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Fomesafen Programs for Palmer Amaranth (*Amaranthus palmeri*) Control in Sweetpotato

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Studies were conducted in 2012 and 2013 to determine the effect of fomesafen based Palmer amaranth control program in 'Covington' and 'Evangeline' sweetpotato cultivars. Treatments consisted of fomesafen pretransplant alone at 0.20, 0.28, 0.36, 0.42, 0.56, and 0.84 kg ai ha^{-1} or followed by (fb) *S*-metolachlor at 1.12 kg ai ha^{-1} 0 to 7 d after transplanting (DAP), fomesafen at 0.28 kg ha^{-1} fb *S*-metolachlor at 1.12 kg ha^{-1}14 DAP, flumioxazin pretransplant at 0.105 kg ai ha^{-1}, *S*-metolachlor at 1.12 kg ha^{-1} 0 to 7 DAP, clomazone at 0.63 kg ha^{-1} 0 to 7 DAP, napropamide at 2.24 kg ha^{-1} 0 to7 DAP, flumioxazin fb *S*-metolachlor 0 to 7 DAP, and flumioxazin fb clomazone fb *S*-metolachlor 14 DAP. Fomesafen pretransplant at 0.28 to 0.84 kg ha^{-1} alone or followed by *S*-metolachlor at 1.12 kg ha^{-1} 0 to 7 DAP provided 80 to 100% Palmer amaranth control without reduction of yield and significant (< 13%) injury in Covington and Evangeline sweetpotato. Flumioxazin alone or fb *S*-metolachlor and flumioxazin fb clomazone fb *S*-metolachlor provided Palmer amaranth control (≥ 95%) with little injury (≤ 5%) and similar yield to the weed-free check. Clomazone alone did not cause injury, but controlled only 24 to 32% of Palmer amaranth at 50 DAP, which resulted in reduced no. 1, marketable, and total sweetpotato yield. Napropamide provided inconsistent control of Palmer amaranth in both years; therefore jumbo and total sweetpotato yield was reduced as compared to the weed-free check in 2012. Palmer amaranth control, sweetpotato cultivar tolerance, and yield in treatments with fomesafen fb *S*-metolachlor were similar to flumioxazin fb *S*-metolachlor. In conclusion, a herbicide program consisting of pretransplant fomesafen (0.28 to 0.42 kg ha^{-1}) fb *S*-metolachlor (1.12 kg ha^{-1}) is a potential option to control Palmer amaranth without causing significant injury and yield reduction in sweetpotato.

Nomenclature: Clomazone; flumioxazin; fomesafen; *S*-metolachlor; napropamide; Palmer amaranth, *Amaranthus palmeri* S. Wats.; sweetpotato, *Ipomoea batatas* (L.) Lam. 'Covington', 'Evangeline'.

Key words: Application rate, crop tolerance, herbicide, weed control.

En 2012 y 2013, se realizaron estudios para determinar el efecto de programas de control de *Amaranthus palmeri* basados en el uso de fomesafen sobre los cultivares de batata 'Covington' y 'Evangeline'. Los tratamientos consistieron de fomesafen solo en pre-trasplante a 0.20, 0.28, 0.36, 0.42, 0.56, y 0.84 kg ai ha^{-1} o seguido por (fb) *S*-metolachlor a 1.12 kg ai ha^{-1} 0 a 7 d después del trasplante (DAP), fomesafen a 0.28 kg ha^{-1} fb *S*-metolachlor a 1.12 kg ha^{-1} 14 DAP, flumioxazin en pre-trasplante a 0.105 kg ai ha^{-1}, *S*-metolachlor a 1.12 kg ha^{-1} 0 a 7 DAP, clomazone a 0.63 kg ha^{-1} 0 a 7 DAP, napropamide a 2.24 kg ha^{-1} 0 a 7 DAP, flumioxazin fb *S*-metolachlor 0 a 7 DAP, y flumioxazin fb clomazone fb *S*-metolachlor 14 DAP. Fomesafen solo en pre-trasplante de 0.28 a 0.84 kg ha^{-1} o seguido por *S*-metolachlor a 1.12 kg ha^{-1} 0 a 7 DAP brindó 80 a 100% de control de *A. palmeri* sin reducir el rendimiento ni causar daño significativo (<13%) en batata Covington y Evangeline. Flumioxazin solo o fb *S*-metolachlor y flumioxazin fb clomazone fb *S*-metolachlor controlaron *A. palmeri* (≥95%), causaron poco daño (≤5%), y el rendimiento fue similar al testigo libre de malezas. Clomazone solo no causó daño, pero el control de *A. palmeri* fue sólo 24 a 32% a 50 DAP, lo que resultó en un rendimiento reducido de batata no. 1, comercializable, y total. Napropamide brindó un control inconsistente de *A. palmeri* en ambos año, por lo que el rendimiento de la batata jumbo y total fue reducido al compararse con el testigo libre de malezas en 2012. El control de *A. palmeri*, la tolerancia de los cultivares de batata, y el rendimiento en tratamientos con fomesafen fb *S*-metolachlor fueron similares a flumioxazin fb *S*-metolachlor. En conclusión, un programa de herbicidas que consista de fomesafen en pre-

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trasplante (0.28 a 0.42 kg ha^{-1}) fb *S*-metolachlor (1.12 kg ha) es una opción potencial para el control de *A. palmeri* sin causar daño significativo ni reducciones en el rendimiento de la batata.

