Weed Technology 2012 26:243–247

Weed Management—Other Crops/Areas

Effect of Drip-Applied Herbicides on Yellow Nutsedge (*Cyperus esculentus*) in Plasticulture

Peter J. Dittmar, David W. Monks, and Katherine M. Jennings*

Greenhouse and field studies were conducted to determine the effect of halosulfuron, imazosulfuron, and trifloxysulfuron applied through drip irrigation on yellow nutsedge. In greenhouse studies, yellow nutsedge control by halosulfuron, imazosulfuron, and trifloxysulfuron was greater (69 to 91%) than the nontreated control (0%). Yellow nutsedge treated with halosulfuron POST had a lower photosynthetic rate (0.6 to 22.6 μmol m^{-2} s^{-1}) at 4, 7, and 14 d after treatment than the nontreated control (3.3 to 26.2 μmol m^{-2} s^{-1}). Yellow nutsedge treated with trifloxysulfuron had lower photosynthetic rate and stomatal conductance than the nontreated plants. In field studies at Clinton, NC, yellow nutsedge density increased from treatment (day 0) to 56 d after treatment in all treatments. Increase in yellow nutsedge density was 72 and 95% in drip-applied halosulfuron and imazosulfuron treatments compared with yellow nutsedge density increases of 876% for the same period in the nontreated plots. Yellow nutsedge density increased 69 and 57% at Clinton and Kinston, NC, respectively, in the drip-applied 15 g ha^{-1} trifloxysulfuron treatment compared with 876% in the nontreated control. In field studies at Clinton and Kinston, NC, suppression of yellow nutsedge emergence in POST and drip-applied herbicide treatments was similar. Emergence of yellow nutsedge was similar in the imazosulfuron POST and the nontreated yellow nutsedge. Based on these studies, drip-applied herbicides may be beneficial as a part of a yellow nutsedge control program, but additional measures, such as a POST herbicide, would be needed for effective control. Drip-applied herbicides may give growers an option for herbicide application after drip irrigation tape and polyethylene mulch have been installed in the current vegetable crops. This application method would also allow herbicide treatment under plastic mulch used for multicropping systems.
Nomenclature: Halosulfuron; imazosulfuron; trifloxysulfuron; yellow nutsedge, *Cyperus esculentus* L.
Key words: Sulfonylurea, herbicide application method, methyl bromide alternatives, drip irrigation.

Se condujeron estudios de invernadero y de campo para determinar el efecto de halosulfuron, imazosulfuron y trifloxysulfuron aplicados a través de irrigación por goteo en *Cyperus esculentus.* En los estudios de invernadero, el control de *C. esculentus* por halosulfuron, imazosulfuron y trifloxysulfuron fue mayor (69 a 91%) que el testigo no tratado (0%). La *C. esculentus* tratada con halosulfuron POST, tuvo una tasa fotosintética menor (0.6 a 22.6 μmol m^{-2} s^{-1}) a 4, 7 y 14 días después del tratamiento (DAT) comparado con el testigo no tratado (3.3 a 26.2 μmol m^{-2} s^{-1}). La *C. esculentus* tratada con trifloxysulfuron tuvo una tasa fotosintética y una conductancia estomática menor que la no tratada. En estudios de campo en Clinton, la densidad de *C. esculentus* se incrementó desde el tratamiento (día 0) hasta 56 DAT, en todos los tratamientos. El incremento en la densidad de *C. esculentus* fue 72 y 95% en tratamientos aplicados por goteo de halosulfuron e imazosulfuron, comparado a los incrementos de densidad de *C. esculentus* de 876% para el mismo período de tiempo pero sin tratar. La densidad de *C. esculentus* se incrementó 69 y 57% en Clinton y Kinston respectivamente, en el tratamiento de 15 g ha^{-1} de trifloxysulfuron aplicado por goteo, comparado a un incremento de 876% en el testigo no tratado. En los estudios de campo de Clinton y Kinston, la supresión de la emergencia de *C. esculentus* en tratamientos de herbicidas POST y en aplicaciones por goteo fue similar. La emergencia de *C. esculentus* fue similar en imazosulfuron POST y la no tratada. Con base en estos estudios, los herbicidas aplicados por goteo pueden ser benéficos como parte del programa de control de *C. esculentus*, pero medidas adicionales tales como un herbicida POST, serían necesarias para un efectivo control. Los herbicidas aplicados por goteo pueden ofrecer a los agricultores una opción de aplicación de los mismos después que la cinta de irrigación por goteo y la cobertera de polietileno, hayan sido instaladas en el cultivo de hortalizas. Este método de aplicación permitiría también usar tratamientos de herbicida bajo cobertera de plástico en sistemas de multi-cultivo.

