Determining Growth Characteristics and Control Programs for Nealley's Sprangletop (Leptochloa nealleyi Vasey)

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DETERMINING GROWTH CHARACTERISTICS AND CONTROL PROGRAMS FOR NEALLEY’S SPRANGETOP (LEPTOCHLOA NEALLEYI VASEY)

A Thesis

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Master of Science

in

The Department of Plant, Environmental, and Soil Sciences

by

Trace Buck
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First and foremost, glory be to God. Without his guidance, patience, and love I would be lost. I have been blessed.

I would be remise not to thank my family for all the love and support they have provided over the years. My love for agriculture and respect for hard work were bestowed upon me from my grandfathers. To both of my grandmothers I am grateful for the love and kindness you have given our family throughout the years. My parents have always been there to support me through the highs and lows no matter what the obstacle and for that I cannot express enough gratitude. Without your constant push to better myself I would not be the man I am today. To my brother, looking back it has always been our childhood competitiveness that has given me the edge in all of my endeavors. To all, I would not have made it this far without you and will consistently rely on your love and support as you can rely on me.

Thank you to my committee members and my undergraduate advisor, Dr. Daniel O. Stephenson, IV, Dr. Eric P. Webster, Dr. Donnie K. Miller, and Dr. Alan C. York. The opportunity to pursue this degree in the betterment of my future is beyond repayment. I will never forget the guidance, knowledge, and motivation as I have progressed as student. I know at times it may have been trying but I am appreciative of the time you have invested in me as I have grown immensely throughout this process.

Thank you to my fellow graduate students who not only assisted along the way but offered me lifelong friendships, Sam Rustom, James McKibben, Connor
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ABSTRACT

Research was conducted at the LSU AgCenter Dean Lee Research and Extension center near Alexandria, La in 2016 and 2017 to evaluate the growth characteristics and control of Nealley’s sprangletop. Nealley’s sprangletop is a relatively new weed with little research available to understand its growth habit and effective control strategies.

Nealley’s sprangletop undergoes a more drastic height increase of 212 to 742 mm, 4 to 6 WAE than Amazon sprangletop 377 to 612 mm in the same time frame. Averaged across harvest interval tiller and leaf number of Nealley’s sprangletop was approximately 50 and 40% less than Amazon sprangletop. Nealley’s sprangletop reached a maximum LAR 4 WAE of 52.2 cm² g⁻¹ at the same harvest interval Amazon sprangletop LAR was 91.5 cm² g⁻¹, which may be a function of lesser photosynthetic capacity. Amazon sprangletop NAR was greater than Nealley’s sprangletop 4 to 6 WAE with 30 g cm² d⁻¹ compared with 12.9 g cm² d⁻¹, respectively. There were no differences for RGR between the two species, however SLA, a major contributor to RGR yielded differences. Averaged across harvest interval Amazon sprangletop SLA was 157.2 cm² g⁻¹ which was greater than Nealley’s sprangletop at 112.9 cm² g⁻¹. The lowest SLR coincided with the highest LAR harvest interval at 4 WAE harvest interval, indicating the period in which plant growth is most rapid regardless of species. There were no differences between Amazon and Nealley’s sprangletop SLW.

All glyphosate based applications initialized at 10 cm were greater than 94% control 28 DAT. When treatments were delayed to 31 cm Nealley’s sprangletop, the
addition of graminicides increased control >94% 28 DAT. Glufosinate applied alone failed to control Nealley's sprangletop at 10 or 31 cm timings regardless of the addition of sequential applications. Quizalofop co-applied with glufosinate to 10 cm resulted in 95% control 28 DAT, however was ineffective at 31 cm timing with 77% control 28 DAT with a single application. Clethodim or quizalofop co-applied with glufosinate in sequential applications resulted in 86 and 98% control 21 DAT compared to 77% by glufosinate alone at 31 cm Nealley's sprangletop.
CHAPTER 1
INTRODUCTION

Nealley’s sprangletop (*Leptochloa nealleyi* Vasey), a monocot in the Poaceae family (Hitchcock 1950), is a clump grass native to Arizona, Florida, Louisiana, and parts of Texas and thrives in the marsh-like ecosystems. In southern Louisiana, Nealley’s sprangletop is commonly found along roadsides and ditches. Bergeron et al. (2015) stated that although it is an annual, it oftentimes exhibits a perennial growth habit in southern Louisiana due to mild winter temperatures. Nealley’s sprangletop is an erect annual with flat culms 1 to 1.5 m tall and an estimated growth rate of greater than 2.5 cm day\(^{-1}\) (Bergeron et al. 2015; LSUAC-CES 2015). It has a short-fringed membranous ligule and sparse pubescence on the leaf sheath near the bottom portion of the plant and the inflorescence is very distinct with a 25- to 50 cm panicle, 2 to 4 cm long racemes, and 1.5 mm long seed (Bergeron et al. 2015). Nealley’s sprangletop is a prolific seed producer with high seed viability at maturity.

It is important to correctly identify Nealley’s sprangletop in order to select the appropriate weed management program (LSUAC-CES 2015). Amazon sprangletop [*Diplachne panicoides* (J. Presl) McNeill] and bearded sprangletop [*Diplachne fusca* (L.) P. Beauv. Ex Roem. & Schult. ssp. *fascicularis* (Lam.) P.M. Peterson & N. Snow] are two other sprangletop species that are pest in Louisiana rice growing areas. Sprangletop species have been described as one of the seven most prevalent and hard to kill weeds in rice (Smith 1988). The sparse pubescence on the leaf sheath is key for separating Nealley’s sprangletop from Amazon and
bearded sprangletop. Furthermore, Nealley’s sprangletop displays an upright growth characteristic with fewer tillers as compared Amazon sprangletop, which can produce prolific tillers.

Smith (1983) first reported that Nealley’s sprangletop was problematic in rice production. Over the past few years, it has become more widespread in Louisiana rice with its predominate distribution in Southwest and Southeast Louisiana (LSUAC-CES 2015); thus, has become an issue in rice production because of its capacity to grow quickly and over-winter in southern Louisiana’s mild climate (EP Webster, personal communication). The over-wintering capacity can lead to a perennial growth habit, which makes Nealley’s sprangletop more difficult to control with herbicides and necessitates alternative control strategies.

Nealley’s sprangletop is a relatively new weed with little research available to understand its growth habit in comparison to other sprangletop species. Growth analysis is a widely used analytical tool for characterization of plant growth (Hoffmann and Poorter 2002) and, when referring to an individual plant, growth is the irreversible change over time in size, form, and occasionally number (Hunt 2016). It utilizes a set of quantitative methods which can be used to determine the performance of the whole plant system and establish its competitive ability grown under natural, semi natural, or controlled conditions. Total dry matter production and leaf area are basic measurements of plants’ vegetative growth (Radosevich et al. 1997), which can be used to describe the species growth characteristics and potential. Measurements such as plant height, dry matter, and leaf area can be used to show the productivity, relative size, and photosynthetic capacity of the plant.
Furthermore, leaf area ratio, leaf weight ratio, and specific leaf area demonstrate the photosynthetic area per unit area of dry matter (Bond and Oliver 2006). Dry matter partitioning coefficients can be used to observe a plant’s capacity to acquire resources and compete with neighboring plants (Radosevich et al. 1997).