Sweetpotato is a valuable commodity in the United States and was worth over $698 million gross farm value in 2014 (USDA 2015a) with North Carolina, California, Mississippi, and Louisiana farmers planting over 89% of the production area (USDA 2015b). North Carolina alone planted approximately 29,000 ha which was worth over $354 million gross farm value (USDA 2015a,b). Sweetpotato yield, quality, and subsequent value can be negatively affected by weeds (Meyers et al. 2010a; Seem et al. 2003). Palmer amaranth (*Amaranthus palmeri* S. Wats.) and yellow nutsedge (*Cyperus esculentus* L.) are two of the most common and troublesome weeds in sweetpotato grown in North Carolina (Webster 2010). The North Carolina Sweet Potato Commission, consisting of sweetpotato farmers, has identified development of new herbicides for Palmer amaranth and yellow nutsedge management as critical to the success of their strategic plan (S. Langdon, personal communication).

Palmer amaranth is an annual, herbaceous weed that has an upright, branching habit. Some of the characteristics that contribute to its competiveness are its C_4 photosynthetic mechanism, rapid growth at high temperatures, and high water-use efficiency (Guo and Al-Khatib 2003; Horak and Loughlin 2000). Palmer amaranth can grow over 5 cm in 1 d (Horak and Loughlin 2000) and can grow over 2 m tall in one growing season (Horak and Loughlin 2000; Meyers et al. 2010a; Sellers et al. 2003). Competition of this weed with vegetable crops has been well documented. Meyers et al. (2010a) reported that season-long interference of Palmer amaranth in 'Beauregard' and 'Covington' sweetpotato reduced total marketable yield 36 to 81% at densities of 0.5 to 6.5 Palmer amaranth plants m^{-1} of crop row.

Commercial sweetpotato growers control Palmer amaranth with herbicides, cultivation, mowing, wicking, and hand removal. According to a survey conducted in North Carolina in 2006, 95% of growers cultivate sweetpotato fields an average of three times per growing season (J. Haley and J. Curtis, unpublished data). However, due to the prostrate growth habit of sweetpotato, crop canopy closure limits cultivation by midseason. Approximately 33% of growers mow late-emerging Palmer amaranth; however, this method encourages lateral growth and increased vegetative growth of Palmer amaranth above the sweetpotato canopy and shades the crop (Meyers et al. 2010a). Herbicide-wicking of weeds in row middles consists of applying concentrated glyphosate solution directly to target weeds (Anonymous 2009; Keeley et al. 1984). However, weeds must be above the sweetpotato canopy and in direct contact of the wick for the herbicide to have its desired effect. Also, due to the increased occurrence of glyphosate-resistant Palmer amaranth populations in the southeastern United States, the use of glyphosate might not be advisable (Culpepper et al. 2006; Norsworthy et al. 2008). Hand hoeing or weeding is used by 62% of growers an average of 1.4 times per growing season (J. Haley and J. Curtis, unpublished data). Growers estimate hand removal of weeds cost approximately $105

Table 1. Sources of herbicides used in this study.

Common name	Trade name	Rates	Manufacturer
		kg ai ha^{-1}	
Fomesafen	Reflex	0.20, 0.28, 0.36, 0.42, 0.56, 0.84	Syngenta Crop Protection, Inc., Greensboro, NC; http://www.syngentacropprotection-us.com
S-metoalachlor	Dual Magnum	1.12	Syngenta Crop Protection, Inc., Greensboro, NC; http://www.syngentacropprotection-us.com
Flumioxazin	Valor SX	0.105	Valent U.S.A. Corp., Walnut Creek, CA; http://www.valent.com
Clomazone	Command 3ME	0.63	FMC Corp., Philadelphia, PA; http://www.fmccrop.com
Napropamide	Devrinol 50DF	2.24	United Phosphorous Inc., Trenton, NJ; http://www.upi-usa.com

Table 2. Herbicide treatments applied to 'Covington' and 'Evangeline' sweetpotato at Clinton, NC in 2012 and 2013.[a]