Vegetable crop production using polyethylene mulch and fertigation increases yield, reduces nutrient leaching, produces a cleaner harvested product, and allows multicropping compared with bare ground (Lamont 1993). Polyethylene mulches provide excellent control of grass and broadleaf weeds; however, these weeds emerge through the crop hole in the mulch. The most troublesome weeds in plasticulture vegetable crops are yellow and purple nutsedge (*Cyperus rotundus* L.), which not only emerge from the hole in the mulch where the crop is transplanted, but can also penetrate through polyethylene mulch (Adcock et al. 2008; Henson and Little 1969; Johnson and Mullinix 2008; Webster 2005).

Plasticulture systems use drip irrigation to deliver water and fertilizer to the root zone of vegetables (Lamont 1993). The wetting front from drip irrigation is U shaped, with vertical movement predominating over lateral water movement (Csinos et al. 2002). The 1,3-dichloropropene plus chloropicrin applied

DOI: 10.1614/WT-D-11-00052.1
* Assistant Professor, Horticultural Sciences Department, University of Florida, Gainesville, FL 32611; Professor and Research Assistant Professor, Department of Horticultural Science, North Carolina State University, Raleigh, NC 27695. Corresponding author's E-mail: pdittmar@ufl.edu

https://doi.org/10.1614/WT-D-11-00052.1 Published online by Cambridge University Press

through drip irrigation gave greater control of the fungi *Phytophthora capsici* and *Rhizoctonia solani* 10 cm below the emitter (vertical movement) than it did 20 cm away from the emitter (10 cm deep)(horizontal movement)(Candole et al. 2007). Chloropicrin EC at 200 L ha^{-1}, and 1,3-dichloropropene plus chloropicrin at 236 to 393 L ha^{-1} applied through drip irrigation provided weed control similar to shank-applied methyl bromide : chloropicrin (67 : 33) mixture (Fennimore et al. 2003). The 1,3-dichloropropene plus chloropicrin and chloropicrin EC applied through drip irrigation in strawberry (*Fragaria* × *ananassa* Duchesne)on bedded rows provided greater control of little mallow (*Malva parviflora* L.) and prostrate knotweed (*Polygonum aviculare* L.) in the center of the bed than at the edges (Fennimore et al. 2003). Thus, drip-applied pesticides have great potential for controlling pests in vegetables grown in plasticulture.

Sulfonylureas are a family of herbicides that includes halosulfuron, imazosulfuron, and trifloxysulfuron, all which give varying levels of suppression or control of nutsedge species. Control of purple and yellow nutsedge is greater when halosulfuron is applied POST than PRE (Adcock et al. 2008). However, Vencill et al. (1995) reported no difference in dry weight of purple and yellow nutsedge shoots and roots when halosulfuron was applied to foliage or soil. Halosulfuron also controlled other broadleaf weeds, including Palmer pigweed (*Amaranthus palmeri* S. Wats.) and tumble pigweed (*Amaranthus albus* L.), eclipta [*Eclipta prostrata* (L.) L.], and cutleaf groundcherry (*Physalis angulata* L.) in watermelon [*Citrullus lanatus* (Thunb.) Matsumura & Nakai var. *lanatus*](Shrefler et al. 2007). Eggplant (*Solanum melongena* L.) height, fruit number, and fruit yield followed an inverse linear relationship to halosulfuron rate (0, 26, 39, and 52 g ai ha^{-1}) applied pretransplant through the drip irrigation (Webster and Culpepper 2005). Total fruit yield from halosulfuron at 26 g ai ha^{-1} applied 1, 2, and 3 wk after transplant was similar to the nontreated check (Webster and Culpepper 2005). Halosulfuron applied POST at 39 g ha^{-1} lowered marketable and average individual fruit weight and vine length compared with the nontreated check (Dittmar et al. 2008).

