ABSTRACT

BLANKENSHIP, COLTON DAVID. Cultivation, Weed-Suppressive Clones and Flumioxazin in Sweetpotato Production Systems. (Under the direction of Dr. Katherine M. Jennings).

Sweetpotato is an economically important crop in North Carolina, generating $333 million in production value in 2020. Weed management is challenging in sweetpotato; in both organic and conventional production systems, hand-weeding is regularly used and is expensive. Our research objectives were to examine cultivar selection as a potential avenue of weed management in organic sweetpotato systems as well as address current grower concerns with flumioxazin and *S*-metolachlor (critically important herbicides for conventional sweetpotato production in North Carolina).

Field studies were conducted in 2020 and 2021 to determine whether selected sweetpotato cultivars (Covington, Murasaki, and Monaco) with different canopy architectures respond differently to cultivation and weed interference. Cultivation treatments included no cultivation weedy and weed-free checks, cultivation weekly and biweekly (every 2 weeks) from 2 to 6 weeks after planting (WAP), 6 WAP cultivation only, cultivation at 2 WAP followed by hand removal from 2 to 6 WAP, and cultivation at the first and first two weed emergences.

Cultivation treatments generally provided better Palmer amaranth control in 2021 than in 2020, except for the 2-week followed by hand removal and one cultivation at 1st weed emergence at 10 WAP rating. In 2020 all cultivation treatments resulted in poor control at the 10 WAP rating except for the 2 wk cultivation followed by hand removal from 2 to 6 WAP. Murasaki provided significantly greater Palmer amaranth control than Covington; Palmer amaranth control from Monaco was not statistically different from that of either Murasaki or Covington. Sweetpotato cultivar selection has potential as a cultural weed management practice as part of an integrated weed management program. However, selected cultivar treatments exhibited no interactions with cultivation treatments. For total sweetpotato yield (sum of canner, No. 1, and jumbo grades) the biweekly, 2 WAP followed by hand removal, weekly, 2 cultivations at the first two weed emergences, and 1 cultivation at the first weed emergence treatments did not differ in total yield compared to the non-treated check. The 6 WAP only and non-cultivated weedy treatments resulted in a significant reduction in total yield compared to the non-cultivated weedy treatment.

Flumioxazin and *S*-metolachlor are widely used on conventional sweetpotato hectarage in North Carolina; however, some growers have recently expressed concerns about potential effects of these herbicides on sweetpotato yield and quality. Previous research indicates that activated charcoal can improve crop safety and reduce herbicide injury in some conditions. Field studies were conducted in 2021 and 2022 to determine whether flumioxazin applied pre-planting and *S*-metolachlor applied before and after transplanting negatively affect sweetpotato yield and quality when activated charcoal is applied with transplant water. The studies consisted of five herbicide treatments by two activated charcoal treatments. Herbicide treatments included two rates of flumioxazin, one rate of *S*-metolachlor applied immediately before and immediately after transplanting, and no herbicide. Charcoal treatments consisted of activated charcoal applied at 9 kg ha^{-1} and no charcoal. No visual injury was observed. There was no effect of herbicide or charcoal treatment on No. 1, marketable (sum of No. 1 and jumbo grades), or total yield (sum of canner, No. 1, and jumbo grades). Additionally, shape analysis conducted on calculated length-to-width ratio (LWR) for No. 1 sweetpotato roots found no effect from flumioxazin at either rate on sweetpotato root shape. However, both *S*-metolachlor treatments resulted in lower LWR of No. 1 sweetpotato roots in 2021. Results are consistent with those of prior research and indicate that flumioxazin and *S*-metolachlor are safe for continued use in sweetpotato at registered rates.

Cultivation, Weed-Suppressive Clones and Flumioxazin in Sweetpotato Production Systems

by
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BIOGRAPHY

Colton Blankenship grew up on his family farm in Preston, Georgia. He gained an appreciation of agriculture from a young age, riding the peanut picker with his grandfather and helping his father pick cotton. Colton attended the University of Alabama after graduating from high school, earning his Bachelor of Science in biology in 2020. Colton began to pursue graduate opportunities in agriculture and was given the opportunity to work under Dr. Katie Jennings in the small fruit and vegetable weed science program at North Carolina State University.