Trt no.	Herbicide	Rate	Application timing
		kg ai ha^{-1}	
1	Weed-free	—	—
2	Weedy	—	—
3	Fomesafen	0.20	Pretran
4	Fomesafen	0.28	Pretran
5	Fomesafen	0.36	Pretran
6	Fomesafen	0.42	Pretran
7	Fomesafen	0.56	Pretran
8	Fomesafen	0.84	Pretran
9	Fomesafen fb *S*-metolachlor	0.20 fb 1.12	Pretran fb 0 to 7 DAP
10	Fomesafen fb *S*-metolachlor	0.28 fb 1.12	Pretran fb 0 to 7 DAP
11	Fomesafen fb *S*-metolachlor	0.36 fb 1.12	Pretran fb 0 to 7 DAP
12	Fomesafen fb *S*-metolachlor	0.42 fb 1.12	Pretran fb 0 to 7 DAP
13	Fomesafen fb *S*-metolachlor	0.56 fb 1.12	Pretran fb 0 to 7 DAP
14	Fomesafen fb *S*-metolachlor	0.84 fb 1.12	Pretran fb 0 to 7 DAP
15	Fomesafen fb *S*-metolachlor	0.28 fb 1.12	Pretran fb 14 DAP
16	Flumioxazin	0.105	Pretran
17	Flumioxazin fb *S*-metolachlor	0.105 fb 1.12	Pretran fb 0 to 7 DAP
18	*S*-metolachlor	1.12	0 to 7 DAP
19	Flumioxazin fb clomazone fb *S*-metolachlor	0.105 fb 0.63 fb 1.12	Pretran fb 0 to 7 DAP fb 14 DAP
20	Clomazone	0.63	0 to 7 DAP
21	Napropamide	2.24	0 to 7 DAP

[a] Abbreviations: DAP, days after transplanting; fb, followed by; Pretran, pretransplant.

ha^{-1} or more, depending on severity of weed populations (J. Jones, Jones Farm, personal communication). However, Palmer amaranth, even when pulled, can re-establish when moisture is present. Thus some growers prefer to remove these plants from the field after pulling, which increases the cost of hand weeding. Weed control methods that allow even moderate growth of this weed will increase problems associated with this weed in the following growing season.

Clomazone, DCPA, flumioxazin, glyphosate, *S*-metolachlor, napropamide, carfentrazone-ethyl, clethodim, fluazifop, and sethoxydim are registered for application in sweetpotato in North Carolina. Flumioxazin pretransplant fb *S*-metolachlor is the standard herbicide system used by North Carolina growers and provides at least 90% residual Palmer amaranth control (Meyers et al. 2010b, 2013b). However, both herbicides require rainfall or irrigation for activation, and weed control can be compromised if the soil surface is disturbed after application or if a rainfall event does not occur before weeds germinate (Anonymous 2010, 2014).

The investigation of other potential herbicides for control of Palmer amaranth in sweetpotato is important due to the limited number of registered herbicides (Kemble 2013). Fomesafen is a soil-applied PRE and POST protoporphyrinogen oxidase (PPO) inhibitor that is not currently registered for use in sweetpotato. Peachey et al. (2012) found that fomesafen PRE at 0.28 kg ha^{-1} provided 92 to 100% control of redroot pigweed (*Amaranthus retroflexus* L.), Powell amaranth (*Amaranthus powellii* S. Wats.), and velvetleaf (*Abutilon theophrasti* Medik.) in cucurbits. Duff et al. (2008) reported *S*-metolachlor plus fomesafen provided inconsistent control of common waterhemp (*Amaranthus rudis* Sauer.) in soybean [*Glycine max* (L). Merr.], > 88 and 60% at one study location and 100 and 95% at another location, 2 and 8 wk after treatment (WAT), respectively. Meyers et al. (2013a) reported that systems containing fomesafen provided $\geq$ 97% control through 74 d after transplanting (DAP) in sweetpotato. Meyers et al. (2013a) reported 'Covington' sweetpotato crop injury in systems containing fomesafen (0.28 kg ha^{-1}) and fomesafen fb *S*-metolachlor (0.8 kg ai ha^{-1}) to be $\leq$ 8%. However, crop tolerance can vary among different cultivars. Peachey et al. (2012) reported that 'Eureka' cucumber (*Cucumis sativus*) was less tolerant of

Table 3. The effect of herbicide treatments on Palmer amaranth control and sweetpotato injury at Clinton, NC in 2012 and 2013.[a]