Imazosulfuron is an experimental herbicide being developed for garden tomato (*Solanum lycopersicum* L.), cayenne pepper (*Capsicum annuum* L.), Irish potato (*Solanum tuberosum* L.), and certain agronomic crops. Imazosulfuron applied directed POST (POST-DIR) at 0.11 and 0.22 kg ai ha^{-1} controlled yellow nutsedge and hairy galinsoga (*Galinsoga quadriradiata* Cav.)(Pekarek 2008). Imazosulfuron applied sequentially at 0.34, 0.45, and 0.56 kg ai ha^{-1} provided $< 92\%$ yellow nutsedge control at 21 d after POST application (Felix and Boydston 2010). Imazosulfuron at 0.1 and 0.2 kg ha^{-1} caused less injury to diploid watermelon when applied at the 30.5-cm vining stage than it did with application at the two- to four-leaf stage (Dittmar et al. 2010).

Trifloxysulfuron is a sulfonylurea herbicide registered for use in cotton (*Gossypium hirsutum* L.), tomato, and sugarcane (*Saccharum officinarum* L.) to control redroot pigweed (*Amaranthus retroflexus* L.), tumble pigweed, yellow nutsedge, and morningglory (*Ipomoea* L. spp.), and provides suppression of purple nutsedge (Anonymous 2009). Trifloxysulfuron at 11.2, 16.8, and 33.4 g ha^{-1} provided 75 to 100% control of redroot pigweed, ivyleaf morningglory (*Ipomoea hederacea* Jacq.) and pitted morningglory (*Ipomoea lacunosa* L.), sicklepod [*Senna obtusifolia* (L.) H.S. Irwin & Barneby], and velvetleaf (*Abutilon theophrasti* Medik.)(Buckelew et al. 2007). Soil application of trifloxysulfuron decreased shoot number, shoot weight, and root weight of purple and yellow nutsedge more than did a foliar application (McElroy et al. 2003). Trifloxysulfuron applied POST at 21 to 63 g ha^{-1} with 0.25% (v/v) nonionic surfactant applied to six-leaf yellow nutsedge reduced fresh weight 91 to 93% of the control (Singh and Singh 2004).

Sulfonylurea herbicide injury in susceptible plants is characterized by chlorosis of new growth. Leaf chlorosis in tomato caused from nitrogen stress caused photosynthesis and stomatal conductance to decrease over time compared with tomato with sufficient nitrogen (Chapin et al. 1988). Black nightshade (*Solanum nigrum* L.) treated with metsulfuron (sulfonylurea herbicide) 16 g ai ha^{-1} had lower photosynthesis than the nontreated check (Riethmuller-Haage 2006). Wine grape (*Vitis vinifera* L.) treated three times with chlorimuron to simulate drift had greater chlorosis and lower photosynthetic rate than did nontreated grape (Bhatti et al. 1998).

Although halosulfuron, imazosulfuron, and trifloxysulfuron have been evaluated PRE and POST for nutsedge control, few studies have evaluated drip-applied sulfonylurea herbicides in plasticulture. The objectives of these studies were to determine the response (photosynthesis, stomatal conductance, and chlorophyll content) and effect on control of yellow nutsedge to drip-applied halosulfuron, imazosulfuron, and trifloxysulfuron under greenhouse and field conditions.

Materials and Methods

Greenhouse Studies 1. Studies were conducted at the Mary Anne Fox Greenhouses at North Carolina State University (Raleigh, NC). Yellow nutsedge tubers were planted, five per pot, into Orangeburg loamy sand (fine-loamy, kaolinitic, thermic Typic Kandiudults) having a pH of 5.7 and 0.27% humic matter, collected from the Horticultural Crops Research Station (Clinton, NC), in 20-cm-wide by 15-cm-deep polyethylene pots (15-cm Azalea Polyethylene Pots, ITML Horticultural Products, 75 Plant Farm Blvd., Brantford, ON N3S 7W2, Canada). Plants were fertilized twice with a 20–20–20 ($N–P_2O_2–K_2O$) fertilizer at 238 ppm nitrogen. Greenhouse temperatures were 24 to 28 C, and plants were exposed to natural sunlight with no artificial lighting. Treatments were arranged in a randomized complete-block design with four replications and three pots per replication. Herbicide treatments were soil-applied halosulfuron at 13, 26, 53, and 80 g ha^{-1}; imazosulfuron at 112, 224, 336, and 504 g ha^{-1}; and trifloxysulfuron at 5, 11, 16, and 24 g ha^{-1}. Quantity of herbicide was based on the area of soil surface and was applied with 3 ml of water equally across the soil surface. Soil-applied treatments were included to determine the effect of herbicides on yellow nutsedge when applied to the root system as occurs with a drip-applied herbicide treatment in the field. The POST treatments of halosulfuron at 26 and 53 g ha^{-1}, imazosulfuron at 224 and

https://doi.org/10.1614/WT-D-11-00052.1 Published online by Cambridge University Press