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CHAPTER 1

Effect of Cultivation Regimes on Weed Control and Sweetpotato Cultivar Yield and Quality

(In the format appropriate for submission to Weed Technology)

Effect of Three Cultivation Regimes on Weed Control and Sweetpotato Cultivar Yield and Quality

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Abstract

Field studies were conducted in 2020 and 2021 to determine whether selected sweetpotato cultivars (Covington, Murasaki, and Monaco) with different canopy architectures respond differently to cultivation and weed interference. Cultivation treatments included no cultivation weedy and weed-free checks, cultivation weekly and biweekly (every 2 weeks) from 2 to 6 weeks after planting (WAP), 6 WAP cultivation only, cultivation at 2 WAP followed by hand removal from 2 to 6 WAP, and cultivation at the first and first two weed emergences. Cultivation treatments generally provided better Palmer amaranth control in 2021 than in 2020, except for the 2-week followed by hand removal and one cultivation at 1st weed emergence at 10 WAP rating. In 2020 all cultivation treatments resulted in poor control at the 10 WAP rating except for the 2 wk cultivation followed by hand removal from 2 to 6 WAP Murasaki provided significantly greater Palmer amaranth control than Covington; Palmer amaranth control from Monaco was not statistically different from that of either Murasaki or Covington. Sweetpotato cultivar selection has potential as a cultural weed management practice as part of an integrated weed management program. However, selected cultivar treatments exhibited no interactions with cultivation treatments. This suggests that cultivar selection alone may not influence the selection of an effective cultivation regime. For total sweetpotato yield (sum of canner, No. 1, and jumbo grades) the biweekly, 2 WAP followed by hand removal, weekly, 2 cultivations at the first two weed emergences, and 1 cultivation at the first weed emergence treatments did not differ in total yield compared to the non-treated check. The 6 WAP only and non-cultivated weedy treatments resulted in a significant reduction in total yield compared to the non-cultivated weedy treatment.

Nomenclature: Palmer amaranth; *Amaranthus palmeri* S. Watson; sweetpotato; Ipomoea batatas (L.) Lam.

Keywords: Weed management; vegetable; organic

Introduction

Sweetpotato generates over $680 million on over 375,600 ha planted in the United States (USDA-NASS 2021). Organically produced sweetpotato hectarage has increased over 100% from 2011 to 2019 with certified organic sweetpotato harvested nationally increasing from 1759 ha to 3694 ha (USDA-NASS Organic Survey 2012, USDA-NASS Organic survey 2019). Sweetpotato was the fourth most economically important crop in North Carolina in 2020 (USDA-NASS 2021). Limited weed control options exist in conventional sweetpotato production, and even fewer options are available in organically produced sweetpotato systems (Jennings et al. 2019).

Previous research has shown that the critical weed-free period in 'Beauregard' sweetpotato is 2 to 6 weeks after transplanting (Seem et al. 2003). Furthermore, the critical timing of Palmer amaranth (*Amaranthus palmeri*) removal in sweetpotato was determined to be 2 weeks after planting (Smith et al. 2020). It is extremely important to control weeds in during this critical period during sweetpotato production. Weed competition can reduce marketable sweetpotato yield by as much as 95% (Barkley et al. 2016; Basinger et al. 2019; Meyers et al. 2010; Smith et al. 2020). Mechanical weed management strategies in organic sweetpotato systems include hand-weeding and between-row cultivation (2019 Smith and Moore unpublished survey). Hand-weeding is expensive, with some growers self-reporting costs of up to $370/ha (2019 Smith and Moore unpublished survey). However, research on the optimal cultivation frequency and timing for best weed control and crop yield and quality is limited for organic sweetpotato production systems.