Leaf Area Ratio (LAR) is the driving variable of plant growth and describes the “leafiness” of a plant (Radosevich et al. 1997). LAR is comprised of two components, allocation (Leaf Weight Ratio, LWR) and leaf morphology (Specific Leaf Area, SLA), which combine to constitute a positive correlation between LAR and Relative Growth Rate (RGR) (Poorter and Remkes 1990). RGR is the increase in total dry weight of a plant over a specified time. This makes RGR an effective tool for measuring the efficiency of plant growth in respect to mass (Atwell et al. 1999). It is widely considered to be the central plant growth parameter. Grotkopp et al. (2002) stated RGR's power comes from the ability to combine aspects of anatomy, morphology, and physiology. Many studies have shown that SLA is the main contributor to RGR, which can be observed as a positive correlation between high SLA and high RGR. SLA by definition is the ratio of leaf area to leaf mass (Atwell et al. 1999). A high SLA reflects rapid leaf production of a plant and its’ photosynthetic capacity; moreover, said plants ability for acquisition of light and soil resources (Grotkopp and Rejmánek 2007). Specific Leaf Weight (SLW), the opposite of SLA by definition, is a predictive index of previous light and net photosynthetic potential (Pearce et al. 1969). SLW is the ratio of leaf blade mass to leaf blade area resulting in an accurate indicator of leaf thickness and mesophyll development (Jurik 1986). This plant growth parameter is very sensitive to nitrogen status, light accumulation,
among other stresses and gives insight into the overall canopy function (Field and Mooney 1986). Net Assimilation Rate (NAR) is a physiological index closely related to the photosynthetic activity of plant leaves (Radošević et al. 1997). NAR is the result of carbon gain through photosynthesis and carbon losses through processes such as respiration and is expressed per unit leaf area (Poorter and Remkes 1990). Stem-to-leaf Ratio (SLR) is used to show allocation of resources within a plant and is defined as the ratio of stem to leaf dry matter. Marcelis (1996) stated that dry matter partitioning is a coordinated set of metabolic and transport processes that govern the flow of assimilates from source organs to sink organs.

Due to biological differences in plant growth and development, photosynthetic allocation of resources, and competitiveness, we can characterize weedy plant species (Bond and Oliver 2006). Others have used various growth parameters to investigate growth characteristics of soybean (*Glycine max* L.) (Patterson and Flint 1983) and weed species including common cocklebur (*Xanthium strumarium* L.), waterhemp (*Amaranthus rudis* J.D. Sauer), jimsonweed (*Datura stramonium* L.), Palmer amaranth (*Amaranthus palmeri* S. Wats), prickly sida (*Sida spinosa* L.), prostrate pigweed (*Amaranthus biltoides* S. Watson), redroot pigweed (*Amaranthus retroflexus* L.), sicklepod [*Senna obtusifolia* (L.) H.S. Irwin & Barneby], smooth pigweed (*Amaranthus hybridus* L.), spurred anoda [*Anoda cristata* (L.) Schlecht.], and velvetleaf (*Abitulon theophrasti* Medic.) (Bond and Oliver 2006, Horak and Loughin 2000, Patterson and Flint 1983). Palmer amaranth had the highest LAR value when compared to other *Amaranthus* species (Horak and Loughin 2000). Bond and Oliver (2006) found that Palmer amaranth accessions originating
in the southeastern U.S. displayed greater LAR than in other regions. Among the eight species tested, smooth pigweed, common cocklebur, and soybean had the lowest LAR with no differences observed between jimsonweed, prickly sida, sicklepod, spurred anoda, and velvetleaf (Patterson and Flint 1983). These species with higher LAR values can be expected to have a greater photosynthetic capacity leading to a competitive advantage (Bond and Oliver 2006; Horak and Loughin 2000). In addition to having the highest LAR value, Palmer amaranth also had the highest RGR value among other *Amaranthus* species (Horak and Loughin 2000). According to Radosevich et al. (1997), this means that Palmer amaranth has a greater production of biomass per unit of current biomass compared to other *Amaranthus* species. They also observed that in most instances, Palmer amaranth had the highest SLA values indicating more leaf surface per unit biomass, thus, a higher affinity for photosynthesis and shading of competitors. Of the eight species tested by Patterson and Flint (1983), the highest NAR was observed in smooth pigweed, a C4 plant. The highest value of the remaining C3 species was jimsonweed due to its low total leaf area and open canopy structure. Similarly, Bond and Oliver (2006) found that western accessions of Palmer amaranth, which displayed smaller leaves, had higher NAR values. In accordance to this, prostate pigweed having smaller leaf areas than other *Amaranthus* species also had the highest NAR value (Horak and Loughin 2000). They hypothesized this greater photosynthetic rate could be due to selection over time that compensates for smaller leaf areas. Increasing SLR of Palmer amaranth throughout the growing season indicates that stems and reproductive structures are enlarging resulting in fewer resources being
allocated to leaves as plant growth progresses (Bond and Oliver 2006). All aforementioned studies evaluated problematic weed species prominent in a soybean production. However, little to no information is available investigating growth parameters and the competitive ability of Nealley’s sprangletop.

Prior to the development of POST graminicides for use in broadleaf crops, grass control was accomplished by hand removal, cultivation, and soil applied residual herbicides such as the dinitroanilines (Vidrine et al. 1995). Following the commercialization of acetyl-CoA carboxylase (ACCase) inhibitors, grass control in soybean was primarily accomplished with applications of ACCase-inhibitors alone or in combination with either glyphosate or glufosinate in glyphosate- or glufosinate-resistant soybean, respectively. ACCase-inhibitors block the enzyme catalyzing the first committed step in de novo fatty acid synthesis (Focke and Lichtenthaler 1987) and are widely used to control a broad range of grass species in a vast range of crops (Maneechote et al. 2005). ACCase-inhibiting herbicides are commonly utilized to control grass weeds in many crops including soybean (Glycine max L.) (Abit et al. 2012). The mode of action (MOA) of these herbicides can be useful in dicotyledonous crops due to their limited effect on plants other than grasses (Brewster and Spinney 1989). The selectivity of this MOA stems from the absence of the herbicide-insensitive prokaryote form of ACCase in grasses that broadleaf plants possess (Turner and Pernich 2002).

ACCase herbicides encompass three separate chemical families: aryloxyphenoxypropionate (FOPs), cyclohexanedione (DIMs), and phenylpyrazolin. Quizalofop and clethodim are ACCase-inhibitors in the FOP and DIM families,
respectively. Quizalofop has been shown to control grass species in soybean (Vidrine et al. 1995). Foliar applied quizalofop controls barnyardgrass, green foxtail [Setaria viridis (L.) Beauv], yellow foxtail [Setaria pumila (Poir.) Roemer & J.A. Schultes] and wild oat (Avena fatua L.) (Friesen 1988; Parsells 1985). Clethodim is widely used and provides broad-spectrum control of both annual and perennial grass species (Burke et al. 2005). Clethodim is a graminicide registered for use in cotton (Gossypium hirsutum L.), peanut (Arachis hypogaea L.), and soybean (Anonymous 2017). While both of the afore mentioned herbicides control annual grasses, their effectiveness differs among certain species. When glyphosate-resistant soybean follow glyphosate-resistant corn (Zea maize L.) in rotation, control of volunteer corn has become a major problem (Deen et al. 2006). Mixtures of glyphosate plus clethodim controlled glyphosate-resistant corn in soybean up to 99% 35 DAT, while glyphosate and quizalofop achieved up to 100% control 35 DAT.

