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# Impact of Reduced Rates of Hormonal Herbicides aon Sweetpotato (Ipomoea batatas Lam.) Growth and Development

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# IMPACT OF REDUCED RATES OF HORMONAL HERBICIDES ON SWEETPOTATO (*IPOMOEA BATATAS* LAM.) GROWTH AND DEVELOPMENT

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## ABSTRACT

Studies evaluated impact of dicamba, 2,4-D, and glyphosate at reduced rates to sweetpotato at root formation (RF) and development (RD) growth stages. For DGA salt of dicamba at RF, glyphosate plus dicamba at 1/10x reduced storage root number 42%, canner grade yield 33%, and total yield 36%. With choline salt of 2,4-D at RF, storage root number compared to the non-treated (6.5) was reduced with glyphosate alone at 1/100x (5.1), 2,4-D alone at 1/250x (5.1), and glyphosate plus 2,4-D applied at 1/10 (4.2) and 1/1000x (5). Canner yield was reduced 32% with glyphosate alone 1/10x, 26 and 27% with 2,4-D alone at 1/10 and 1/500x, and 40% with glyphosate plus 2,4-D at 1/10x. Total yield was reduced 40% with glyphosate plus 2,4-D at 1/10x. For BAPMA salt of dicamba at RF, storage root number was reduced 34 and 23% with dicamba alone at 1/10 and 1/100x and 23% with glyphosate plus dicamba at 1/10x. Total yield was reduced with glyphosate alone at 1/750x, dicamba alone at 1/500x, and glyphosate plus dicamba at 1/10 and 1/250x.

With DGA salt of dicamba at RD, U.S. no. 1 yield was reduced 70 and 91% with dicamba alone and plus glyphosate at 1/10x. Total yield was reduced 46 and 64% with dicamba alone and glyphosate plus dicamba at 1/10x. For choline salt of 2,4-D at RD, U.S. no. 1 yield was reduced 67 and 54% with 2,4-D alone at 1/10 and 1/100x, and 87 and 62% with 2,4-D plus glyphosate at similar rates. Compared to the non-treated, canner yield was reduced only with glyphosate plus 2,4-D at 1/10x. Total yield was reduced 60 and 85% with 2,4-D alone and glyphosate plus 2,4-D at 1/10x. With BAPMA salt of dicamba at RD, U.S. no. 1 yield was reduced with glyphosate at 1/10x (31%), dicamba at 1/10 (68%) and 1/500x (37%), and the 1/10 (83%), 1/250 (34%), and 1/1000x (30%) rate of glyphosate plus dicamba. Compared to the non-treated, total yield was reduced with glyphosate alone at 1/100x, dicamba alone at 1/10 and 1/750x, and the combination herbicide at 1/10, 1/100, 1/250, and 1/500x.

# CHAPTER 1
# INTRODUCTION

Sweetpotato (*Ipomoea batatas* Lam.) is believed to be one of the oldest crops cultivated in the new world, with some estimates as early as 3000 BC in Central and South America (O'Brien 1972). It is believed that Christopher Columbus, at the end of the fifteenth century, observed Central Americans cultivating the crop upon his arrival and returned to Spain with plants as a gift for Queen Isabella (de Candolle 1892). After introduction to Europe, the plant was known by the Indian name of "batata" or "padada", which is where the English word "potato" is derived (Cooley 1951). At least 60 yrs later, the Irish potato was introduced into Europe, and referred to by the same name. Therefore, to avoid confusion, the sweet potato was renamed as the "Spanish potato" or the "sweet potato" (Cooley, 1951). Records indicate that sweetpotato was cultivated as early as 1548 in Virginia and spread to Carolina by 1723 and New England by 1764 (Smith et al. 2009). In Louisiana in order to distinguish their potatoes from those grown on the east coast, farmers began marketing sweetpotatoes as yams, which is a very similar edible tuber of the genus *Dioscorea*, indigenous to Africa (Schultheis and Wilson 1998). Sweetpotato is agreed to have originated in northern South America (Schultheis and Wilson 1998). To avoid confusion, the United States Department of Agriculture requires that all sweetpotatoes marketed as yams must have the word sweetpotato present on the packaging (Smith et al. 2009).

Sweetpotato is a low growing vine crop that is a member of the *Ipomoea* genus in the *Convolvulaceae* family (Schultheis and Wilson 1998). It is not commercially propagated sexually by seed, but rather asexually by what is referred to as seed stock from the previous year's harvest (Smith et al. 2009). The process of obtaining seed stock starts the previous year. Following harvest, freshly dug roots endure a curing process which serves to heal wounds resulting from harvest and increase eating quality (Smith et al. 2009). Curing is achieved by placing sweetpotatoes in rooms that maintain temperature range between 26 to 30° C and 90% humidity for approximately five to ten days. (Schultheis et al. 2005). In California, sweetpotatoes are allowed to field cure, which involves withholding water for two to four weeks prior to harvest (Smith et al. 2009). For long term storage, sweetpotatoes should be maintained between 12 to 15° C at approximately 85% humidity. Roots are then selected to be "seed" for the following year.

In early March, selected "seed" roots are exposed to temperature ranging from 24 to 30° C and 90% humidity for two to four weeks with proper ventilation of one to two air changes/day in a process called pre-sprouting (Coolong et al. 2014; Schultheis and Wilson 2015). Pre-sprouting encourages a two to three fold increase in sprouting (Schultheis and Wilson 2015). Roots that are pre-sprouted are then placed in an area called a hotbed and covered with five to seven cm of soil (Smith et al. 2009). To produce enough cuttings to plant a hectare of sweetpotato, approximately 363 to 681 kg of seed potatoes are required (Smith et al. 2009). These beds are then covered with plastic to increase soil temperature and accelerate sprouting. Once shoots have sprouted, plastic is removed and cuttings can be made with resulting "slips" transplanted in approximately four weeks (Clark et al. 2013).

Prior to planting in early May, beds are established and fertilizer and soil insecticides are incorporated (Tara Smith, Personal Communication). In the southeast, nitrogen is applied at a rate of 39 to 90 kg $ha^{-1}$ either broadcast prior to transplanting or as a sidedress application 25 to 30 days after transplant usually in conjunction with a cultivation event (Smith et al. 2009). Phosphorus and potassium are applied at rates of 101 to 135 and 135 to 247 kg $ha^{-1}$, respectively (Smith et al. 2009). At the time of planting in late May/early June, slips with at least one node are placed below ground using a mechanical transplanter. Nodes produce adventitious roots which promotes plant survival and ultimately the production of storage roots around 10 d after transplanting. Maximum yield production requires adventitious roots to effectively produce lateral roots that swell produce storage roots around 30 d after transplant that become mature potatoes (Villordon et al. 2014). The crop will mature within 90 to 130 days depending on cultivar. This determination of harvest date is primarily based on markets, however, research has been established to identify an accurate prediction of harvest using growing degree days (GDD). Villordon et al. (2009) reported that test harvest (sampling representative plants for maturity) can begin at approximately 2600 GDD.

At time of harvest, which traditionally has occurred between August and October in Louisiana, two major operations are performed. First, above ground vines are removed from the mature potato using a flail mower, which shreds the vines and separates them from the roots. Roots are then "dug" utilizing either a chain digger that excavates the roots via a blade and undulating chain that separates soil from the root or a modified moldboard plow that simply "flips" the root onto the soil surface (Smith et al. 2009). Harvested roots are hand graded in accordance with United States Department of Agriculture standards (2005). There are various grades, but for fresh market the primary grade most desired is a U.S. number 1. A U.S. number 1 sweetpotato should weigh no more than 1.25 pounds and is between three and nine inches long and 1.8 and3.5 inches in diameter (USDA, 2005). For processing operations, (i.e., canning, fries, etc.) the goal is tonnage and grading is not necessary.

In 2014, Louisiana produced 26880 kg, or 1186.1 bushel ha$^{-1}$ of sweetpotatoes on 3437 hectares, which resulted in \$66.7 million in gross farm value (Anonymous 2014a). Sweetpotato was grown in 15 parishes, with the majority grown in West Carroll (\$12,305,664 gross farm value), Franklin (\$18,729,296 gross farm value), Avoyelles (\$12,187,500 gross farm value), and Acadia (\$10,981,082 gross farm value) (Anonymous 2014b). There are two main cultivars utilized in sweetpotato production in the U.S., 'Beauregard' and 'Covington' (Smith et al. 2009).

‘Covington’ accounts for 65% of the hectares grown in North Carolina while ‘Beauregard’ has remained an industry standard in other parts of the U.S. (Smith et al. 2009). Production cost is approximately $7,400 to $8,650 per hectare (Anonymous 2014a). Given this high level of production costs, there is little margin for error in terms of external factors that could negatively impact yield.

Overreliance of glyphosate in Roundup Ready® corn, cotton, and soybean cropping systems first introduced in 1995 has resulted in increasing presence of glyphosate resistant weed populations. In 2001 and 2003, glyphosate-resistant marestail (*Conyza canadensis*) was confirmed in Tennessee, Mississippi, and Arkansas (Heap 2015). In 2005, glyphosate-resistant Palmer amaranth (*Amaranthus palmeri* S. Wats.) was confirmed in Georgia (Culpepper et al. 2006). In 2006, suspected populations of glyphosate-resistant Palmer amaranth were identified in North and South Carolina, Tennessee, and Arkansas (Culpepper et al. 2008), and by years end were determined to be resistant (Heap 2015, Scott et al. 2007, York et al. 2007). In 2005, it was determined that a population of Italian ryegrass (*Lolium perenne* var. *multiflorum*) present in a filbert (*Corylus maxima* mill.) orchard located near Portland, Oregon was glyphosate resistant (Heap 2015, Perez-Jones et al. 2005). Glyphosate resistant ryegrass was subsequently confirmed in Mississippi, Arkansas, and Louisiana in 2005, 2008, and 2014, respectively (Heap 2015). Glyphosate-resistant johnsongrass [*Sorghum halepense* (L.) Pers.] was confirmed in Arkansas in 2007 and in 2010 in Louisiana (Heap 2015).

With increasing populations of glyphosate-resistant weeds, herbicide development has shifted toward developing new technologies using older herbicides. Two new technologies will allow application of dicamba (3,6-dichloro-2-methoxybenzoic acid) and 2,4-D [(2,4-dichlorophenoxy)acetic acid] in cotton and soybeans. Because dicamba and 2,4-D control most dicotyledonous plants including morningglory (Siebert et al. 2004), Palmer amaranth

(Norsworthy et al. 2008) and marestail (Bruce and Kells 1990), crop technologies with tolerance to dicamba and 2,4-D may serve an important future role in management of glyphosate-resistant weeds.

Even though dicamba was discovered in 1958 by S. B. Richter, its exact mechanism of action is somewhat unknown. However, it is believed to be similar to endogenous auxin, or indoleacetic acid (IAA), which is naturally present in plants (Senseman 2007). Growth inhibition is due to extreme high levels of auxin, which is thought to cause ethylene production, which in turn causes relative inhibition of plant growth (Cobb and Reade 2010). It is also thought that the biosynthesis of abscisic acid (ABA) is also a byproduct of high auxin levels. Whereas ethylene induces senescence, ABA induces stomatal closure, which causes carbon fixation by photosynthesis to cease (Cobb and Reade 2010). These hormones combined in the presence of light, are also thought to cause accumulation of $H_2O_2$, resulting in oxidative damage and contributing to overall phytotoxicity (Cobb and Reade 2010).

Dicamba plus glyphosate-tolerant soybean has been developed and will be marketed as the Roundup Ready Xtend Crop System® (Fran Deville, Personal Communication). Cotton containing these traits will be marketed as the Bollgard II Xtendflex Crop System® and will allow applications of dicamba, glyphosate, and glufosinate. Herbicides to be marketed with this technology will be either Roundup Xtend (glyphosate + dicamba) 3L with VaporGrip Technology® or Xtendimax (dicamba alone) 4L with VaporGrip Technology®. These formulations will contain diglycolamine (DGA) salt of dicamba with Vaporgrip® being a polybasic polymer to reduce off target movement and volatility. Engenia® herbicide is a N, N-Bis-(aminopropyl) methylamine (BAPMA) tridentate amine salt formulation of dicamba under development that will be registered for application to Roundup Ready Xtend® crops. These herbicides are being marketed as having reduced volatility compared with current DMA or DGA salt formulations of dicamba.  Crop tolerance to dicamba in transformed plants is achieved by insertion of a gene that encodes for a bacterial dicamba monooxygenase enzyme.  Production of this enzyme results in breakdown of the herbicide to a non-herbicidal form, 3,6-dichlorosalicylic acid.

