Weed Technology 2012 26:474–479

Response of Sweetpotato Cultivars to *S*-metolachlor Rate and Application Time

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Studies were conducted in 2008 and 2009 to determine the effect of *S*-metolachlor rate and application time on sweetpotato cultivar injury and storage root shape under conditions of excessive moisture at the time of application. *S*-metolachlor at 1.1, 2.2, or 3.4 kg ai ha^{-1} was applied immediately after transplanting or 2 wk after transplanting (WATP) to 'Beauregard', 'Covington', 'DM02-180', 'Hatteras', and 'Murasaki-29' sweetpotato. One and three d after *S*-metolachlor application plots received 1.9 cm rainfall or irrigation. *S*-metolachlor applied immediately after transplanting resulted in increased sweetpotato stunting 4 and 12 WATP, decreased no. 1 and marketable sweetpotato yields, and decreased storage root length to width ratio compared with the nontreated check. Sweetpotato stunting, no. 1 and marketable yields, and storage root length to width ratio in treatments receiving *S*-metolachlor 2 WATP were similar to the nontreated check. In 2008, Covington and Hatteras stunting 12 WATP was greater at 2.2 and 3.4 kg ha^{-1} (11 to 16%) than 1.1 kg ha^{-1} (1 to 2%). In 2009, *S*-metolachlor at 3.4 kg ha^{-1} was more injurious 4 WATP than 2.2 kg ha^{-1} and 1.1 kg ha^{-1}. While cultivar by treatment interactions did exist, injury, yield, and storage root length to width ratio trends were similar among all cultivars used in this study.

Nomenclature: *S*-metolachlor; sweetpotato, *Ipomoea batatas* L. Lam. 'Beauregard', 'Covington', 'DM02-180', 'Hatteras', and 'Murasaki-29'.

Key words: Crop tolerance, herbicide rate.

En 2008 y 2009, se realizaron estudios para determinar el efecto de la dosis de *S*-metolachlor y el momento de aplicación en el daño y la forma de las raíces de almacenamiento en diferentes cultivares de batata, bajo condiciones de humedad excesiva al momento de la aplicación. El *S*-metolachlor fue aplicado a 1.1, 2.2 ó 3.4 kg ai ha^{-1}, inmediatamente después del trasplante o 2 semanas después del trasplante (WATP) a los cultivares de batata 'Beauregard', 'Covington', 'DM02-180', 'Hatteras' y 'Murasaki-29'. Uno y tres días después de la aplicación de *S*-metolachlor, las parcelas recibieron 1.9 cm de lluvia o riego. El *S*-metolachlor aplicado inmediatamente después del trasplante resultó en un crecimiento limitado 4 y 12 WATP, disminución en el rendimiento de batatas no. 1 y comercializables, y un menor ratio entre el largo y el grosor de la raíz de almacenamiento, comparado con el tratamiento testigo sin aplicación. El crecimiento limitado, los rendimientos no. 1 y comercializable, y el ratio entre largo y grosor de la raíz de almacenamiento en los tratamientos que recibieron *S*-metolachlor 2 WATP fueron similares al testigo no tratado. En 2008, el crecimiento limitado mostrado por Covington y Hatteras 12 WATP fue mayor a 2.2 y 3.4 kg ha^{-1} (11 a 16%) que a 1.1 kg ha^{-1} (1 a 2%). En 2009, el *S*-metolachlor a 3.4 kg ha^{-1} fue mucho más dañino 4 WATP que a 2.2 y 1.1 kg ha^{-1}. Aunque existieron interacciones entre cultivares y tratamientos, las tendencias en daño, rendimiento, y el ratio entre largo y grosor de la raíz de almacenamiento fueron similares entre todos los cultivares usados en este estudio.

More than 40% of sweetpotato ha grown in the U.S. (USDA-NASS 2009) are produced in North Carolina. In 2008, 18,600 ha of marketable sweetpotato roots were harvested in North Carolina, with an average yield of 25,000 kg ha^{-1} and a gross farm value greater than $170 million (NCDA & CS 2009). Palmer amaranth (*Amaranthus palmeri* S. Wats.) is the most common and troublesome weed in North Carolina sweetpotato production (Webster 2010). This upright and branching, annual, herbaceous weed species grows rapidly (Horak and Loughlin 2000; Monks and Oliver 1988) and has the potential to reach heights greater than 2 m (Horak and Loughlin 2000; Meyers et al. 2010a; Norsworthy et al. 2008; Sellers et al. 2003).