Sweetpotato cultivars with different growth habits and canopy architectures have been shown to respond differently to weed interference (Harrison and Jackson 2011). Crop cultivar selection based on growth habit and canopy architectures has been highlighted as a weed management technique in crops including wheat and other cereal grains (Seavers and Wright 1999; Wicks et al. 1986). Selection of optimal cultivars for tolerance to weed interference is a potential weed management practice for organic sweetpotato systems. Cultivars with different canopy architectures may also potentially respond differently to between-row cultivation frequency and timing, allowing for more aggressive cultivation regimes over the course of the season. Cultivating too frequently or too late in the season could result in damage to sweetpotato vines and a reduction in yield (Allan Thornton, personal communication, October 4, 2022); cultivating too infrequently could result in reduced weed control and increased weed interference. Three table-stock sweetpotato cultivars with different canopy architecture types are among the cultivars grown commercially in North Carolina. 'Covington' is an orange-fleshed sweetpotato with a dense, weed competitive canopy commercially released in 2008 (Yencho et al. 2008). 'Murasaki' is a purple-skinned white-fleshed sweetpotato cultivar with a greater canopy biomass than that of 'Beauregard' (La Bonte et al. 2008). Murasaki has a widely vining growth habit. 'Monaco' is a rose-skinned orange-fleshed sweetpotato developed primarily for organic sweetpotato production and possessing a compact canopy architecture (North Carolina State University). Thus, optimizing the cultivation frequency and timing for specific sweetpotato cultivars is a possible practice for improving existing weed management systems in organic sweetpotato production. Although research on weed removal in sweetpotato exists, no research has been conducted to determine the interaction of cultivation and sweetpotato cultivar on weed control and crop yield. Thus, studies were conducted to determine the effect of cultivation regimes on weed control and yield of sweetpotato cultivars with different canopy architecture types.

Materials and Methods

Field studies were conducted at the Horticultural Crops Research Station in Clinton, NC beginning June 15, 2020 (35.024°N, -78.280°W) and June 24, 2021 (35.022°N, -78.281°W). Soil at this site was an Orangeburg loamy sand (fine-loamy, kaolinitic, thermic Typic Kandiudults) with pH 6.4 and 0.51% organic matter in 2020 and a Norfolk sandy loam (fine-loamy, kaolinitic, thermic Typic Kandiudults) with pH 5.9 and 0.4% organic matter in 2021. Nonrooted sweetpotato cuttings were transplanted mechanically to a 30-cm in-row spacing. No herbicides were applied for the duration of this study. Other production practices including fertility, insect, and disease management were conducted according to recommendations by Kemble (2022).

The study design consisted of a randomized complete block design with a factorial of eight cultivation schedules by three sweetpotato cultivars (Covington, Murasaki, Monaco) in a split-plot arrangement with four replications, wherein the whole plot factor was cultivation schedule, and the sub-plot factor was sweetpotato cultivar (Table 1). Treatments included cultivation weekly from 2 to 6 WAP, cultivation biweekly (every 2 wk) from 2 to 6 WAP, cultivation at 2 WAP followed by hand-removal from 2 to 6 WAP, cultivation at 6 WAP only, cultivation at first weed emergence, and cultivation at first weed emergence followed by cultivation at second weed emergence. The cultivation at first and first and second weed emergence treatments were conducted at 11 and 21 days after planting (DAP) in 2020 and at 7 and 18 DAP in 2021. Additional treatments included weed and hand-weeded checks. Whole plots consisted of four rows: each 1.07 wide by 6.1 m long. The first row in each whole plot was a border containing Covington sweetpotato. The sub-plots consisted of one row, each composed of one of the sweetpotato cultivars assigned at random (Table 1.1). Cultivation treatments were conducted with a tractor-mounted Lilliston rolling cultivator (Bigham Ag; Lubbock, TX) early in the season and a sweep-type cultivator starting at 5 wk after planting (WAP) in order to limit damage to sweetpotato vines. The tractor drove down all plots at the time of each cultivation event to ensure even distribution of damage from tire crushing to sweetpotato vines across all treatments. Weeds in hand-weeded plots were removed weekly.

Visual Palmer amaranth (*Amaranthus palmeri*) control ratings and canopy coverage ratings were collected at 1, 2, 3, 4, 6, 8, and 10 WAP. Visual Palmer amaranth (*Amaranthus palmeri*) weed control ratings were recorded as a percent total control compared to the weedy check. Sweetpotato storage roots were harvested and hand-graded into canner, no. 1, and jumbo grades at 110 days after planting in 2020 and 117 days after planting in 2021. Total sweetpotato yield was calculated as a combination of canner, U.S. No. 1, and jumbo grades.

Data were assessed for homogeneity of variance by plotting residuals. Yield data required a square root transformation and Palmer amaranth control data required an arcsine square root transformation to meet the assumptions of ANOVA. Palmer amaranth control data from the non-treated checks were excluded from analysis due to a lack of variance. The non-treated checks were also excluded from standardized yield analysis due to a lack of variance. Data analyses were conducted in SAS (Version 9.4) using Tukey's HSD ($\alpha = 0.05$). Cultivar, cultivation, and year were treated as fixed effects while replication within year and replication by cultivation within year were treated as random effects.