Similar to dicamba, the mechanism of action of 2,4-D is not entirely known, but it is similar to IAA and the pathway previously stated for dicamba (Senseman 2007).  2,4-D was synthesized in 1941 by Robert Porkorny as part of the war effort and therefore was developed in secret.  Its growth regulatory effects were observed in 1942 by P. W. Zimmerman and A. E. Hitchcock (Cobb and Reade 2010).  It was one of the first selective, non-toxic organic herbicides effective at low doses (Cobb and Reade 2010).  Since its registration 70 years ago, 2,4-D has become a major component of weed management systems throughout the world.  Estimates have shown that if 2,4-D was to be banned, the agronomic and economic losses incurred in the United States would equal $2,559 million.  Of that estimate 37% is believed to be due to increases in weed control costs while 36% is caused by crop yield loss with the final 27% due to higher retail commodity prices (Burnside 1996).  2,4-D is formulated in many chemical structural arrangements, the primary being esters and amines.  Esters contain a long branched carbon chain covalently bound to the 2,4-D group, whereas amines contain a positively charged amine group which is ionically bound to the 2,4-D group, the most common of which is the dimethylamine salt (Senseman 2007).  2,4-D ester formulations are known to be very volatile, while 2,4-D amine formulations are less volatile, but may still volatilize somewhat and cause damage to non-target vegetation.

Transgenic technology has also led to development of crops able to tolerate 2,4-D and will be marketed as Enlist® crops.  A new choline salt of 2,4-D has been developed for application in these cropping systems (Dr. Jonathan Siebert, Personal Communication).  This choline salt formulation, touted to be much less volatile than both ester and amine formulations, will be marketed in combination with glyphosate as Enlist Duo®. Enlist® corn will have greater tolerance to Enlist Duo® and to aryloxphenoxyproprionate herbicides while Enlist® soybean and cotton will be tolerant to applications of Enlist Duo® and glufosinate. To help mitigate potential herbicide resistance from occurring in weeds, other 2,4-D formulations will not be allowed to be applied to the Enlist® crops. Crop tolerance in plants in the Enlist® system is achieved by insertion of the aad-12 gene that encodes for a bacterial aryloxyalkanoate dioxygenase enzyme. The enzyme produced results in a breakdown of 2,4-D to a non-herbicidal form, dichlorophenol. In corn, this will result in a breakdown of the aryloxyphenoxyproprionate herbicides. (Personal Communication, Dr. Donnie Miller, 2015).

The active ingredients 2,4-D and dicamba are historically known to cause injury to non-target vegetation through volatilization, drift, or sprayer contamination events. Dicamba has been documented to cause symptoms up to 60 m from the deposition point (Behrens and Lueschen 1979). Research has shown that application of the dimethylamine formulation of dicamba at 1/1000 of the use rate can result in vapor drift at 20 m (Egan and Mortensen 2012). Both dicamba and 2,4-D volatility increase with increasing temperature (Behrens and Lueschen 1979; Grover 1975). Distance between crop production fields in Louisiana can range from as far as kms to as little as 15 m (Personal Communication, Dr. Tara Smith). With sweetpotato fields in close proximity to cotton, corn, and soybeans, there is concern among sweetpotato producers as to the effects of off-target movement of 2,4-D and dicamba.

Merchant et al. (2013) found that morningglories (*Ipomoea spp.*) were completely controlled, when exposed torates as low as 1.2 L $ha^{-1}$ of 2,4-D and 0.6 L $ha^{-1}$ for dicamba. Glyphosate applied at 1120 g ai $ha^{-1}$ controlled 2 to 5 cm entireleaf (*Ipomoea hederacea* L.) and pitted morningglory (*Ipomoea lacunosa* L.), while the same species at 8 to 10 cm were controlled around 85% (Corbett et al. 2004). Previous research with sweetpotato, also an

*Ipomoea* species, showed complete kill of 'Beauregard' sweetpotato within 2 wks when exposed to 1/4 of the recommended rate of 2,4-D 27 d after transplant will result in complete kill of 'Beauregard' sweetpotato within 2 wks (Clark and Braverman 1998). At similar rates of dicamba and triclopyr, chlorosis and severe stunting of plants was observed. Sweetpotato yield reduction was near 100% for dicamba, 2,4-D, and triclopyr at ¼ and 2,4-D at 1/10 recommended use rate. Dicamba and 2,4-D applied at 1/100 of the recommended use rate resulted in intermediate yield reduction. They also observed that stored roots from plants treated with dicamba at 1/10 of the use rate produced shoots with epinastic symptomology 8 mo after application. In a another study, Clark and Braverman (1998) reported that glyphosate applied at 1/2, 1/4, and 1/10 of the use rate, 27 d after transplant reduced 'Beauregard' U.S. no. 1 and total marketable yield. When applied 41 d after transplant, yield reduction was observed with the 1/2 and 1/4 x glyphosate rates, but not for the 1/10 rate.

In soybeans, research showed that at 187 g $ha^{-1}$ (1/3 of the use rate), dicamba, applied to 2 to 3 trifoliate reduced yield at least 75% (Al-Khatib and Peterson 1999). Johnson et al (2012) reported yield reduction in soybean with both dicamba and 2,4-D at rates as low as 41 g $ha^{-1}$ (1/8 of the use rate). Visual injury was greater with dicamba compared with 2,4-D when the herbicides were applied at the same fraction of the use rates. In Louisiana, when soybeans were exposed to 1/2 the labeled rate of dicamba (280 g $ha^{-1}$) at the 2 to 3 trifoliate stage, a yield reduction of 85%, and a height reduction of 72% were observed (Griffin et al. 2013). Cotton exposed to 41 g $ha^{-1}$ (1/8 recommended use rate) was injured 40 to 60% and 60 to 80% for 1 and 2 wks after treatment, respectively (Johnson et al. 2012). Cotton exposed to 1/8 use rate of dicamba (41 g $ha^{-1}$)resulted in injury of 20 to 40% and 40 to 70% for 1 and 2 wks after treatment, respectively (Johnson et al. 2012). At 1/1000 of the use rate, 0.00028 kg ai $ha^{-1}$, 2,4-D injured cotton 35 to 40% injury at 1 wk after treatment (Everitt and Keeling 2009). For application of

2,4-D at 1/200 the recommended use rate (2.805 g ae $ha^{-1}$) at 3 to 4 leaf cotton, injury 28 d after treatment was 76% in 2005 and 88% in 2006 (Marple et al. 2008). When applied at 4 to 5 leaf cotton, 1/2 the use rate of dicamba (0.28 kg $ha^{-1}$) resulted in a 36% lint yield reduction (Everitt and Keeling 2009).

In cauliflower (*Brassica oleracea* L.), pepper (*Capsicum annuum* L.), radish (*Raphanus sativus* L.), and tomato (*Solanum lycopersicum* L.), adverse effects from 2,4-D was observed at a rates as low as 2.1 g $ha^{-1}$ (Hemphill and Montgomery 1981). In pepper, Gilreath et al. (2000) reported a reduction in non-marketable yield following application of glyphosate at 0.14 kg $ha^{-1}$. Potato (*Solanum tuberosum* L. 'Norland') exhibited phytotoxic symptomology following application of dicamba at 2.8 g ai $ha^{-1}$ (Wall 1994). At 22.2 g ai $ha^{-1}$ dicamba, marketable yield loss was 70 to 75%. Potato is also sensitive to glyphosate and at 0.5 kg $ha^{-1}$, complete control of volunteer plants was observed (Lutman and Richardson 1978). Tomato yield was reduced following early applications of sub-lethal glyphosate rates but reduction in yield was not observed when applied late season (Romanowski 1980). Merchant et al. (2012) reported injury of 35% for pepper, 41% for tomato, and 49% for squash when exposed to 1/50 of the normal use rate of 2,4-D (16.8 g $ha^{-1}$). Yield was reduced by 51, 23, and 27% respectively. For pepper, 2,4-D at a rate of 2.1 g $ha^{-1}$ (1/400 of the use rate) reduced yield 14.5%.

With impending use of dicamba in Xtend technology and use of 2,4-D in Enlist technology, there is concern for off-target movement of these herbicides to sensitive crops. Because both herbicides will be applied in combination with glyphosate, there is also concern as to the effect of glyphosate on sweetpotato as well as any additive effect of glyphosate applied with dicamba or 2,4-D. This research addresses sweetpotato response to rates ranging from 1/10 to 1/1000 of the use rates for glyphosate, the DGA and BAPMA salts of dicamba, and the choline salt of 2,4-D each applied alone and for glyphosate plus the DGA salts of dicamba, glyphosate plus the BAPMA salt of dicamba, or glyphosate plus the choline salt of 2,4-D. Herbicides were applied either 10 days after transplanting, during storage root formation or 30 d after transplanting when storage root growth was occurring. Sweetpotato response to the herbicides was evaluated based on both visual injury of aboveground biomass and belowground yield components.

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## CHAPTER 2
## REDUCED RATE EFFECTS OF HORMONAL HERBICIDES AND GLYPHOSATE ON SWEETPOTATO 1. APPLICATION 10 DAYS AFTER TRANSPLANT(EARLY STORAGE ROOT FORMATION)

### Introduction

In 2014, Louisiana produced 26880 kg, or 1186.1 bushel $ha^{-1}$ of sweetpotatoes on 3437 hectares, which resulted in $66.7 million in gross farm value (Anonymous 2014a). Sweetpotato was grown in 15 parishes, with the majority grown in West Carroll ($12,305,664 gross farm value), Franklin ($18,729,296 gross farm value), Avoyelles ($12,187,500 gross farm value), and Acadia ($10,981,082 gross farm value) (Anonymous 2014b). There are two main cultivars utilized in sweetpotato production in the U.S., 'Beauregard' and 'Covington' (Smith et al. 2009). 'Covington' accounts for 65% of the hectares grown in North Carolina while 'Beauregard' has remained an industry standard in other parts of the U.S. (Smith et al. 2009). Production cost is approximately $7,400 to $8,650 per hectare (Anonymous 2014a). Given this high level of production costs, there is little margin for error in terms of external factors that could negatively impact yield.

Sweetpotato is a low growing vine crop that is a member of the *Ipomoea* genus in the *Convolvulaceae* family (Schultheis and Wilson 1998). It is not commercially propagated sexually by seed, but rather asexually by what is referred to as seed stock from the previous year's harvest (Smith et al. 2009). Maximum yield production requires adventitious roots to effectively produce lateral roots that swell and produce mature potatoes (Villordon et al. 2014). Previous studies have indicated that in pot studies at approximately 5 to 15 d post-transplant, adventitious roots, representing 80% of the final yield, progressively grow and produce lateral roots depending on the internal auxin signaling (need citation). Villordon et al. (2009) differentiated storage root development into a three stage phenology scheme, SR1, SR2, and SR3. SR1 consists of the presence of at least one adventitious root greater than 0.5 cm in length in at least 50% of transplanted slips. SR2 consists of the presence of anomalous cambium in at least one adventitious root on 50% of the plants. SR3 consists of at least one visible storage root, an adventitious root that is swollen 0.5 cm at its widest point, in at least 50% of the plants. Storage root formation begins between 13 and 20 d in the field. Lateral root development is fundamentally dependent on auxin signaling and anything that interferes with this process interferes with storage root formation. This is the precise window for targeting negative impacts, such as herbicide injury, to determine maximum potential to reduce yield due to reduction in storage root number (Arthur Villordon, Personal Communication).

With increasing populations of glyphosate-resistant weeds, herbicide development has shifted toward developing new technologies using older herbicides. Two new technologies will allow for application of dicamba (3,6-dichloro-2-methoxybenzoic acid) (alone or in combination with glyphosate) and 2,4-D [(2,4-dichlorophenoxy)acetic acid] (in combination with glyphosate) in cotton and soybeans. Because dicamba and 2,4-D control most dicotyledonous plants including morningglory (Siebert et al. 2004), Palmer amaranth (Norsworthy et al. 2008) and marestail (Bruce and Kells 1990), crop technologies with tolerance to dicamba and 2,4-D may serve an important future role in management of glyphosate-resistant weeds.

Dicamba plus glyphosate-tolerant soybean has been developed and will be marketed as the Roundup Ready Xtend Crop System® (Fran Deville, Personal Communication). Cotton containing these traits will be marketed as the Bollgard II Xtendflex Crop System® and will allow applications of dicamba, glyphosate, and glufosinate. Herbicides to be marketed with this technology will be either Roundup Xtend (glyphosate + dicamba) 3L with VaporGrip Technology® or Xtendimax (dicamba alone) 4L with VaporGrip Technology®. These formulations will contain diglycolamine (DGA) salt of dicamba with Vaporgrip® being a polybasic polymer to reduce off target movement and volatility. Engenia® herbicide is a N, N-Bis-(aminopropyl) methylamine

(BAPMA) tridentate amine salt formulation of dicamba under development that will be registered for application to Roundup Ready Xtend® crops. These herbicides are being marketed as having reduced volatility compared with current DMA or DGA salt formulations of dicamba. Crop tolerance to dicamba in transformed plants is achieved by insertion of a gene that encodes for a bacterial dicamba monooxygenase enzyme. Production of this enzyme results in breakdown of the herbicide to a non-herbicidal form, 3,6-dichlorosalicylic acid.