336 g ha^{-1}, and trifloxysulfuron at 11 and 16 g ha^{-1} were also included. A nonionic surfactant (X-77 [alkylphenol ethoxylate, alcohol ethoxylate, tall oil fatty acid, 2,2′-dihydroxydiethyl ether, and dimethylpolysiloxane], Loveland Products Inc., P.O. Box 1286, Greeley, CO 80632-1286) at 0.25% (v/v) was added to all herbicide spray solutions applied POST. The POST treatments were applied in a spray chamber equipped with an 8002EVS nozzle (8002EVS TeeJet even flat spray tip, TeeJet Technologies, P.O. Box 7900. Wheaton, IL, 61087) calibrated to deliver 167 L ha^{-1} at 276 kPa and 4.8 km h^{-1}. The POST application method is similar to current growers' practices in plasticulture (Kemble 2010). Nontreated plants were included for control comparison.

Yellow nutsedge was treated on May 10, 2008, and June 3, 2010, when plants were 20 to 25 cm tall. Yellow nutsedge control was based on estimates (0% as no control; 100% as complete control)(Frans et al. 1986) at 14 and 21 d after treatment (DAT). Plant height was measured from the soil surface to leaf tip at 14 DAT.

Greenhouse Studies 2. Separate studies were conducted to determine the effect of herbicide treatments on photosynthesis and stomatal conductance of yellow nutsedge. Yellow nutsedge plants were planted and grown similar to plants in the previously described greenhouse studies. Yellow nutsedge was treated August 25, 2010, and October 1, 2010. Herbicide treatments included soil- or POST-applied halosulfuron at 53 g ha^{-1}, imazosulfuron at 336 g ha^{-1}, trifloxysulfuron at 16 g ha^{-1}, and a nontreated check. Herbicide treatments were applied to the yellow nutsedge similar to applications in the previous greenhouse studies.

Photosynthetic rate and stomatal conductance were measured using a LiCor 6400 Portable Photosynthesis System (LI-6400XT portable photosynthesis system, LiCor Biosciences, 4647 Superior St., P.O. Box 4425, Lincoln, NE 68504-0425). The light source was set at 1,500 μmol m^{-2} s^{-1}, and the reference CO_2 was set to 350 μmol. Photosynthetic rate and stomatal conductance were measured on yellow nutsedge at 1, 4, 7, 11, and 14 DAT. Photosynthetic rate and stomatal conductance was measured on the most recently expanded leaf. Soil Plant Analysis Development (SPAD) readings were measured on the most recently expanded leaf for each day during the experiment with a Minolta Chlorophyll Meter SPAD-502 Plus (Minolta chlorophyll meter SPAD-502Plus, Konica Minolta Sensing Americas, Inc., 101 Williams Dr. Ramsey, NJ 07446). Data were analyzed with a general linear model, and means were separated with Duncan's multiple range test ($P \leq 0.10$)(SAS Institute, Inc. , 100 SAS Campus Drive, Cary, NC 27513-2414).