North Carolina sweetpotato growers control Palmer amaranth through the use of PRE-applied herbicides, cultivation, mowing, wicking of row middles, and hand removal (Haley and Curtis, unpublished data). Herbicide systems consisting of flumioxazin preplant plus *S*-metolachlor after transplanting provided > 90% residual Palmer amaranth control in 'Beauregard' and 'Covington' sweetpotato (Meyers et al. 2010b). However, some North Carolina sweetpotato growers are reluctant to use *S*-metolachlor, citing concerns of the impact of the herbicide on sweetpotato storage root shape.

S-metolachlor is a soil-applied chloroacetamide herbicide that inhibits the biosynthesis of fatty acids, lipids, proteins, isoprenoids, and flavanoids in susceptible plant species (Senseman 2007). In North Carolina, *S*-metolachlor is registered at 0.8 to 1.1 kg ha^{-1} for sweetpotato by a section 24(c) special local need registration. Haley and Curtis (unpublished data) reported that 22% of North Carolina sweetpotato growers used *S*-metolachlor in 2005. Since that time, *S*-metolachlor use has remained stable (B. Little, Extension Agent, Wilson Co., N.C. Cooperative Extension Service, personal communication).

S-metolachlor is a nonionic compound with a water solubility of 488 mg L^{-1} at 20 C. Soil K_{oc} and K_d values are 21.6 and 0.11 ml g^{-1}, respectively, for sandy soil with 0.9% organic matter, 2.2% clay, and pH 6.5 (Senseman

DOI: 10.1614/WT-D-11-00135.1

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2007). According to the herbicide product label, *S*-metolachlor has the potential to leach through soil under certain conditions (Anonymous 2004). On a Dothan loamy sand, a soil series representative of those used for sweetpotato production, ^{14}C-metolachlor leached farther into the soil profile from time of application to 360 d after application, with the greatest amount of ^{14}C-metolachlor between 0 and 16 cm (Keller and Weber 1995). The authors cite organic matter as the most important soil property influencing metolachlor sorption (Keller and Weber 1995). The product label further warns against excessive rainfall or irrigation near the time of application, stating that no more than 1.2 cm of water should be applied at the first irrigation event (Anonymous 2006). Bollman and Sprague (2008) reported that 4 cm of rainfall within 7 d of *S*-metolachlor application greatly reduced sugarbeet (*Beta vulgaris* L.) plant density. Excessive rainfall also contributed to greater soybean (*Glycine max* (L.) Merr.) injury when excessive rates of metolachlor were applied (Osborne et al. 1995b).

Accounts of the effect of *S*-metolachlor on sweetpotato root shape have been inconclusive. Porter (1994) reported that metolachlor at 2.2 kg ha^{-1} caused some sweetpotato storage roots to be shorter and rounder than roots from the nontreated check and treatments with reduced rates of metolachlor. However, Porter in 1995 reported metolachlor at 1.1, 2.2, and 3.4 kg ha^{-1} showed no evidence of misshapen roots in Beauregard, 'Hernandez', 'Jewel', and 'Darby' sweetpotato. Monks et al. (1998) reported PRE-applied at 1.1 or 2.2 kg ha^{-1} in Beauregard and Jewel sweetpotatoes did not result in shorter roots when compared with the cultivated control.

Shorter, rounder sweetpotato roots have been described as a symptom of chloroacetamide (metolachlor) injury (Clark and Moyer 1988). Osborne et al. (1995a) reported shorter soybean roots in 12 of 32 cultivars grown hydroponically with 83 ppb (w/w) metolachlor, four with $> 20\%$ reduction in length. In sweetpotato, the same symptoms can be associated with drought, excess fertilizer, weed competition, and other stresses (Clark and Moyer 1988). Meyers et al. (2010b) reported that sweetpotato storage root length to width ratio differed slightly over *S*-metolachlor application time. Root length-to-width ratios were 2.1 and 2.2 for treatments containing *S*-metolachlor applied immediately after transplanting and 2 WATP, respectively (Meyers et al. 2010b). However, the study site received a modest amount (0.6 cm) of rainfall and irrigation near the time of application and weeds were not removed from *S*-metolachlor-treated plots. La Bonte et al. (2008) reported variability in root shape of 'Murasaki-29' sweetpotato as a result of soil type and environment. The authors stated that the shape of Murasaki-29 roots was round to elliptic in Louisiana and round, elliptic, to ovoid in California (La Bonte et al. 2008). Shorter, rounder sweetpotato storage roots may result in reduced quality by decreasing the proportion of total sweetpotato yield that can be marketed as no. 1 grade roots (USDA 2005).

