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Herbicide Combinations in Tomato to Prevent Nutsedge (*Cyperus esulentus*) Punctures in Plastic Mulch for Multi-Cropping Systems

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Yellow nutsedge can readily puncture the plastic mulch used in plasticulture tomato production, compromising the benefits of the mulch and hastening its deterioration. Our objective was to identify a PRE-applied (i.e., under the plastic) treatment to minimize yellow nutsedge puncturing. In a greenhouse study a series of halosulfuron rates were PRE-applied to soil planted with yellow nutsedge tubers. These rates were also applied to established plants but with selective spray contact. Nonlinear regression revealed that the concentration of halosulfuron required to reduce dry weights by 90% (GR_{90}) for PRE-applied halosulfuron was 11.6 g/ha. The GR_{90} for POST-applied halosulfuron was 17.1, 28.1, and 11.6 g/ha for foliar-only, soil-only and foliar plus soil spray contact, respectively. Thus halosulfuron was more effective as a POST-applied, foliar-contacting treatment. However, soil activity was deemed likely sufficient to suppress plastic puncturing. In a noncrop field study, suppression of puncturing was influenced ($P < 0.05$) by the rate of both PRE-applied halosulfuron and *S*-metolachlor. A field study with tomato was conducted to evaluate six selective treatments using plastic mulch, PRE-applied *S*-metolachlor, and the combination of PRE or PRE/POST-split applications of halosulfuron. Plastic alone increased tomato yield threefold compared with bare ground. The addition of various herbicide programs neither increased nor reduced yield compared with plastic alone. Selected herbicide treatments did reduce mulch puncturing but not to the extent or duration that would allow sequential crops to receive the full benefit of nonpunctured plastic.

Nomenclature: Halosulfuron; *S*-metolachlor; yellow nutsedge, *Cyperus esculentus* L. CYPES; tomato, *Lycopersicon esculentum* Mill. 'Florida 91'.

Key words: Herbicide combinations, herbicide interactions, polyethylene mulch, sulfonylurea, tank mixtures.

In the southeastern United States, tomatoes are frequently grown with polyethylene mulch stretched over the row. This practice, called plastic mulching or plasticulture, is rapidly becoming the preferred method over the alternative of no plastic mulch, i.e., bare ground culture (Lamont 1993). The merits of plastic mulch include soil warming for earlier planting; increasing and maintaining even soil moisture; preventing soil–foliage contact, which reduces various foliar diseases; sealing of soil fumigant; and preventing soil–fruit contact, resulting in a more marketable product. The merits of plasticulture have been reviewed by several authors (Lamont 1993; Loy et al. 1989; Preece and Read 2005). The use of plasticulture was introduced in the early 1950s (Lamont 1993). Tomatoes, okra (*Abelmoschus esculentus* L. Moench), eggplant (*Solanum melongena* L.), squash (*Cucurbita pepo* L.), and peppers (*Capsicum* spp.) have all shown significant increases in earliness, yield, and quality with use of plastic mulch (Lamont 1993).

Tomato production in the southeast is hampered by several species of broadleaf weeds, and plastic mulch is an effective component in their control (Chase et al. 1998; Patterson 1998). However, many weed species are capable of establishing themselves in the access holes that are punched in the mulch through which tomato seedlings are transplanted (Bonanno 1996). In addition, both yellow and purple nutsedge (*Cyperus rotundus* L.) are capable of piercing plastic mulches (Chase et al. 1998; Johnson and Mullinix 2002; Webster 2005), which hastens its degradation. Ideally, plastic mulch can serve for several cropping cycles, amortizing the cost of the mulch over several crops. Removal, disposal, and replacement of deteriorating mulch can be a significant cost (Preece and Read 2005). Soil fumigation before the laying of the plastic mulch has been an effective means of weed control. However, the fumigant methyl bromide is being cancelled. Thus the need exists to find alternative methods for nutsedge control in plasticulture tomato production with the additional goal of preserving the plastic for multi-cropping cost benefits.