Transgenic technology has led to development of crops able to tolerate 2,4-D and will be marketed as Enlist® crops. A new choline salt of 2,4-D has been developed for use in these cropping systems (Dr. Jonathan Siebert, Personal Communication). This choline salt formulation, touted to be much less volatile than both ester and amine formulations,will be marketed in combination with glyphosate as Enlist Duo®. Enlist® corn will have tolerance to Enlist Duo® and tolerance to aryloxphenoxyproprionate herbicides while Enlist® soybean and cotton will be tolerant to applications of Enlist Duo® and glufosinate. To help mitigate potential herbicide resistance from developing in weeds, other 2,4-D formulations will not be allowed to be applied to the Enlist® crops. Crop tolerance in plants in the Enlist® system is achieved by insertion of the aad-12 gene that encodes for a bacterial aryloxyalkanoate dioxygenase enzyme. The enzyme produced results in a breakdown of 2,4-D to a non-herbicidal form, dichlorophenol. In corn, this will result in a breakdown of the aryloxyphenoxyproprionate herbicides. (Personal Communication, Dr. Donnie Miller, 2015).

Previous research evaluating impacts of reduced rates of herbicides have reported increased injury when carrier volumes are varied proportionally with lower herbicide rates (Ellis et al. 2002; Roider et al. 2008). Other researchers, however, have suggested that proportionally reducing carrier volume with herbicide rate may yield unrealistic results and confound result obtained (Everitt and Keeling 2009). Merchant et al. (2013) found that morningglories

(*Ipomoea spp.*) were completely controlled, when exposed torates as low as 1.2 L $ha^{-1}$ of 2,4-D and 0.6 L $ha^{-1}$ for dicamba. Glyphosate applied at 1120 g ai $ha^{-1}$ controlled 2 to 5 cm entireleaf (*Ipomoea hederacea* L.) and pitted morningglory (*Ipomoea lacunosa* L.), while the same species at 8 to 10 cm were controlled around 85% (Corbett et al. 2004). Previous research with sweetpotato, also an *Ipomoea* species, showed complete kill of 'Beauregard' sweetpotato within 2 wks when exposed to 1/4 of the recommended rate of 2,4-D 27 d after transplant will result in complete kill of 'Beauregard' sweetpotato within 2 wks (Clark and Braverman 1998). At similar rates of dicamba and triclopyr, chlorosis and severe stunting of plants was observed. Sweetpotato yield reduction was near 100% for dicamba, 2,4-D, and triclopyr at ¼ and 2,4-D at 1/10 recommended use rate. Dicamba and 2,4-D applied at 1/100 of the recommended use rate resulted in intermediate yield reduction. They also observed that stored roots from plants treated with dicamba at 1/10 of the use rate produced shoots with epinastic symptomology 8 mo after application. In a another study, Clark and Braverman (1998) reported that glyphosate applied at 1/2, 1/4, and 1/10 of the use rate, 27 d after transplant reduced 'Beauregard' U.S. no. 1 and total marketable yield. When applied 41 d after transplant, yield reduction was observed with the 1/2 and 1/4 x glyphosate rates, but not for the 1/10 rate.

With impending use of dicamba in Xtend technology and use of 2,4-D in Enlist technology, there is concern for off-target movement of these herbicides to sensitive crops. Because both herbicides will be applied in combination with glyphosate, there is also concern as to the effect of glyphosate on sweetpotato as well as any additive effect of glyphosate applied with dicamba or 2,4-D. This research addresses sweetpotato response to rates ranging from 1/10 to 1/1000 of the use rates for glyphosate, the DGA and BAPMA salts of dicamba, and the choline salt of 2,4-D each applied alone and for glyphosate plus the DGA salts of dicamba, glyphosate plus the BAPMA salt of dicamba, or glyphosate plus the choline salt of 2,4-D.

Sweetpotato response to the herbicides was evaluated based on both visual injury of aboveground biomass and belowground yield components.

## Materials and Methods

Three field studies were initiated in 2014 at the Sweet Potato Research Station near Chase, LA to compare sweetpotato response to glyphosate, dicamba and 2,4-D. Fertilizer was applied pre-plant at 45 kg N, 123 kg P, and 123 kg K per hectare. Chlorpyrifos at 2.1 kg ai $ha^{-1}$ and clothianidin at 0.22 kg ai $ha^{-1}$ soil applied insecticides were applied in furrow prior to planting. 'Beauregard' sweetpotato was mechanically transplanted at a population of 32,294 plants per hectare into a 5.8 pH Gigger silt loam (Fine-silty, mixed, active, thermic Typic Fragiudalfs) with an organic matter content of 1.5-1.8%. Flumioxazin at 71.4 g ai $ha^{-1}$ pre-transplant followed by S-metolachlor at 1.4 kg ai $ha^{-1}$ immediately post-transplant were applied to eliminate weed interference. Subsequent applications of clethodim (170 g ai $ha^{-1}$) were made throughout the growing season as needed for grass control in addition to hand weeding for broadleaf weed control. Plants were monitored during the growing season and insect control as well as irrigation was scheduled as needed.

Three experiments were conducted each year utilizing a randomized complete block experimental design with treatments placed in a factorial arrangement replicated four times. Factor A consisted of the herbicide treatments (glyphosate alone, the DGAsalt of dicamba, the BAPMA salt of dicamba, or the choline salt of 2,4-D applied alone, and in combination with glyphosate) and Factor B consisted of rates of 1/10, 1/100, 1/250, 1/500, 1/750, and 1/1000 of the 1x use rate of each or the herbicides. For both the DGA salt of dicamba and BAPMA salt experiments, 1x use rates of the herbicides were as follows: glyphosate at 1.12 kg $ha^{-1}$, DGA and

BAPMA salts of dicamba at 0.56 kg $ha^{-1}$, and glyphosate at 1.12 kg $ha^{-1}$ plus DGA and BAPMA salts of dicamba at 0.56 kg $ha^{-1}$. For the 2,4-D choline salt experiment, 1x use rates were as follows: glyphosate at 1.12 kg $ha^{-1}$, 2,4-D choline at 1.05 kg $ha^{-1}$, glyphosate at 1.12 kg $ha^{-1}$ plus 2,4-D choline at 1.05 kg $ha^{-1}$. For each experiment, herbicide treatment s were applied at a constant 140 L $ha^{-1}$ carrier volume using a compressed air tractor mounted sprayer 10 days after transplanting corresponding to early storage root formation. Plots were 3 rows (3 m) wide by 7.62 m long. Two rows were treated (one to be used for root measurements and the other for yield) and the third row served as a border row. Each study included a non-treated control.

At 10 d and 30 d after each application, five plants were sampled and roots were examined to determine storage root number, as well as diameter, and weight. Visual ratings of plant injury based on a scale of 0=no effect to 100=plant death were recorded at 7, 14, and 28 d after herbicide application. A single row from all plots was mechanically harvested and potatoes were separated into U.S. No. 1, canner, and jumbo categories based on USDA standards (USDA 2005).to determine yield.

The MIXED procedure of SAS was used for all data analyses. The fixed effects for the model for yield data included the herbicide, rate, and non-treated control treatments. The fixed effects for the model for injury and root data were treatment and repeated measures effects for DAT. Data were averaged across rating dates. The random effects for all models were year, replications, and plots. Protected LSD test was used for mean separation. For each variable, pairwise comparisons were made using the glyphosate plus dicamba salt or 2,4-D salt applied at the same fractional rate versus glyphosate and dicamba salt or 2,4-D salt applied alone. Additional comparison of treatments to the non-treated control to denote significant reductions were made. The significance level was 0.05 for all tests.

## Results and Discussion

### Sweetpotato injury.

A significant treatment by rate interaction was noted for crop injury (Tables 2.1). Averaged across rating intervals, visual injury was 53% and greatest for the glyphosate plus the DGA salt of dicamba (DGA) combination at the 1/10 rate, the highest rate evaluated (Table 2.1). Injury was expressed as epinastic symptoms and overall plant stunting. Injury for the 1/10 rate combination treatment was greater than for the 1/10 rates of DGA (46%) and glyphosate (10%) applied alone. For individual fractional rates of 1/100 to 1/1000 injury was less for glyphosate applied alone (11 to 7%) compared with the same fractional rates for glyphosate applied with DGA (24 to 14%). Because injury for individual fractional rates of 1/100 to 1/100 for DGA alone was equivalent to DGA applied with glyphosate shows that injury was primarily attributed to the DGA component.

Averaged across evaluation timings, injury of 38 and 43% was observed For the 1/10 rate of the BAPMA salt of dicamba (BAPMA) applied alone and in combination glyphosate with BAPMA, each applied at the highest rate (Table 2.1). For the fractional rates of 1/10, 1/100 and 1/250 greater injury was observed for the combination of glyphosate plus BAPMA (21 to 43%) compared with glyphosate alone (13 to 16%).

Averaged across evaluation intervals, injury was 38% and greatest when glyphosate was applied with 2,4-D choline salt at 1/10 fractional rates (Table 2.1). Injury for this treatment was greater than that observed for the 1/10 fractional rate of glyphosate (23%) and 2,4-D choline (31%) applied alone. At all other fractional rates, injury for glyphosate plus 2,4-D choline was no greater than for glyphosate or 2,4-D applied alone.

Table 2.1. Sweet potato injury following reduced rate applications of glyphosate, dicamba DGA and BAPMA salts, and 2,4-D choline salt 10 days after transplanting.[1]

| Herbicide rate[2] | Herbicide treatment | Injury %[3] | Herbicide treatment | Injury %[3] | Herbicide treatment | Injury %[3] |
|---|---|---|---|---|---|---|
| 1/10x | glyphosate | 10 * | glyphosate | 16* | glyphosate | 23* |
| 1/100x | | 11* | | 15* | | 16 |
| 1/250x | | 14 * | | 13* | | 17 |
| 1/500x | | 12 * | | 14 | | 12 |
| 1/750x | | 8 * | | 17 | | 12 |
| 1/1000x | | 7 * | | 14 | | 15 |
| 1/10x | Dicamba DGA salt | 46 * | Dicamba BAPMA salt | 38 | 2,4-D choline salt | 31* |
| 1/100x | | 24 | | 23 | | 23 |
| 1/250x | | 20 | | 20 | | 20 |
| 1/500x | | 20 | | 17 | | 16 |
| 1/750x | | 21 | | 18 | | 14 |
| 1/1000x | | 16 | | 16 | | 13 |
| 1/10x | glyphosate + dicamba DGA salt | 53 | Glyphosate + dicamba BAPMA salt | 43 | Glyphosate + 2,4-D choline salt | 38 |
| 1/100x | | 24 | | 27 | | 21 |
| 1/250x | | 21 | | 21 | | 11 |
| 1/500x | | 20 | | 17 | | 12 |
| 1/750x | | 16 | | 15 | | 12 |
| 1/1000x | | 14 | | 17 | | 15 |

[1]Herbicides treatments included glyphosate applied alone, dicamba DGA and BAPMA salts, and 2,4-D choline salt applied alone, and combinations of DGA and BAPMA salts of dicamba, and choline salt of 2,4-D with glyphosate. Applications were made 10 day after transplanting on June 20, 2014 and June 12, 2015 corresponding to sweet potato storage root formation.

[2]Herbicide rates were based on the X rates of 1.12 kg/ha$^{-1}$ glyphosate, 0.56 kg/ha$^{-1}$ dicamba DGA and BAPMA salts, and 1.05 kg/ha$^{-1}$ 2,4-D choline salt.

[3]Injury based on 0 to 100% with 0= no injury and 100=plant death. Data averaged across ratings intervals of 7, 14, and 28 days after treatment.

[4]An asterick (*) indicates that injury was significantly lower than that observed for glyphosate plus dicamba DGA salt, dicamba BAPMA salt, or 2,4-D choline salt when applied at the same fractional rate.

**Sweetpotato Root Number**

For any herbicide, there was not a significant effect for root diameter or weight therefore data is not shown. Averaged across samplings at 10 and 30 d after herbicide applications, sweetpotato root number compared with the non-treated control was reduced for only glyphosate plus DGA at the 1/10 rate (3.3 vs. 5.7; 42% reduction) (Table 2.2). Root number associated with the 1/10 fractional rate of the glyphosate plus DGA combination (3.3) was less than that for the same fractional rate of glyphosate alone (6.8) and DGA alone (5.3).

Averaged across evaluation intervals, sweetpotato storage root number was reduced 34 and 23% following application of BAPMA alone at the two highest rates and 23% following application of the glyphosate plus BAPMA combination at the lowest rate in comparison to the non-treated control (Table 2.2). Within each fractional rate, storage root number was equal for the combination of glyphosate plus BAPMA (4.9 to 6.5) in comparison to glyphosate (5.5 to 7.2) and BAPMA (4.2 to 6.6) applied alone.