Results and Discussion

Palmer amaranth Control

Visual Palmer amaranth control ratings were collected at 4 and 10 WAP. A significant interaction between cultivation and year ($p < 0.0126$) was observed; thus, Palmer amaranth control data were presented by year. Palmer amaranth control data were pooled across cultivars for analysis of the effect of cultivation treatments and pooled across cultivation treatments for the analysis of the effect of cultivars on Palmer amaranth control.

In 2020, only the 2 wk cultivation followed by hand removal treatment provided better Palmer amaranth control at 10 WAP than the other treatments (Table 1.a2). All other treatments were not different from one another at 10 WAP. In 2021, the 2 wk cultivation followed by hand removal, weekly cultivation, and biweekly cultivation treatments provided greater Palmer amaranth control than the 1 cultivation at first weed emergence treatment. The 2 cultivations at the first two weed emergences and 6 WAP only treatments were not different from the 2 wk followed by hand removal, weekly cultivation, and biweekly treatments nor the 1 cultivation at the first weed emergence treatment.

Cultivation treatments generally provided better Palmer amaranth control in 2021 than in 2020, except for the 2-week followed by hand removal and one cultivation at 1st weed emergence at 10 WAP rating. In 2020 all cultivation treatments resulted in poor control at the 10 WAP rating except for the 2 wk cultivation followed by hand removal from 2 to 6 WAP. The biweekly and weekly treatments provided at least 57% Palmer amaranth control in 2021 compared to the non-treated weedy check.

Cultivar had a significant effect on Palmer amaranth control ($p = 0.0061$). There were no interactions between cultivar and year nor between cultivar and cultivation treatment. Thus, data were pooled across cultivation treatments and years. Palmer amaranth control from cultivar treatments was 38.6 percent control from Covington, 42.8 percent control from Monaco, and 45 percent control from Murasaki. Murasaki provided significantly greater Palmer amaranth control than Covington; Palmer amaranth control from Monaco was not statistically different from that of either Murasaki or Covington. The difference in control between Murasaki and Covington is 45 percent control compared to 38.6 percent control. This difference indicates that sweetpotato cultivar selection has potential as a cultural weed management practice as part of an integrated weed management program. However, selected cultivar treatments exhibited no interactions with cultivation treatments. This suggests that cultivar selection alone may not influence the selection of an effective cultivation regime.

Sweetpotato Yield

There were no significant interactions between cultivation treatments and year nor cultivar. Cultivation treatment had a significant effect on total yield ($p = 0.0023$). Data were pooled across cultivars to assess the effect of cultivation. Cultivar treatments resulted in no observable effect on total yield. The biweekly, 2 WAP followed by hand removal, weekly, 2 cultivations at the first two weed emergence, and 1 cultivation at the first weed emergence treatments did not differ in total yield compared to the non-treated check. The 6 WAP only and non-cultivated weedy treatments resulted in a significant reduction in total yield compared to the non-cultivated weedy treatment.

In addition to analysis of raw yield data, further analyses were performed to account for different maturity and yield characteristics of different cultivars. Sweetpotato yield data were standardized by cultivar based on the weed-free yield achieved by each respective cultivar (data not shown). Cultivation treatment had a significant effect on standardized yield reduction ($p = 0.0023$). There were no significant interactions between cultivation and year or cultivar; additionally, cultivar treatments had no effect on standardized yield reduction. The overall trend for standardized yield reduction was similar to that shown for the effect of cultivation treatment on total yield (Table 1.3). Because selected sweetpotato cultivars had no observable effect on standardized yield reduction, there was no differential tolerance to cultivation treatments by cultivar observed in this study.