Previous attempts have been made to control sedges in plasticulture with fumigants other than methyl bromide, in combination with various herbicides. Results tend to underscore the need for fumigants in addition to herbicides for efficacy. Johnson and Mullinix (2002) evaluated weed control in watermelon (*Citrullus lanatus* Thunb.) and cantaloupe (*Cucumis melo* L.) grown on polyethylene-covered seedbeds in conjunction with various herbicide programs, including soil fumigation with metham sodium and PRE applications of either ethalfluralin alone (0.8 kg ai/ha) or ethalfluralin plus halosulfuron (0.8 kg ai/ha and 37 g ai/ha, respectively). These authors noted that the plastic mulch itself was effective in controlling weeds, in that none of the dicot and annual grass species present in the test were able to penetrate the plastic mulch. Any infestation of these species was limited to what became established in the crop access holes. However, yellow nutsedge readily penetrated through the plastic mulch. Soil fumigation, with metham-sodium followed by ethalfluralin plus halosulfuron applied PRE, controlled yellow nutsedge at least 89%. But without the metham-sodium application, control was markedly reduced.

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Fumigants are inherently expensive to apply but have the advantage of excellent efficacy, low injury, and no residual carryover to future crops. A control system based exclusively on PRE-applied herbicides that is equal to the fumigant effect may be more cost effective and could be the only alternative if metham-sodium becomes unavailable.

When our study was initiated, *S*-metolachlor and halosulfuron were the only two herbicides that were registered for tomato and were known to have soil-based activity against nutsedge. *S*-Metolachlor can be applied either PPI or PRE (before transplanting). The rate is dependent on soil type and ranges from 1.06 to 2.14 kg ai/ha. The ability of *S*-metolachlor to control sedges has been established in other crops (Grichar 1992; Obrigawitch et al. 1980). However, in tomato plasticulture, little has been published on the use of *S*-metolachlor alone. Santos et al. (2006) and Gilreath and Santos (2004) have published results of combining *S*-metolachlor with potential methyl bromide replacements, such as a combination of 1,3-dichloropropene and chloropicrin. Santos et al. (2006) reported that metolachlor (assumed to be racemic mixture) applied PPI, followed by a shank-injected application of 1,3-dichlorpropene plus chloropicrin, and then followed by a POST application of trifloxysulfuron provided control of *Cyperus* spp. similar to the industry standard, i.e., methyl bromide plus chloropicrin. Gilreath and Santos (2004) reported that purple nutsedge control in plastic-mulched tomatoes was improved with a high rate of metolachlor as compared with 1,3-dichloropropene (83%) or chloropicrin (17%).

When this research was initiated halosulfuron was registered as either a PRE- or POST-directed application at rates up to 39 g ai/ha (in 2005, the maximum rate was raised to 53 g ai/ha). For halosulfuron applied PRE, tomato transplanting had to be delayed until 7 d after application. That delay can be cost prohibitive because it requires an extra trip across the field by workers and is not, therefore, labor efficient. In previous nonreplicated field studies by the authors (unpublished data), transplanting immediately after application of halosulfuron resulted in no detriment to tomato performance when compared with nontreated, plastic-mulched treatments.

Halosulfuron controls yellow nutsedge, and that control is the result of both foliar and soil activity (Blum et al. 2000; Derr et al. 1996; Vencill et al. 1995, Vencill 2002). Based on a greenhouse study, Vencill et al. (1995) reported that POST-applied halosulfuron at 53 g ai/ha was nearly equally effective in controlling yellow nutsedge whether the application was limited to foliar-only, soil-only, or foliar plus soil contact. As previously mentioned, Johnson and Mullinix (2002) demonstrated that PRE-applied halosulfuron did have activity against yellow nutsedge. However, the product label states that PRE applications provide only yellow nutsedge suppression. Thus, we hypothesized that PRE-applied halosulfuron, without the 7-d waiting period, might be beneficial in limiting mulch piercing by yellow nutsedge.