Averaged across evaluation intervals, storage root number when compared to the non-treated control (6.5) was reduced with glyphosate alone at the 1/100x rate (5.1), 2,4-D alone at the 1/250x rate (5.1), and glyphosate plus 2,4-D applied at the highest (4.2) and lowest (5) rates(Table 2.2). Within each fractional rate, the glyphosate plus 2,4-D combination herbicide resulted in lower storage root number than only 2,4-D alone at the 1/10 (4.2 vs 5.7) and 1/1000 (5 vs 6.6) x rates.

**Sweetpotato Yield**

In comparison to the non-treated control, a reduction in yield of canner grade sweetpotatoes was observed only with the glyphosate plus DGA combination applied at the highest rate (8154 vs 12,179 kg $ha^{-1}$) (Table 2.3). Canner yield for this treatment was equal to that for DGA alone at the same fractional rate (9608 kg $ha^{-1}$) but lower than that for glyphosate

Table 2.2. Sweet potato storage root number following reduced rate applications of glyphosate, dicamba DGA and BAPMA salts, and 2,4-D choline salt 10 days after transplanting.[1]

| Herbicide rate[2] | Herbicide treatment | Root no.[3] | Herbicide treatment | Root no.[3] | Herbicide treatment | Root no.[3] |
|---|---|---|---|---|---|---|
| 1/10x | glyphosate | 6.8* | glyphosate | 6.7 | glyphosate | 5.3 |
| 1/100x | | 6.2 | | 5.8 | | 5.1+ |
| 1/250x | | 7.1 | | 6.3 | | 5.5 |
| 1/500x | | 5.2 | | 7.2 | | 5.8 |
| 1/750x | | 6.4 | | 5.5 | | 6.2 |
| 1/1000x | | 6.3 | | 6.3 | | 6.2 |
| 1/10x | Dicamba DGA salt | 5.3* | Dicamba BAPMA salt | 4.2+ | 2,4-D choline salt | 5.7* |
| 1/100x | | 6.2 | | 4.9+ | | 6 |
| 1/250x | | 6.7 | | 6.5 | | 5.1+ |
| 1/500x | | 5.8 | | 6.6 | | 6.9 |
| 1/750x | | 5.4 | | 5.8 | | 5.9 |
| 1/1000x | | 5.9 | | 5.9 | | 6.6* |
| 1/10x | glyphosate + dicamba DGA salt | 3.3 + | Glyphosate + dicamba BAPMA salt | 5.5 | Glyphosate + 2,4-D choline salt | 4.2+ |
| 1/100x | | 5.9 | | 6.1 | | 5.9 |
| 1/250x | | 6.7 | | 5.9 | | 6 |
| 1/500x | | 6.3 | | 6.5 | | 5.9 |
| 1/750x | | 7.1 | | 6.5 | | 5.2 |
| 1/1000x | | 6.4 | | 4.9+ | | 5+ |
| Nontreated | --- | 5.7 | --- | 6.4 | --- | 6.5 |

[1]Herbicides treatments included glyphosate applied alone, dicamba DGA and BAPMA salts, and 2,4-D choline salt applied alone, and combinations of DGA and BAPMA salts of dicamba, and choline salt of 2,4-D with glyphosate. Applications were made 10 day after transplanting on June 20, 2014 and June 12, 2015 corresponding to sweet potato storage root formation.

[2]Herbicide rates were based on the X rates of 1.12 kg/ha$^{-1}$ glyphosate, 0.56 kg/ha$^{-1}$ dicamba DGA and BAPMA salts, and 1.05 kg/ha$^{-1}$ 2,4-D choline salt.

[3]Storage root number averaged for data collected 10 and 30 d after herbicide application.

[4]An asterisk (*) indicates that injury was significantly lower than that observed for glyphosate plus dicamba DGA salt, dicamba BAPMA salt, or 2,4-D choline salt when applied at the same fractional rate. A plus symbol ($^{+}$) indicates a significant reduction compared with the nontreated.

alone (13,335 kg ha$^{-1}$). At all other fractional rates, canner yield was similar among the combination treatment and the component herbicides.

Total sweet potato yield reduction in comparison to the non-treated control was observed only with the highest rate of the glyphosate plus DGA combination (36%) (Table 2.3). Within the highest rate applied, glyphosate alone resulted in a total yield of 28,473 kg ha$^{-1}$, which was greater than that observed with the combination herbicide (15,925 kg ha$^{-1}$). Total yield following application at any other fractional rate was equal among the combination and it's component herbicides.

Total yield of sweet potato was reduced following application of glyphosate alone at the 1/750x rate (27,965 kg ha$^{-1}$), BAPMA applied alone at the 1/500x rate (28,683 kg ha$^{-1}$), and the glyphosate plus BAPMA combination at the 1/10 (22,888 kg ha$^{-1}$) and 1/250 (27,299 kg ha$^{-1}$) x rates when compared to the non-treated control (35,227 kg ha$^{-1}$) (Table 2.4). Within each fractional rate, a reduction in total yield with the glyphosate plus BAPMA combination was observed only in comparison with glyphosate applied alone at the highest rate (22,888 vs 33,267 kg ha$^{-1}$).

Canner grade sweetpotato yield was reduced 32% following application of glyphosate alone at the highest rate, 26 and 27% following application of 2,4-D alone at the highest and 1/500x rates, and 40% following application of glyphosate plus 2,4-D at the highest rate in comparison to the non-treated control (Table 2.5). Within each fractional rate, the glyphosate plus 2,4-D combination reduced canner grade yield only in comparison with glyphosate applied alone at the 1/750 x rate (26%). Total yield was reduced 40% with glyphosate plus 2,4-D at the highest rate in comparison with the non-treated control while all other treatments resulted in similar total yield in comparison. Within each fractional rate, with the exception of the highest rate where the combination herbicide resulted in reduced yield (15,258 kg ha$^{-1}$) in comparison

Table 2.3 Canner grade yield, and total yield following application of glyphosate and DGA salt of dicamba to sweetpotato 10 days after transplant

| Treatment[1] | Rate[2] | Yield | | | |
|---|---|---|---|---|---|
| | | Jumbo Grade | US Number 1 Grade | Canner Grade | Total |
| | | ---kg ha$^{-1}$--- | | | |
| glyphosate | 1/10x | 8033 | 7105 | 13335* | 28473* |
| | 1/100x | 6370 | 6790 | 10099 | 23450 |
| | 1/250x | 7542 | 7403 | 14385 | 29330 |
| | 1/500x | 5582 | 5653 | 15259 | 26513 |
| | 1/750x | 5513 | 6842 | 16730 | 29086 |
| | 1/1000x | 7752 | 8838 | 11165 | 27756 |
| DGA salt of dicamba | 1/10x | 5775 | 5687 | 9608 | 21070 |
| | 1/100x | 6860 | 6702 | 12232 | 25795 |
| | 1/250x | 6212 | 7053 | 12249 | 25514 |
| | 1/500x | 5705 | 6195 | 13861 | 25761 |
| | 1/750x | 7122 | 8032 | 10675 | 25829 |
| | 1/1000x | 6143 | 8365 | 12407 | 26914 |
| glyphosate + DGA salt of dicamba | 1/10x | 3378 | 4393 | 8154+ | 15925+ |
| | 1/100x | 5128 | 6860 | 13107 | 25095 |
| | 1/250x | 7245 | 6422 | 12249 | 25919 |
| | 1/500x | 4270 | 7494 | 13737 | 25375 |
| | 1/750x | 5390 | 7542 | 14139 | 27072 |
| | 1/1000x | 6143 | 7473 | 11549 | 25164 |
| Non-treated | N/A | 5023 | 7875 | 12179 | 25078 |

[1]Herbicides treatments included glyphosate applied alone, dicamba DGA applied alone, and combination of DGA salt of dicamba with glyphosate. Applications were made 10 day after transplanting on June 20, 2014 and June 12, 2015 corresponding to sweet potato storage root formation.
[2]X rates are as follows: 1.12 kg ha$^{-1}$ glyphosate, 0.56 kg ha$^{-1}$ DGA salt of dicamba, and 1.12 kg ha$^{-1}$ glyphosate plus 0.56 kg ha$^{-1}$ DGA salt of dicamba.
[3]An asterisk (*) indicates that injury was significantly lower than that observed for glyphosate plus dicamba DGA salt when applied at the same fractional rate. A plus symbol ($^{+}$) indicates a significant reduction compared with the nontreated.

Table 2.4. Total yield following application of glyphosate and BAPMA salt of dicamba to sweetpotato 10 days after transplant

| Treatment[1] | Rate[2] | Yield | | | |
|---|---|---|---|---|---|
| | | Jumbo Grade | US Number 1 Grade | Canner Grade | Total |
| | | -----------------------------kg ha$^{-1}$----------------------------- | | | |
| glyphosate | 1/10x | 5758 | 11567 | 15943 | 33267* |
| | 1/100x | 7175 | 9153 | 14998 | 31323 |
| | 1/250x | 9555 | 5670 | 17010 | 32067 |
| | 1/500x | 10780 | 9328 | 16695 | 36803 |
| | 1/750x | 6458 | 7542 | 13965 | 27965+ |
| | 1/1000x | 8208 | 7998 | 15172 | 31377 |
| BAPMA salt of dicamba | 1/10x | 7263 | 6668 | 15033 | 28961 |
| | 1/100x | 8365 | 7315 | 15715 | 31394 |
| | 1/250x | 8138 | 9100 | 14227 | 31459 |
| | 1/500x | 8610 | 6143 | 13930 | 28683+ |
| | 1/750x | 8155 | 8977 | 16485 | 33616 |
| | 1/1000x | 8557 | 7122 | 13212 | 28891 |
| glyphosate + BAPMA salt of dicamba | 1/10x | 5828 | 6650 | 10412 | 22888+ |
| | 1/100x | 9975 | 7910 | 13422 | 31306 |
| | 1/250x | 5635 | 7018 | 14420 | 27299+ |
| | 1/500x | 8067 | 8680 | 16223 | 33669 |
| | 1/750x | 5670 | 7857 | 15943 | 29469 |
| | 1/1000x | 9205 | 8767 | 14420 | 32392 |
| Non-treated | N/A | 11270 | 8628 | 15330 | 35227 |

[1]Herbicides treatments included glyphosate applied alone, dicamba BAPMA salt applied alone, and combinations of BAPMA salt of dicamba with glyphosate. Applications were made 10 day after transplanting on June 20, 2014 and June 12, 2015 corresponding to sweet potato storage root formation.

[2]X rates are as follows: 1.12 kg ha$^{-1}$ glyphosate, 0.56 kg ha$^{-1}$ BAPMA salt of dicamba, and 1.12 kg ha$^{-1}$ glyphosate plus 0.56 kg ha$^{-1}$ BAPMA salt of dicamba.

[3]An asterisk (*) indicates that injury was significantly lower than that observed for glyphosate plus dicamba BAPMA salt when applied at the same fractional rate. A plus symbol ($^{+}$) indicates a significant reduction compared with the nontreated.

Table 2.5. Canner grade yield, and total yield following application of glyphosate and choline salt of 2,4-D to sweetpotato 10 days after transplant

| Treatment[1] | Rate[2] | Yield | | | |
|---|---|---|---|---|---|
| | | Jumbo Grade | US Number 1 Grade | Canner Grade | Total |
| | | ----------kg ha$^{-1}$---------- | | | |
| glyphosate | 1/10x | 5985 | 6283 | 9344+ | 21612* |
| | 1/100x | 5635 | 8733 | 14280 | 28646 |
| | 1/250x | 3850 | 8628 | 11498 | 23974 |
| | 1/500x | 2520 | 8628 | 12021 | 23170 |
| | 1/750x | 2817 | 7227 | 13877* | 23921 |
| | 1/1000x | 3920 | 7280 | 12443 | 23643 |
| choline salt of 2,4-D | 1/10x | 4708 | 7000 | 10151+ | 21856* |
| | 1/100x | 7000 | 6545 | 12407 | 25951 |
| | 1/250x | 4708 | 9607 | 11532 | 24796 |
| | 1/500x | 7175 | 8855 | 10201+ | 26967 |
| | 1/750x | 4008 | 7630 | 12355 | 23991 |
| | 1/1000x | 6440 | 5618 | 11217 | 23274 |
| glyphosate + choline salt of 2,4-D | 1/10x | 2170 | 4830 | 8260+ | 15258+ |
| | 1/100x | 3412 | 6317 | 13562 | 23291 |
| | 1/250x | 3640 | 7437 | 13526 | 24604 |
| | 1/500x | 5443 | 7017 | 13264 | 25724 |
| | 1/750x | 4113 | 8086 | 10325 | 2252 |
| | 1/1000x | 4970 | 8697 | 11112 | 24779 |
| Non-treated | N/A | 4882 | 6510 | 13842 | 25234 |

[1]Herbicides treatments included glyphosate applied alone, 2,4-D choline salt applied alone, and combinations choline salt of 2,4-D with glyphosate. Applications were made 10 day after transplanting on June 20, 2014 and June 12, 2015 corresponding to sweet potato storage root formation.