Sweetpotato cultivar greatly influences root shape (Yencho et al. 2008) and has been reported to affect sweetpotato herbicide tolerance (Harrison et al. 1985, 1987; Motsenbocker and Monaco 1991, 1993). Differences in cultivar tolerance to *S*-metolachlor or metolachlor have been reported in corn (*Zea mays* L.) (Cottingham et al. 1993), soybean (Osborne et al. 1995a; Osborne et al. 1995b), and sugarbeet (Bollman and Sprague 2008; Bollman et al. 2008).

The objective of this research was to determine the influence of *S*-metolachlor rate and application time on sweetpotato cultivar injury and storage root yield, quality, and shape under excessive moisture conditions near the time of application.

Materials and Methods

Studies were conducted at the Horticultural Crops Research Station (35°1.4010″N, 78°16.7580″W) near Clinton, NC in 2008 and 2009. Transplants were cut from field propagation beds by hand, and fields were transplanted with nonrooted sweetpotato slips on June 6, 2008 and June 10, 2009. Both fields were an Orangeburg loamy sand (fine-loamy, siliceous, thermic Typic Paleudults) with pH 6.1 and $< 1\%$ humic matter. Plot size was five rows, each 106 cm wide and 5.5 m long. The first row of each plot was nontreated and served as a border row; the second through fifth rows were treated and contained one cultivar each of Beauregard, Covington, 'DM02-180', and 'Hatteras' in 2008 and Covington, DM02-180, Hatteras, and Murasaki-29 in 2009. Beauregard, Covington, and Hatteras are rose-skinned, orange-fleshed tablestock varieties (Rolston et al. 1987; Yencho et al. 2008). Murasaki-29 is a dark purple-skinned, white-fleshed specialty-type tablestock variety with greater dry matter content than traditional U.S. tablestock varieties (La Bonte et al. 2008). DM02-180 is a variety grown for high dry matter and used as a feedstock in biofuel production. The experimental design was a randomized complete block with four replications.

Treatments consisted of *S*-metolachlor (Dual Magnum®, 0.9 kg ai L^{-1}, Syngenta Crop Protection, Inc., Greensboro, NC) at 1.1, 2.2, or 3.4 kg ha^{-1} (1, 2, and 3 times the registered rate, respectively) PRE immediately after transplanting (0 WATP) or 2 WATP. A nontreated check was included for comparison. *S*-metolachlor applications 2 WATP occurred immediately after cultivation of the entire study. All plots were maintained weed-free by hand removing emerged weeds weekly. Sethoxydim (Poast®, 0.18 kg ai L^{-1}, BASF Corp, Research Triangle Park, NC.) at 0.34 kg ai ha^{-1} plus 1% v/v crop oil (Agri-Dex, Helena Chemical Co., Collierville, TN) was applied POST to both studies as needed to control goosegrass [*Eleusine indica* (L.) Gaertn.] and large crabgrass [*Digitaria sanguinalis* (L.) Scop.]. Treatments were applied with a CO_2 pressurized backpack sprayer calibrated to deliver 187 L ha^{-1} with DG8002 nozzle tips (Teejet DG 8002, Teejet® Technologies, Springfield, IL) at 260 kPa. To activate the herbicide and move it into the soil, herbicide applications were followed by 1.9 cm irrigation or rainfall 1 and 3 d after application.

Sweetpotato injury above ground was recorded 2, 4, and 12 WATP. These ratings were based on a scale of 0 (no crop injury) to 100% (crop death). Sweetpotato storage roots were harvested 131 and 121 d after transplanting (DATP) in 2008 and 2009, respectively, using a tractor-mounted single row

Table 1. Effect of *S*-metolachlor application time on above ground sweetpotato stunting 4 WATP at Clinton, NC, in 2008.

S-metolachlor application time	Sweetpotato stunting 4 WATP[a,b] in 2008.			
	Beauregard	Covington	DM02-180	Hatteras
WATP	%			
0	15	18	11	20
2	0	0	0	0
LSD (0.05)	9	11	9	11

[a] Abbreviations: WATP, wk after transplanting.
[b] Rating: 0% = no injury; 100% = plant death.