Similarly, the control of glyphosate-tolerant wheat in glyphosate-resistant soybean creates management problems. Blackshaw et al. (2006) stated that quizalofop was clearly more effective than clethodim. Applications of quizalofop controlled volunteer wheat >90% in all six site years, while applications of clethodim only achieved >90% control in three of the six site years. Both clethodim and quizalofop have been shown to control barnyardgrass 97 to 99% in soybean (Vidrine et al. 1995). When evaluating preplant burndown programs for rice in a greenhouse, Bergeron (2017) observed 99% and 89% control of Nealley's sprangletop with quizalofop and clethodim 28 days after treatment (DAT), respectively.
Glyphosate and glufosinate are nonselective POST herbicides that were traditionally used for weed control in orchards, vineyards, and non-cropland sites (Lyon 1991; Singh and Tucker 1987). These herbicides have been widely utilized and control many weeds commonly found in agronomic row crops (Culpepper and York 1998; Duke et al. 1991). These technologies were released for large-scale commercialization in 1996 and 1998, respectively (Craigmyle et al. 2013). Glyphosate-resistant crops were highly successful in achieving weed control (Culpepper et al. 2000). Glyphosate inhibits 5-enolpyruvylshikimate-3-phosphate synthase, the enzyme involved in the conversion of 5-enolpyruvylshikimate-3-phosphate into aromatic amino acids tyrosine, tryptophan, and phenylalanine (Devine et al. 1993; Franz et al. 1997). Glyphosate controls annual and perennial grass and broadleaf weeds (Sprankle et al. 1994). However, due to the high frequency of glyphosate use over the years, there are now 17 resistant weed species in the United States (Culpepper et al. 2006, Heap 2018). Therefore, alternate herbicide resistant crops and diversified herbicide programs are required to effectively manage these resistant weeds, which has led to the shift towards glufosinate (Aulakh and Jhala 2015).

Phosphinothricin [homoalanin-4-yl-(methyl)phosphinic acid], the active portion of the glufosinate molecule, inhibits glutamine synthetase, the enzyme involved in the conversion of glutamic acid and ammonia into glutamine (Hinchee et al. 1993). Glufosinate activity is highly dependent upon weather conditions, with weed control increasing when applied during high light intensity and relative humidity (Aherns 1994; Coetzer et al. 2002). Both of afore mentioned
environmental conditions are common in a typical southern Louisiana summer; therefore, it may be an option for control of grassy weeds. Glufosinate controls many annual weeds (Haas and Muller 1987). In addition to the broad spectrum control of broadleaf weeds that it is known for, glufosinate also controls several annual grass species, including broadleaf signalgrass (*Urochloa platyphylla* (Nash) R.D. Webster), large crabgrass (*Digitaria sanguinalis* (L.) Scop.), fall panicum (*Panicum dichotomiflorum* Michx.), and *Setaria* species, (Bradley et al. 2000; Burke et al. 2005; Corbett et al. 2004; Culpepper and York 1999; Culpepper et al. 2000; Hamill et al. 2000; Steckel et al. 1997). However, Ritter and Menbere (2001) reported that glufosinate displays variable control on certain grass weed species.

In soybean, weed competition is responsible for endangering up to 37% of attainable yield (Oerke 2006). Gianessi and Sankula (2003) reported that Louisiana farmers spent an estimated 158 million dollars in herbicide cost compared with the national expenditure of 6.6 billion dollars. To optimize soybean yield and profitability in Louisiana, it is important to establish effective control strategies for Nealley’s sprangletop. Survival and reproduction of plants rely heavily on plant size and growth rate (Shipley 2006). Thus, it is important to understand Nealley’s sprangletop growth in order to determine the optimum timing of control measures. Also, this research evaluates the efficacy of herbicides applied throughout different stages of Nealley’s sprangletop development. This research is an important first step in understanding chemical control options for a new weed in soybean production. The objectives of this research were to determine the comparative growth characteristics and optimum control strategy for Nealley’s sprangletop.
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CHAPTER 2
COMPARATIVE GROWTH OF NEALLEY’S SPRANGETOP (*Leptochloa nealleyi* Vasey)

Introduction

Nealley’s sprangletop (*Leptochloa nealleyi* Vasey) is a monocot in the Poaceae family (Hitchcock 1950). Nealley’s sprangletop is a clump grass native to Arizona, Florida, Louisiana, and parts of Texas and thrives in the marsh-like ecosystems. In southern Louisiana, Nealley’s sprangletop is commonly found along roadsides and ditches and displays over-wintering capacity (Bergeron et al. 2015). Nealley’s sprangletop is an erect annual with flat culms 1 to 1.5 m tall and an estimated growth rate of greater than 2.5 cm day$^{-1}$ (Bergeron et al. 2015; LSUAC-CES 2015). It has a short-fringed membranous ligule and sparse pubescence on the leaf sheath near the bottom portion of the plant and the inflorescence is very distinct with a 25 to 50 cm panicle, 2 to 4 cm long racemes, and 1.5 mm long seed (Bergeron et al. 2015).

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Leaf Area Ratio (LAR) is the driving variable of plant growth and describes the “leafiness” of a plant (Radosevich et al. 1997). LAR is comprised of two components, allocation (Leaf Weight Ratio, LWR) and leaf morphology (Specific Leaf Area, SLA), which combine to constitute a positive correlation between LAR and Relative Growth Rate (RGR) (Poorter and Remkes 1990). RGR is the increase in total dry weight of a plant over a specified unit time. This makes RGR an effective tool for measuring the efficiency of plant growth in respect to mass (Atwell et al. 1999). It is widely considered to be the central plant growth parameter. Grotkopp et al. (2002) stated RGR’s power comes from the ability to combine aspects of anatomy, morphology, and physiology. Many studies have shown that SLA is the main contributor to RGR, which can be observed as a positive correlation between high SLA and high RGR. SLA by definition is the ratio of leaf area to leaf mass (Atwell et al. 1999). A high SLA reflects rapid leaf production of a plant and its photosynthetic capacity; moreover, said plants ability for acquisition of light and soil resources (Grotkopp and Rejmánek 2007). Specific Leaf Weight (SLW), the opposite of SLA by definition, is a predictive index of previous light and net photosynthetic potential (Pearce et al. 1969). SLW is the ratio of leaf blade mass to leaf blade area resulting in an accurate indicator of leaf thickness and mesophyll development (Jurik 1986). This plant growth parameter is very sensitive to nitrogen status, light accumulation, among other stresses and gives insight into the overall canopy function (Field and Mooney 1986). Net Assimilation Rate (NAR) is a physiological index closely related to the photosynthetic activity of leaves (Radosevich et al. 1997). NAR is the result of carbon gain through photosynthesis and carbon losses through processes such as respiration and is expressed per unit leaf area (Poorter and Remkes 1990). Stem-to-leaf Ratio (SLR) is used to show
allocation of resources within a plant and is defined as the ratio of stem to leaf dry matter. Marcelis (1996) stated that dry matter partitioning is a coordinated set of metabolic and transport processes that govern the flow of assimilates from source organs to sink organs.

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To optimize soybean yield and profitability in Louisiana, it is important to establish effective control strategies for Nealley’s sprangletop. Survival and reproduction of plants rely heavily on plant size and growth rate (Shipley 2006). Thus, it is important to understand Nealley’s sprangletop growth in order to determine the optimum timing of control measures. Therefore, the objectives of this research were to determine the
comparative growth characteristics of Nealley’s and Amazon sprangletop during a time period representing the critical weed-free period for soybean.