[2]X rates are as follows: 1.12 kg ha$^{-1}$ glyphosate, 1.05 kg ha$^{-1}$ choline salt of 2,4-D, and 1.12 kg ha$^{-1}$ glyphosate plus 1.05 kg ha$^{-1}$ choline salt of 2,4-D.

[3]An asterisk (*) indicates that injury was significantly lower than that observed for glyphosate plus 2,4-D choline salt when applied at the same fractional rate. A plus symbol ($^{+}$) indicates a significant reduction compared with the nontreated.

to glyphosate (21,612 kg ha$^{-1}$) and 2,4-D (21,856 kg ha$^{-1}$) applied alone, all combination and component treatments resulted in similar total yield.

In general, injury to sweetpotato with each combination herbicide evaluated was greatest at the highest rate of 1/10 x of the anticipated labeled use rate, although injury observed at lower rates (especially toward the upper end range) would be cause for concern after initial observation by sweetpotato producers. Injury with each herbicide combination that included dicamba was generally equal to that observed for the dicamba component applied alone and greater than glyphosate applied alone at equivalent fractional rates, indicating that injury is most attributable to the dicamba in the combination. This was not the case where 2,4-D was a component of the combination. Braverman and Clark in 1998 reported that the effects of glyphosate at low rates on 'Beauregard' sweetpotato were not as pronounced as those observed with hormone herbicides 2,4-D, dicamba, and triclopyr. In all studies, yield of U.S. no. 1 sweetpotato was not reduced following application of the herbicide combination or its individual components. This is of especial importance to producers of sweetpotatoes intended for fresh market use where production of U.S. no. 1 grade sweetpotatoes is most desirable. Likewise yield of jumbo grade sweetpotatoes was unaffected. The 1/10x rate of each combination herbicide did, however, reduce both canner grade and total sweetpotato yield. This is of concern to producers who intend to sell the crop for processing use, where total tonnage is most important. Braverman and Clark in 1998 reported that 2,4-D applied at a 1/10x rate resulted in almost nonexistent yield while the 1/100x rate of 2,4-D, the 1/10 and 1/100x rates of dicamba, and the 1/10x rate of glyphosate resulted in intermediate yield reduction. Herbicide in this research, however, were applied 27 d post-transplant as opposed to 10 d post-transplant in the current research. The data suggest that injury and subsequent total yield reduction concerns from the combination herbicides evaluated are valid with sublethal rates as low as 1/10 x rate that may be encountered in sprayer contamination events and off-target spray applications during storage root formation. Therefore, producers with multi-crop farming operations are cautioned to thoroughly follow all sprayer cleanout procedures when previously spraying one of the combination herbicides evaluated or to devote different equipment to spraying Xtend® and Enlist® crops. In addition, proper consideration should be given to planting these crops in close proximity to sweetpotato production fields and make herbicide applications under environmental conditions that are not conducive to off-target spray movement.

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## CHAPTER 3
## REDUCED RATE EFFECTS OF HORMONAL HERBICIDES AND GLYPHOSATE ON SWEETPOTATO 2. APPLICATION 30 DAYS AFTER TRANSPLANT(STORAGE ROOT GROWTH)

### Introduction

Sweetpotato is a low growing vine crop that is a member of the *Ipomoea* genus in the *Convolvulaceae* family (Schultheis and Wilson 1998). It is not commercially propagated sexually by seed, but rather asexually by what is referred to as seed stock from the previous year's harvest (Smith et al. 2009). Maximum yield production requires adventitious roots to effectively produce lateral roots that swell and produce mature potatoes (Villordon et al. 2014). Previous studies have indicated that in pot studies at approximately 5 to 15 d post-transplant, adventitious roots, representing 80% of the final yield, progressively grow and produce lateral roots depending on the internal auxin signaling (Dr. Arthur Villordon, Personal Communication). Villordon et al. (2009) differentiated storage root development into a three stage phenology scheme, SR1, SR2, and SR3. SR1 consists of the presence of at least one adventitious root greater than 0.5 cm in length in at least 50% of transplanted slips. SR2 consists of the presence of anomalous cambium in at least one adventitious root on 50% of the plants. SR3 consists of at least one visible storage root, an adventitious root that is swollen 0.5 cm at its widest point, in at least 50% of the plants. Togari (1950) found that storage roots started to swell at 25 days after transplant (DAT) and continued to develop until harvest. Immediately following harvest, storage roots are the separated into different classifications, or "grades" as set by the United States Department of Agriculture (USDA). These grades typically include Jumbo grade, US Number 1 grade, and canner grade (USDA, 2005). These grades are based upon the amount of root swelling that takes place during the SR3 stage, which usually occurs between 26 and 35 d after transplant (Villordon et al. 2009). During this time it is possible that any negative effects, such as injury from herbicides, on storage root yield and quality can be observed (Arthur Villordon, Personal Communication).

In 2014, Louisiana produced 26880 kg, or 1186.1 bushel $ha^{-1}$ of sweetpotatoes on 3437 hectares, which resulted in \$66.7 million in gross farm value (Anonymous 2014a). Sweetpotato was grown in 15 parishes, with the majority grown in West Carroll (\$12,305,664 gross farm value), Franklin (\$18,729,296 gross farm value), Avoyelles (\$12,187,500 gross farm value), and Acadia (\$10,981,082 gross farm value) (Anonymous 2014b). There are two main cultivars utilized in sweetpotato production in the U.S., 'Beauregard' and 'Covington' (Smith et al. 2009). 'Covington' accounts for 65% of the hectares grown in North Carolina while 'Beauregard' has remained an industry standard in other parts of the U.S. (Smith et al. 2009). Production cost is approximately \$7,400 to \$8,650 per hectare (Anonymous 2014a). Given this high level of production costs, there is little margin for error in terms of external factors that could negatively impact yield.

With increasing populations of glyphosate-resistant weeds, herbicide development has shifted toward developing new technologies using older herbicides. Two new technologies will allow for application of dicamba (3,6-dichloro-2-methoxybenzoic acid) (alone or in combination with glyphosate) and 2,4-D [(2,4-dichlorophenoxy)acetic acid] (in combination with glyphosate) in cotton and soybeans. Because dicamba and 2,4-D control most dicotyledonous plants including morningglory (Siebert et al. 2004), Palmer amaranth (Norsworthy et al. 2008) and marestail (Bruce and Kells 1990), crop technologies with tolerance to dicamba and 2,4-D may serve an important future role in management of glyphosate-resistant weeds.

Dicamba plus glyphosate-tolerant soybean has been developed and will be marketed as the Roundup Ready Xtend Crop System® (Fran Deville, Personal Communication). Cotton containing these traits will be marketed as the Bollgard II Xtendflex Crop System® and will allow applications of dicamba, glyphosate, and glufosinate. Herbicides to be marketed with this technology will be either Roundup Xtend (glyphosate + dicamba) 3L with VaporGrip Technology® or Xtendimax (dicamba alone) 4L with VaporGrip Technology®. These formulations will contain diglycolamine (DGA) salt of dicamba with Vaporgrip® being a polybasic polymer to reduce off target movement and volatility. Engenia® herbicide is a N, N-Bis-(aminopropyl) methylamine (BAPMA) tridentate amine salt formulation of dicamba under development that will be registered for application to Roundup Ready Xtend® crops. These herbicides are being marketed as having reduced volatility compared with current DMA or DGA salt formulations of dicamba. Crop tolerance to dicamba in transformed plants is achieved by insertion of a gene that encodes for a bacterial dicamba monooxygenase enzyme. Production of this enzyme results in breakdown of the herbicide to a non-herbicidal form, 3,6-dichlorosalicylic acid.

Transgenic technology has led to development of crops able to tolerate 2,4-D and will be marketed as Enlist® crops. A new choline salt of 2,4-D has been developed for use in these cropping systems (Dr. Jonathan Siebert, Personal Communication). This choline salt formulation, touted to be much less volatile than both ester and amine formulations,will be marketed in combination with glyphosate as Enlist Duo®. Enlist® corn will have tolerance to Enlist Duo® and tolerance to aryloxphenoxyproprionate herbicides while Enlist® soybean and cotton will be tolerant to applications of Enlist Duo® and glufosinate. To help mitigate potential herbicide resistance from developing in weeds, other 2,4-D formulations will not be allowed to be applied to the Enlist® crops. Crop tolerance in plants in the Enlist® system is achieved by insertion of the aad-12 gene that encodes for a bacterial aryloxyalkanoate dioxygenase enzyme. The enzyme produced results in a breakdown of 2,4-D to a non-herbicidal form, dichlorophenol. In corn, this will result in a breakdown of the aryloxyphenoxyproprionate herbicides. (Personal Communication, Dr. Donnie Miller, 2015).

Previous research evaluating impacts of reduced rates of herbicides have reported increased injury when carrier volumes are varied proportionally with lower herbicide rates (Ellis et al. 2002; Roider et al. 2008). Other researchers, however, have suggested that proportionally reducing carrier volume with herbicide rate may yield unrealistic results and confound result obtained (Everitt and Keeling 2009). Merchant et al. (2013) found that morningglories (*Ipomoea spp.*) were completely controlled, when exposed torates as low as 1.2 L $ha^{-1}$ of 2,4-D and 0.6 L $ha^{-1}$ for dicamba. Glyphosate applied at 1120 g ai $ha^{-1}$ controlled 2 to 5 cm entireleaf (*Ipomoea hederacea* L.) and pitted morningglory (*Ipomoea lacunosa* L.), while the same species at 8 to 10 cm were controlled around 85% (Corbett et al. 2004). Previous research with sweetpotato, also an *Ipomoea* species, showed complete kill of 'Beauregard' sweetpotato within 2 wks when exposed to 1/4 of the recommended rate of 2,4-D 27 d after transplant will result in complete kill of 'Beauregard' sweetpotato within 2 wks (Clark and Braverman 1998). At similar rates of dicamba and triclopyr, chlorosis and severe stunting of plants was observed. Sweetpotato yield reduction was near 100% for dicamba, 2,4-D, and triclopyr at ¼ and 2,4-D at 1/10 recommended use rate. Dicamba and 2,4-D applied at 1/100 of the recommended use rate resulted in intermediate yield reduction. They also observed that stored roots from plants treated with dicamba at 1/10 of the use rate produced shoots with epinastic symptomology 8 mo after application. In a another study, Clark and Braverman (1998) reported that glyphosate applied at 1/2, 1/4, and 1/10 of the use rate, 27 d after transplant reduced 'Beauregard' U.S. no. 1 and total marketable yield. When applied 41 d after transplant, yield reduction was observed with the 1/2 and 1/4 x glyphosate rates, but not for the 1/10 rate.

With impending use of dicamba in Xtend technology and use of 2,4-D in Enlist technology, there is concern for off-target movement of these herbicides to sensitive crops. Because both herbicides will be applied in combination with glyphosate, there is also concern as to the effect of glyphosate on sweetpotato as well as any additive effect of glyphosate applied with dicamba or 2,4-D.  This research addresses sweetpotato response to rates ranging from 1/10 to 1/1000 of the use rates for glyphosate, the DGA and BAPMA salts of dicamba, and the choline salt of 2,4-D each applied alone and for glyphosate plus the DGA salts of dicamba, glyphosate plus the BAPMA salt of dicamba, or glyphosate plus the choline salt of 2,4-D. Sweetpotato response to the herbicides was evaluated based on both visual injury of aboveground biomass and belowground yield components.

## Materials and Methods

Three field studies were initiated in 2014 at the Sweet Potato Research Station near Chase, LA to compare sweetpotato response to glyphosate, dicamba and 2,4-D.  Fertilizer was applied pre-plant at 45 kg N, 123 kg P, and 123 kg K per hectare.  Chlorpyrifos at 2.1 kg ai $ha^{-1}$ and clothianidin at 0.22 kg ai $ha^{-1}$ soil applied insecticides were applied in furrow prior to planting.    'Beauregard' sweetpotato was mechanically transplanted at a population of 32,294 plants per hectare into a 5.8 pH Gigger silt loam (Fine-silty, mixed, active, thermic Typic Fragiudalfs) with an organic matter content of 1.5-1.8%.  Flumioxazin at 71.4 g ai $ha^{-1}$ pre-transplant followed by S-metolachlor at 1.4 kg ai $ha^{-1}$ immediately post-transplant were applied to eliminate weed interference.  Subsequent applications of clethodim (170 g ai $ha^{-1}$) were made throughout the growing season as needed for grass control in addition to hand weeding for broadleaf weed control.  Plants were monitored during the growing season and insect control as well as irrigation was scheduled as needed.