Table 3. Effect of *S*-metolachlor application rate by *S*-metolachlor application time on above ground sweetpotato stunting injury 4 WATP at Clinton, NC, in 2009.

S-metolachlor application rate	Sweetpotato stunting injury by *S*-metolachlor application time 4 WATP[a,b] 2009	
	At transplanting	2 WATP
kg ai ha^{-1}	%	
1.1	0	0
2.2	7	0
3.4	28	0
LSD (0.05)	6	NS

[a] Abbreviations: WATP, wk after transplanting.
[b] Rating: 0% = no injury; 100% = plant death.

chain digger and tablestock cultivars were hand graded into jumbo (> 8.9 cm in diam), no. 1 (> 4.4 cm but < 8.9 cm), and canner (> 2.5 cm but < 4.4 cm) (USDA 2005) and then weighted. Total marketable yield was calculated as the sum of jumbo, no. 1, and canner grades. Twenty no. 1 storage roots were randomly chosen from each plot to determine the influence of treatment on storage root shape. The length and width of each storage root was measured using a digital caliper according to grading standards (USDA 2005) and length to width ratio calculated. DM02-180 was harvested in the same manner, but graded into marketable and cull storage roots where marketable were sound roots and culls were roots exhibiting any degree of rot.

Data were subjected to ANOVA and analyzed by SAS (SAS/STAT® 9.1, SAS Institute Inc., Cary, NC) PROC GLM. Means separation procedures for sweetpotato injury ratings were analyzed using an arcsin transformation. However, untransformed data are presented to facilitate the interpretation of results. Means were separated using *t*-tests with LSD and $P \leq 0.05$. Nontreated checks were included in yield and root length to width ratio analysis. Crop injury data from this treatment were not included in data analysis as crop injury was 0% and had a variance of 0.

Results and Discussion

Sweetpotato Injury. Stunting was the only form of sweetpotato injury observed. Because of treatment by year interaction, injury data were analyzed by year. In addition, because of treatment by cultivar interaction, data were further analyzed by cultivar within year with the exception of stunting 4 WATP in 2009 that was analyzed across cultivars. Sweetpotato stunting 2 WATP ranged from 0 to 2% and 4 to 7% in 2008 and 2009, respectively. However, data did not directly correspond to treatment (data not shown).

2008. In 2008, stunting of all sweetpotato cultivars 4 WATP was strongly associated with *S*-metolachlor application time (Table 1). Treatments receiving *S*-metolachlor immediately after transplanting displayed greater stunting in Beauregard (15%), Covington (18%), DM02-180 (11%), and Hatteras (20%) compared with *S*-metolachlor applied 2 WATP (0% for all cultivars). *S*-metolachlor rate did not correspond to stunting injury 4 WATP. Stunting injury 12 WATP (Table 2) was similar to 4 WATP; the greatest stunting observed in treatments receiving *S*-metolachlor immediately after transplanting to Beauregard (14%), Covington (15%), DM02-180 (7%), and Hatteras (20%) compared with *S*-metolachlor applied 2 WATP (0 to 1%). Covington and Hatteras stunting 12 WATP corresponded to *S*-metolachlor application rate (data not shown). Covington (1, 11, and 11%) and Hatteras (2, 12, and 16%) injury for *S*-metolachlor at 1.1, 2.2, and 3.4 kg ha^{-1}, respectively. For both cultivars, injury was greater for the 2.2 and 3.4 kg ha^{-1} rates than for the 1.1 kg ha^{-1} rate.

2009. Because of *S*-metolachlor rate by application time interaction, stunting 4 WATP was analyzed by *S*-metolachlor application time at each rate and each rate at each application time across all cultivars. Within treatments receiving *S*-metolachlor immediately after transplanting, stunting was greatest at 3.4 kg ha^{-1} (23%), less for 2.2 kg ha^{-1} (6%) and least for 1.1 kg ha^{-1} (0%) (Table 3). Stunting was 0% for all rates of *S*-metolachlor applied 2 WATP. Within treatments receiving *S*-metolachlor at 1.1 kg ha^{-1}, stunting injury (0%)

Table 2. Effect of *S*-metolachlor application time on above ground sweetpotato stunting injury 12 WATP at Clinton, NC, in 2008 and 2009.