Herbicide	Rate	Application timing	Palmer amaranth control				Sweetpotato injury			
			2012		2013		2012		2013	
			28 DAP	50 DAP	28 DAP	50 DAP	17 DAP	28 DAP	28 DAP	50 DAP
	kg ai ha^{-1}		%							
Fomesafen	0.20	Pretran	40	5	95	89	0	0	0	0
Fomesafen	0.28	Pretran	99	80	100	98	0	3	0	0
Fomesafen	0.36	Pretran	100	93	99	97	0	3	0	0
Fomesafen	0.42	Pretran	99	87	91	84	0	3	0	0
Fomesafen	0.56	Pretran	100	94	99	98	0	5	0	2
Fomesafen	0.84	Pretran	100	90	100	98	8	13	3	2
Fomesafen fb *S*-metolachlor	0.20 fb 1.12	Pretran fb 0 to 7 DAP	98	83	98	95	0	6	4	8
Fomesafen fb *S*-metolachlor	0.28 fb 1.12	Pretran fb 0 to 7 DAP	100	97	99	94	0	8	1	3
Fomesafen fb *S*-metolachlor	0.36 fb 1.12	Pretran fb 0 to 7 DAP	99	80	99	93	17	9	0	1
Fomesafen fb *S*-metolachlor	0.42 fb 1.12	Pretran fb 0 to 7 DAP	99	94	99	96	9	9	4	3
Fomesafen fb *S*-metolachlor	0.56 fb 1.12	Pretran fb 0 to 7 DAP	99	98	99	94	0	6	0	0
Fomesafen fb *S*-metolachlor	0.84 fb 1.12	Pretran fb 0 to 7 DAP	100	100	97	90	4	9	0	3
Fomesafen fb *S*-metolachlor	0.28 fb 1.12	Pretran fb 14 DAP	90	99	95	82	0	0	0	13
Flumioxazin	0.105	Pretran	100	100	98	95	0	2	0	0
Flumioxazin fb *S*-metolachlor	0.105 fb 1.12	Pretran fb 0 to 7 DAP	100	100	99	98	2	3	1	1
S-metolachlor	1.12	0 to 7 DAP	93	45	92	86	0	0	0	0
Flumioxazin fb clomazone fb *S*-metolachlor	0.105 fb 0.63 fb 1.12	Pretran fb 0 to 7 DAP fb 14 DAP	100	100	100	100	0	4	0	1
Clomazone	0.63	0 to 7 DAP	68	24	51	32	2	0	3	0
Napropamide	2.24	0 to 7 DAP	90	65	92	91	0	0	0	0
HSD (0.05)			15	42	21	30	9	10	NS	7
Contrast										
Fomesafen[b] vs. flumioxazin			NS	NS	NS	NS	NS	NS	NS	NS
Fomesafen[b] vs. fomesafen fb *S*-metolachlor[c]			NS	NS	NS	NS	*	NS	NS	NS
Fomesafen fb *S*-metolachlor 0 to 7 DAP vs. fomesafen fb *S*-metolachlor 14 DAP			*	NS	NS	NS	NS	*	NS	*
Fomesafen fb *S*-metolachlor[c] vs. flumioxazin fb *S*-metolachlor			NS	NS	NS	NS	NS	NS	NS	NS
Fomesafen fb *S*-metolachlor[c] vs. flumioxazin fb clomazone fb *S*-metolachlor			NS	NS	NS	NS	*	NS	NS	NS

[a] Abbreviations: DAP, days after transplanting; fb, followed by; NS, not significant; Pretran, pretransplant.

[b] Averaged across treatments 4, 5, 6, 7, and 8 (see Table 2).

[c] Averaged across treatments 10, 11, 12, 13, and 14.

* thinsp;Significant at $P = 0.05$.

Table 4. The effect of herbicide treatments on sweetpotato yield at Clinton, NC in 2012 and 2013.[a]

Herbicide	Rate	Application timing
	kg ai ha^{-1}	
Weed-free	—	—
Weedy	—	—
Fomesafen	0.20	Pretran
Fomesafen	0.28	Pretran
Fomesafen	0.36	Pretran
Fomesafen	0.42	Pretran
Fomesafen	0.56	Pretran
Fomesafen	0.84	Pretran
Fomesafen fb *S*-metolachlor	0.20 fb 1.12	Pretran fb 0 to 7 DAP
Fomesafen fb *S*-metolachlor	0.28 fb 1.12	Pretran fb 0 to 7 DAP
Fomesafen fb *S*-metolachlor	0.36 fb 1.12	Pretran fb 0 to 7 DAP
Fomesafen fb *S*-metolachlor	0.42 fb 1.12	Pretran fb 0 to 7 DAP
Fomesafen fb *S*-metolachlor	0.56 fb 1.12	Pretran fb 0 to 7 DAP
Fomesafen fb *S*-metolachlor	0.84 fb 1.12	Pretran fb 0 to 7 DAP
Fomesafen fb *S*-metolachlor	0.28 fb 1.12	Pretran fb 14 DAP
Flumioxazin	0.105	Pretran
Flumioxazin fb *S*-metolachlor	0.105 fb 1.12	Pretran fb 0 to 7 DAP
S-metolachlor	1.12	0 to 7 DAP
Flumioxazin fb clomazone fb *S*-metolachlor	0.105 fb 0.63 fb 1.12	Pretran fb 0 to 7 DAP fb 14 DAP
Clomazone	0.63	0 to 7 DAP
Napropamide	2.24	0 to 7 DAP
HSD (0.05)		
Contrast		
Fomesafen[d] vs. flumioxazin		
Fomesafen[d] vs. fomesafen fb *S*-metolachlor[e]		
Fomesafen fb *S*-metolachlor 0 to 7 DAP vs. Fomesafen fb *S*-metolachlor 14 DAP		
Fomesafen fb *S*-metolachlor[e] vs. Flumioxazin fb *S*-metolachlor		
Fomesafen fb *S*-metolachlor[e] vs. Flumioxazin fb clomazone fb *S*-metolachlor		