**Materials and Methods**

Research was conducted in 2016 and 2017 at the Louisiana State University Agricultural Center Dean Lee Research and Extension Center near Alexandria, LA to evaluate growth characteristics of Amazon and Nealley’s sprangletop. Growth characteristics were evaluated utilizing a factorial arranged in a completely randomized design with 12 replications. Factors include Amazon or Nealley’s sprangletop and destructive harvest intervals of 2, 4, 6 wk after emergence (WAE). Amazon sprangletop was included for comparison. Harvest intervals were based upon soybean critical weed-free period of 21 to 30 d after emergence (Burnside 1979, Grymes et al. 1999, Knezevic et al. 2003, Maun 1977, Van Acker et al. 1993). Individual plants were considered separate experimental units. Nealley’s sprangletop seed was collected from a grower locations in Acadia Parish, LA (30.39325 N, 92.57553”W) while Amazon sprangletop seed was commercially purchased (Azlin Seed Services, Greenville, MS 38756). Amazon and Nealley’s sprangletop were seeded in separate trays in the greenhouse for germination. Greenhouse conditions included an ambient air temperature of 30 C (day) and 22 C (night) with no supplemental light. Following emergence, 1-If Amazon and Nealley’s sprangletop seedling was transplanted to 43 cm by 31 cm pot (GL 6900S #10 Squat, BWI Companies, Forest Hill, LA 71430) placed in the field containing 50/50 mixture of inert sand and potting soil (Metro-Mix 840, Sungro Horticulture, Inc., 770 Silver St., Agawarn, MA 01001). Each pot contained one Amazon or Nealley’s sprangletop plant. Supplemental fertilizer
(Miracle-Gro Water Soluble All Purpose Plant Food, The Scotts Miracle-Gro Company, LLC, Marysville, OH 43040) was applied at 2.5 grams (0.6 g N, 0.09 g P, and 0.3 g K) mixed with 0.9 L of water every other week for the duration of the trial.

Prior to destructive harvest, Amazon and Nealley’s sprangletop plant height, canopy width, tiller number, and leaf number were recorded for 12 Amazon and Nealley’s sprangletop plants. Height of the plant was measured from the base of the plant to the tallest vertical point without straightening a leaf, excluding inflorescence. Canopy width was measured at the outermost points of the plant without straightening a leaf. At each destructive harvest interval, Amazon and Nealley’s sprangletop plants were clipped at the soil surface and leaves were separated from the stem at the leaf collar. Below ground biomass was not evaluated. Total leaf area (cm$^2$) was determined photometrically using a leaf area meter (LI-3000 Area Meter, LI-COR, Lincoln, NE 68504). Leaves and stems of each plant were then oven-dried separately for 7 days at 49°C to obtain leaf and stem dry weight. After drying, leaf and stem weight were measured and individual total dry weights were determined.

Values of leaf area ratio (LAR), net assimilation rate (NAR), relative growth rate (RGR), specific leaf area (SLA), specific leaf weight (SLW), and stem-to-leaf ratio (SLR) were calculated on a per-plant basis at each harvest interval. The following formulas were used to calculate these values:

\[ LAR = L_a \times \frac{W_t}{t} \]  \[ \text{[1]} \]
\[ NAR = \left[ \frac{(W_{t2} - W_{t1}) \times (T_2 - T_1)^{-1}}{\left( \ln L_{a2} - \ln L_{a1} \right) \times (L_{a2} - L_{a1})^{-1}} \right] \]  \[ \text{[2]} \]
\[ RGR = \left( \ln W_{t2} - \ln W_{t1} \right) \times (T_2 - T_1)^{-1} \]  \[ \text{[3]} \]
\[ SLA = L_a \times \frac{W_l}{t} \]  \[ \text{[4]} \]
\[ SLR = W_s x W_{t1} \] \[ \text{[5]} \]
\[ SLW = W_l x L_{a1} \] \[ \text{[6]} \]

where \( L_a \) is the total leaf area, \( L_{a1} \) is the total leaf area at time 1; \( L_{a2} \) is the total leaf area at time 2, \( W_t \) is dry wt of whole plants (total), leaves, and stems, respectively; \( W_{t1} \) is whole plant wt at time 1; \( W_{t2} \) is whole plant wt at time 2; \( T_1 \) is harvest time at time 1; \( T_2 \) is harvest time at time 2.

All data were subjected to analysis of variance using PROC MIXED in SAS (release 9.4, SAS Institute, 100 SAS Campus Drive, Cary, NC 27513) with species, harvest interval, and their interaction as fixed effects and year as a random variable. Considering year as a random effect allows for inferences about the effects of treatments over broad populations of environments (Blouin et al. 2011). Least square means were calculated for main effects and their interactions, and separated using Tukey’s honest significant difference test at the \( P \leq 0.05 \).

\section*{Results and Discussion}

Quantitative measurements, plant height, tiller count, and leaf number, were used to track phenotypical difference between the two sprangletop species. All main effects or interactions shown in Table 2.1 that are not significant can be found in the Appendix.

\textbf{Plant Height.} Early season height differences can provide a predictor of weed competitiveness (McDonald et al. 2009). Differences were observed for the interaction of species and harvest interval (Table 2.1). The interaction of species by
Table 2.1. Significance of the main effects of species, harvest interval, and interactions among main effects pooled across environments. \(^{a,b}\)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Species</th>
<th>Harvest Interval</th>
<th>Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P-value</td>
<td>P-value</td>
<td>P-value</td>
</tr>
<tr>
<td>Plant height</td>
<td>0.4846</td>
<td>&lt; 0.0001</td>
<td>0.0004</td>
</tr>
<tr>
<td>Tiller count</td>
<td>&lt; 0.0001</td>
<td>&lt; 0.0001</td>
<td>0.0003</td>
</tr>
<tr>
<td>Leaf number</td>
<td>&lt; 0.0001</td>
<td>&lt; 0.0001</td>
<td>0.0021</td>
</tr>
<tr>
<td>Leaf area ratio (LAR)</td>
<td>&lt; 0.0001</td>
<td>0.0013</td>
<td>0.0479</td>
</tr>
<tr>
<td>Net assimilation rate (NAR)</td>
<td>&lt; 0.0001</td>
<td>&lt; 0.0001</td>
<td>0.0004</td>
</tr>
<tr>
<td>Relative growth rate (RGR)</td>
<td>0.8240</td>
<td>0.5022</td>
<td>0.6071</td>
</tr>
<tr>
<td>Specific leaf area (SLA)</td>
<td>0.0154</td>
<td>0.1126</td>
<td>0.2279</td>
</tr>
<tr>
<td>Stem leaf ratio (SLR)</td>
<td>0.2578</td>
<td>0.0008</td>
<td>0.0595</td>
</tr>
<tr>
<td>Specific leaf weight (SLW)</td>
<td>0.9912</td>
<td>0.0025</td>
<td>0.1695</td>
</tr>
</tbody>
</table>

\(^{a}\) Main effects and interactions considered significant for Type III error if P \(\leq 0.05\).

\(^{b}\) Data for main effects and interactions not significant at P \(\leq 0.05\) are shown in Appendices.

Harvest interval indicates that between 4 and 6 WAE Nealley's sprangletop undergoes a more drastic height increase from 212 to 742 mm than Amazon sprangletop from 377 to 612 mm (Table 2.2). This height increase can be used to pinpoint optimum control timing before robust growth occurs.

