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Sweetpotato Tolerance and Palmer Amaranth Control with Metribuzin and Oryzalin

Stephen L. Meyers, Katherine M. Jennings, and David W. Monks*

Field studies were conducted in Clinton, NC in 2007 and 2009 to determine sweetpotato crop response and Palmer amaranth control with metribuzin and oryzalin. Treatments consisted of 140 and 202 g ai ha^{-1} metribuzin applied immediately after transplanting [0 wk after transplanting (WAP)] or 2 WAP, 560 and 1121 g ha^{-1} oryzalin 0 WAP, and tank mixes of metribuzin (140 or 202 g ha^{-1}) and oryzalin (560 or 1,121 g ha^{-1}) 0 WAP. At 2 WAP, metribuzin alone applied 0 WAP resulted in greater crop injury (33%) than oryzalin alone (1%), and the tank mix of metribuzin plus oryzalin resulted in greater crop injury (49%) than either herbicide applied alone. Greater crop injury occurred when metribuzin was applied at 202 g ha^{-1} (54%) than 140 g ha^{-1} (34%). Levels of injury were similar at 4 WAP (34, 8, and 52% for metribuzin, oryzalin, and the tank mix, respectively). At 4 WAP, injury from metribuzin was greater when it was applied 0 WAP (34%) compared to 2 WAP (18%). By 10 WAP, injury from metribuzin applied at 2 WAP was only 4%. At 4 WAP, Palmer amaranth control was excellent for all treatments and ≥98%. At 10 WAP, control among treatments ranged from 77% to 85%. Palmer amaranth control provided by metribuzin was similar for applications made 0 WAP (78%) and 2 WAP (77%). Oryzalin alone provided similar control (85%) to metribuzin alone 0 WAP, but greater control than the tank mix (77%). Neither metribuzin nor oryzalin rate differed in weed control provided at 10 WAP. Oryzalin 0 WAP and metribuzin 2 WAP provided no. 1 sweetpotato yields equivalent to the hand-weeded check. No. 1 yields of all other treatments were less than the hand-weeded check but greater than the weedy check.

Nomenclature: Metribuzin; oryzalin; Palmer amaranth, *Amaranthus palmeri* S. Wats.; sweetpotato, *Ipomoea batatas* L. Lam. 'Beauregard' and 'Covington'
Key words: Herbicide tolerance, weed control

In 2015, North Carolina producers planted 35,200 ha of sweetpotatoes with a production value of $331.7 million (NCDA & CS 2016). Production of sweetpotato consists of transplanting 20- to 25-cm non-rooted cuttings (slips) into raised beds 20 to 25 cm tall and 92 to 106 cm apart. In North Carolina, sweetpotato is transplanted from May through June and harvested 3 to 4 months later. Sweetpotato has a decumbent growth habit; therefore, to minimize losses due to interference by weeds, sweetpotato should be maintained weed-free for 2 to 6 wk after transplanting (WAP) (Seem et al. 2003).

Sweetpotato producers control weeds through the use of PRE, cultivation, mowing, and hand removal (J. Haley and J. Curtis, unpublished data). PRE herbicides flumioxazin, clomazone, and *S*-metolachlor can provide excellent residual weed control (Barkley et al. 2016; Meyers et al. 2013a) but require rainfall or irrigation for activation, and weed control can be compromised if the soil surface is disturbed after application. In North Carolina, growers have some reluctance to use *S*-metolachlor because of the possibility of decreased yield and negative effects on storage root shape when herbicide application occurs just after transplanting and followed by moderate to heavy rainfall (Meyers et al. 2010, 2012, 2013a, 2013b; Monks et al. 2013). Although flumioxazin can provide excellent weed control in sweetpotato

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* First, second, and third authors: Graduate Research Assistant, Assistant Professor, and Professor, Department of Horticultural Science, North Carolina State University, Raleigh, NC 27695. Current address of first author: Assistant Professor, North Missisippi Research and Extension Center–Pontotoc Ridge–Flatwoods Branch Experiment Station, Mississippi State University, Pontotoc, MS 38863. Corresponding author's E-mail: stephen.meyers@msstate.edu

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production systems, there are increasing reports of PPO-resistance in North Carolina (W. Everman, personal communication). Currently, growers rely heavily on flumioxazin for weed control in fields dominated by *Amaranthus* spp., including Palmer amaranth. POST herbicides in sweetpotato are limited. Clethodim, fluazifop, and sethoxydim are registered for POST grass control but do not control broadleaf weeds.