Results from yield analysis show that all cultivation treatments except for the non-cultivated weedy treatment and the 6 WAP cultivation only treatment were not different from the non-cultivated weed-free treatment. Some cultivation is necessary to preserve sweetpotato yield; however, further research is necessary to determine the optimal cultivation frequency. Data from 2020 and 2021 show differences in Palmer amaranth control due to environmental variability. More research is necessary to determine the optimal frequency and timing of cultivation for weed management in sweetpotato. In years with unfavorable environmental conditions that inhibit timely cultivation, more hand-weeding applications may be necessary to control weed interference. Additionally, selected sweetpotato cultivars with different canopy architecture types did not express differential tolerance to cultivation nor result in differences in Palmer amaranth control. Cultivation alone is not likely to provide sufficient Palmer amaranth control in organic sweetpotato production but should be considered as part of integrated weed management strategies. That selected sweetpotato cultivars exhibited differences in Palmer amaranth control at 10 WAP highlights the possible utility of cultivar selection as a cultural weed management practice in organic sweetpotato production. Future research should examine other cultivars in a wide range of environments and production scenarios to further investigate the potential of cultivar selection as a weed management tool in sweetpotato.

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Table 1.1 Cultivation treatments and sweetpotato cultivars.

Cultivation schedule	Sweetpotato cultivar
Cultivation weekly (2-6 WAP)	Covington
Cultivation biweekly (every 2 wk) (2-6 WAP)	Murasaki
Cultivation at 1st weed emergence	Monaco
Cultivation at first weed emergence followed by cultivation at second weed emergence	
Cultivation 6 WAP only	
Cultivation at 2 WAP followed by hand removal (2-6 WAP)	
No cultivation, weedy check	
No cultivation, weed-free check	

Table 1.2 Effect of cultivation treatment on visual Palmer amaranth control at Clinton, NC in 2020 and 2021

	Visual Palmer amaranth control[ab]			
	---- 2020 ----		---- 2021 ----	
Treatment	4 WAP	10 WAP	4 WAP[1]	10 WAP
Biweekly (2 to 6 WAP)	49	28 b	79	58 a
2 Week fb[c] hand removal (2 to 6 WAP)	-	90 a	-	71 a
Weekly (2 to 6 WAP)	41	22 b	88	75 a
2 Cultivation at 1st 2 weed emergences	45	29 b	70	50 ab
1 Cultivation at 1st weed emergence	46	33 b	51	7 b
6 WAP only	-	13 b	-	31 ab

[a]Means were separated by Tukey's HSD at $\alpha = 0.05$. Means within the same column and followed by different letters are significantly different. Means with no variance were excluded from analysis to meet the assumptions of ANOVA. Means required an arcsine square root transformation and were back transformed for presentation.

[b]Ratings were evaluated on a scale from 0 to 100: 0 being based on the weedy check and 100 being completely weed-free. Palmer amaranth control was evaluated based on number and size of weeds present compared to weedy check.

[c]followed by

Table 1.3 The effect of cultivation treatment on sweetpotato total marketable yield in Clinton, NC in 2020 and 2021[a]

Treatment	Total yield
	kg ha^{-1}
Non-cultivated weed-free	22590 a
Biweekly (2 to 6 WAP)	12630 abc
2 Week fb hand removal (2 to 6 WAP)	16700 ab
Weekly (2 to 6 WAP)	11470 abc
2 Cultivation at 1st two weed emergences	10750 abc
1 Cultivation at first weed emergence	12480 abc
6 WAP only	6860 bc
Non-cultivated weedy	4240 c

[a]Means were separated by Fisher's LSD at $\alpha = 0.05$. Means within the same column and followed by different letters are significantly different. Means required a square root transformation and were back transformed for presentation.

CHAPTER 2

Effect of *S*-metolachlor and flumioxazin herbicides on sweetpotato treated with and without activated charcoal applied through transplant water

(In the format appropriate for submission to Weed Technology)

Effect of *S*-metolachlor and flumioxazin herbicides on sweetpotato treated with and without activated charcoal applied through transplant water

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Abstract

Flumioxazin and *S*-metolachlor are widely used on conventional sweetpotato hectarage in North Carolina; however, some growers have recently expressed concerns about potential effects of these herbicides on sweetpotato yield and quality. Previous research indicates that activated charcoal can improve crop safety and reduce herbicide injury in some conditions. Field studies were conducted in 2021 and 2022 to determine whether flumioxazin applied preplant and *S*-metolachlor applied before and after transplanting negatively affect sweetpotato yield and quality when activated charcoal is applied with transplant water. The studies consisted of five herbicide treatments by two activated charcoal treatments. Herbicide treatments included two rates of flumioxazin, one rate of *S*-metolachlor applied immediately before and immediately after transplanting, and no herbicide. Charcoal treatments consisted of activated charcoal applied at 9 kg ha^{-1} and no charcoal. No visual injury was observed. There was no effect of herbicide or charcoal treatment on no. 1, marketable (sum of no. 1 and jumbo grades), or total yield (sum of canner, no. 1, and jumbo grades). Additionally, shape analysis conducted on calculated length-to-width ratio (LWR) for no. 1 sweetpotato roots found no effect from flumioxazin at either rate on sweetpotato root shape. However, both *S*-metolachlor treatments resulted in lower LWR of no. 1 sweetpotato roots in 2021. Results are consistent with those of prior research and indicate that flumioxazin and *S*-metolachlor are safe for continued use in sweetpotato at registered rates.