Three experiments were conducted each year utilizing a randomized complete block experimental design with treatments placed in a factorial arrangement replicated four times.

Factor A consisted of the herbicide treatments (glyphosate alone, the DGAsalt of dicamba, the BAPMA salt of dicamba, or the choline salt of 2,4-D applied alone, and in combination with glyphosate) and Factor B consisted of rates of 1/10, 1/100, 1/250, 1/500, 1/750, and 1/1000 of the 1x use rate of each or the herbicides.  For both the DGA salt of dicamba and BAPMA salt experiments, 1x use rates of the herbicides were as follows: glyphosate at 1.12 kg $ha^{-1}$, DGA and BAPMA salts of dicamba at 0.56 kg $ha^{-1}$, and glyphosate at 1.12 kg $ha^{-1}$ plus DGA and BAPMA salts of dicamba at 0.56 kg $ha^{-1}$.  For the 2,4-D choline salt experiment, 1x use rates were as follows: glyphosate at 1.12 kg $ha^{-1}$, 2,4-D choline at 1.05 kg $ha^{-1}$, glyphosate at 1.12 kg $ha^{-1}$ plus 2,4-D choline at 1.05 kg $ha^{-1}$.  For each experiment,  herbicide treatment s were applied at a constant 140 L $ha^{-1}$ carrier volume using a compressed air tractor mounted sprayer 30 days after transplanting corresponding to storage root growth.  Plots were 3 rows (3 m) wide by 7.62 m long.  Two rows were treated and the third row served as a border row.  Each study included a non-treated control.

Visual ratings of plant injury based on a scale of 0=no effect to 100=plant death were recorded at 7, 14, and 28 d after herbicide application.  A single row from all plots was mechanically harvested and potatoes were separated into U.S. No. 1, canner, and jumbo categories based on USDA standards (USDA 2005).to determine yield.

The MIXED procedure of SAS was used for all data analyses. The fixed effects for the model for yield data included the herbicide, rate, and non-treated control treatments. The fixed effects for the model for injury data were treatment and repeated measures effects for DAT. Data were averaged across rating dates.  The random effects for all models were year, replications, and plots. Protected LSD test was used for mean separation. For each variable, pairwise comparisons were made using the glyphosate plus dicamba salt or 2,4-D salt applied at the same fractional rate versus glyphosate and dicamba salt or 2,4-D salt applied alone.

Additional comparison of treatments to the non-treated control to denote significant reductions were made. The significance level was 0.05 for all tests.

## Results and Discussion

**Sweetpotato Injury.**

A significant treatment by rate by evaluation interval interaction was noted for injury and a significant treatment by rate interaction for jumbo grade, U.S. no. 1, and total yield. At 7 DAT, glyphosate plus the DGA salt of dicamba (DGA) at the highest rate resulted in 40% injury, which was greater than that observed with all other treatments (Table 3.1). With the exception of the highest rate, injury within each fractional rate was equal for the herbicide combination (22 to 29%) and DGA applied alone (21 to 27%), with both greater than glyphosate applied alone (8 to 15%). At 14 DAT, both DGA alone or in combination with glyphosate applied at the highest rate resulted in similar and greatest injury of 39 and 43%, respectively. Similar to 7 DAT, injury within each fractional rate was similar between DGA applied alone (15 to 39%) and in combination with glyphosate (17 to 43%), with both greater than glyphosate applied alone (3 to 7%). By 28 DAT, injury was greatest for DGA applied alone (42%) or in combination with glyphosate (46%) at the highest rate. These same treatments at the 1/100x rate were also the only ones to result in greater than 10% visual injury (22 and 18%, respectively). Injury increased from 7 to 28 DAT for both DGA alone (25 to 42%) and in combination with glyphosate (40 to 46%) at the highest rate, while for glyphosate applied alone injury decreased at this same rate (15 to 1%).

Statistical analysis indicated a significant treatment by rate by evaluation interval interaction with respect to injury and a significant treatment by rate interaction for jumbo grade, U.S. no. 1, and total yield. At 7 DAT, injury was 37% with glyphosate plus the BAPMA salt

Table 3.1. Injury following reduced rate application of glyphosate and DGA salt of dicamba to sweetpotato 30 days after transplant

| Treatment[1] | Rate[2] | Injury 7 DAT | Injury 14 DAT | Injury 28 DAT |
|---|---|---|---|---|
| | | --------% | -------- | -------- |
| glyphosate | 1/10x | 15 * | 7*+ | 1*+ |
| | 1/100x | 14* | 5*+ | 2*+ |
| | 1/250x | 11 | 4*+ | 3+ |
| | 1/500x | 8* | 3* | 2 |
| | 1/750x | 14* | 3*+ | 1+ |
| | 1/1000x | 8* | 5* | 1+ |
| DGA salt of dicamba | 1/10x | 25* | 39+ | 42+ |
| | 1/100x | 22 | 27 | 22 |
| | 1/250x | 23 | 19 | 10+ |
| | 1/500x | 27 | 18+ | 7+ |
| | 1/750x | 21 | 19 | 5+ |
| | 1/1000x | 24 | 15+ | 5+ |
| glyphosate + DGA salt of dicamba | 1/10x | 40 | 43 | 46+ |
| | 1/100x | 23 | 25 | 18+ |
| | 1/250x | 25 | 24 | 8+ |
| | 1/500x | 29 | 21+ | 8+ |
| | 1/750x | 23 | 17 | 5+ |
| | 1/1000x | 22 | 17 | 3+ |

[1]Herbicides were applied July 30, 2014 and July 9, 2015.
[2]X rates are as follows: 1.12 kg $ha^{-1}$ glyphosate, 0.56 kg $ha^{-1}$ DGA salt of dicamba, and 1.12 kg $ha^{-1}$ glyphosate plus 0.56 kg $ha^{-1}$ DGA salt of dicamba.
*Indicates injury significantly lower than that observed with glyphosate + DGA salt of dicamba applied at the same fractional rate.
+ Indicates injury is significantly different from that observed 7 d after treatment.

of dicamba (BAPMA) applied at the highest rate, which was equal to the 33% observed with BAPMA applied alone at the high rate and greater than all other treatments (Table 3.2). Within each fractional rate, injury following application of glyphosate plus BAPMA (25 to 37%) was equal to that for BAPMA alone (22 to 33%) and greater than that for glyphosate alone (10 to 21%). At 14 DAT, BAPMA applied alone (39%) or in combination with glyphosate at the highest rate (38%) resulted in similar injury that was greater than all other treatments. As was noted 7 DAT, injury observed at 14 DAT with the combination treatment (15 to 38%) was equivalent to that for BAPMA applied alone (16 to 39%) and greater than that observed with glyphosate alone (6 to 14%) within each fractional rate. By 28 DAT, with the exception of BAPMA applied alone at the 1/10 (42%) and 1/100 (14%) x rate or in combination with glyphosate at 1/10 (40%) and 1/100 (18%) x rates, all treatments resulted in no greater than 9% injury.

Statistical analysis indicated a significant treatment by rate by evaluation interval interaction with respect to injury and a significant treatment by rate interaction for jumbo grade, canner grade, U.S. no. 1, and total yield. At 7 DAT, glyphosate plus 2,4-D applied at the highest rate resulted in 80% injury, which was greater than all other treatments (Table 3.3). With the exception of the highest rate, injury within each fractional rate for glyphosate plus 2,4-D (15 to 25%) was similar to 2,4-D applied alone (15 to 24%) and greater than glyphosate applied alone (10 to 13%). At 14 DAT, glyphosate plus 2,4-D at the highest rate resulted in 93% injury, which was greater than all other treatments. With the exception of the highest rate (93 vs 74%), within each fractional rate injury observed was equivalent for 2,4-D applied alone (11 to 23%) and in combination with glyphosate (11 to 23%). By 28 DAT, with the exception of 2,4-D applied alone (69%) and in combination with glyphosate (98%), injury for all treatments was no greater than 6%. Of the herbicides evaluated, only 2,4-D in combination with glyphosate applied at the highest rate resulted in increased injury at each evaluation interval.

Table 3.2. Injury following reduced rate application of glyphosate and BAPMA salt of dicamba to sweetpotato 30 days after transplant

| | | Injury | | |
|---|---|---|---|---|
| | | 7 DAT | 14 DAT | 28 DAT |
| Treatment[1] | Rate[2] | ------------------------------------------ | % | ---------------------------------------- |
| Glyphosate | 1/10x | 21* | 11*+ | 1+ |
| | 1/100x | 17* | 6*+ | 2+ |
| | 1/250x | 13* | 14* | 1+ |
| | 1/500x | 11* | 9* | 1+ |
| | 1/750x | 10* | 6* | 2+ |
| | 1/1000x | 14* | 9 | 3+ |
| BAPMA salt of dicamba | 1/10x | 33 | 39 | 42 |
| | 1/100x | 22 | 25 | 14+ |
| | 1/250x | 24 | 17+ | 9+ |
| | 1/500x | 27 | 19+ | 5+ |
| | 1/750x | 26 | 16+ | 4+ |
| | 1/1000x | 23 | 17+ | 3+ |
| glyphosate + BAPMA salt of dicamba | 1/10x | 37 | 38 | 40 |
| | 1/100x | 28 | 27 | 18+ |
| | 1/250x | 29 | 23 | 8+ |
| | 1/500x | 27 | 19+ | 4+ |
| | 1/750x | 25 | 15+ | 2+ |
| | 1/1000x | 26 | 15+ | 4+ |

[1]Herbicides were applied July 30, 2014 and July 9, 2015.

[2]X rates are as follows: 1.12 kg $ha^{-1}$ glyphosate, 0.56 kg $ha^{-1}$ BAPMA salt of dicamba, and 1.12 kg $ha^{-1}$ glyphosate plus 0.56 kg $ha^{-1}$ BAPMA salt of dicamba.

*Indicates injury significantly lower than that observed with glyphosate + BAPMA salt of dicamba applied at the same fractional rate.

+ Indicates injury is significantly different from that observed 7 d after treatment.

Table 3.3. Sweetpotato Injury after exposure to glyphosate and choline salt of 2,4-D at 30 days after transplant

| Treatment[1] | Rate[2] | Injury 7 DAT | 14 DAT | 28 DAT |
|---|---|---|---|---|
| | | ------------------------------------------ | % | ------------------------------------------ |
| glyphosate | 1/10x | 22* | 14*+ | 5*+ |
| | 1/100x | 11* | 5*+ | 0+ |
| | 1/250x | 10* | 7* | 2+ |
| | 1/500x | 11* | 3*+ | 3+ |
| | 1/750x | 11* | 6* | 3+ |
| | 1/1000x | 13* | 4*+ | 0+ |
| choline salt of 2,4-D | 1/10x | 68* | 74*+ | 69* |
| | 1/100x | 24 | 23 | 3+ |
| | 1/250x | 23 | 22 | 4+ |
| | 1/500x | 20 | 19 | 2+ |
| | 1/750x | 21 | 14+ | 3+ |
| | 1/1000x | 15 | 11 | 5+ |
| glyphosate + choline salt of 2,4-D | 1/10x | 80 | 93+ | 98+ |
| | 1/100x | 22 | 21 | 5+ |
| | 1/250x | 25 | 23 | 4+ |
| | 1/500x | 22 | 23 | 4+ |
| | 1/750x | 22 | 18 | 6+ |
| | 1/1000x | 15 | 11 | 3+ |

[1]Herbicides were applied July 30, 2014 and July 9, 2015.

[2]X rates are as follows: 1.12 kg $ha^{-1}$ glyphosate, 1.05 kg $ha^{-1}$ choline salt of 2,4-D, and 1.12 kg $ha^{-1}$ glyphosate plus 1.05 kg $ha^{-1}$ choline salt of 2,4-D.

*Indicates injury significantly lower than that observed with glyphosate + choline salt of 2,4-D applied at the same fractional rate.

+ Indicates injury is significantly different from that observed 7 d after treatment.

## Sweetpotato Yield

When compared to the non-treated control, jumbo grade yield was reduced 82% following application of DGA alone at the 1/10x rate and 98, 72, and 63% with glyphosate plus DGA at 1/10, 1/100, and 1/250 x rates, respectively (Table 3.4). Within each fractional rate, glyphosate plus DGA (140 to 6196 kg $ha^{-1}$) resulted in similar jumbo grade yields to those observed with DGA alone (1103 to 7788 kg $ha^{-1}$). The combination herbicide applied at rates of 1/500 x or greater (140 to 3893 kg $ha^{-1}$), however, did result in reductions when compared to similar fractional rates of glyphosate applied alone (5338 to 7175 kg $ha^{-1}$).