The aforementioned studies have clearly demonstrated that yellow nutsedge control with halosulfuron can be the result of both soil-based and foliar-based activity. However, the halosulfuron rate required to control yellow nutsedge when PRE-applied, as would be the case if applied under plastic mulch, has not been established. Similarly, the rate required when applied POST and limited to foliar-only contact (as would be the case when applied to nutsedge that has pierced through plastic mulch) has not been determined. Therefore, our first objective was to evaluate PRE-applied halosulfuron and POST application with spray contact limited to foliar-only, soil-only, or both, over a series of rates, with the intent of determining the exact rate required for yellow nutsedge control.

We speculated that because both *S*-metolachlor and halosulfuron have soil-based yellow nutsedge activity, combinations may be more effective. Evaluating the efficacy of *S*-metolachlor and halosulfuron combination, applied PRE in a field study with natural yellow nutsedge populations and no confounding presence of a crop, was our second objective. Our third objective was to evaluate selected treatments, using plastic mulch alone and with differing rates of *S*-metolachlor and halosulfuron, with the intent of identifying treatments that would minimize yellow nutsedge–induced damage to the plastic mulch and would, perhaps, allow sequential cropping without any loss of plastic integrity.

Materials and Methods

Yellow Nutsedge Control as a Function of Halosulfuron Rate and Application Type. This study was conducted in a glass-glazed greenhouse, equipped with evaporative cooling. Day/night temperatures were set in the greenhouse to 28/22 C, and photoperiod from natural light at our location averaged 14 to 11 h for May and September, respectively. Total solar radiation for this facility averages 5,200 to 8,000 watts/M^2 during that period. Relative humidity averaged 40 to 50%. Soil used in this study was from the Ap horizon of a Kalmia series. The Kalmia series is a coarse-loamy, siliceous, subactive, Typic Paleudults with 83% sand, 14% silt, and 3% clay. Soil pH was 5.7. Soil was air-dried and sieved to a particle size of $<$ 5 mm. Yellow nutsedge tubers, purchased from a commercial source, were rolled in moist paper towels for approximately 3 d, when the presence of roots and shoots indicated germination. Germinated tubers were planted into 0.95-L Styrofoam cups using the aforementioned soil. Germinated tubers were positioned approximately 2 cm below soil surface. Cup bottoms were perforated to allow drainage. Cups were saturated by hand-watering at 2-d intervals. Plants received no nutrients other than what was available within the soil.

Yellow nutsedge plants used for evaluation of the POST-applied treatments were maintained for approximately 3 wk, at which time plants were well established with foliage of 10 to 20 cm in length. Additional cups were planted with tubers as previously described just before the scheduled application of the PRE-applied treatments. Halosulfuron[1] was applied at a series of 10 rates ranging from 0.18 to 100 g ai/ha. The POST treatments entailed three application methods, i.e., foliar-only, soil-only and foliar plus soil spray contact. The foliar plus soil and the foliar-only applications were applied in an enclosed spray chamber, calibrated to deliver 281 L/ha. In the foliar plus soil application, the spray fell indiscriminately on the foliage or soil surface. Foliar-only application was achieved by applying a 1-cm layer of perlite over the soil surface before treatment. The perlite, which intercepted the herbicide and prevented herbicide–soil contact, was removed within 4 h after application (Wehtje et al. 2006). For the soil-only application, the amount of spray solution that would be intercepted by the soil surface was diluted into 10 ml of water and distributed over the soil surface while avoiding foliar contact. No compensation was made for the quantity that would have been retained by the foliage. This technique has been used previously by the authors to achieve selective spray contact (Wehtje et al. 2006). A nontreated control was also included. Treatments were applied within 6 h of a routine irrigation, and irrigation was not resumed until 48 h after treatment application.

POST-applied and PRE-applied treatments were returned to the greenhouse after application. With the PRE-applied treatments, yellow nutsedge foliage was clipped at the soil surface and the fresh weight determined at 2 wk after treatment. Control was expressed as the percentage of reduction in foliage fresh weight relative to the weight of the nontreated. With the POST-applied treatment, foliage was clipped after 2 wk, and yellow nutsedge was allowed to regrow for an additional 2 wk. At that time, foliage was clipped, weighed, and the control was determined as previously described.