S-metolachlor application time	Sweetpotato stunting injury 12 WATP[a,b]							
	Beauregard	Covington		DM02-180		Hatteras		Murasaki-29
	2008	2008	2009	2008	2009	2008	2009	2009
WATP	%							
0	14	15	10	7	1	20	11	0
2	0	1	0	0	0	0	2	0
LSD (0.05)	9	7	8	5	NS	6	6	NS

[a] Abbreviations: WATP, wk after transplanting.
[b] Rating: 0% = no injury; 100% = plant death.

https://doi.org/10.1614/WT-D-11-00135.1 Published online by Cambridge University Press

Table 4. Effect of *S*-metolachlor application time by *S*-metolachlor application rate on above ground sweetpotato stunting injury 4 WATP at Clinton, NC, in 2009.

S-metolachlor application time	Sweetpotato stunting injury by *S*-metolachlor application rate 4 WATP[a,b] 2009		
	1.1 kg ai ha^{-1}	2.2 kg ai ha^{-1}	3.4 kg ai ha^{-1}
WATP	%		
0	0	7	28
2	0	0	0
LSD (0.05)	NS	5	3

[a] Abbreviations: WATP, wk after transplanting.

[b] Rating: 0% = no injury; 100% = plant death.

did not differ by application time (Table 4). Treatments at the 2.2 and 3.4 kg ha^{-1} rates had stunting of 0% for both rates when applied at 2 WATP, but stunting was 7 and 28%, respectively, for applications made immediately after transplanting. Because of cultivar by treatment interaction, stunting 12 WATP was analyzed by cultivar. Stunting 12 WATP differed by *S*-metolachlor application time for Covington and Hatteras (Table 2). For both cultivars, injury was greater when *S*-metolachlor was applied immediately after transplanting compared with 2 WATP. DM02-180 and Murasaki-29 did not differ in injury between application times.

Increased stunting injury to sweetpotato in treatments receiving *S*-metolachlor immediately after transplanting may be explained by increased injury to sweetpotato roots shortly after transplanting. Belehu et al. (2004) reported that sweetpotato slips contain four to ten macroscopic, preformed root primordia per node on leaf bases that have the ability to form adventitious roots within 24 hr. However, damaged preformed root primordia will not give rise to adventitious roots (Belehu et al. 2004), thereby decreasing root development immediately after transplanting and causing reduced growth. Results are similar to those reported by Osborne et al. (1995b) for soybean, who reported that excessive rainfall (15 cm/wk) contributed to increased soybean injury when accompanied by excessive metolachlor rate.

Sweetpotato Yield. Because of the differences in grading of tablestock and feedstock sweetpotato types, DM02-180 was analyzed separately from tablestock varieties across both years. Tablestock cultivars exhibited treatment by year interaction and a lack of cultivar by treatment interaction. Yield of tablestock cultivars was analyzed by year across all cultivars. Application time influenced sweetpotato yield (Table 5). Therefore, the effect of application time was analyzed across all *S*-metolachlor rates.

2008. In 2008, tablestock sweetpotato in the nontreated check yielded 14,380; 30,070; 9,590; and 54,040 kg ha^{-1} of jumbo, no. 1, canner, and marketable roots, respectively (Table 5). Jumbo yield was similar among all *S*-metolachlor application times. Treatments receiving *S*-metolachlor 2 WATP yielded similar no. 1, canner, and marketable sweetpotato roots as the nontreated check. However, plots receiving *S*-metolachlor immediately after transplanting yielded less no. 1, canner, and marketable roots than the nontreated check. This reduction in yield can be attributed to the stunting injury observed in treatments receiving *S*-metolachlor immediately after planting.

2009. In 2009 tablestock of the nontreated check yielded 8,460; 42,890; 10,070; and 61,420 kg ha^{-1} of jumbo, no. 1, canner, and marketable roots, respectively. Jumbo yield (26,050 kg ha^{-1}) was greatest in treatments receiving *S*-metolachlor immediately after transplanting. However, these treatments had lower no. 1, canner, and marketable yields than both the nontreated check and treatments receiving *S*-metolachlor 2 WATP. When combining jumbo and no. 1 yields, *S*-metolachlor immediately after transplanting was similar to both the nontreated check and *S*-metolachlor 2 WATP. These results may be interpreted in two ways: 1) *S*-metolachlor applied immediately after transplanting may have contributed to an increased rate of storage root sizing, thereby increasing the yield of jumbo roots and correspondingly decreasing the yield of no. 1 roots, 2) jumbo storage roots in treatments receiving *S*-metolachlor immediately after transplanting may be comparable to no. 1 storage roots in mass, but have a width that is greater than allowed for no. 1 roots.