US no. 1 sweetpotato yield was reduced 70 and 91% following application of DGA alone and plus glyphosate at the highest rate, respectively, when compared to the non-treated control (Table 3.4). Within each fractional rate, the only reduction in US no. 1 yield with the glyphosate plus DGA combination was when compared to the highest rate of glyphosate applied alone (12128 vs 1120 kg $ha^{-1}$).

Total yield was reduced 46 and 64% with DGA applied alone and glyphosate plus DGA applied at the highest rate, respectively, when compared to the non-treated control (Table 3.4). Within each fractional rate, the only reduction in total yield observed with the combination herbicide occurred in comparison to glyphosate alone at 1/10 (63%), 1/100 (26%), and 1/250 (21%) x rates.

Jumbo grade sweetpotato yield was reduced 78% by BAPMA applied alone at 1/10x rate and 93 and 48% in combination with glyphosate at the 1/10 and 1/100x rate when compared to the non-treated control (Table 3.5). With the exception of glyphosate plus BAPMA in comparison to glyphosate applied alone at the highest rate (928 vs 12,092 kg $ha^{-1}$), jumbo grade yield was equal for the combination herbicide and all other treatments at each fractional rate.

Table 3.4. Jumbo, number 1, and total yield following application of glyphosate and DGA salt of dicamba to sweetpotato 30 days after transplant

| Treatment[1] | Rate[2] | Yield | | | |
|---|---|---|---|---|---|
| | | Jumbo Grade | US Number 1 Grade | Canner Grade | Total |
| | | ---------------------------------------kg ha----------------------------------------- | | | |
| glyphosate | 1/10x | 5338 | 12128 | 10780 | 28244* |
| | 1/100x | 6773 | 13598 | 12267 | 32637* |
| | 1/250x | 5862 | 13895 | 12180 | 31937* |
| | 1/500x | 7175 | 12460 | 9607 | 29243 |
| | 1/750x | 5634 | 13441 | 11935 | 31008 |
| | 1/1000x | 7437 | 11130 | 12145 | 30710 |
| DGA salt of dicamba | 1/10x | 1103+ | 3832+ | 10780 | 15714+ |
| | 1/100x | 4865 | 11637 | 9468 | 25965 |
| | 1/250x | 3553 | 14403 | 8645 | 26598 |
| | 1/500x | 7788 | 16118 | 9836 | 33740 |
| | 1/750x | 6773 | 14385 | 11498 | 32654 |
| | 1/1000x | 3342 | 12653 | 11970 | 27965 |
| glyphosate + DGA salt of dicamba | 1/10x | 140+ | 1120+ | 9153 | 10412+ |
| | 1/100x | 1767+ | 11323 | 10990 | 24079 |
| | 1/250x | 2309+ | 12687 | 10307 | 25305 |
| | 1/500x | 3693 | 15243 | 10658 | 29592 |
| | 1/750x | 5828 | 15785 | 12303 | 33914 |
| | 1/1000x | 6196 | 13230 | 13336 | 32758 |
| Non-treated | N/A | 6213 | 12897 | 9940 | 29048 |

[1]Herbicides were applied July 30, 2014 and July 9, 2015.

[2]X rates are as follows: 1.12 kg $ha^{-1}$ glyphosate, 0.56 kg $ha^{-1}$ DGA salt of dicamba, and 1.12 kg $ha^{-1}$ glyphosate plus 0.56 kg $ha^{-1}$ DGA salt of dicamba.

+Number represents a significant reduction in comparison to the non-treated control.

*Number is significantly greater in comparison to the glyphosate + DGA salt of dicamba combination applied at the same fractional rate.

Table 3.5. Jumbo grade, Number 1 grade, and Total yield following application of glyphosate and BAPMA salt of dicamba to sweetpotato 30 days after transplant

| Treatment[1] | Rate[2] | Yield | | | |
|---|---|---|---|---|---|
| | | Jumbo Grade | US Number 1 Grade | Canner Grade | Total |
| | | ------kg ha------ | | | |
| glyphosate | 1/10x | 12092 | 10744*+ | 12250 | 35087* |
| | 1/100x | 11270 | 11549 | 9817 | 32637+ |
| | 1/250x | 12057 | 12319 | 9433 | 33179 |
| | 1/500x | 12355 | 15154 | 10955 | 38465 |
| | 1/750x | 11803 | 11102 | 12458 | 35341 |
| | 1/1000x | 9467 | 12634 | 11183 | 33284 |
| BAPMA salt of dicamba | 1/10x | 2852+ | 5023+ | 8050 | 15925+ |
| | 1/100x | 9186 | 13982 | 10342 | 33512 |
| | 1/250x | 9135 | 15067* | 11165 | 35366 |
| | 1/500x | 12372 | 9836+ | 11060 | 33267 |
| | 1/750x | 9765 | 11934 | 10832 | 32530+ |
| | 1/1000x | 12460 | 13930 | 7893 | 34282 |
| glyphosate + BAPMA salt of dicamba | 1/10x | 928+ | 2573+ | 9712 | 13213+ |
| | 1/100x | 6668+ | 12583 | 11760 | 31008+ |
| | 1/250x | 10814 | 10184+ | 10290 | 31290+ |
| | 1/500x | 12389 | 11863 | 8400 | 32654+ |
| | 1/750x | 12249 | 14017 | 11165 | 37432 |
| | 1/1000x | 10080 | 10902+ | 12775 | 33756 |
| Non-treated | N/A | 12862 | 15523 | 11095 | 39480 |

[1]Herbicides were applied July 30, 2014 and July 9, 2015.
[2]X rates are as follows: 1.12 kg $ha^{-1}$ glyphosate, 0.56 kg $ha^{-1}$ BAPMA salt of dicamba, and 1.12 kg $ha^{-1}$ glyphosate plus 0.56 kg $ha^{-1}$ BAPMA salt of dicamba.
+Number represents a significant reduction in comparison to the non-treated control.
*Number is significantly greater in comparison to the glyphosate + BAPMA salt of dicamba combination applied at the same fractional rate.

U.S. no. 1 sweetpotato yield was reduced following application of glyphosate at the highest rate (31%), BAPMA at the highest (68%) and 1/500 (37%) x rate, and the 1/10 (83%), 1/250 (34%), and 1/1000 (30%) x rate of glyphosate plus BAPMA when compared to the non-treated control (Table 3.5). Yield for the combination herbicide was reduced in comparison to component herbicides applied at similar fractional rates for only the highest rate with glyphosate applied alone (10,744 kg $ha^{-1}$) and the 1/500 x rate of BAPMA (9836 kg $ha^{-1}$).

When compared to the non-treated control (39,480 kg $ha^{-1}$), total sweetpotato yield was reduced following application of glyphosate alone at the 1/100x rate (32,637 kg $ha^{-1}$), BAPMA alone at 1/10 (15,925 kg $ha^{-1}$) and 1/750 (32,530 kg $ha^{-1}$) x rates, and the combination herbicide applied at 1/10 (13,213 kg $ha^{-1}$), 1/100 (31,008 kg $ha^{-1}$), 1/250 (31,290 kg $ha^{-1}$), and 1/500 (32,654 kg $ha^{-1}$) x rates (Table 3.5). With the exception of glyphosate plus BAPMA at the highest rate compared to glyphosate alone at the highest rate (13,213 vs 35,087 kg $ha^{-1}$), the combination herbicide resulted in similar total yield to all herbicides at all fractional rates evaluated.

Compared to the non-treated control, jumbo grade sweetpotato yield was reduced 90 and 94% with 2,4-D applied alone and in combination with glyphosate at the highest rate, respectively (Table 3.6). With the exception of the 1/10x rate with glyphosate applied alone (6501 vs 490 kg $ha^{-1}$) and the 1/250 x rate of 2.4-D applied alone (13,037 vs 7664 kg $ha^{-1}$), jumbo grade yield at all fractional rates was equal for the glyphosate plus 2,4-D combination and its components.

When compared with the non-treated control, yield of U.S. no. 1 sweetpotatoes was reduced 67 and 54% following application of 2,4-D alone at the two highest rates, and 87 and 62% following application of 2,4-D in combination with glyphosate at the same rates (Table 3.6). Within each rate, U.S. no. 1 yield was reduced by the glyphosate plus 2,4-D combination in

Table 3.6. Jumbo grade, Number 1 grade, Canner grade and Total yield following application of glyphosate and choline salt of 2,4-D at 30 days after transplant

| Treatment[1] | Rate[2] | Yield | | | |
|---|---|---|---|---|---|
| | | Jumbo Grade | US Number 1 Grade | Canner Grade | Total |
| | | ---------------------------------------- | ----------------kg ha | ---------------- | ---------------------------------------- |
| glyphosate | 1/10x | 6501* | 9257* | 10378* | 26143* |
| | 1/100x | 10220 | 9940* | 12057 | 32215 |
| | 1/250x | 10220 | 13492* | 10570 | 34282+ |
| | 1/500x | 11165 | 9520 | 13018 | 33703*+ |
| | 1/750x | 9152 | 10097 | 8908 | 28157 |
| | 1/1000x | 7088 | 14943 | 10919 | 32952 |
| choline salt of 2,4-D | 1/10x | 841+ | 2992+ | 6492* | 10325*+ |
| | 1/100x | 6894 | 4165+ | 14786 | 25847 |
| | 1/250x | 13037 | 8312 | 12921 | 34263+ |
| | 1/500x | 8820 | 7507 | 11953 | 28280 |
| | 1/750x | 8733 | 9118 | 7664 | 25513 |
| | 1/1000x | 8295 | 11602 | 11323 | 31219 |
| glyphosate + choline salt of 2,4-D | 1/10x | 490+ | 1155+ | 2100+ | 3744+ |
| | 1/100x | 8173 | 3412+ | 16223 | 27807 |
| | 1/250x | 7664 | 8539 | 12966 | 29171 |
| | 1/500x | 8120 | 5845 | 11042 | 25007 |
| | 1/750x | 8592 | 9414 | 10814 | 28821 |
| | 1/1000x | 8627 | 11323 | 9397 | 29346 |
| Non-treated | N/A | 8331 | 9048 | 8347 | 25724 |

[1]Herbicides were applied July 30, 2014 and July 9, 2015.

[2]X rates are as follows: 1.12 kg ha$^{-1}$ glyphosate, 1.05 kg ha$^{-1}$ choline salt of 2,4-D, and 1.12 kg ha$^{-1}$ glyphosate plus 1.05 kg ha$^{-1}$ choline salt of 2,4-D.

+Number represents a significant reduction in comparison to the non-treated control.

*Number is significantly greater in comparison to the glyphosate + choline salt of 2,4-D combination applied at the same fractional rate.

comparison with only glyphosate alone at 1/10 (1155 vs 9257 kg ha$^{-1}$), 1/100 (3412 vs 9940 kg ha$^{-1}$), and 1/250 (8539 vs 13,492 kg ha$^{-1}$) x rates.

When compared to the non-treated control (8347 kg ha$^{-1}$), canner grade yield was reduced only following application of the glyphosate plus 2,4-D combination at 1/10 x rate (2100 kg ha$^{-1}$) (Table 3.6). Within the highest fractional rate, glyphosate plus 2,4-D resulted in an 80 reduction in canner yield when compared to glyphosate applied alone and a 68% reduction when compared to 2,4-D applied alone.

Total yield was reduced 60 and 85% with 2,4-D applied alone and the glyphosate plus 2,4-D combination at the highest rate, respectively, when compared to the non-treated control (Table 3.6). Within each fractional rate, glyphosate plus 2,4-D at the highest rate (3744 kg ha$^{-1}$) reduced total yield only in comparison to that observed for glyphosate applied alone at the 1/10 (26,143 kg ha$^{-1}$), 1/250 (34,282 kg ha$^{-1}$), and 1/500 (33,703 kg ha$^{-1}$), and 2,4-D applied alone at the 1/10 (10,325 kg ha$^{-1}$) and 1/250 (34,263 kg ha$^{-1}$) x rates.