Metribuzin provides control of broadleaf weeds including Palmer amaranth when applied PRE. Metribuzin inhibits photosynthesis at photosystem II and is registered for PRE and POST applications in numerous agronomic and horticulture crops including potato (*Solanum tuberosum* L.) (Shaner 2014). Freitas et al. (1998) applied metribuzin at 0, 300, 600, and 900 g ai ha^{-1} and reported that metribuzin application resulted in "no apparent sign of toxicity" to 'Paulista' sweetpotato. Glaze and Hall (1990) also reported little injury (a maximum of 15% in 1 of 4 years) to 'Georgia Jet' sweetpotato from 0.3 to 0.4 kg ha^{-1} metribuzin applied after transplanting. Of 11 herbicides evaluated, metribuzin application provided the greatest weed control but also resulted in decreased marketable yields compared to a hand-weeded check (Glaze and Hall 1990). Harrison et al. (1985) determined the response of six sweetpotato cultivars to metribuzin at 0 to 2.2 kg ha^{-1}. In general, sweetpotato injury increased and yield decreased with increasing application rates of metribuzin. However, when metribuzin was applied at 0.6 kg ha^{-1}, sweetpotato yield in five of six cultivars was similar to the nontreated check (Harrison et al. 1985). 'Caromex' was the most susceptible to metribuzin injury and had yields similar to the nontreated check in 1 of 2 years when metribuzin was applied at 0.6 kg ha^{-1} (Harrison et al. 1985). Meyers et al. (2013a) evaluated herbicide management systems for Palmer amaranth and reported that metribuzin applied at 2 WAP at 140 g ha^{-1} resulted in greater sweetpotato crop injury (20%) but greater weed control in 1 of 2 years, and equivalent no. 1 and total yields to 800 g ha^{-1} *S*-metolachlor, a grower standard.

Oryzalin inhibits the microtubule protein tubulin, thereby disrupting mitosis (Shaner 2014). Its use is limited to fruit and nut crops, vineyards, rights-of-way, Christmas tree plantations, and landscape nurseries (Anonymous 2014). Glaze and Hall (1990) reported that oryzalin at 0.8 kg ha^{-1} did not injure 'Georgia Jet' sweetpotato and provided 69% to 95% weed control over 4 years depending upon environmental conditions and weed species present. Gossett et al. (1992) reported that 0.8 kg ha^{-1} soil-incorporated oryzalin provided 100% control of dinitroaniline–susceptible Palmer amaranth. Therefore, field studies were conducted to determine sweetpotato tolerance and Palmer amaranth control using metribuzin and oryzalin.

Materials and Methods

Field studies were conducted in 2007 and 2009 at the Horticultural Crops Research Station, Clinton, NC. 'Beauregard' sweetpotato slips (non-rooted cuttings) were transplanted into two fields on June 27, 2007. 'Covington' sweetpotato slips were transplanted into a single field on June 5, 2009. All fields were a Norfolk loamy sand (fine-loamy, kaolinitic, thermic Typic Kandiuldults) with pH 5.8 and 1.3% organic matter. Plots consisted of two rows 106 cm wide by 5.5 and 6.1 m long in 2007 and 2009, respectively. Treatments consisted of 140 and 202 g ha^{-1} metribuzin (TriCor 75DF, United Phosphorus, Inc., King of Prussia, PA 19406) applied immediately after transplanting (0 WAP) or 2 WAP, 560 and 1,121 g ha^{-1} oryzalin (Surflan® 4AS, United Phosphorus, Inc., King of Prussia, PA 19406) applied 0 WAP, and tank mixes of metribuzin (140 or 202 g ha^{-1}) with oryzalin (560 or 1,121 g ha^{-1}) applied 0 WAP. Applications were made with a CO_2-pressurized backpack sprayer calibrated to deliver 187 L ha^{-1} at 276 kPa and fitted with two 8002 DG nozzles (Teejet DG 8002, Teejet® Technologies, Wheaton, IL 60187). Weedy and hand-weeded checks were included for comparison. The experimental design was a randomized complete block with four replications.