A completely randomized design with four single-cup replicates per treatment was used. The experiment was repeated twice in time. All data were subjected to ANOVA using the general linear models in SAS.[2] Data were pooled over the two repetitions of the experiment because preliminary statistical analysis detected no treatment by repetition interaction. Because the experiment used a series of halosulfuron rates, data were subjected to nonlinear regression in addition to ANOVA. In this case, yellow nutsedge control was regressed against the $\log_{10}$ of the halosulfuron rate using SigmaPlot[3] to determine whether the response could be described by a log–logistic dose–response curve.

The log–logistic dose–response curve, commonly referred to as a sigmoid curve, is typical in dose–response studies, where the dose (i.e., rate) ranges from no effect to complete death (Gad and Wiel 1989; Seefeldt et al. 1995). From that curve, the halosulfuron rates required to produce 90% reduction in fresh weight or growth reduction (GR_{90}) were determined.

***S*-Metolachlor and Halosulfuron Interactions.** This no-crop study was conducted in the summer of 2005 at the E. V. Smith Research Center's Horticultural unit located near Tallassee, AL, on a Marvyn sandy loam (fine-loamy, kaolinitic, thermic Typic Kanhapludults) and repeated later that season at the Wiregrass Research Center located near Headland, AL, on a Dothan sandy loam soil (fine-loamy, kaolinitic, thermic Plinthic Kandiudults). At both locations, the soil, naturally infested with yellow nutsedge, was prepared and shaped into a series of eight parallel beds, approximately 100 m in length. Four of the beds were randomly selected to receive plastic mulch after herbicide treatment applications. The remaining four beds remained as bare ground. Beds were separated into 24 plots, each 3 m long. Treatments consisted of a complete factorial arrangement of *S*-metolachlor[4] applied PRE at 0, 0.28, 0.56, 0.98, 1.12, and 1.40 kg ai/ha and halosulfuron applied at 0, 10, 20, and 40 g ai/ha, yielding 24 treatments. Treatments were applied with a backpack sprayer calibrated to deliver 140 L/ha. The sprayer was equipped with four, 11002 T-Jet flat-fan nozzles[5] spaced evenly on a 2.0-m-wide boom. Treatments were applied perpendicular to the beds. After herbicide application, black, low-density, polyethylene mulch,[6] 0.46 m wide, was laid over the appropriate beds with a commercial bed-layer.[7] Bed preparation, spray application, and laying of plastic mulch were completed on the same day. No crop was planted because the sole object was to evaluate nutsedge control and nutsedge piercing the mulch.

Yellow nutsedge control was evaluated 1 mo after treatment application. First, yellow nutsedge punctures of the plastic mulch within each plot were counted. Secondly, yellow nutsedge foliage was harvested, and the fresh weight was determined from a 1.5-m center section of the plot.

Data were pooled over the two repetitions of the experiment because preliminary statistical analysis detected no treatment by repetition interactions.

Performance of Selected *S*-Metolachlor and Halosulfuron Treatments. Results from the *S*-metolachlor and halosulfuron interaction study (described below) indicated that the greatest reduction in plastic mulch piercing was obtained with PRE-applied combinations of *S*-metolachlor and halosulfuron. However, results from that study also established that halosulfuron is less effective when applied PRE than when applied POST. Thus, we hypothesized that a PRE and POST split application of halosulfuron, in conjunction with PRE-applied *S*-metolachlor, might have merit. Testing this hypothesis was the objective of the following study.