Field Studies. Studies were conducted in 2010 at the Cunningham Research Station (Kinston, NC)(35°1′N, 78°15′W) and at the Horticultural Crops Research Station (35°17′N, 77°34′W) in fields with a history of yellow nutsedge. The field was cultivated three times to prepare the soil for raised beds, and low density polyethylene mulch was laid on beds 13 cm tall and 91 cm wide. Soil was a Norfolk sandy loam (fine loamy, siliceous, thermic, Typic Kandiudults) having a pH of 5.9 and 0.27% humic matter at Kinston, NC, and an Orangeburg loamy sand (fine-loamy, kaolinitic, thermic Typic Kandiudults) having a pH of 5.9 and 0.13% humic matter at Clinton, NC. Treatments were a factorial arrangement of two drip-tape treatments (either one drip tape or two drip tapes) by 12 herbicide treatments and a nontreated check. The two drip tapes were positioned 30 cm apart (each 15 cm off center) in the center of the bed. The treatment with one drip tape was in the center of the bed. Herbicide treatments in the field studies were based on greenhouse studies 1 results. Fewer herbicide treatments were used in the field experiments than were used in greenhouse studies 1 because of field space limitations and the amount of time required for drip applications. Soil-applied halosulfuron at 13, 25, and 53 g ha^{-1}; imazosulfuron at 112, 224, and 336 g ha^{-1}; and trifloxysulfuron at 5, 11, and 16 g ha^{-1} were injected through the drip irrigation. The POST herbicide treatments were applied over the top of yellow nutsedge, which had emerged through the mulch, and included halosulfuron at 24 g ha^{-1}, imazosulfuron at 224 g ha^{-1}, and trifloxysulfuron at 11 g ha^{-1}. All POST treatments included a nonionic surfactant at 0.25% (v/v). The POST treatments were applied with a backpack sprayer equipped with DG8002VS nozzles (DG8002 TeeJet drift guard flat spray tip, TeeJet Technologies) calibrated to deliver 167 L ha^{-1}. Injected herbicides were applied with a tank (EZ-FLO hose and drip system 2.8 L tank, EZ-FLO Fertilizing Systems, 3640 Cincinnati Ave., Buildings C&D, Rocklin, CA 95765) pressurized to 82 kPa. Drip tape was cut at the beginning and end of each plot and capped at the end of the plot with the following setup: across the front of each plot was lay flat tape (Figure 1A) to bring water to each plot; attached to the lay flat tape was a backflow valve (Figure 1B) to prevent the herbicide from entering the water source; water displaced the herbicide solution and the spray dye (Highlight spray indicator, Becker Underwood, Inc., 801 Dayton Ave., Ames, IA 50010) in the injection tanks (Figure 1C); the output tubing (Figure 1D), which was dark colored from the

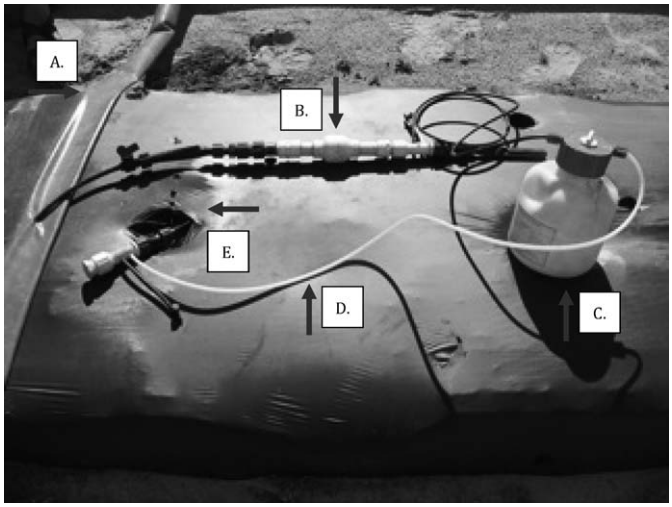


Figure 1. Layout of equipment used for drip-applied herbicide treatments in field studies. Parts are (A) lay flat tape, (B) backflow valve, (C) fertilizer injector tanks, (D) clear tubing, and (E) drip tape.

https://doi.org/10.1614/WT-D-11-00052.1 Published online by Cambridge University Press

Table 1. Effect of halosulfuron, imazosulfuron, and trifloxysulfuron, averaged over rates for POST- and soil-applied treatment of yellow nutsedge control[a] in greenhouse studies, Raleigh, NC.[b]

Herbicide	Placement	Control	
		14 DAT	21 DAT
		%	
Halosulfuron	POST	81 a[c]	87 a
	Soil	78 a	85 a
Imazosulfuron	POST	74 a	82 a
	Soil	69 b	78 a
Trifloxysulfuron	POST	87 a	91 a
	Soil	85 a	90 a

[a] Based on estimates with 0% as no control, and 100% as plant death.

[b] Abbreviation: DAT, days after treatment.

[c] Means within the column by method with the same letter are not statistically different at the $P \leq 0.05$ level using Fisher's Protected LSD.

spray dye, became lighter colored over time; and the output tubing was connected to the drip tape (Figure 1E). When the solution in the transparent output tubing was clear (approximately 45 to 55 min), the tank was disconnected and moved to the next plot. Treatments were applied June 7, 2010, at Kinston, NC, and July 13, 2010, at Clinton, NC, when yellow nutsedge was 8 to 20 cm tall. Yellow nutsedge control was based on estimates (0% as no control; 100% as complete control) at 7, 14, 21, and 56 d DAT, and plants were counted at 0 and 56 DAT to estimate the percentage of increase in population density over time [(*final count* − *initial count*)/*initial count*]. Data were analyzed using ANOVA, and means were compared using Duncan's multiple range test ($P \leq 0.05$).