In general, injury to sweetpotato with each combination herbicide evaluated was greatest at the highest rate of 1/10 x of the anticipated labeled use rate, although injury observed at lower rates (especially toward the upper end range) would be cause for concern after initial observation by sweetpotato producers. Injury with each herbicide combination that included dicamba or 2,4-D was generally equal to that observed for these individual components applied alone and greater than glyphosate applied alone at equivalent fractional rates, indicating that injury is most attributable to the dicamba or 2,4-D in the combination. Braverman and Clark in 1998 reported that the effects of glyphosate at low rates on 'Beauregard' sweetpotato were not as pronounced as those observed with hormone herbicides 2,4-D, dicamba, and triclopyr. In the current research, yield of U.S. no. 1 sweetpotato was reduced with the 1/10, the 1/10 and 1/100, and the 1/10, 1/250, and 1/1000 x rates of glyphosate in combination with either the DGA salt of dicamba, the choline salt of 2,4-D, or the BAPMA salt of dicamba, respectively. In addition, total yield was reduced following application of the highest rate of glyphosate plus either the DGA salt of dicamba or the choline salt of 2,4-D and at the two highest rates when applied in combination with the BAPMA salt of dicamba. This is of especial importance to producers of sweetpotatoes intended for fresh market and processor use, where production of U.S. no. 1 grade sweetpotatoes and total tonnage are both important, respectively. Braverman and Clark in 1998 reported that 2,4-D applied at a 1/10x rate resulted in almost nonexistent yield while the 1/100x rate of 2,4-D, the 1/10 and 1/100x rates of dicamba, and the 1/10x rate of glyphosate resulted in intermediate yield reduction when applied 27 d post-transplant. In the current research, the highest rate of both dicamba formulations and the 2,4-D formulation evaluated resulted in significant yield reduction at the highest rate applied. In only one instance did glyphosate reduce yield, and that occurred at the highest rate applied. The data suggest that injury and subsequent total yield reduction concerns from the combination herbicides evaluated are valid with sublethal rates as low as 1/1000 x that may be encountered in sprayer contamination events and off-target spray applications during storage root development. Therefore, producers with multi-crop farming operations are cautioned to thoroughly follow all sprayer cleanout procedures when previously spraying one of the combination herbicides evaluated or to devote different equipment to spraying Xtend® and Enlist® crops. In addition, proper consideration should be given to planting these crops in close proximity to sweetpotato production fields and make herbicide applications under environmental conditions that are not conducive to off-target spray movement.

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## CHAPTER 4
## SUMMARY

Field studies were initiated in 2014 at the Sweet Potato Research Station near Chase, LA and repeated in 2015 to evaluate impact of herbicides dicamba, 2,4-D, and glyphosate applied at reduced rates to 'Beauregard' sweetpotato. Reduced rates including 1/10, 1/100, 1/250, 1/500, 1/750, and 1/1000 of glyphosate alone, dicamba or 2,4-D alone or dicamba or 2,4-D in combination with glyphosate were applied at the storage root formation or developmental stages. Herbicide differentiated the studies conducted with one including a choline salt 2,4-D formulation and the other two utilizing a DGA salt of dicamba or a BAPMA salt of dicamba. Within the 2,4-D choline study, 1x use rates of the herbicides were as follows: glyphosate at 1.12 kg ha$^{-1}$, 2,4-D choline at 1.05 kg ha$^{-1}$, glyphosate at 1.12 kg ha$^{-1}$ plus 2,4-D choline at 1.05 kg ha$^{-1}$. Within the DGA salt of dicamba study, 1x rate of the herbicides were as follows: glyphosate at 1.12 kg ha$^{-1}$, DGA salt of dicamba at 0.56 kg ha$^{-1}$, and glyphosate at 1.12 kg ha$^{-1}$ plus DGA salt of dicamba at 0.56 kg ha$^{-1}$. Within the BAPMA salt of dicamba study, 1x rate of the herbicides were as follows: glyphosate at 1.12 kg ha$^{-1}$, BAPMA salt of dicamba at 0.56 kg ha$^{-1}$, and glyphosate at 1.12 kg ha$^{-1}$ plus BAPMA salt of dicamba at 0.56 kg ha$^{-1}$.

For the DGA salt of dicamba study conducted at the root formation stage of growth, averaged across rating intervals, the glyphosate plus dicamba combination at the highest rate evaluated resulted in 53% visual injury in the form of epinastic symptoms and overall plant stunting, which was greater than that observed for all other treatments. Averaged across evaluation intervals, the glyphosate plus dicamba combination applied at the highest rate resulted in a storage root number of 3.3, which was a 42% reduction from the non-treated control. No other treatment resulted in a reduction in storage root number in comparison with the non-treated control. In comparison to the non-treated control, a reduction in yield of canner grade sweetpotatoes was observed only with the glyphosate plus dicamba combination applied at the highest rate (8154 vs 12,179 kg $ha^{-1}$) (Table 2.2). Canner yield for this treatment was equal to that for dicamba alone at the same fractional rate (9608 kg $ha^{-1}$) but lower than that for glyphosate alone (13,335 kg $ha^{-1}$). Total sweet potato yield reduction in comparison to the non-treated control was observed only with the highest rate of the glyphosate plus dicamba combination (36%).

In the choline salt of 2,4-D study conducted at the storage root formation growth stage, averaged across evaluation intervals, greatest injury of 38% was observed following application of the combination of glyphosate plus 2,4-D. Averaged across evaluation intervals, storage root number when compared to the non-treated control (6.5) was reduced with glyphosate alone at the 1/100x rate (5.1), 2,4-D alone at the 1/250x rate (5.1), and glyphosate plus 2,4-D applied at the highest (4.2) and lowest (5) rates. Canner grade sweetpotato yield was reduced 32% following application of glyphosate alone at the highest rate, 26 and 27% following application of 2,4-D alone at the highest and 1/500x rates, and 40% following application of glyphosate plus 2,4-D at the highest rate in comparison to the non-treated control. Total yield was reduced 40% with glyphosate plus 2,4-D at the highest rate in comparison with the non-treated control while all other treatments resulted in similar total yield in comparison

In the BAPMA salt of dicamba study conducted at the storage root formation growth stage, averaged across evaluation timings, greatest injury of 38 and 43% were observed with dicamba applied alone and glyphosate in combination with dicamba, each applied at the highest rate. Averaged across evaluation intervals, sweetpotato storage root number was reduced 34 and 23% following application of dicamba alone at the two highest rates and 23% following application of the glyphosate plus dicamba combination at the lowest rate in comparison to the non-treated control. Total yield of sweet potato was reduced following application of glyphosate alone at the 1/750x rate (27,965 kg $ha^{-1}$), dicamba applied alone at the 1/500x rate

(28,683 kg $ha^{-1}$), and the glyphosate plus dicamba combination at the 1/10 (22,888 kg $ha^{-1}$) and 1/250 (27,299 kg $ha^{-1}$) x rates when compared to the non-treated control (35,227 kg $ha^{-1}$).

In the DGA salt of dicamba study conducted at the storage root development growth stage, at 7 DAT, glyphosate plus dicamba at the highest rate resulted in 40% injury, which was greater than that observed with all other treatments. At 14 DAT, both dicamba alone or in combination with glyphosate applied at the highest rate resulted in similar and greatest injury of 39 and 43%, respectively. By 28 DAT, injury was greatest for dicamba applied alone (42%) or in combination with glyphosate (46%) at the highest rate. These same treatments at the 1/100x rate were also the only ones to result in greater than 10% visual injury (22 and 18%, respectively). When compared to the non-treated control, jumbo grade yield was reduced 82% following application of dicamba alone at the 1/10x rate and 98, 72, and 63% with glyphosate plus dicamba at 1/10, 1/100, and 1/250 x rates, respectively. US no. 1 sweetpotato yield was reduced 70 and 91% following application of dicamba alone and plus glyphosate at the highest rate, respectively, when compared to the non-treated control. Total yield was reduced 46 and 64% with dicamba applied alone and glyphosate plus dicamba applied at the highest rate, respectively, when compared to the non-treated control.

In the Choline salt of 2,4-D study conducted at the storage root development growth stage, at 7 DAT, glyphosate plus 2,4-D applied at the highest rate resulted in 80% injury, which was greater than all other treatments. At 14 DAT, glyphosate plus 2,4-D at the highest rate resulted in 93% injury, which was greater than all other treatments. By 28 DAT, with the exception of 2,4-D applied alone (69%) and in combination with glyphosate (98%), injury for all treatments was no greater than 6%. Compared to the non-treated control, jumbo grade sweetpotato yield was reduced 90 and 94% with 2,4-D applied alone and in combination with glyphosate at the highest rate, respectively. When compared with the non-treated control, yield of U.S. no. 1 sweetpotatoes was reduced 67 and 54% following application of 2,4-D alone at the two highest rates, and 87 and 62% following application of 2,4-D in combination with glyphosate at the same rates. When compared to the non-treated control (8347 kg $ha^{-1}$), canner grade yield was reduced only following application of the glyphosate plus 2,4-D combination at 1/10 x rate (2100 kg $ha^{-1}$). Total yield was reduced 60 and 85% with 2,4-D applied alone and the glyphosate plus 2,4-D combination at the highest rate, respectively, when compared to the non-treated control.

In the BAPMA salt of dicamba study conducted at the storage root development growth stage, at 7 DAT, injury was 37% with glyphosate plus dicamba applied at the highest rate, which was equal to the 33% observed with dicamba applied alone at the high rate, and greater than all other treatments. At 14 DAT, dicamba applied alone (39%) or in combination with glyphosate at the highest rate (38%) resulted in similar injury that was greater than all other treatments. By 28 DAT, with the exception of dicamba applied alone at the 1/10 (42%) and 1/100 (14%) x rate or in combination with glyphosate at 1/10 (40%) and 1/100 (18%) x rates, all treatments resulted in no greater than 9% injury. Jumbo grade sweetpotato yield was reduced 78% by dicamba applied alone at 1/10x rate and 93 and 48% in combination with glyphosate at the 1/10 and 1/100x rate when compared to the non-treated control. U.S. no. 1 sweetpotato yield was reduced following application of glyphosate at the highest rate (31%), dicamba at the highest (68%) and 1/500 (37%) x rate, and the 1/10 (83%), 1/250 (34%), and 1/1000 (30%) x rate of glyphosate plus dicamba when compared to the non-treated control. When compared to the non-treated control (39,480 kg $ha^{-1}$), total sweetpotato yield was reduced following application of glyphosate alone at the 1/100x rate (32,637 kg $ha^{-1}$), dicamba alone at 1/10 (15,925 kg $ha^{-1}$) and 1/750 (32,530 kg $ha^{-1}$) x rates, and the combination herbicide applied at 1/10 (13,213 kg $ha^{-1}$), 1/100 (31,008 kg $ha^{-1}$), 1/250 (31,290 kg $ha^{-1}$), and 1/500 (32,654 kg $ha^{-1}$) x rates.

In general, injury to sweetpotato at the storage root formation growth stage with each combination herbicide evaluated was greatest at the highest rate of 1/10 x of the anticipated labeled use rate, although injury observed at lower rates (especially toward the upper end range) would be cause for concern after initial observation by sweetpotato producers. In all studies conducted at the storage root formation growth stage, yield of U.S. no. 1 sweetpotato was not reduced following application of the herbicide combination or its individual components. This is of especial importance to producers of sweetpotatoes intended for fresh market use where production of U.S. no. 1 grade sweetpotatoes is most desirable. Likewise yield of jumbo grade sweetpotatoes was unaffected. The 1/10x rate of each combination herbicide did, however, reduce both canner grade and total sweetpotato yield. This is of concern to producers who intend to sell the crop for processing use, where total tonnage is most important.

In the studies conducted at the storage root development growth stages, yield of U.S. no. 1 sweetpotato was reduced with the 1/10, the 1/10 and 1/100, and the 1/10, 1/250, and 1/1000 x rates of glyphosate in combination with either the DGA salt of dicamba, the choline salt of 2,4-D, or the BAPMA salt of dicamba, respectively. In addition, total yield was reduced following application of the highest rate of glyphosate plus either the DGA salt of dicamba or the choline salt of 2,4-D and at the two highest rates when applied in combination with the BAPMA salt of dicamba. This is of especial importance to producers of sweetpotatoes intended for fresh market and processor use, where production of U.S. no. 1 grade sweetpotatoes and total tonnage are both important, respectively. The data suggest that injury and subsequent total yield reduction concerns from the combination herbicides evaluated are valid with sublethal rates as low as 1/1000 x that may be encountered in sprayer contamination events and off-target spray applications during storage root development. Based on cumulative results, producers with multi-crop farming operations are cautioned to thoroughly follow all sprayer cleanout procedures when previously spraying one of the combination herbicides evaluated or to devote different equipment to spraying Xtend® and Enlist® crops. In addition, proper consideration should be given to planting these crops in close proximity to sweetpotato production fields and make herbicide applications under environmental conditions that are not conducive to off-target spray movement.

## VITA

Thomas Michael Batts was born in October 1991 to Roger and Susan Batts of Wendell, North Carolina. He was raised being exposed agricultural research as his father, Roger, conducts agricultural research for North Carolina State University. Thomas attended East Wake High School, where he graduated with honors in May 2009. He pursued a bachelor's degree in Horticultural Science and a minor in Crop Science at North Carolina State University, graduating in December 2013. He then moved to Louisiana to pursue a Master of Science degree in the School of Plant, Environmental, and Soil Sciences at Louisiana State University under the direction of Dr. Donnie K. Miller. He is currently a candidate for graduation with a degree in agronomy with an emphasis in weed science. After graduation, Thomas plans to move to Gainesville, Florida to pursue a Doctorate of Philosophy in weed science at the University of Florida.