[a] Abbreviations: Cov, Covington; DAP, days after transplanting; Evan, Evangeline; NS, not significant; Pretran, pretransplant.

[b] Marketable yield = no. 1 + jumbo grades; Total yield = no. 1 + jumbo + canner.

[c] Values represented by † significantly different than weed-free at P = 0.05.

[d] Averaged across treatments 4, 5, 6, 7, and 8 (see Table 2).

[e] Averaged across treatments 10, 11, 12, 13, and 14.

* Significant at P = 0.05.

fomesafen than 'Speedway' with 43 and 33% injury at 2 and 4 WAT, respectively, from fomesafen pretransplant at 0.28 kg ha^{-1}. Thus, further research into cultivar differences and crop tolerance of sweetpotato is still necessary.

The objectives of this research were to determine the effect of fomesafen pretransplant alone or fb *S*-metolachlor after transplanting on Palmer amaranth control, and 'Covington' and 'Evangeline' sweetpotato tolerance, storage root yield, and quality.

Materials and Methods

Studies were conducted during 2012 and 2013 at the Horticultural Crops Research Station (35.02°N, 78.27°W) near Clinton, NC in a field heavily infested (50 to 100 plants m^{-2}) with Palmer amaranth. 'Covington' and 'Evangeline' sweetpotato transplants (nonrooted cuttings) were cut from field propagation beds by hand, and transplanted on June 20, 2012 and July 10, 2013 using a mechanical transplanter. Covington, a rose-skinned,

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Table 4. Extended.

Sweetpotato yield[b,c]								
2012					2013			
No. 1								
Cov	Evan	Jumbo	Marketable	Total	No. 1	Jumbo	Marketable	Total
kg ha^{-1}								
20,800	23,930	14,030	36,390	40,380	10,935	120	11,060	17,500
1,980†	1,600†	0†	1,790†	3,730†	4,850†	90	4,940†	9,390†
9,030†	7,020†	2,360†	10,390†	11,780†	11,047	1,270	12,310	17,870
24,030	17,600	10,560	33,050	37,420	10,980	910	11,890	17,360
21,540	22,540	18,710	40,750	44,130	13,340	260	13,600	19,560
25,260	21,350	16,810	40,120	43,530	8,760	640	9,400	14,530
20,970	23,290	14,900	37,030	41,620	9,570	1,900	11,470	15,650
13,950	14,750	15,160	29,510	31,810	10,730	790	11,520	16,070
19,350	22,660	12,720	33,730	37,540	10,290	460	10,750	15,920
21,740	27,120	8,920	33,350	38,100	10,710	1,750	12,460	18,100
17,620	18,580	14,400	32,410	35,930	11,940	1,260	13,100	19,080
17,190	31,460	16,630	40,950	43,960	12,610	1,850	14,460	19,230
25,980	22,790	16,060	40,450	43,870	12,770	1,340	14,110	19,420
22,430	30,560	15,600	42,100	44,800	10,300	1,570	11,860	15,700
30,130	17,810	24,570	47,310	51,160	8,590	1,020	9,610	14,270
22,100	26,980	20,270	44,810	48,030	12,470	1,210	13,680	19,500
18,750	25,190	22,420	44,120	47,290	14,340	1,200	15,540	20,890
14,130	23,050	8,270	25,970	31,150	13,190	1,030	14,220	20,810
22,190	26,500	16,300	40,650	44,820	13,470	920	14,390	20,330
13,820†	9,390	4,910†	16,520†	19,080†	4,390†	130	4,530†	9,760†
20,430	13,570	6,690†	23,690†	27,370	15,030	1,960	16,990	22,350
15,170	20,920	12,370	18,150	18,420	6,830	NS	7,380	8,470
NS	NS	NS	*	NS	NS	NS	NS	NS
NS	*	NS	NS	NS	NS	NS	NS	NS
NS	NS	*	*	*	NS	NS	NS	NS
NS	NS	*	NS	NS	NS	NS	NS	NS
NS	NS	NS	NS	NS	NS	NS	NS	NS