Results and Discussion

Greenhouse Studies 1. Year and herbicide rate were not significantly different, thus the means of control and plant height were combined. Herbicide type was significantly different and was analyzed and presented separately. All herbicide treatments provided greater control than did the nontreated controls (data not shown). Yellow nutsedge was controlled 69 to 91% by the soil- and POST-applied halosulfuron, imazosulfuron, and trifloxysulfuron treatments (Table 1). At 14 DAT, control from POST and soil applications was similar for halosulfuron and trifloxysulfuron herbicides. But soil-applied imazosulfuron had less control than it did when applied POST. Yellow nutsedge control did not differ between herbicide placement (soil or POST) at 21 DAT. With one exception, similar results were observed 14 DAT. No differences in yellow nutsedge visual control were observed for rate within each herbicide during the study (data not shown).

Greenhouse Studies 2. Yellow nutsedge photosynthetic rate did not differ among treatments at 1, 4, 7, and 11 DAT (data not shown). At 14 DAT, halosulfuron applied POST and soil-applied imazosulfuron decreased photosynthetic rate (22.6 μmol m^{-2} s^{-1} and 22.5 μmol m^{-2} s^{-1}, respectively) compared with the nontreated plants (26.2 μmol m^{-2} s^{-1}, $P \leq 0.1$). Trifloxysulfuron, POST and soil applied, lowered yellow nutsedge photosynthetic rate (23.0 and 22.4 μmol m^{-2} s^{-1}, respectively) compared with the nontreated plants (26.2 μmol m^{-2} s^{-1}).

Table 2. Effect of halosulfuron, imazosulfuron, and trifloxysulfuron applied through the drip-tape irrigation or POST over-the-top on percentage of increase in yellow nutsedge density[a] from 0 to 56 d after herbicide application in North Carolina.

Herbicide	Method	Rate	Yellow nutsedge	
			Clinton	Kinston
		g ha^{-1}	%	
Halosulfuron	Drip	13	78 b[b]	248 b
		26	68 b	297 b
		53	69 b	255 b
	POST	26	62 b	108 b
		0	270 a	876 a
Imazosulfuron	Drip	112	193 ab	366 b
		224	45 b	381 b
		336	48 b	315 b
	POST	224	90 b	981 a
		0	270 a	876 a
Trifloxysulfuron	Drip	5	130 ab	1237 a
		11	133 ab	527 bc
		15	69 b	57 c
	POST	11	115 b	259 bc
		0	270 a	876 ab

[a] *Density* = [(*final count* − *initial count*)/*initial count*].

[b] Letters following numerical values are statistically different based on Duncan's Multiple Range Test ($P \leq 0.05$) within herbicide.

All herbicide-treated and nontreated plants had similar stomatal conductance at 1, 11, and 14 DAT (data not shown). At 4 DAT, plants treated with halosulfuron and imazosulfuron had stomatal conductance (0.04 to 0.09 cm s^{-1}) similar to that of the nontreated plants (0.09 cm s^{-1}, $P \leq 0.1$). However, trifloxysulfuron applied to the soil and POST applied reduced stomatal conductance (0.03 cm s^{-1}) compared with the nontreated check (0.09 cm s^{-1}, $P \leq 0.1$). At 7 DAT, all herbicide treatments reduced stomatal conductance (0.01 to 0.02 cm s^{-1}) compared with the nontreated control (0.04 cm s^{-1}, $P \leq 0.1$).

Chlorophyll content was not different among treatments from 1 to 4 DAT (data not shown). Yellow nutsedge treated with POST halosulfuron had lower chlorophyll content than did the nontreated control at 6 to 14 DAT (data not shown). Halosulfuron applied to the soil had chlorophyll content lower than the nontreated check at 6 DAT and at 10 to 14 DAT. Imazosulfuron and trifloxysulfuron applied to the soil and applied POST had lower chlorophyll content than did the nontreated control at 6 to 14 DAT.

Field Studies. No differences were observed between 1 and 2 drip tapes per planting bed; thus, the data were pooled and analyzed for herbicide effect. Yellow nutsedge emergence and the resulting population density differed between locations, and the data are presented separately.