Nomenclature: sweetpotato; Ipomoea batatas (L.) Lam.

Keywords: weed management; vegetable; flumioxazin; *S*-metolachlor

Introduction

Sweetpotato is an economically important crop in North Carolina and in 2021, North Carolina growers harvested 42,370 ha valued at $391,950,000 (USDA-NASS 2022). Nationally over the same period, the United States had 61,795 harvested ha of sweetpotato for a total production value of $680,420,000 (USDA-NASS 2022).

Weed competition can reduce marketable sweetpotato yield by as much as 95% (Barkley et al. 2016; Basinger et al. 2019; Meyers et al. 2010; Smith et al. 2020). A limited number of herbicides are registered for preemergence (PRE) control of weeds in sweetpotato including *S*-metolachlor, flumioxazin, clomazone, DCPA, and fomesafen. Not all these herbicides are registered nationally; for example, *S*-metolachlor and fomesafen have a section 24(c) special local need registration for specific regions. In addition to herbicides, hand-weeding is a widely used and expensive method of weed control in sweetpotato; North Carolina growers have self-reported hand-weeding costs of up to $370 per hectare (SC Smith and LD Moore, unpublished data).

Flumioxazin, used on approximately 90% of conventional sweetpotato hectarage planted in North Carolina (K.M. Jennings, personal communication, October 4, 2022), delays weed emergence until later in the season and reduces the frequency of expensive hand-weeding. Previous research has indicated that sweetpotato injury and yield reduction from flumioxazin applied pre-transplanting is minimal (Coleman et al. 2016, Meyers et al. 2010, Kelly et al. 2006). Though flumioxazin is widely used in sweetpotato, some growers have concerns that flumioxazin may reduce sweetpotato yield or negatively affect root shape. As flumioxazin is a vital component of many conventional weed management strategies in sweetpotato, it is important to investigate grower concerns and determine whether flumioxazin is responsible for perceived yield and quality reduction. Likewise, growers have expressed similar concerns about potential injury from *S*-metolachlor to sweetpotato. Researchers have reported that *S*-metolachlor has potential to injure sweetpotato at high rates and when rain occurs after application (Abukari et al. 2015; Meyers et al. 2013; Meyers et al. 2012).

Charcoal and high-carbon soil additives have been shown to reduce herbicide efficacy and crop injury in field conditions (Singh 2019; Soni et al. 2015). Previous research has also shown that root dips of activated charcoal can reduce herbicide injury in transplanted crops such as strawberry (*Fragaria ananassa*) and tobacco (*Nicotiana tabacum*) (Ahrens 1967; Yelverton et al. 1992). However, no information has been published on the potential for charcoal to reduce or eliminate herbicide injury to sweetpotato. Thus, studies were conducted to determine the effect of flumioxazin (preplant) or *S*-metolachlor (preplant or after transplanting) on sweetpotato injury, storage root yield and quality with and without activated charcoal applied in transplant water when transplanting sweetpotato slips.

Materials and Methods

Field studies were conducted at the Horticultural Crops Research Station in Clinton, NC in 2021 (35.023°N, -78.280°W) and 2022 (35.022°N, -78.280°W). Soil was a Norfolk sandy loam (fine-loamy, kaolinitic, thermic Typic Kandiudults) with pH 6.6 and 0.5% organic matter in 2021 and an Orangeburg loamy sand (fine-loamy, kaolinitic, thermic Typic Kandiudults) with pH 6.0 and 0.46% organic matter in 2022. On July 8, 2021, and June 9, 2022 nonrooted ‘Covington’ sweetpotato cuttings (slips) were transplanted onto weed-free, bedded rows using a commercial mechanical transplanter (Checchi and Magli, Lehi, UT) with an in-row spacing of 30 cm. Plots were two rows, each 1 m wide by 6.1 m long. The first row was a nontreated border row while the second row was used for data collection. All plots were maintained weed-free with between–row cultivation and hand removal of weeds as needed. The statistical design was a randomized complete block design with four replications.