Biofuel feedstock sweetpotato cultivar DM02-180 yielded 40,390 and 3,990 kg ha^{-1} of marketable and cull roots, respectively, in the nontreated check. Cull yield was similar among the nontreated check and both *S*-metolachlor application times. Marketable yield for treatments receiving *S*-metolachlor 2 WATP (42,840 kg ha^{-1}) was similar to the nontreated check. Yield of marketable sweetpotato storage roots in treatments receiving *S*-metolachlor immediately after

Table 5. Effect of *S*-metolachlor application time on sweetpotato yield at Clinton, NC, in 2008 and 2009.

S-metolachlor application time	Tablestock sweetpotato yield[a]										DM02-180	
	Jumbo		No. 1		Jumbo + No. 1		Canner		Total marketable[b]			
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	Marketable	Cull
WATP[c]	kg ha^{-1}											
Non-treated check	14,380	8,460	30,070	42,890	44,450	52,350	9,590	10,070	54,040	61,420	40,390	3,990
0	10,880	26,050	14,930	18,480	25,820	44,530	7,300	4,500	33,110	49,030	26,330	3,450
2	12,640	10,710	26,940	42,740	39,580	53,450	9,370	10,200	48,950	63,650	42,840	2,700
LSD (0.05)	NS	5,780	7,580	7,820	11,880	7,650	1,690	1,810	12,050	7,650	7,370	NS

[a] Data combined across Covington, Murasaki-29, Hattaras, DM02-180 in 2008; Covington, Beauregard, Hattaras, and DM02-180 in 2009.

[b] Total marketable is the aggregate of jumbo, no. 1, and canner grads.

[c] Abbreviation: WATP, wk after planting.

Table 6. Effect of S-metolachlor application time on sweetpotato storage root length to width ratio at Clinton, NC, in 2008 and 2009.

S-metolachlor application time	Sweetpotato root length to width ratio[a]	
	2008	2009
WATP[b]		
Non-treated check	2.5	2.5
0	2.1	1.8
2	2.3	2.4
LSD (0.05)	0.2	0.2

[a] Data combined across Covington, Murasaki-29, and Hatteras in 2008; Covington, Beauregard, and Hatteras in 2009.

[b] Abbreviation: WATP, wk after planting.

transplanting (26,330 kg ha^{-1}) was less than both the nontreated check and *S*-metolachlor 2 WATP. Similar to the tablestock cultivars, a reduction in yield of treatments receiving *S*-metolachlor immediately after transplanting was likely the result of injury experienced in these treatments.

Miller et al. (2011) reported a reduction in no. 1 sweetpotato yield in treatments of *S*-metolachlor applied at transplanting compared with 10 DATP. Miller also reported that neither application time (0, 5, and 10 DATP) nor rate (0, 0.8, and 1.5 kg ha^{-1}) of *S*-metolachlor affected marketable sweetpotato yields. The relationship between such findings and the present data are inconclusive. In the current study, no. 1 and marketable yields differed between *S*-metolachlor application times and, to a lesser extent, *S*-metolachlor rate. However, considering the rapid development of sweetpotato roots during early root ontogeny, the differences in application times [(0 and 2 WATP in the current study; 0, 5, and 10 DATP in Miller et al. (2011)] and rates [0, 1.1, 2.2, and 3.4 kg ha^{-1} in the current study; 0, 0.8, and 1.5 kg ha^{-1} in Miller et al. (2011)] makes direct comparisons difficult. The decreased yield in treatments receiving *S*-metolachlor immediately after transplanting can be explained by reports from Villordon et al. (2009) who stated that a high proportion of Beauregard and 'Georgia Jet' storage roots develop from adventitious roots that formed within one wk of transplanting. Injury to developing roots during this period would likely reduce sweetpotato yield.

Sweetpotato Storage Root Length to Width Ratio. Because of treatment by year interaction, and a lack of cultivar by treatment interaction, storage root length to width ratio was analyzed by year across all tablestock cultivars (Beauregard, Covington, and Hatteras in 2008; Covington, Hatteras, and Murasaki-29 in 2009).