Drip-applied halosulfuron at all rates resulted in less nutsedge emergence (68 to 78% at Clinton, NC, and 248 to 297% at Kinston, NC) compared with the nontreated check (270% and 876%)(Table 2). The suppression of yellow nutsedge by drip-applied halosulfuron at all rates was similar to that of halosulfuron applied POST. Drip-applied imazosulfuron at the highest two rates suppressed yellow

https://doi.org/10.1614/WT-D-11-00052.1 Published online by Cambridge University Press

nutsedge emergence (45 to 48% and 315 to 381%) compared with the nontreated control (270 and 876%). Imazosulfuron treatment applied POST (981%) had an emergence similar to that of yellow nutsedge in the nontreated check (876%). However, at Clinton, NC, imazosulfuron applied POST (90%) had lower emergence than did the nontreated check (270%). The higher natural population of nutsedge at Kinston, NC, caused no observed difference between imazosulfuron applied POST and the nontreated control. At both locations, the drip-applied trifloxysulfuron at 15 g ha^{-1} suppressed yellow nutsedge growth (69 and 57%) more than the nontreated control (270 and 876%). This control (69 and 57%) was similar to the trifloxysulfuron applied POST at 11 g ha^{-1} (115 and 259%).

In the greenhouse, the application of herbicides, regardless of placement (POST or soil applied), provided 74% yellow nutsedge control. Applying halosulfuron, imazosulfuron, and trifloxysulfuron through drip irrigation reduced the emergence of yellow nutsedge. However, at Kinston, NC, yellow nutsedge emergence was higher in the trifloxysulfuron treatment compared with emergence after halosulfuron and imazosulfuron treatments. Halosulfuron at registered and lower rates provided 72% yellow nutsedge control.

Fennimore et al. (2003) and Candole et al. (2007) reported lowered weed control at distances farther from the drip irrigation emitters; however, those studies used fumigants that stay in the soil for shorter periods. In this study, some yellow nutsedge had emerged and weed counts were over a longer period than in the studies by Fennimore et al. (2003) or Candole et al. (2007). This extended period allowed observation of POST and PRE control of the yellow nutsedge. The application of these herbicides through drip irrigation provides control or suppression to the subterranean parts of the yellow nutsedge, which is important in weed–tomato competition (Morales-Payan et al. 1997).

Photosynthesis of yellow nutsedge was reduced only at 14 DAT when chlorophyll content was lowest and plants were severely chlorotic and had necrotic spots on leaves. Riethmuller-Haage et al. (2006) reported reduced CO_2 fixation when black nightshade was treated with metsulfuron-methyl compared with the nontreated control at 4 DAT of black nightshade and no necrosis. Bhatti et al. (1998) reported reduced leaf photosynthesis and greater chlorosis with three applications of chlorimuron to wine grape compared with one or two applications.

Although drip-applied herbicides would provide some reduction in the emergence of yellow nutsedge, other methods, such as halosulfuron or trifloxysulfuron applied POST, would also need to be included in the weed management system for effective yellow nutsedge control. An application of herbicides through drip irrigation would also be valuable in a plasticulture system that reuses the mulch, such as in multicropping systems.

Literature Cited

Anonymous. 2009. Envoke® herbicide product label. Syngenta Publication No. SCP1132AL1E1210. Greensboro, NC Syngenta Group Company.

Adcock, C. W., W. G. Foshee III., G. R. Wehtje, and C. H. Gilliam. 2008. Herbicide combinations in tomato to prevent nutsedge (*Cyperus esculentus*) punctures in plastic mulch for multi-cropping systems. Weed Technol. 22:136–141.

Bhatti, M. A., A. S. Felsot, R. Parker, and G. Mink. 1998. Leaf photosynthesis, stomatal resistance, and growth of wine grapes (*Vitis vinifera* L.) after exposure to simulated chlorsulfuron drift. J. Environ. Sci. Health, B 33:67–81.

Buckelew, J. K., D. W. Monks, and K. M. Jennings. 2007. Response of transplanted plasticulture tomato to post-directed thifensulfuron and trifloxysulfuron. Pages 142. *in* Proceedings of the 60th Annual Meeting of the Southern Weed Science Society. Champaign, IL: SWSS.

Candole, B. L., A. S. Csinos, and D. Wang. 2007. Concentrations in soil and efficacy of drip-applied 1,3-D + chloropicrin and metam sodium in plastic-mulched sandy soil beds. Crop Prot. 26:1801–1809.