Treatments consisted of a factorial arrangement of five herbicide treatments (no herbicide, flumioxazin (Valor® SX; Valent U.S.A. LLC, CA, USA) pretransplant at 107 g ai ha^{-1}, flumioxazin pretransplant at 214 g ai ha^{-1}, *S*-metolachlor (Dual Magnum®; Syngenta, CH), pretransplant at 1.6 kg ai ha^{-1}, and *S*-metolachlor immediately after transplanting at 1.6 kg ai ha^{-1}) by two activated charcoal treatments (no activated charcoal or activated charcoal at 9 kg ha^{-1} plus nonionic surfactant (Induce®; Helena Agri Enterprises LLC, TN, USA) at 0.5% v/v applied in transplant water. Transplant water was applied to each individual slip through the mechanical transplanter at a rate of 3648 L ha^{-1} across all plots. An activated charcoal slurry was made before mixing with transplant water to improve mixing. The activated charcoal suspension was regularly agitated during transplanting to ensure constant mixing and prevent settling. Herbicide applications were made with a CO_2-pressurized backpack sprayer calibrated to deliver 187 L ha^1 at 173 kPa with a 2-nozzle boom equipped with TeeJet XR 8003-VS flat fan nozzles (Spraying Systems Co., Wheaton, IL, USA). Other production practices including fertility, insect, and disease management were conducted in accordance with recommendations by Kemble (2022).

Visual estimates of foliar sweetpotato injury (stunting and chlorosis) were rated on a scale of 0 (no crop injury) to 100% (crop death) at 1, 2, 4, and 8 wk after transplanting (WAT) (Frans et. al 1986). Sweetpotato storage roots were harvested 110 d after transplanting (DAP) with a commercial chain digger, hand-sorted 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) grades, and weighed. Marketable yield was calculated as the sum of jumbo and no. 1 yields. Additionally, no. 1 sweetpotato storage roots were also graded using a high-throughput optical grader (Exeter Engineering, Exeter, CA) to quantify treatment effects on storage root shape. Shape analysis was performed using a calculated average length-width ratio (LWR) per plot for no. 1 sweetpotato roots from Exeter optical grader data. LWR is a metric that indicates overall sweetpotato root shape; a smaller LWR value indicates a rounder sweetpotato root. Average LWR was calculated as the length divided by the diameter for each individual root and then averaged with other roots from the same plot.

Residuals were plotted and visually examined to ensure homogeneity of variance. Yield data required a square root transformation to meet the assumptions of ANOVA. ANOVA was conducted in SAS (Version 9.4) using PROC MIXED. Means were separated using Tukey's HSD ($\alpha = 0.05$). Herbicide, charcoal, and year were treated as fixed effects while replication within year was treated as a random effect.

Results and Discussion

Crop Injury. No visual injury was observed from flumioxazin preplant at rates as high as 214 g ai ha^{-1} (2x registered rate) or *S*-metolachlor as high as 1.6 kg ai ha^{-1} (2x recommended rate: Kemble 2022) (Data not shown). The lack of observed injury is consistent with previous research (Meyers et al. 2010; Kelly et al. 2006).

Sweetpotato Yield. Yield data were combined across years as no significant treatment-by-year interactions were observed. There was no effect of herbicide or charcoal treatment on no. 1, marketable, or total yield. Results indicate that flumioxazin at the labeled rate does not reduce sweetpotato yield compared to the nontreated check (Table 1). Additionally, *S*-metolachlor at 2 times the recommended rate (Kemble 2022) did not reduce sweetpotato yield. Previous research indicates that *S*-metolachlor can reduce sweetpotato yield under certain conditions (Abukari et al.2015, Meyers et al. 2012) but yield reductions due to *S*-metolachlor application were not observed in this study. The addition of activated charcoal in the transplant water also resulted in no effect on sweetpotato yield. The results of this study confirm the conclusions of prior research and indicate that flumioxazin applied pretransplant at registered rates does not reduce no. 1, marketable, or total yields.