orange-fleshed cultivar, was selected because it is the most-planted cultivar, accounting for 88% of the acreage in North Carolina (NCCIA 2014; Yencho et al. 2008). Evangeline, a rose-skinned and deep orange-fleshed cultivar with higher total sugars, was selected due to special interest from growers in marketing as a microwavable sweetpotato (La Bonte et al. 2008). Soil was Norfolk (fine-loamy, kaolinitic, thermic Typic Kandiudults), Orangeburg (fine-loamy, kaolinitic, thermic Typic Kandiudults), or Goldsboro (fine-loamy, siliceous, subactive, thermic Aquic Paleudults) loamy sand with pH 5.9 and cation exchange capacity (CEC) 2.9. Plot size was three (2012) or four (2013) rows, each 1 m wide by 6.1 m long. The first, and first and fourth rows of each plot were nontreated and served as border rows in 2012 and 2013, respectively. The second and third rows were treated and planted with Covington and Evangeline, respectively. The experimental design was a randomized complete block with three (2012) or four (2013) replications.

Herbicides included clomazone, flumioxazin, fomesafen, napropamide, and *S*-metolachlor (Table 1). The selected herbicides rates and application timing are given in Table 2. Weedy and weed-free checks were included for comparison. The weed-free check was maintained weed-free by cultivation until sweetpotato canopy closure and was hand weeded all season. Sethoxydim at 0.34 kg ai ha^{-1} plus 1% v/v crop oil was applied POST as needed to control goosegrass [*Eleusine indica* (L.) Gaertn.] and large crabgrass [*Digitaria sanguinalis* (L.)

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Scop.]. Treatments were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 187 L ha^{-1} with DG8003 nozzle tips (TeeJet DG 8003, TeeJet Technologies, Wheaton, IL 60187) at 144 kPa.

Visual sweetpotato injury was recorded at 7, 17, 28, and 50 d after transplanting (DAP) and Palmer amaranth control was recorded 28 and 50 DAP. Ratings for injury and control were based on a scale of 0 (no crop injury or no Palmer amaranth control) to 100% (crop death or complete Palmer amaranth control). Sweetpotato storage roots were harvested 113 and 96 DAP in 2012 and 2013, respectively, using a tractor-mounted chain digger, and were picked up by hand and hand-graded into jumbo (> 8.9 cm diameter), no. 1 (> 4.4 cm but < 8.9 cm), and canner (> 2.5 cm but < 4.4 cm) grades (USDA 2005) and weighed. Total marketable yield was calculated as the sum of jumbo and no. 1 grades. Total yield was calculated as the sum of no. 1, jumbo, and canner grades.

Data were analyzed using PROC GLM in SAS (SAS 9.4; SAS Institute, Inc.; Cary, NC). ANOVA was used to test for significant main effects and interactions. All data were checked for homogeneity of variance before statistical analysis by plotting residuals. Means were separated using Tukey HSD (honest significant difference) test at the 0.05 significance level. Weed-free and weedy treatments were included in the yield analysis. However, data from these treatments were not included in analysis of crop injury and Palmer amaranth control because crop injury was always 0% and Palmer amaranth control was 100 and 0% for weed-free and weedy plots, respectively.

Results and Discussion

There was an interaction between treatment and year for Palmer amaranth control, sweetpotato crop injury, and sweetpotato yield; therefore, the data were analyzed separately by year.

Palmer Amaranth Control. *Year 2012*. With the exception of 0.63 kg ha^{-1} clomazone and 0.20 kg ha^{-1} fomesafen, Palmer amaranth control in all treatments at 28 DAP was similar (≥ 90%) (Table 3). At 50 DAP, all rates of fomesafen fb *S*-metolachlor 0 to 7 DAP provided at least 94% control except fomesafen at 0.20 and 0.36 kg ha^{-1} which provided 80 to 83% control (Table 3). Fomesafen alone at 0.20 kg ha^{-1} (5%) provided the least Palmer amaranth control of all treatments and was similar to clomazone at 0.63 kg ha^{-1} (24%) 50 DAP. Napropamide provided only 65% control at 50 DAP, in contrast to 90% at 28 DAP. Flumioxazin alone, flumioxazin fb *S*-metolachlor, and flumioxazin fb clomazone fb *S*-metolachlor provided 100% control at 28 and 50 DAP.