Data collection included visual sweetpotato crop tolerance and Palmer amaranth control 2, 4, and 10 WAP using a scale of 0 (no crop injury, no weed control) to 100% (crop death, complete weed control) (Frans et al. 1986). Sweetpotato storage roots were harvested 110 ± 5 d after planting with a chain digger and hand-graded into jumbo (≥8.9 cm in diameter), no. 1 (≥4.4 cm but < 8.9 cm), and canner (≥2.5 cm but <4.4 cm) (USDA 2005) and weighed. Total marketable yield was calculated as the sum of jumbo, no. 1, and canner yields.

Each repetition of the study (two locations in 2007, one location in 2009) was treated as an independent environment. Data were subjected to

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ANOVA by SAS Proc GLM (SAS 9.4, SAS Institute, Inc., Cary, NC) with the fixed effect of treatment and random effects of environment and replication within environment. Sweetpotato injury and weed control data were subjected to arcsine transformation. However, nontransformed data are presented. When ANOVA indicated a significant treatment effect, means were separated by Fisher's protected LSD ($P \leq 0.05$). Weedy and hand-weeded check plots were included in analysis for sweetpotato yield. However, because of a lack of variance, these treatments were not included in the analysis of sweetpotato injury and weed control data. Additionally, orthogonal contrasts were constructed to make planned pairwise comparisons of herbicide type, application timing, and rate.

Results and Discussion

Because there was no interaction of environment by treatment, sweetpotato tolerance, Palmer amaranth control, and sweetpotato yield for all grades were pooled across all three environments.

Sweetpotato Tolerance. Injury from metribuzin presented as a general chlorosis followed by necrosis and stunting. At 2 WAP, metribuzin alone applied 0 WAP resulted in greater crop injury (33%) than oryzalin alone (1%), and the tank mix of metribuzin plus oryzalin resulted in greater crop injury (49%) than either herbicide applied alone (Table 1). Levels of injury were similar at 4 WAP (34%, 8%, and 52% for metribuzin, oryzalin, and the tank mix, respectively). At 4 WAP, injury from metribuzin was greater when it was applied 0 WAP (34%) compared to 2 WAP (18%). For all treatments, injury declined by 10 WAP. At 10 WAP, injury from metribuzin or oryzalin applied 0 WAP was similar (8% and 5%, respectively). However, all other injury trends observed at 2 and 4 WAP were maintained. By 10 WAP, injury from metribuzin applied at 2 WAP was 4%.

At 2 WAP, greater crop injury was observed when metribuzin was applied at 202 g ha^{-1} (54%) than at 140 g ha^{-1} (34%) (Table 2). Although injury declined through 10 WAP, the the trend was similar at 4 and 10 WAP. Harrison et al. (1985) and Motsenbocker and Monaco (1993) also observed a metribuzin rate effect on sweetpotato injury. Harrison et al. (1985) reported increasing injury as metribuzin rate increased from 0 to 2.2 kg ha^{-1}. Motsenbocker and Monaco (1993) reported that 2.2 kg ha^{-1} resulted in greater injury than 1.1 kg ha^{-1}. Injury from all metribuzin-containing treatments was $\leq$13% by 10 WAP (Tables 1 and 2). This finding differs somewhat from that of Motsenbocker and Monaco (1993), who reported >30% crop injury at harvest from metribuzin applied immediately after transplanting and 3 WAP; however, the researchers in that study applied a higher rate of metribuzin (1.1 to 2.2 kg ha^{-1}) than that used in the present study. Sweetpotato tolerance did not differ between the two oryzalin rates used in the study.