A study was conducted in 2005 and 2006 at E. V. Smith Research Center. Six treatments were evaluated; the first was the nontreated control, i.e., neither plastic mulch nor herbicides. The second treatment was solely plastic mulch. The third treatment was *S*-metolachlor applied PRE (1.40 kg ai/ha) followed by mulch. The fourth treatment was similar to the third but also included POST-applied halosulfuron (53 g ai/ha). The fifth treatment was *S*-metolachlor plus halosulfuron (1.40 kg ai/ha and 53 g ai/ha, respectively) applied PRE, with mulch, and no POST application. The sixth treatment was *S*-metolachlor plus halosulfuron (1.40 kg ai/ha and 26 g ai/ha, respectively) applied PRE, then mulched, and followed by halosulfuron applied POST at 26 g ai/ha. All treatments were applied with a CO_2-pressurized backpack sprayer as described above. Black, low-density, polyethylene mulch was laid over the rows (0.91 m width) with a commercial bed-layer,[8] and drip-tape[9] was used for irrigation. Tomatoes (Florida 91) were grown in the aforementioned greenhouse using procedures in keeping with commercial production. Seedlings were 5 wk old at the time of transplanting and had been hardened off for 7 d as described by Kemble et al. (2004). Fifteen transplants were planted every 0.46 m within the row, with the beds spaced 1.8 m apart. Based on soil analysis and crop nutritional requirements, the site received a broadcast application of 446 kg/ha of 15–0–15 (N–P–K) starter fertilizer (Kemble et al. 2004). Beginning 2 wk after transplanting, tomatoes

Table 1. Growth rate reduction of 90% (GR_{90}) of greenhouse-grown yellow nutsedge treated with selective applications of halosulfuron as determined by non linear regression. Data pooled over two experiment repetitions.

Treatment[a]	GR_{90}	R^2
	g ai/ha	
POST foliar + soil	11.6	0.94
POST foliar	17.1	0.86
POST soil	28.1	0.58
PRE soil	19.2	0.65

[a] Applied to germinating tubers, placed approximately 2 cm below soil surface.

were fertilized weekly using a fertilizer injector[10] with potassium nitrate (KNO_3) alternated with calcium nitrate [$Ca(NO_3)_2$]. Alternating the two fertilizers was done for the duration of the experiment and was scheduled as described by Kemble et al. (2004). During production, suckers were removed, and plants were tied up as needed on 1.2-m wooden stakes placed between every other plant (Kemble et al. 2004). Data collection included fruit weight, grades of marketable fruit (USDA 1991), nutsedge puncture counts, nutsedge biomass weight, and biomass weight of large crabgrass (*Digitaria sanguinalis* L.), pitted morningglory (*Ipomoea lacunose* L.), eclipta (*Eclipta prostrate* L.), and redroot pigweed (*Amaranthus retroflexus* L.). Only the total marketable fruit (totaled over nine pickings) is presented here. Data were pooled over 2005 and 2006 because preliminary statistical analysis detected no treatment by repetition interactions.

Results and Discussion

Yellow Nutsedge Control as a Function of Halosulfuron Rate and Application Type. Control of yellow nutsedge with PRE-applied halosulfuron could be described with the log–logistic dose–response curve (Table 1 and Figure 1). The GR_{90} rate for PRE-applied was 19.2 g ai/ha (Table 1). Yellow nutsedge control with selective POST-applied halosulfuron could also be described with log–logistic dose–response curves. The GR_{90} rates with foliar-only and soil-only POST treatments were 17.1 and 28.1 g ai/ha, respectively. When the POST-applied halosulfuron was allowed to contact both foliage and the soil, the GR_{90} value was only 11.6 g ai/ha (Table 1 and Figure 2). Thus, maximum control with POST-applied halosulfuron requires that the spray contact both the foliage and the soil, with foliar contact being the more important.

Although it has been previously established that halosulfuron has both soil and foliar activity, our data established the GR_{90} for halosulfuron. Furthermore, our work reveals that acceptable yellow nutsedge control can be achieved with a POST application that allows soil contact (GR_{90} = 11.6 g ai/ha). Also, foliar contact alone had greater efficacy (GR_{90} = 17.1 g ai/ha) than soil contact only (GR_{90} = 28.0 g ai/ha). As previously mentioned, halosulfuron is registered as a PRE application (with a 7 d interval until transplant) for nutsedge suppression, and as a POST-directed application for nutsedge control. To optimize the control of yellow nutsedge, we hypothesized that halosulfuron applied PRE immediately after bed preparation might reduce the ability of yellow nutsedge to pierce the plastic.