2008. In 2008, the sweetpotato storage root length to width ratio of the nontreated check was 2.5 (Table 6). The length to width ratio of storage roots from treatments receiving *S*-metolachlor 2 WATP was lower than the check (2.3). The ratio of storage roots (2.1) from treatments receiving *S*-metolachlor immediately after planting was lower than both the check and 2 WATP. Averaged across *S*-metolachlor application times and rates, sweetpotato storage root length to width ratio was 2.3 for Hatteras, 2.1 for Murasaki-29, and 2.0 for Covington.

2009. In 2009, the sweetpotato storage root length to width ratio of the nontreated check was 2.5. Storage roots from treatments receiving *S*-metolachlor 2 WATP were similar to the nontreated check in length to width ratio (2.4). However, the ratio of no. 1 storage roots from treatments receiving *S*-metolachlor immediately after planting was lower (1.8) than both the check and 2 WATP. Averaged across *S*-metolachlor application times and rates, sweetpotato storage root length to width ratio was 2.3 for Hatteras, 2.2 for Murasaki-29, and 1.8 for Covington.

Result trends were similar to those reported by Meyers et al. (2010b) who found that *S*-metolachlor application time influenced sweetpotato storage root length to width ratio in one of two years and reduced the ratio of 2.2 to 2.1 for treatments receiving *S*-metolachlor 2 WATP and immediately after transplanting, respectively. However, the differences among application times and the nontreated check in the present study are far greater than those reported by Meyers et al. (2010b). Although the length to width ratio in 2008 was greater than 2.0 for all *S*-metolachlor application times, the reduction of this measurement may contribute to less aesthetically pleasing storage roots and storage roots that are less indicative of the particular cultivar being grown. The decrease in storage root aesthetics was more evident in 2009 when sweetpotatoes in treatments receiving *S*-metolachlor immediately after transplanting had a length to width ratio of 1.8. Typical length to width ratios of Beauregard and Covington sweetpotato are 2.5 and 2.0, respectively (Yencho et al. 2008).

A decreased storage root length to width ratio was likely the result of injury to the distal end of the storage root. This end is responsible for longitudinal expansion of the storage root early in root ontogeny (Firon et al. 2009; Wilson and Lowe 1973). After establishment of the storage root, distal root tissues function as normal secondarily thickened roots with normal secondary root structure and complete lignification of the stele (Wilson and Lowe 1973). Decreased root length was reported for 12 of 32 cultivars by Osborne et al. (1995a) in soybean grown in a hydroponic environment containing 83 ppb (w/w) metolachlor.

S-metolachlor application time greatly influenced sweetpotato stunting, yield, and root length to width ratio. Stunting injury 4 WATP for treatments consisting of *S*-metolachlor immediately after transplanting was greater than *S*-metolachlor applied 2 WATP, with the exception of treatments receiving *S*-metolachlor at 1.1 kg ai ha^{-1} in 2009. The trend was similar 12 WATP with the exception of Murasaki-29 and DM02-180 in 2009 that did not differ by application time. The stunting injury contributed to decreased yields in treatments receiving *S*-metolachlor immediately after transplanting, as no. 1 and marketable sweetpotato yields were lower in these treatments compared with both the nontreated check and 2 WATP. Sweetpotato root length to width ratio was also greatly reduced in these treatments. *S*-metolachlor application rate influenced sweetpotato stunting in Covington and Hatteras in 2008 and all varieties in 2009. Sweetpotato plants in treatments receiving *S*-metolachlor at 3.4 kg ha^{-1} were more injured than 1.1 and 2.2 kg ha^{-1}. In 2009 *S*-metolachlor at 1.1 kg ha^{-1} caused no stunting regardless of application time. However, the effect of herbicide rate did not influence yield or root length to width ratio. Under conditions of excessive moisture, application time is an important component of a weed management program that includes *S*-metolachlor. Sweetpotato growers applying *S*-metolachlor on sandy loam or coarser textured soils in N.C. should be aware of weather forecasts consisting of excessive rainfall and avoid applications that immediately precede such rainfall events. More research must be done to determine if an application time between transplanting and 2 WATP would offer a greater opportunity for efficacious weed control while limiting sweetpotato injury, yield loss, and misshapen storage roots. While the effect of cultivar was minimal in this study, continuing to determine sweetpotato cultivar tolerance to new and existing herbicides and application methods should be considered an important part of a weed management system.

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Received September 27, 2011, and approved April 27, 2012.