Contrast statements comparing treatments with fomesafen, fomesafen fb *S*-metolachlor, flumioxazin or flumioxazin fb *S*-metolachlor, indicated no differences in Palmer amaranth control at 28 and 50 DAP (Table 3). However, contrast statements indicated that Palmer amaranth control 28 DAP by fomesafen 0.28 kg ha^{-1} fb *S*-metolachlor 1.12 kg ha^{-1} 14 DAP was 90%, which was less than fomesafen at 0.28 kg ha^{-1} fb *S*-metolachlor 1.12 kg ha^{-1} 0 to 7 DAP (100%). However, at 50 DAP there was no difference between these two treatments (Table 3).

Year 2013. All herbicide treatments at 28 or 50 DAP were similar and provided ≥ 82% or ≥ 91% Palmer amaranth control, respectively, except for 0.63 kg ha^{-1} clomazone (32 to 51%). Contrast statements indicated no differences in Palmer amaranth control at 28 and 50 DAP when comparing treatments of fomesafen, fomesafen fb *S*-metolachlor, flumioxazin, or flumioxazin fb *S*-metolachlor (Table 3).

Sweetpotato Injury. *Year 2012*. Foliar injury characterized by chlorosis and necrosis was reported at 7, 17 and 28 DAP. No foliar injury was shown at 7 DAP from any of the herbicide treatments (data not shown). At 17 DAP minimal injury (≤ 17%) was observed and only fomesafen 0.84 kg ha^{-1} and fomesafen 0.36 or 0.42 kg ha^{-1} fb *S*-metolachlor 1.12 kg ha^{-1} 0 to 7 DAP resulted in greater injury (8, 17, and 9%, respectively) than other treatments (Table 3). Injury declined and was ≤ 9% at 28 DAP except fomesafen (0.84 kg ha^{-1}), which caused the greatest injury (13%) of all treatments (Table 3). Cultivar differences were only observed 28 DAP when Covington was more susceptible to injury (5%) than Evangeline (3%) (data not shown). Although sweetpotato injury differed statistically by cultivar at 28 DAP, practical differences were not evident.

Contrast statements indicate that sweetpotato injury at 17 DAP was greater (≤ 17%) in

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treatments consisting of fomesafen fb *S*-metolachlor than in treatments containing fomesafen alone ($\leq$ 8%) (Table 3). However, by 28 DAP, injury was similar, $\leq$ 13% in treatments containing fomesafen or fomesafen fb *S*-metolachlor. Crop stunting at 50 DAP was $\leq$ 8% and no significant difference was observed in terms of cultivar and herbicides (data not shown).

Year 2013. Foliar injury (chlorosis and necrosis) was reported at 17, 28, and 50 DAP and stunting was reported at 28 DAP. The effect of sweetpotato cultivar was not significant for both injury and stunting at any data reporting time. No injury was observed at 17 DAP (data not shown). At 28 DAP, sweetpotato injury was $\leq$ 4% with no difference among herbicide treatments (Table 3). At 50 DAP, injury was less from fomesafen 0.20 kg ha^{-1} fb *S*-metolachlor 1.12 kg ha^{-1} 0 to 7 DAP (8%) than from fomesafen 0.28 kg ha^{-1} fb *S*-metolachlor 14 DAP (13%). All other treatments showed $\leq$ 3% injury (Table 3). Crop stunting at 28 DAP was $\leq$ 4% and no differences in crop stunting were observed from herbicide treatments (data not shown).

Sweetpotato Yield. *Year 2012*. No cultivar by treatment interaction was observed for different sweetpotato yields except for no. 1 yield; however, both main effects of cultivar and herbicide treatments was significant for jumbo, marketable, and total sweetpotato yields. Only main effect of cultivar was significant for canner sweetpotato yield. Jumbo, marketable and total yields were greater for Evangeline sweetpotato cultivar (15,250, 36,750, and 39,870 kg ha^{-1}, respectively) than Covington sweetpotato (11,250, 30,440, and 34,240 kg ha^{-1}, respectively) (data not shown). Conversely, canner yield was greater for Covington cultivar (3,800 kg ha^{-1}) as compared to Evangeline cultivar (3,080 kg ha^{-1}) (data not shown). Other researchers have reported greater jumbo and no. 1 yields of Evangeline relative to Covington (Nair et al. 2012).

No. 1 sweetpotato yield of either Covington or Evangeline for herbicide treatments were not different from the weed-free control treatment except for reduced yield in the fomesafen 0.20 kg ha^{-1} (9,030 and 7,020 kg ha^{-1}, respectively), and clomazone 0.63 kg ha^{-1} (9,390 kg ha^{-1} only in Covington sweetpotato) (Table 4). All treatments, except the weedy, fomesafen 0.20 kg ha^{-1}, clomazone 0.63 kg ha^{-1}, and napropamide 2.24 kg ha^{-1} produced jumbo and total sweetpotato yields similar to the weed-free control (Table 4). Marketable yield was significantly lower in fomesafen 0.20 kg ha^{-1} (10,390 kg ha^{-1}) and clomazone 0.63 kg ha^{-1} (16,520 kg ha^{-1}) as compared to weed-free treatment (36,390 kg ha^{-1}) because these were the least effective treatments controlling Palmer amaranth. Canner yield was not different for the weed-free treatment compared to all other herbicide treatments and ranged from 5,180 to 1,400 kg ha^{-1} (data not shown).