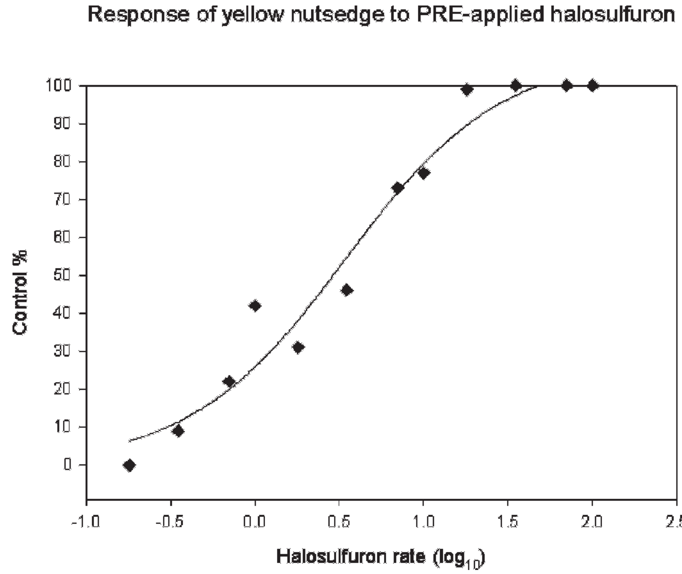

Figure 1. Response of yellow nutsedge to PRE-applied halosulfuron applied to germinating tubers. R^2 = 0.65 and 90% growth rate reduction (GR_{90}) = 19.2.

Johnson and Mullinix (2002) reported that applying halosulfuron PRE, tank mixed with ethalfluralin, did not provide complete plastic mulch protection. Johnson and Mullinix (2005) also reported that yellow nutsedge was not completely controlled (88% control) with PRE applications of halosulfuron at 36 g ai/ha underneath plastic mulch. Thus, PRE applications would likely require additional herbicide if plastic mulch protection is the goal.

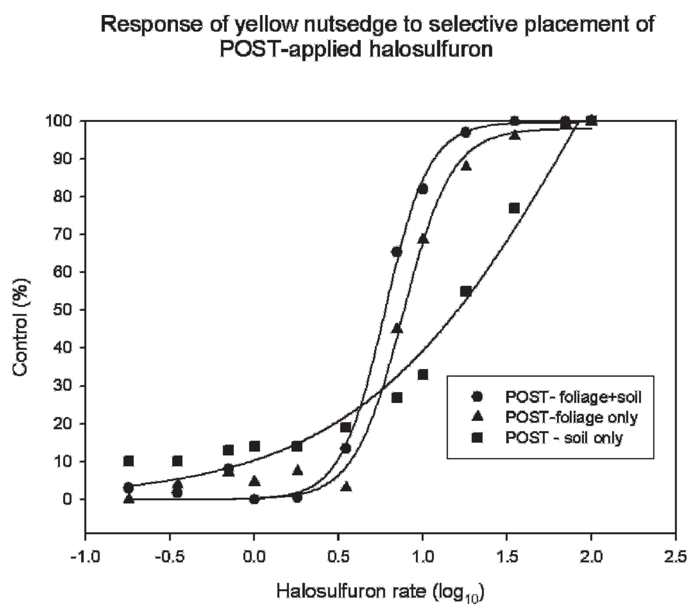

Figure 2. Response of yellow nutsedge to selective placement of POST-applied halosulfuron (foliar-only, soil only, and foliar plus soil). R^2 values for soil plus foliar, foliar-only, and soil-only applications = 0.94, 0.96, and 0.58, respectively. Growth rate reduction of 90% (GR_{90}) values = 11.6, 17.1, and 28.1 g/ha, respectively.

Table 2. Main effects for no-crop study of *S*-metolachlor and halosulfuron when applied PRE as a tank mixture and followed either with or without plastic mulch for yellow nutsedge control.