Table 1. Effect of metribuzin application timing and metribuzin and oryzalin alone and in combination on Palmer amaranth control and sweetpotato injury and yield at Clinton, NC in 2007 and 2009.

Treatment	Crop injury (WAP)[a]			Palmer amaranth control (WAP)		Sweetpotato yield			
Herbicide	2	4	10	4	10	Jumbo	No. 1	Canner	Marketable[b]
	%					kg ha^{-1}			
Metribuzin alone (0 WAP)	33	34	8	100	78	5,130	15,860	6,260	27,250
Metribuzin alone (2 WAP)	–	18	4	99	77	5,730	19,400	6,320	31,450
Oryzalin alone (0 WAP)	1	8	5	98	85	11,150	22,090	5,940	39,180
Oryzalin + metribuzin (0 WAP)	49	52	13	100	77	6,200	15,000	6,250	27,450
Contrast[c]									
Metribuzin 0 WAP vs 2 WAP	–	***	*	NS	NS	NS	NS	NS	NS
Oryzalin vs metribuzin	***	***	NS	NS	NS	***	***	NS	***
Oryzalin alone vs + metribuzin	***	***	***	NS	*	***	***	NS	***
Metribuzin alone vs + oryzalin	***	***	***	NS	NS	NS	NS	NS	NS

[a] Abbreviations: NS, not significant; WAP, week after transplanting.

[b] Marketable is the aggregate of jumbo, no. 1, and canner grades.

[c] Levels of significance: * $P = 0.10$; ** $P = 0.05$; *** $P = 0.01$.

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Table 2. Effect of metribuzin and oryzalin rate on Palmer amaranth control and sweetpotato injury and yield at Clinton, NC in 2007 and 2009.

Treatment	Crop injury (WAP)[a]			Palmer amaranth control (WAP)		Sweetpotato yield			
Herbicide	2	4	10	4	10	Jumbo	No. 1	Canner	Marketable[b]
	%					kg ha^{-1}			
Metribuzin 140 g ha^{-1}	34	25	8	99	77	6,740	17,020	6,790	30,550
Metribuzin 202 g ha^{-1}	54	40	11	100	77	4,890	15,610	5,750	26,250
Oryzalin 560 g ha^{-1}	33	29	10	99	77	7,140	18,010	6,110	31,260
Oryzalin 1,121 g ha^{-1}	33	30	10	99	81	8,550	16,710	6,170	31,430
Contrast[c]									
Metribuzin 140 g vs 202 g	***	***	**	NS	NS	NS	NS	NS	**
Oryzalin 560 g vs 1,121 g	NS	NS	NS	NS	NS	NS	NS	NS	NS

[a] Abbreviations: NS, not significant; WAP, week after transplanting.

[b] Marketable is the aggregate of jumbo, no. 1, and canner grades.

[c] Levels of significance: * $P = 0.10$; ** $P = 0.05$; *** $P = 0.01$.

Palmer Amaranth Control. At 4 WAP, Palmer amaranth control was excellent for all treatments and ≥98% (Tables 1 and 2). At 10 WAP, Palmer amaranth control among treatments ranged from 77% to 85%. Weed control provided by metribuzin was similar for applications made 0 WAP (78%) and 2 WAP (77%) (Table 1). Oryzalin alone provided similar control (85%) to metribuzin alone 0 WAP, but greater control than the tank mix (77%). Neither the metribuzin rate nor the oryzalin rate differed in weed control provided at 10 WAP (Table 2).