Sweetpotato Storage Root Shape. There was a significant herbicide-by-year interaction ($p = 0.0102$) for shape data; thus LWR was assessed by year. Charcoal had no effect on no. 1 LWR. Herbicide affected LWR in 2021 ($p < 0.0001$) but not ($p = 0.3115$) in 2022 (Table 2). In 2021 the no herbicide, flumioxazin 107 g ai ha^{-1} and flumioxazin 214 g ai ha^{-1} treatments were not different from one another with regards to LWR. Both the *S*-metolachlor 1.6 kg ai ha^{-1} applied before transplanting and the *S*-metolachlor 1.6 kg ai ha^{-1} applied after transplanting treatments reduced LWR compared to the no-herbicide treatment in 2021, indicating that both *S*-metolachlor treatments resulted in rounder no. 1 sweetpotato roots. These results are consistent with previous research that indicates that *S*-metolachlor applied directly after transplanting can reduce sweetpotato LWR under certain environmental conditions (Meyers et al. 2012). Flumioxazin did not affect root shape at either the 107 g ai ha^{-1} (1x registered) or the 214 g ai ha^{-1} (2x registered) rates, which is consistent with previous research (Meyers et al. 2010).

Conclusions. Activated charcoal had no effect on sweetpotato yield or quality across any treatment, indicating either that flumioxazin and *S*-metolachlor are not injurious enough at the tested rates for the charcoal to make a difference or that activated charcoal is not an effective safener when mixed with transplant water in sweetpotato for *S*-metolachlor or flumioxazin. More research with additional herbicides is necessary to fully evaluate the potential of activated charcoal mixed with transplant water as a safener for preemergence herbicides in sweetpotato.

Neither flumioxazin nor *S*-metolachlor reduced sweetpotato yield in this study. The results of this study are consistent with those reported in prior research and indicate that flumioxazin and *S*-metolachlor are not detrimental to sweetpotato yield when used according to registered rates. Flumioxazin did not affect sweetpotato root shape in either year; however, *S*-metolachlor resulted in rounder sweetpotato roots in 2021, indicating that *S*-metolachlor may affect sweetpotato root shape when applied at higher than registered rates under certain environmental conditions. These results are consistent with those found in prior research and indicate that flumioxazin and *S*-metolachlor are safe for continued use in sweetpotato.

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Table 2.1. Sweetpotato yield by treatment.

Activated charcoal	Herbicide	Canner	No. 1	Jumbo	Marketable[b]	Total marketable[c]
		Sweetpotato yield[a]				
		---kg ha^{-1}---				
No	None	4317	22627	5653	28280	32597
Yes	None	4982	22506	7221	29728	34710
No	Flumioxazin 107 g ai ha^{-1} preplant	3906	20219	6956	27175	31081
Yes	Flumioxazin 107 g ai ha^{-1} preplant	4274	21064	6734	27681	31912
No	Flumioxazin 214 g ai ha^{-1} preplant	4069	17091	8669	25643	29671
Yes	Flumioxazin 214 g ai ha^{-1} preplant	4376	20692	4911	25603	29979
No	*S*-metolachlor 1.6 kg ai ha^{-1} preplant	5207	18441	4609	23050	28257
Yes	*S*-metolachlor 1.6 kg ai ha^{-1} preplant	5036	19852	6026	25878	30914
No	*S*-metolachlor 1.6 kg ai ha^{-1} after planting	5153	19258	7248	26506	31659
Yes	*S*-metolachlor 1.6 kg ai ha^{-1} after planting	4271	20940	5903	26842	31113

[a]Means were separated by Tukey's HSD at $\alpha = 0.05$. Means with different letters are significantly different.

[b]Marketable yield is the sum of no. 1 and jumbo grades.

[c]Total marketable yield is the sum of canner, no. 1, and jumbo grades.

Table 2.2 Effect of herbicide on length to width ratio (LWR) of no. 1 sweetpotato storage roots in Clinton in 2020 and 2021.

Herbicide	Average length to width ratio[a]	
	2021	2022
None	1.75a	2.05
Flumioxazin 107 g ai ha^{-1}	1.70a	2.05
Flumioxazin 214 g ai ha^{-1}	1.68ab	2.02
S-metolachlor 1.6 kg ai ha^{-1} before planting	1.55b	1.99
S-metolachlor 1.6 kg ai ha^{-1} after planting	1.56b	2.08

[a]Means were separated by Tukey's HSD at $\alpha = 0.05$. Means with different letters are significantly different.