Herbicide (units of rate)	Rate	Yellow nutsedge foliar biomass		Plastic mulch punctures
		Bare ground	Plastic mulch	
		% control[a,b]		no./m^{2}[b]
S-metolachlor (kg ai/ha)	0	26 c	25 b	39.5 b
	0.28	29 c	31 b	34.6 b
	0.56	31 bc	31 b	38.3 b
	0.84	46 a	35 b	34.6 b
	1.12	43 ab	38 ab	25.9 ab
	1.40	56 a	51 a	13.6 a
Halosulfuron (g ai/ha)	0	28 c	24 b	38.3 b
	10	32 bc	30 b	28.4 ab
	20	43 ab	42 a	29.6 ab
	40	51 a	45 a	24.7 a

[a] Control represents suppression of yellow nutsedge fresh wt relative to the nontreated control, i.e., 65 and 63 g/plot, with and without plastic mulch, respectively. Yellow nutsedge wt averaged over all treatments was 46 and 42 g/plot, with and without plastic mulch, respectively. Yellow nutsedge density averaged 31 plants/m^2 in the bare ground nontreated.

[b] Means within a column followed by the same letter are equivalent according to Fisher's Protect LSD value ($P = 0.05$).

***S*-Metolachlor and Halosulfuron Interactions.** In bare ground and with plastic mulch, both *S*- metolachlor and halosulfuron resulted in a rate-dependent reduction in yellow nutsedge foliage (Table 2). However, neither herbicide applied alone resulted in complete yellow nutsedge control. Although the main effects of both herbicides were significant, the interaction was not ($P = 0.16$ and $P = 0.97$, with and without plastic mulch, respectively). Thus, these two herbicides are additive with respect to their ability to control yellow nutsedge. The most effective individual treatment was a combination of halosulfuron and *S*-metolachlor applied at 40 g ai/ha and 1.4 kg ai/ha, respectively. This treatment reduced yellow nutsedge foliage weight 73 and 59% in the bare ground and mulched plots, respectively. Mulch punctures were reduced 80% (data not shown).

Performance of Selected *S*-Metolachlor and Halosulfuron Treatments. The nontreated control (i.e., neither herbicides nor plastic mulch) became infested with both grass and broadleaf weeds in addition to yellow nutsedge (Table 3). The nontreated tomato yield was the lowest of all treatments evaluated, i.e., 7.1 kg/plot. Complete control of all pertinent weed species other than yellow nutsedge was obtained in the plastic mulch alone treatment (Table 3). However yellow nutsedge proliferated resulting in 133 g/plot of foliage weight and 14.2 punctures/m^2. This increase in yellow nutsedge can likely be attributed to the combined effects of its ability to puncture the mulch, and the lack of competition from other weed species. Yield with plastic mulch alone was 24.1 kg/plot, which represents a greater than threefold increase over the comparable no-mulch treatment. The mulch-induced yield increase we found can likely be attributed to weed control, along with the favorable growing conditions that plastic mulch provides, such as warming the soil, maintaining even soil moisture, and a reduction of soil–foliage contact, which reduces foliar diseases and leads to higher yields and improved vegetable quality (Lamont 1993; Loy et al. 1989; Preece and Read 2005). *S*-Metolachlor applied alone PRE (i.e., under mulch) improved neither yellow nutsedge control nor yield relative to mulch alone. The two treatments in which a tank mixture of *S*-metolachlor and halosulfuron were applied PRE were no more effective than *S*-metolachlor alone (Table 3). The most effective treatment with respect to yellow nutsedge control (foliar biomass) and without yield suppression was *S*-metolachlor alone PRE, followed by halosulfuron applied

Table 3. Performance of selected treatments using plastic mulch, *S*-metolachlor, and halosulfuron on weed control and field grown tomato yields; pooled data from two experimental repeats.

