A.J., J.E. Eger, Jr., A.S. Csinos, J.P. Gilreath, S.M. Olson, and T.M. Webster. 2004. Movement and biological activity of drip-applied 1,3-dichloropropene and chloropicrin in raised mulched beds in the southeastern USA. Pest Mgt. Sci. 60:1220-1230.
- Dowler, C.C., H.R. Sumner, and A.W. Johnson. 1997. Herbicide efficacy of metham and methyl iodide applied through irrigation systems in Georgia. Proc. Annu. Intl. Res. Conf. Methyl Bromide Alter. Emissions Reductions 41.1-41.2.
- Duniway, J.M. 2002. Status of chemical alternatives to methyl bromide for pre-plant fumigation of soil. Phytopathology 92:1337-1343.
- Earl, H.J., J.A. Ferrell, W.K. Vencill, M.W. van Iersel, and M.A. Czarnota. 2004. Effects of three herbi-

- cides on whole-plant carbon fixation and water use by yellow nutsedge (*Cyperus esculentus*). *Weed Sci.* 52:213–216.
- Fennimore, S.A., M.J. Haar, and H.A. Ajwa. 2003. Weed control in strawberry provided by shank and drip-applied methyl bromide alternative fumigants. *Hortscience* 38:55–61.
- Ferrell, J.A., H.J. Earl, and W.K. Vencill. 2004. Duration of yellow nutsedge (*Cyperus esculentus*) competitiveness after herbicide treatment. *Weed Sci.* 52:24–27.
- Flanders, J.T. and A.S. Culpepper. 2002. Eggplant response to topical and precision-directed applications of Sandea (halosulfuron), p. 51–52. In: W.T. Kelley (ed.). *Proc. 2002 Ga. Veg. Conf., Savannah*.
- Gilreath, J.P. and B.M. Santos. 2004. Efficacy of methyl bromide alternatives on purple nutsedge (*Cyperus rotundus*) control in tomato and pepper. *Weed Technol.* 18:341–345.
- Gilreath, J.P., J.P. Jones, B.M. Santos, and A.J. Overman. 2004. Soil fumigant evaluations for soilborne pest and *Cyperus rotundus* control in fresh market tomato. *Crop Protection* 23:889–893.
- Granberry, D.M. 1990. Commercial eggplant production. *Univ. Ga. Coll. Agr. Environ. Sci. Coop. Ext. Serv. (Athens) Circ.* 812.
- Grichar, W.J., B.A. Besler, and K.D. Brewer. 2003. Purple nutsedge control and potato (*Solanum tuberosum*) tolerance to sulfentrazone and halosulfuron. *Weed Technol.* 17:485–490.
- Gullino, M.L., A. Minuto, G. Gilardi, A. Garibaldi, H. Ajwa, and T. Duafala. 2002. Efficacy of preplant soil fumigation with chloropicrin for tomato production in Italy. *Crop Protection* 21:741–749.
- Haar, M.J., S.A. Fennimore, M.E. McGiffen, W.T. Lanini, and C.E. Bell. 2002. Evaluation of preemergence herbicides in vegetable crops. *Horttechnology* 12:95–99.
- Johnson, III, W.C. and B.G. Mullinix, Jr. 2002. Weed management in watermelon (*Citrullus lanatus*) and cantaloupe (*Cucumis melo*) transplanted on polyethylene-covered seedbeds. *Weed Technol.* 16:860–866.
- Johnson, III, W.C. and B.G. Mullinix, Jr. 2005. Effect of herbicide application method on weed management and crop injury in transplanted cantaloupe (*Cucumis melo*) production. *Weed Technol.* (in press).
- Julian, J.W., G.H. Sullivan, and S.C. Weller. 1998. Assessment of potential impacts from the elimination of methyl bromide in the fruit and vegetable trade. *Hortscience* 33:794–797.
- Kashyap, V., S.V. Kumar, C. Collonnier, F. Fusari, R. Haicour, G.L. Rotino, D. Sihachakr, and M.V. Rajam. 2003. Biotechnology of eggplant. *Scientia Hort.* 97:1–25.
- Leib, B.G., A.R. Jarrett, M.D. Orzolek, and R.O. Mumma. 2000. Drip chemigation of imidacloprid under plastic mulch increased yield and decreased leaching caused by rainfall. *Trans. ASAE* 43:615–622.
- Lowe, D.B., T. Whitwell, S.B. Martin, and L.B. McCarty. 2000. Yellow nutsedge (*Cyperus esculentus*) management and tuber reduction in bermudagrass (*Cynodon dactylon* × *C. transvaalensis*) turf with selected herbicide programs. *Weed Technol.* 14:72–76.