**Tiller Number.** Differences in tillering capacity affect growth, development, and competitiveness of weeds (Estorninos Jr. et al. 2005). Strong competitors have more tillers...
Table 2.2. Plant height, tiller count, leaf number, leaf area ratio (LAR), and net assimilation rate (NAR) as influenced by the interaction of two sprangletop species and three harvest intervals grown at Alexandria, LA in 2016 and 2017.\textsuperscript{a,b}

<table>
<thead>
<tr>
<th>Sprangletop species</th>
<th>Harvest Interval</th>
<th>Plant Height</th>
<th>Tiller Count</th>
<th>Leaf Number</th>
<th>LAR</th>
<th>NAR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>\textsuperscript{mm}</td>
<td>\textsuperscript{number}</td>
<td>\textsuperscript{number}</td>
<td>\textsuperscript{cm}^2 \textsuperscript{g}^{-1}</td>
<td>\textsuperscript{g} \textsuperscript{cm}^2 \textsuperscript{d}^{-1}</td>
<td></td>
</tr>
<tr>
<td>Amazon sprangletop</td>
<td>2 WAE</td>
<td>93.3 \textsuperscript{c}</td>
<td>1.1 \textsuperscript{c}</td>
<td>6.5 \textsuperscript{d}</td>
<td>63.2 \textsuperscript{ab}</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 WAE</td>
<td>376.5 \textsuperscript{b}</td>
<td>11.3 \textsuperscript{c}</td>
<td>84.1 \textsuperscript{c}</td>
<td>91.5 \textsuperscript{a}</td>
<td>1.4 \textsuperscript{c}</td>
</tr>
<tr>
<td></td>
<td>6 WAE</td>
<td>611.6 \textsuperscript{a}</td>
<td>51.7 \textsuperscript{a}</td>
<td>322.0 \textsuperscript{a}</td>
<td>53.8 \textsuperscript{bc}</td>
<td>30.0 \textsuperscript{a}</td>
</tr>
<tr>
<td>Nealley's sprangletop</td>
<td>2 WAE</td>
<td>65.6 \textsuperscript{c}</td>
<td>0.6 \textsuperscript{c}</td>
<td>5.3 \textsuperscript{d}</td>
<td>32.6 \textsuperscript{c}</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 WAE</td>
<td>211.7 \textsuperscript{c}</td>
<td>5.0 \textsuperscript{c}</td>
<td>39.1 \textsuperscript{cd}</td>
<td>52.2 \textsuperscript{bc}</td>
<td>0 \textsuperscript{c}</td>
</tr>
<tr>
<td></td>
<td>6 WAE</td>
<td>742.1 \textsuperscript{a}</td>
<td>26.8 \textsuperscript{b}</td>
<td>199.4 \textsuperscript{b}</td>
<td>48.1 \textsuperscript{bc}</td>
<td>12.9 \textsuperscript{b}</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Means followed by the same letter for each parameter are not significantly different according to Tukey's honest significant difference test at \( P \leq 0.05 \).

\textsuperscript{b} NAR was calculated over time from 2 to 4 WAE, and from 4 to 6 WAE. Since you cannot measure a plant prior to emergence changes from 0 to 2 WAE were not recorded.
than weak competitors (Jennings and Aquino 1968). Differences for the interaction of species and harvest interval were detected for tiller number (Table 2.1). While both species experienced prolific tiller production between 4 and 6 WAE, Amazon sprangletop produced 52 tillers compared to 27 for Nealley’s sprangletop 6 WAE (Table 2.2). This can explain greater leaf number and leaf area observed with Amazon sprangletop, which potentially indicates a greater competitive advantage.

**Leaf Number.** Leaf number was greater for strong competitors compared with weaker competitors (Jennings and Aquino 1968). Statistical differences were observed for the interaction of species and harvest interval for leaf number (Table 2.1). Both Amazon and Nealley’s sprangletop experienced prolific leaf production between 4 and 6 WAE with increases of 383 and 510%, respectively, with Amazon sprangletop producing more leaves (Table 2.2). This time frame of rapid leaf production coincides with expansion in both plant height and tiller production, thus indicating a period of vast plant growth.

**Leaf Area Ratio.** LAR is an index of plant leafiness (Radosevich et al. 1997). Differences were detected for the interaction of species and harvest interval (Table 2.1). LAR for Amazon sprangletop was greater than Nealley’s sprangletop 2 and 4 WAE (Table 2.2). Amazon reached a maximum LAR of 91.5 compared with Nealley’s sprangletop at 52.2 cm² g⁻¹ 4 WAE, which may be a function of greater photosynthetic capacity. Plants with higher LAR values could have a competitive advantage resulting from greater photosynthetic capacity (Bond and Oliver 2006; Horak and Loughin 2000). Visual observations noted that Amazon sprangletop plants were larger, more vigorous plants having 49 and 41% more tillers and leaves than Nealley’s sprangletop. Also, the reduction of LAR values with both
species from 4 to 6 WAE harvest intervals suggests the allocation of resources to leaf production was greater for the plants harvested 2 and 4 WAE (Table 2.2).

**Net Assimilation Rate.** NAR is a physiological index closely related to the photosynthetic activity of plant leaves (Radosevich et al. 1997). NAR is a result of carbon gains and carbon losses and is expressed per unit leaf area (Poorter and Remkes 1990). Statistical differences were observed for the interaction of species and harvest interval for NAR (Table 2.1). Amazon sprangletop NAR was greater than Nealley’s sprangletop 4 to 6 WAE with 30 g cm$^{-2}$ d$^{-1}$ compared with 12.9 g cm$^{-2}$ d$^{-1}$, respectively, indicating more efficient use of photosynthates by existing leaf matter. Visual observation noted that Amazon sprangletop had a horizontal growth habit compared with Nealley’s sprangletop’s upright growth habit due primarily to tiller production, which is supported by tiller number data. This horizontal growth creates a less dense canopy promoting higher leaf efficiency, which is similar to the findings of Patterson and Flint (1983), who observed an open canopy structure in jimsonweed.

**Relative Growth Rate and Specific Leaf Area.** RGR is the increase in plant dry weight over a unit time (Atwell et al. 1999). RGR is recognized as the central growth parameter pulling together all important aspects of plant development (Grotkopp et al. 2002). SLA is the ratio of leaf area to leaf mass (Atwell et al. 1999). SLA has been shown to be a main contributor to RGR, thus a high SLA should result in a high RGR. The higher observed SLA value the greater leaf surface per unit biomass, thus, greater photosynthesis and outcompeting other species through shading (Horak and Loughin 2000). RGR for Amazon and Nealley’s sprangletop were 0.27 and 0.26 g g$^{-1}$ d$^{-1}$ and did not differ (data not shown; Appendix 2.1). While no difference were observed for RGR between species, Amazon
sprangletop SLA was 157.2 cm$^2$ g$^{-1}$ which was greater than Nealley’s sprangletop at 112.9 cm$^2$ g$^{-1}$ (data not shown; Appendix 2.1). Amazon sprangletop leaf number and LAR were greater than Nealley’s sprangletop 6 WAE for leaf number and 2 and 4 WAE for LAR (Table 2.2). Even though greater SLA implies that more leaf area is available for photosynthesis, which is supported by greater leaf number and LAR for Amazon sprangletop, these differences may not have been great enough to influence RGR. RGR takes into account whole plant functions as opposed SLA, which focuses on leaves; therefore, the lack of RGR differences between species may have negated the differences observed in SLA.