Contrast statements showed that jumbo, marketable, and total sweetpotato yield were lower in the fomesafen 0.28 kg ha^{-1} fb *S*-metolachlor 0 to 7 DAP in comparison to fomesafen 0.28 kg ai ha^{-1} fb *S*-metolachlor 14 DAP (Table 4). This difference agrees with findings of Meyers et al. (2013b) that a delayed application of *S*-metolachlor from 0 to 14 DAP displayed a positive linear and quadratic response to no. 1 and total marketable sweetpotato yields, respectively. Contrast statements comparing treatments with fomesafen fb *S*-metolachlor vs. standard Palmer amaranth control treatment of flumioxazin fb *S*-metolachlor, indicated no differences for sweetpotato no. 1, marketable, and total root yields (Table 4).

Year 2013. Overall sweetpotato yield was lower in 2013 as compared to 2012 due to the wet and cold weather in 2013. No cultivar by treatment interaction was observed for sweetpotato yield. However, both main effects of cultivar and herbicide treatments were significant for no. 1, canner, marketable, and total sweetpotato yield except herbicide treatment effect was not significant for jumbo and canner sweetpotato yield. No. 1, canner, marketable, and total sweetpotato yield were significantly higher from Evangeline (11,720, 6,090, 12,720, and 18,810 kg ha^{-1}, respectively) as compared to Covington (10,210, 4,500, 11,280, and 15,790 kg ha^{-1}, respectively) (data not shown).

Clomazone 0.63 kg ha^{-1} had lower no. 1, marketable, and total yield than the weed-free check and yielded similar to the weedy check (Table 4). Reduced yields in clomazone-treated sweetpotato were due to poor Palmer amaranth control (51 and 32% at 28 and 50 DAP, respectively). However, no. 1, marketable, and total yield in all other herbicide treatments were similar to the weed-free control. Contrast statements indicated no differences in no. 1, jumbo, marketable and total sweetpotato yield when comparing treatments of fomesafen, fomesafen fb S-metolachlor, flumioxazin, or flumioxazin fb *S*-metolachlor (Table 4).

In summary, fomesafen rates at 0.28 to 0.56 kg ha^{-1} alone or fb *S*-metolachlor provided adequate Palmer amaranth control ($\geq$ 80% at 50 DAP) without a yield reduction and with minimal initial crop foliar injury in Covington and Evangeline sweetpotato. Systems containing flumioxazin alone, or fb *S*-metolachlor, or fb clomazone fb *S*-metolachlor provided excellent Palmer amaranth control ($\geq$ 95% at 50 DAP) with little crop foliar injury ($\leq$ 5%) and similar yield (no. 1, jumbo, canner, marketable, and total) to the weed-free check. Clomazone at 0.63 kg ha^{-1} and fomesafen at 0.20 kg ha^{-1} did not cause injury, but Palmer amaranth control was lower, which reduced yield of no. 1, marketable, and total sweetpotato. Other researchers have also reported lack of Palmer amaranth control with only clomazone preemergence application (Westberg et al. 1989). Low rate of fomesafen (0.20 kg ha^{-1}) are reported to control Palmer amaranth only at the two true-leaf stage applied as postemergence (Anonymous 2015). Napropamide resulted in good Palmer amaranth control at 28 and 50 DAP in 2013 (92 and 91%, respectively) and less control was observed in 2012 (90 and 65%, respectively). As a result, jumbo and total sweetpotato yield was reduced from napropamide in 2012.

Results from this research demonstrate that fomesafen pretransplant (not registered in sweetpotato) provides good Palmer amaranth control, minimal crop injury, and comparable yield to flumioxazin. Fomesafen will provide growers with another option against hard-to-control Palmer amaranth in sweetpotato production systems. Fomesafen should be followed by *S*-metolachlor early POST for season-long Palmer amaranth control. Although the current investigation focused on Palmer amaranth, the prospect of yellow nutsedge suppression would give fomesafen a secondary purpose of weed control in sweetpotato. Meyers and Shankle (2015) reported 5 to 90 yellow nutsedge shoots m^{-2} reduced marketable sweetpotato yield 18 to 80% and 6 to 67% in 2 different yr. Cotton seed yield was greater from herbicide programs containing fomesafen, and this increase in yield was associated with yellow nutsedge control (Wilcut et al. 1997). Thus, more research is needed to determine the effect of fomesafen on yellow nutsedge control in sweetpotato.

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