- Majek, B.A. and P.E. Neary. 1991. Selective wavelength transmitting mulch for yellow nutsedge control. *Proc. Brighton Crop Prot. Conf.* 1:263–268.
- Martin, F.N. 2003. Development of alternative strategies for management of soilborne pathogens currently controlled with methyl bromide. *Annu. Rev. Phytopathol.* 41:325–350.
- Molin, W.T., A.A. Maricic, R.A. Khan, and C.F. Mancino. 1999. Effect of MON 12037 on the growth and tuber viability of purple nutsedge (*Cyperus rotundus*). *Weed Technol.* 13:1–5.
- Motis, T.N., S.J. Locascio, and J.P. Gilreath. 2004. Critical yellow nutsedge-free period for polyethylene-mulched bell pepper. *Hortscience* 39:1045–1049.
- Motis, T.N., S.J. Locascio, J.P. Gilreath, and W.M. Stall. 2003. Season-long interference of yellow nutsedge (*Cyperus esculentus*) with polyethylene-mulched bell pepper (*Capsicum annuum*). *Weed Technol.* 17:543–549.
- Nelson, K.A. and K.A. Renner. 2002. Yellow nutsedge (*Cyperus esculentus*) control and tuber production with glyphosate and ALS-inhibiting herbicides. *Weed Technol.* 16:512–519.
- Patterson, D.T. 1998. Suppression of purple nutsedge (*Cyperus rotundus*) with polyethylene film mulch. *Weed Technol.* 12:275–280.
- Ragsdale, N.N. and W.B. Wheeler. 1995. Methyl bromide: risks, benefits, and current status in pest control. *Rev. Pest. Toxicol.* 3:21–44.
- Sargent, S. 1998. Handling Florida vegetables—Eggplant. 12 May 2005. *Fla. Coop. Ext. Serv. Doc. SS-VEC 931*. <http://edis.ifas.ufl.edu/pdffiles/VH/VH08000.pdf>.
- Schonbeck, M.W. 1998. Weed suppression and labor costs associated with organic, plastic, and paper mulches in small-scale vegetable production. *J. Sustainable Agr.* 13:13–33.
- Stall, W.M. 1999. Tolerance of bell pepper to rimsulfuron and halosulfuron. *Proc. S. Weed Sci. Soc.* 52:83.
- U.S. EPA. 2002. Harmonizing the Clean Air Act & Montreal Protocol methyl bromide phaseouts. 29 Nov. 2004. <http://www.epa.gov/spdpublic/mbr/harmoniz.html>.
- USDA–AMS. 1997. United States standards for grades of eggplant. 12 May 2005. <http://www.ams.usda.gov/standards/eggplant.pdf>.
- USDA–NRCS–Soil-Survey Division. 2001. Official soil series descriptions. 1 July 2003. <http://ortho.ftw.nrcs.usda.gov/osd/>.
- Vencill, W.K. 2002. *Herbicide handbook*. 8th ed. Weed Sci, Soc. Amer., Lawrence, Kans.
- Vencill, W.K., J.S. Richburg, J.W. Wilcut, and L.R. Hawf. 1995. Effect of Mon-12037 on purple (*Cyperus rotundus*) and yellow (*Cyperus esculentus*) nutsedge. *Weed Technol.* 9:148–152.
- Wang, D. and S.R. Yates. 1999. Spatial and temporal distributions of 1,3-dichloropropene in soil under drip and shank application and implications for pest control efficacy using concentration-time index. *Pesticide Sci.* 55:154–160.
- Warren, L.S. and H.D. Coble. 1999. Managing purple nutsedge (*Cyperus rotundus*) populations utilizing herbicide strategies and crop rotation sequences. *Weed Technol.* 13:494–503.
- Webster, T.M. 2002. Weed survey - southern states: vegetable, fruit and nut crops subsection. *Proc. S. Weed Sci. Soc.* 55:237–258.
- Webster, T.M. 2005. Mulch type affects growth and tuber production of yellow nutsedge (*Cyperus esculentus*) and purple nutsedge (*Cyperus rotundus*). *Weed Sci.* (in press).
- Webster, T.M. and G.E. MacDonald. 2001. A survey of weeds in various crops in Georgia. *Weed Technol.* 15:771–790.
- Webster, T.M. and A.S. Culpepper. 2005. Halosulfuron has a variable effect on cucurbit growth and yield. *Hortscience* 40(3):707–710.
- Webster, T.M., A.S. Culpepper, and W.C. Johnson. 2003. Response of squash and cucumber cultivars to halosulfuron. *Weed Technol.* 17:173–176.
- Webster, T.M., A.S. Csinos, A.W. Johnson, C.C. Dowler, D.R. Sumner, and R.L. Fery. 2001. Methyl bromide alternatives in a bell pepper-squash rotation. *Crop Protection* 20:605–614.