**Stem to Leaf Ratio.** Differences in SLR for harvest interval were observed, but there were no significant differences among species or their interaction (Table 2.1). Regardless of species, SLR was 1.9 g g$^{-1}$ at the 6 WAE, which was greater than 4 WAE, but not different than 2 WAE (Table 2.3).

<table>
<thead>
<tr>
<th>Harvest Interval</th>
<th>SLR</th>
<th>SLW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 wk after emergence</td>
<td>1.5</td>
<td>ab</td>
</tr>
<tr>
<td>4 wk after emergence</td>
<td>1.0</td>
<td>b</td>
</tr>
<tr>
<td>6 wk after emergence</td>
<td>1.9</td>
<td>a</td>
</tr>
</tbody>
</table>

*Data pooled over Amazon and Nealley’s sprangletop species. Means followed by the same letter for each parameter are not significantly different according to Tukey’s honest significant difference test at $P \leq 0.05$. Similarly to results for Palmer amaranth, increasing SLR from 4 to 6 WAE indicates that stems and reproductive tissues are enlarging, which result in less resource partitioning to leaves (Bond and Oliver 2006). Also, the lowest SLR coincided with the highest LAR.
harvest interval at 4 WAE, indicating the period in which plant growth is most rapid regardless of species (data not shown; Appendix 2.2).

**Specific Leaf Weight.** SLW is a predictive index of previous light and net photosynthetic potential (Pearce et al. 1969). Opposite of SLA, SLW is the ratio of leaf blade mass to leaf blade area resulting in an accurate indicator of leaf thickness and mesophyll development (Jurik 1986). Differences in SLW for harvest intervals were observed, but there were no significant differences among species or their interaction (Table 2.1). Averaged across species, SLW differed only at the 2 and 4 WAE harvest intervals (Table 2.3). Since this plant growth parameter takes into account nitrogen status, light accumulation, and other stresses (Field and Mooney 1986), overall canopy function of Amazon and Nealley’s sprangletop were greatest earlier in the growing season.

Differences in Amazon and Nealley’s sprangletop growth and development were observed for plant height, tiller and leaf number, LAR, NAR, and SLA. Data indicate that size, photosynthetic capacity, and competitive ability were increased for Amazon sprangletop compared with Nealley’s sprangletop. These data suggests Amazon sprangletop could have a greater potential to reduce soybean yield compared to Nealley’s sprangletop. Also, data indicate that both sprangletop species where undergoing the most growth, maximum LAR and minimum SLR, around 4 WAE.

**Literature Cited**


CHAPTER 3
HERBICIDE EVALUATION FOR NEALLEY’S SPRANGLETOP (*Leptochloa nealleyi* Vasey) CONTROL

Introduction

Newly emerging weeds in agricultural crops often lead to the necessity of alternate management strategies. Research devoted to evaluating weed control methods is needed to develop new and effective management programs. Nealley’s sprangletop (*Leptochloa nealleyi* Vasey) is a clump grass native to Arizona, Florida, Louisiana, and parts of Texas and thrives in the marsh-like ecosystems found in its native states. In south Louisiana, Nealley’s sprangletop is commonly found along roadsides and ditches. Smith (1983) mentioned Nealley's sprangletop as a problematic weed in rice, however very little researched has been published concerning the biology, management, and control of this weed. Sprangletop species have been described as one of the seven most prevalent and hard to kill weeds in rice (Smith 1988). Nealley’s sprangletop has become more widespread in Louisiana rice over the past few years with its predominate distribution in Southwest Louisiana (LSUAC-CES 2015). This weed has become an issue for two major reasons: quick growth and over-wintering capacity (EP Webtser, personal communication). Furthermore, Bergeron et al. (2015) stated that although Nealley’s sprangletop is an annual, it oftentimes exhibits a perennial growth habit in south Louisiana due to mild winter temperatures, which makes it more difficult to control with herbicides and necessitates the need for alternative control strategies. However, no published research has ever been conducted with this weed in soybean production.
Glyphosate and glufosinate have been widely utilized in glyphosate and glufosinate-resistant crops and provide good to excellent weed control (Duke et al. 1991). These technologies were released for large-scale commercialization in 1996 and 1998, respectively (Craigmyle et al. 2013). Glyphosate-resistant crops were highly successful in achieving excellent levels of weed control (Culpepper et al. 2000). However, due to the high frequency of glyphosate use over the years, there are now 17 resistant weed species in the United States (Culpepper et al. 2006, Heap 2018). Therefore, alternate herbicide resistant crops and diversified herbicide programs are required to effectively manage these resistant weeds, which has led to the shift towards glufosinate (Aulakh and Jhala 2015). However, Ritter and Menbere (2001) indicate that glufosinate displays variable control on grass weed species.

Glyphosate and glufosinate are nonselective POST herbicides that were traditionally used for weed control in orchards, vineyards, and non-cropland sites (Lyon 1991; Singh and Tucker 1987). These herbicides control many weeds commonly found in agronomic row crops (Culpepper and York 1998). Glyphosate inhibits 5-enolpyruvylshikimate-3-phosphate synthase, the enzyme involved in the conversion of 5-enolpyruvylshikimate-3-phosphate into aromatic amino acids tyrosine, tryptophan, and phenylalanine (Devine et al. 1993; Franz et al. 1997). Glyphosate is the world’s most important herbicide due to its versatility, wide spectrum of weed control, low mammalian toxicity, and negligible soil activity (Powles and Preston 2006). Glyphosate controls annual and perennial grass and broadleaf weeds (Sprankle et al. 1994). The effectiveness of glyphosate on grass
species makes it a viable option for control of Nealley’s sprangletop in south Louisiana.

Phosphinothricin [homoalanin-4-yl-(methyl)phosphinic acid], the active portion of the glufosinate molecule, inhibits glutamine synthetase, the enzyme involved in the conversion of glutamic acid and ammonia into glutamine (Hinchee et al. 1993). Glufosinate controls many annual weeds (Haas and Muller 1987); however, it is less effective on grass than broadleaf species (Steckel et al. 1997). While broad spectrum control of broadleaf weeds is the primary use of glufosinate, it also has shown control of several annual grass species, including broadleaf signalgrass [Urochloa platyphylla (Nash) R.D. Webster], large crabgrass [Digitaria sanguinalis (L.) Scop.], fall panicum (Panicum dichotomiflorum Michx.), and Setaria species, (Bradley et al. 2000; Burke et al. 2005; Corbett et al. 2004; Culpepper and York 1999; Culpepper et al. 2000; Hamill et al. 2000; Steckel et al. 1997).

Glufosinate activity is highly dependent upon weather conditions, with increased control when applied during high light intensity and relative humidity (Aherns 1994; Coetzer et al. 2002). Both of afore mentioned environmental conditions are common in a typical southern Louisiana summer; therefore, it may be an option for control of grassy weeds.

Prior to the development of POST graminicides for use in broadleaf crops, grass control was accomplished by hand removal, cultivation, and soil applied residual herbicides such as the dinitroanilines (Vidrine et al. 1995). Following the commercialization of acetyl-CoA carboxylase (ACCase) inhibitors, grass control in soybean was primarily accomplished with applications of ACCase-inhibitors alone.
or in combination with either glyphosate or glufosinate in glyphosate- or
 glufosinate-resistant soybean, respectively. ACCase-inhibitors inhibit the enzyme
catalyzing the first committed step in de novo fatty acid synthesis (Focke and
Lichtenthaler 1987) and are widely used to control a broad range of grass species in
a vast range of crops (Maneechote et al. 2005). The mode of action (MOA) of these
herbicides can be useful in dicotyledonous crops due to their limited effect on plants
other than grasses (Brewster and Spinney 1989). The selectivity of this MOA stems
from the absence of the herbicide-insensitive prokaryote form of ACCase in grasses
that broadleaf plants possess (Turner and Pernich 2002).