Chapin, F. S. III., C.H.S. Walter, and D. T. Clarkson. 1988. Growth response of barley and tomato to nitrogen stress and its control by abscisic acid, water relations and photosynthesis. Planta 173:352–366.

Csinos, A. S., J. E. Laska, and S. Childers. 2002. Dye injection for predicting pesticide movement in micro-irrigated polyethylene film mulch beds. Pest Manag. Sci. 58:381–384.

Dittmar, P. J., D. W. Monks, J. R. Schultheis, and K. M. Jennings. 2008. Effects of postemergence and postemergence-directed halosulfuron on triploid watermelon (*Citrullus lanatus*). Weed Technol. 22:467–471.

Dittmar, P. J., K. M. Jennings, and D. W. Monks. 2010. Response of diploid watermelon to imazosulfuron POST. Weed Technol. 24:127–129.

Felix, J. and R. A. Boydston. 2010. Evaluation of imazosulfuron for yellow nutsedge (*Cyperus esculentus*) and broadleaf control in potato. Weed Technol. 24:471–477.

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.

Frans, R. E., R. Talbert, D. Marx, and H. Crowley. 1986. Experimental design and techniques for measuring and analyzing plant responses to weed control practices. Pages 37–38. *in* N. D. Camper, ed. Research Methods in Weed Science. 3rd ed. Champaign, IL: Southern Weed Science Society.

Henson, I. E. and C. S. Little. 1969. Penetration of polyethylene film by the shoots of *Cyperus rotundus.* PANS Pest Artic. News Summ. 15:64–66.

Johnson, W. C. III. and B. G. Mullinix Jr.. 2008. Cultural control of yellow nutsedge (*Cyperus esculentus*) in transplanted cantaloupe (*Cucumis melo*) by varying application timing and type of thin-film mulches. Crop Prot. 27:735–739.

Kemble, J. M., ed. 2010. Vegetable Crop Handbook for Southeastern United States—2010. Lincolnshire, IL: Vance Publishing. Pp. 271–272.

Lamont, W. J. Jr. 1993. Plastic mulches for the production of vegetable crops. Horttechnology 3:35–39.

McElroy, S., F. H. Yelverton, S. C. Troxler, and J. W. Wilcut. 2003. Selective exposure of yellow (*Cyperus esculentus*) and purple nutsedge (*Cyperus rotundus*) to postemergence treatments of CGA-362622, imazaquin, and MSMA. Weed Technol. 17:554–559.

Morales-Payan, J. P., B. M. Santos, W. M. Stall, T., and A. Bewick. 1997. Effects of purple nutsedge (*Cyperus rotundus*) on tomato (*Lycopersicon esculentum*) and bell pepper (*Capsicum annuum*) vegetative growth and fruit yield. Weed Technol. 11:762–767.

Pekarek, R. A. 2008. Evaluation of a 'Caliente' Mustard Cover Crop, *S*-Metolachlor, Imazosulfuron, and Thifensulfuron-Methyl for Weed Control in Bell Pepper. M.S. thesis. Raleigh, NC: North Carolina State University. Pp. 110–111.

Riethmuller-Haage, I. L. Bastiaans, J. Harbinson, C. Kempenaar, and M. J. Kropff. 2006. Influence of the acetolactate synthase inhibitor metsulfuron-methyl on the operation, regulation and organization of photosynthesis in *Solanum nigrum*. Photosynth. Res. 88:331–341.

Shrefler, J. W., L. P. Brandenberger, C. L. Webber III., W. Roberts, M. E. Payton, and L. K. Wells. 2007. POST weed control using halosulfuron in direct-seeded watermelon. Weed Technol. 21:851–856.

Singh, S. and M. Singh. 2004. Effect of growth stage on trifloxysulfuron and glyphosate efficacy in twelve weed species of citrus groves. Weed Technol. 18:1031–1036.

Vencill, W. K., J. S. Richburg III., 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.

Webster, T. M. 2005. Mulch type affects growth and tuber production of yellow nutsedge (*Cyperus esculentus*) and purple nutsedge (*Cyperus rotundus*). Weed Sci. 53:834–838.

Webster, T. and A. Culpepper. 2005. Eggplant tolerance to halosulfuron applied through drip irrigation. Hortscience 40:1796–1800.

Received April 13, 2011, and approved November 2, 2011.

https://doi.org/10.1614/WT-D-11-00052.1 Published online by Cambridge University Press