Sweetpotato Yield. Sweetpotato yields in the hand-weeded check were 9,230 kg ha^{-1} (jumbo), 24,470 kg ha^{-1} (no. 1), 6,740 kg ha^{-1} (canner), and 40,440 kg ha^{-1} (marketable) (Table 3). Yields in the weedy check were 2,030 kg ha^{-1} (jumbo), 5,490 kg ha^{-1} (no. 1), 4,150 kg ha^{-1} (canner), and 11,670 kg ha^{-1} (marketable). Jumbo yields of all treatments were numerically greater than the hand-weeded check and less than the weedy check, with the exception of the yield with the oryzalin treatment alone, which was numerically greater than that with the hand-weeded check. Oryzalin alone 0 WAP and metribuzin alone 2 WAP provided no. 1 yields equivalent to the hand-weeded check. No. 1 yields with all other treatments were less than the hand-weeded check but greater than the weedy check.

Table 3. Effect of metribuzin and oryzalin treatments on sweetpotato yield at Clinton, NC in 2007 and 2009.

Treatment			Sweetpotato yield			
Herbicide	Rate	Timing	Jumbo	No. 1	Canner	Marketable[b]
	g ai ha^{-1}	WAP[a]	kg ha^{-1}			
Hand-weeded check	–	–	9,230	24,470	6,740	40,440
Weedy check	–	–	2,030	5,490	4,150	11,670
Metribuzin	140	0	5,950	16,710	7,100	29,760
Metribuzin	202	0	4,310	15,010	5,410	24,730
Metribuzin	140	2	5,890	19,250	6,250	31,390
Metribuzin	202	2	5,560	19,550	6,390	31,500
Oryzalin	560	0	11,340	22,630	5,330	39,300
Oryzalin	1121	0	10,960	21,550	6,550	39,060
Metribuzin + oryzalin	140 + 560	0	6,550	16,840	7,360	30,750
Metribuzin + oryzalin	140 + 1,121	0	8,560	15,280	6,440	30,280
Metribuzin + oryzalin	202 + 560	0	3,540	14,570	5,650	23,760
Metribuzin + oryzalin	202 + 1121	0	6,140	13,300	5,530	24,970
LSD ($P \leq 0.05$)			4,730	6,230	NS	7,920

[a] Abbreviations: NS, not significant; WAP, week after transplanting.

[b] Marketable is the aggregate of jumbo, no. 1, and canner grades.

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Canner yield was not influenced by treatment. Oryzalin alone resulted in marketable yields nearly equivalent to the hand-weeded check. All other treatments resulted in marketable yields less than the hand-weeded check but greater than the weedy check.

Oryzalin applied alone 0 WAP resulted in greater jumbo, no. 1, and marketable yields compared to metribuzin alone and the tank mix of metribuzin plus oryzalin (Table 1). Metribuzin applied alone resulted in similar yields whether it was applied 0 or 2 WAP. Similarly metribuzin applied alone 0 WAP resulted in sweetpotato yields similar to the tank mix of metribuzin plus oryzalin. Metribuzin at 140 g ha^{-1} resulted in slightly greater marketable sweetpotato yield (30,550 kg ha^{-1}) than 202 g ha^{-1} (26,250 kg ha^{-1}) (Table 2). Neither metribuzin nor oryzalin rate differed for any other grade of sweetpotato.

Crop tolerance to oryzalin alone was very good, and it provided greater season-long Palmer amaranth control than metribuzin. All metribuzin and oryzalin treatments provided excellent early-season Palmer amaranth control (≥97% at 4 WAP). However, neither metribuzin alone, oryzalin alone, nor their combination provided acceptable season-long Palmer amaranth control. This result is not unexpected. Meyers et al. (2013a) reported that a single herbicide application timing provided less Palmer amaranth control than multiple application timings. It is plausible that oryzalin and metribuzin would be useful in a sweetpotato weed management system. However, to limit sweetpotato injury, metribuzin should be applied at 140 g ha^{-1} and delayed until at least 2 WAP.

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