ACCase herbicides encompass three separate chemical families:
aryloxyphenoxypropionate (FOPs), cyclohexanedione (DIMs), and phenylpyrazolin.
Quizalofop and clethodim are ACCase-inhibitors in the FOP and DIM families,
respectively. Quizalofop has been shown to control grass species in soybean
(Vidrine et al. 1995). Foliar applied quizalofop controls barnyardgrass, green foxtail
[Setaria viridis (L.) Beauv], yellow foxtail [Setaria pumila (Poir.) Roemer & J.A.
Schultes] and wild oat (Avena fatua L.) (Friesen 1988; Parsells 1985). Clethodim is
widely used and provides broad-spectrum control of both annual and perennial
grass species (Burke et al. 2005). Clethodim is registered for use in cotton
(Gossypium hirsutum L.), peanut (Arachis hypogaea L.), and soybean (Anonymous
2017). While both clethodim and quizalofop control annual grasses, their
effectiveness differs among certain species. When glyphosate-resistant soybean
follow glyphosate-resistant corn (Zea maize L.) in rotation, control of volunteer corn
has become a major problem (Deen et al. 2006). Additionally mixtures of
glyphosate and clethodim controlled glyphosate-resistant corn in soybean up to 99% 35 DAT, while glyphosate and quizalofop achieved up to 100% control 35 DAT. Similarly, the control of glyphosate-tolerant wheat in glyphosate-resistant soybean creates management problems. Blackshaw et al. (2006) observed that quizalofop controlled volunteer wheat greater than 90% in all six site years, while applications of clethodim only achieved greater than 90% control in three of the six site years. Both clethodim and quizalofop have been shown to control barnyardgrass 97 to 99% in soybean (Vidrine et al. 1995). In a glass house study quizalofop and clethodim controlled Nealley’s sprangletop 99 and 89%, respectively (Bergeron 2017).

To optimize soybean yield and profitability in Louisiana it is important to establish effective control strategies for Nealley’s sprangletop. Survival and reproduction of plants rely heavily on plant size and growth rate (Shipley 2006). Thus, this research evaluates the efficacy of herbicides applied at different stages of Nealley’s sprangletop development. This research is an important first step in understanding chemical control options for a new weed in soybean production.

**Materials and Methods**

Research was conducted in a greenhouse at the LSU AgCenter Dean Lee Research and Extension Center near Alexandria, LA in 2016 and 2017 to evaluate control options for Nealley’s sprangletop. Herbicide treatments were evaluated in a randomized complete block design with 6 replications. Herbicide treatments included glyphosate or glufosinate, applied alone or in combination with clethodim
or quizalofop. Glyphosate- and glufosinate-based treatments were evaluated in separate studies. Herbicide common and trade names, formulation, application rates, and manufacturer are shown in Table 3.1.

Table 3.1. Herbicide common and trade names, formulations, application rates, and manufacturer.

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Trade names</th>
<th>Formulation</th>
<th>Application rate</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>clethodim</td>
<td>Select Max</td>
<td>116 g ai L(^{-1}) 102 g ai ha(^{-1})</td>
<td>Valent U.S.A. Corp., Walnut Creek, CA</td>
<td></td>
</tr>
<tr>
<td>glufosinate</td>
<td>Liberty</td>
<td>540 g ai L(^{-1}) 594 g ai ha(^{-1})</td>
<td>Bayer Crop Protection, LLC, Greensboro, NC</td>
<td></td>
</tr>
<tr>
<td>glyphosate</td>
<td>Roundup</td>
<td>280 g ae L(^{-1}) 1120 g ae ha(^{-1})</td>
<td>Monsanto Co., St. Louis, MO</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PowerMax</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>quizalofop</td>
<td>Assure II</td>
<td>105 g ai L(^{-1}) 93 g ai ha(^{-1})</td>
<td>DuPont Crop Protection, Wilmington, DE</td>
<td></td>
</tr>
</tbody>
</table>

All herbicide treatments were applied once or sequentially with the second application occurring 28 d after the initial application. Initial applications were applied to either 10 or 31 cm Nealley’s sprangletop. All treatments were applied using a CO\(_2\)-pressurized backpack sprayer calibrated to deliver 187 L ha\(^{-1}\) at 145 kPa using TeeJet AIXR 11002 nozzles.

Nealley’s sprangletop seed was collected from various grower locations in Acadia parish, LA (30.42658 N 92.57553 W). Seeds were broadcast planted into flats filled with commercial potting soil (Metro-Mix 840, Sungro Horticulture, Inc., 770 Silver St., Agwarn, MA 01001). At the 1- to 2-leaf stage Nealley’s sprangletop was transplanted into 16.5- by 16.5-cm cylindrical pots each representing a
separate plot. Each pot was filled with a 50/50 mixture of inert sand and commercial potting soil and contained two Nealley's sprangletop seedlings. The pots were placed in plastic lined racks filled with 150 L of water for subsurface irrigation. The water was held for the duration of the study to eliminate water stress. Prior to the herbicide application, pots were removed from the greenhouse and placed outside for one hour prior to and after treatment to allow for acclimation and complete drying of herbicide. For all studies, visual control was evaluated 7, 14, 21, 28 d after treatment (DAT). After final evaluation, plants were removed even with the soil surface, dried for 7 d, and dry weight was recorded.

All data were subjected to analysis of variance using PROC MIXED in SAS (release 9.4, SAS Institute, 100 SAS Campus Drive, Cary, NC 27513) with treatment as a fixed effects and replication and year nested within replication as a random variable. Considering year as a random effect allows for inferences about the effects of treatments over broad populations of environments (Blouin et al. 2011). Least square means were calculated and separated using Tukey's honest significant difference test at the P ≤ 0.05.

Results and Discussion

Nealley's sprangletop control with glyphosate-based programs. In the absence of clethodim or quizalofop, single and sequential applications of glyphosate controlled Nealley's sprangletop greater when the initial application was made at the 10 cm timing compared to the 31 cm 7, 14, 21, and 28 DAT (Table 3.2). Timing is critical in controlling weeds with glyphosate (Jordan et al. 1997). Ahmadi et al.
(1980) observed reduced control when glyphosate was applied to barnyardgrass greater than 10 cm in height. At the 10 cm application timing, single and sequential glyphosate applications differed 7 DAT, but were similar across all other evaluation dates (Table 3.2). These data show that spraying 10 cm Nealley’s sprangletop with an initial application of glyphosate can effectively control Nealley’s sprangletop without sequential treatments. When applied to 31 cm Nealley’s sprangletop, control following sequential applications of glyphosate were consistently higher than a single application, but control did not exceed 70% at any evaluation date (Table 3.2). If herbicide applications are delayed, weeds become too large for glyphosate to control; therefore, sequential applications are required (Payne and Oliver 2000). No differences occurred between all single treatments at the 10 cm timing with Nealley’s sprangletop control 93 to 99% 14, 21, and 28 DAT (Table 3.2). Similarly, all sequential applications that were initiated at the 10 cm timing did not differ from one another with Nealley’s sprangletop control exceeding 94% at all evaluation dates (Table 3.2). Single applications of glyphosate plus clethodim or quizalofop resulted in greater Nealley’s sprangletop control than glyphosate alone when applied to 31 cm Nealley’s sprangletop 14 through 28 DAT, but did not increase Nealley’s sprangletop control following application to 10 cm weed size (Table 3.2). Nealley’s sprangletop treated with sequential applications of glyphosate plus clethodim or quizalofop controlled 31 cm Nealley’s sprangletop
Table 3.2. Control and dry wt of Nealley’s sprangletop with single (initial) or sequential applications of glyphosate with or without clethodim or quizalofop in a greenhouse at Alexandria, LA.\(^a\), \(^b\)