Treatment			Weed foliar biomass				Yellow nutsedge[a]		
PRE-applied herbicides[b]	Plastic mulch	POST-applied herbicides	Large crabgrass	Pitted morningglory	Eclipta	Redroot Pigweed	Foliar biomass	Plastic mulch punctures	Tomato yield
			kg/plot				g/plot	no./m^2	kg/plot
None	No	None	5.36	1.28	1.31	0.21	17 c	n/a[c]	7.1b
None	Yes	None	0	0	0	0	133 ab	14.2 a	24.1 a
S-metolachlor	Yes	None	0	0	0	0	163 a	12.3 a	24.2 a
S-metolachlor	Yes	Halosulfuron 1.0×	0	0	0	0	74 b	10.0 a	18.6 a
S-metolachlor + halosulfuron 1×	Yes	None	0	0	0	0	105 ab	11.9 a	18.5 a
S-metolachlor + halosulfuron 0.5×	Yes	Halosulfuron 0.5×	0	0	0	0	154 a	14.6 a	19.6 a

[a] Means separation ($P \leq 0.05$) by Waller-Duncan. Yellow nutsedge density averaged 12.6 plants/m^2 in all treatments except the nontreated control.

[b] *S*-Metolachlor was applied at 1.40 kg ai/ha; halosulfuron 1×, 53 g ai/ha; 0.5×, 26 g ai/ha.

[c] n/a, not applicable.

POST (Table 3). This treatment reduced yellow nutsedge biomass and plastic punctures 44% and 29%, respectively, compared with plastic mulch alone.

Because of weed control and other previously described factors (Lamont 1993; Loy et al. 1989; Preece and Read 2005), plastic mulch increased tomato yield approximately threefold. Unfortunately, plastic mulch was readily penetrated by yellow nutsedge, and no PRE-applied treatment was identified that reduced nutsedge mulch penetration. None of the herbicide treatments resulted in a yield response (Table 3). Morales-Payan (1999) reported that 25 nutsedge plants/m^2 reduced tomato yield on thin-film plastic by 10%. Our data confirms that work because our average yellow nutsedge density averaged only 12.6 plants/m^2. Our early results, from the determination of the GR_{90} of PRE-applied halosulfuron and from the performance of PRE-applied *S*-metolachlor and halosulfuron tank mixtures in the no-crop field study, led to the hypothesis that these tank mixtures should be effective in limiting puncturing by nutsedge during tomato production and allow for subsequent mulch use. However, results did not completely support our goal of preserving the plastic mulch for multi-cropping purposes. One possible explanation may be the limited soil longevity of these herbicides. The reported soil half life of *S*-metolachlor is 15 to 25 d in southern areas (Humburg 1983). The soil half life of halosulfuron is 4 to 34 d, depending on location and environmental conditions (Vencill 2002). Yellow nutsedge puncturing was evaluated 3 to 4 wk after application in the no-crop field study. However yellow nutsedge control was evaluated midway through tomato harvest (i.e., 16 wk after application) in the crop-included study. Early season, herbicide-based yellow nutsedge control may have dissipated after this length of time. Furthermore, the increased soil surface temperature due to the plastic mulch, combined with soil moisture constantly near field capacity from drip irrigation, may have accelerated herbicide degradation or dissipation. None of the PRE-applied treatments alone were effective in completely preventing yellow nutsedge puncturing. *S*-Metolachlor applied PRE, followed by halosulfuron applied POST was the most effective treatment in reducing plastic puncturing. However, this reduction likely would not allow for multiple subsequent cropping cycles. Alternatives may include thicker or multiple layers of plastic mulch in addition to the aforementioned herbicides.

Sources of Materials

[1] Sandea,® Gowan Company, P.O. Box 5569, Yuma, AZ 85366.

[2] SAS software, Version 9.1. SAS Institute, Inc., P.O. Box 8000, Cary, NC 25712.

[3] Sigma Plot,® Version 9.0. SYSTAT Software Inc., San Jose, CA 95110.

[4] Dual Magnum,® Syngenta Crop Protection, Inc., Greensboro, NC 27409.

[5] Spraying Systems Co., P.O. Box 7900, Wheaton, IL 60189.

[6] Black, low-density, polyethylene mulch (0.038 mm thick), Pliant Corp., Schaumburg, IL 60173.

[7] Reddick Inc., Williamston, NC 27892.

[8] Kennco Inc., Ruskin, FL 35475.

[9] T-Systems International., San Diego, CA 92182.

[10] Dosatron Inc., Clearwater, FL 33765.

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