<table>
<thead>
<tr>
<th>Initial trt</th>
<th>Seq. trt</th>
<th>7 DAT</th>
<th>14 DAT</th>
<th>21 DAT</th>
<th>28 DAT</th>
<th>Dry wt</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>10 cm</td>
<td>31 cm</td>
<td>10 cm</td>
<td>31 cm</td>
<td>10 cm</td>
</tr>
<tr>
<td>none</td>
<td>none</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>glyp</td>
<td>none</td>
<td>48 bc</td>
<td>30 c</td>
<td>97 a</td>
<td>40 d</td>
<td>99 a</td>
</tr>
<tr>
<td>glyp + clet</td>
<td>none</td>
<td>53 b</td>
<td>39 bc</td>
<td>93 a</td>
<td>82 ab</td>
<td>99 a</td>
</tr>
<tr>
<td>glyp + quiz</td>
<td>none</td>
<td>49 bc</td>
<td>50 bc</td>
<td>95 a</td>
<td>72 bc</td>
<td>95 a</td>
</tr>
<tr>
<td>glyp</td>
<td>glyp</td>
<td>99 a</td>
<td>58 b</td>
<td>99 a</td>
<td>56 cd</td>
<td>98 a</td>
</tr>
<tr>
<td>glyp + clet</td>
<td>glyp + clet</td>
<td>99 a</td>
<td>99 a</td>
<td>99 a</td>
<td>99 a</td>
<td>99 a</td>
</tr>
<tr>
<td>glyp + quiz</td>
<td>glyp + quiz</td>
<td>99 a</td>
<td>95 a</td>
<td>99 a</td>
<td>95 a</td>
<td>99 a</td>
</tr>
</tbody>
</table>

\(^a\) Data are pooled over two experiment runs. Means followed by the same letter at each evaluation date and for dry wt are not significantly different according to Tukey’s honest significant difference test at \(P \leq 0.05\).

\(^b\) Abbreviations: clet, clethodim; DAT, d after treatment; glyp, glyphosate; quiz, quizalofop; Seq, sequential; trt, treatment.
greater than 95% across all application dates compared with a maximum control of 70% by sequential applications of glyphosate alone (Table 3.2). These data justify the need for the addition of a graminicide when treatments are delayed to larger weed size. All treatments, regardless of Nealley’s sprangletop size at initial application, reduced biomass compared with the nontreated (Table 3.2). These dry weight biomass data support control observed with all herbicide treatments (Table 3.2).

**Nealley’s sprangletop control with glufosinate-based programs.** Single applications of glufosinate alone at 10 cm Nealley’s sprangletop size resulted in 80% Nealley’s sprangletop control 21 DAT compares with 43% control when treated at the 31 cm application timing (Table 3.3). Gardner et al. (2006) reported early season glufosinate applications resulted in higher control of annual grass than midseason applications. However, there were no differences between 10 and 31 cm application timing across all evaluation dates following sequential applications of glufosinate (Table 3.3). Single and sequential applications of glufosinate at the 10 cm timing did not differ across any evaluation date (Table 3.3). This was not the case at the 31 cm application timing, as sequential treatments of glufosinate resulted in greater Nealley’s sprangletop control than single applications 14, 21, and 28 DAT (Table 3.3). This justifies the necessity of sequential glufosinate applications when the initial application is delayed. These results are similar to that reported by Bergeron (2017) who reported 77% control 14 DAT, but control decreased over time. Single applications of glufosinate plus clethodim did not increase control of Nealley’s sprangletop compared to Nealley’s sprangletop control
### Table 3.3. Control and dry wt of Nealley's sprangletop with single (initial) or sequential applications of glufosinate with or without clethodim or quizalofop in a greenhouse at Alexandria, LA.\(^a, b\)

<table>
<thead>
<tr>
<th>Initial trt</th>
<th>Seq. trt</th>
<th><strong>7 DAT</strong></th>
<th><strong>14 DAT</strong></th>
<th><strong>21 DAT</strong></th>
<th><strong>28 DAT</strong></th>
<th><strong>Dry wt</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>10 cm</td>
<td>31 cm</td>
<td>10 cm</td>
<td>31 cm</td>
<td>10 cm</td>
</tr>
<tr>
<td>none</td>
<td>none</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>gluf</td>
<td>none</td>
<td>77 cde</td>
<td>60 ef</td>
<td>69 bcd</td>
<td>50 d</td>
<td>80 ab</td>
</tr>
<tr>
<td>gluf + clet</td>
<td>none</td>
<td>83 a-d</td>
<td>55 f</td>
<td>91 ab</td>
<td>65 cd</td>
<td>84 ab</td>
</tr>
<tr>
<td>gluf + quiz</td>
<td>none</td>
<td>85 a-d</td>
<td>55 f</td>
<td>98 a</td>
<td>80 abc</td>
<td>95 a</td>
</tr>
<tr>
<td>gluf</td>
<td>gluf</td>
<td>76 cde</td>
<td>74 de</td>
<td>70 bcd</td>
<td>76 abc</td>
<td>66 bc</td>
</tr>
<tr>
<td>gluf + clet</td>
<td>gluf + clet</td>
<td>95 ab</td>
<td>79 bcd</td>
<td>97 a</td>
<td>83 abc</td>
<td>96 a</td>
</tr>
<tr>
<td>gluf + quiz</td>
<td>gluf + quiz</td>
<td>96 a</td>
<td>92 abc</td>
<td>99 a</td>
<td>97 a</td>
<td>99 a</td>
</tr>
</tbody>
</table>

\(^a\) Data are pooled over two experiment runs. Means followed by the same letter at each evaluation date and for dry wt are not significantly different according to Tukey's honest significant difference test at \(P \leq 0.05\).

\(^b\) Abbreviations: clet, clethodim; DAT, d after treatment; gluf, glufosinate; quiz, quizalofop; Seq, sequential; trt, treatment.
by glufosinate alone at any evaluation date when the initial application began at 10 cm Nealley's sprangletop (Table 3.3). Similarly, applications of clethodim at 31 cm timing failed to increase Nealley's sprangletop control (Table 3.3). Single applications of glufosinate plus quizalfop at the 10 cm timing provided 98% control of Nealley's sprangletop compared with 69% when treated with glufosinate alone 14 DAT, but were not different from clethodim at any evaluation date (Table 3.3). Single treatments containing quizalofop applied to 31 cm Nealley's sprangletop provided greater control than glufosinate alone 14, 21, and 28 DAT and greater control than clethodim treatments 21 and 28 DAT (Table 3.3). When applied to 10 cm Nealley's sprangletop, control following sequential applications of glufosinate plus clethodim or quizalofop were consistently higher than glufosinate alone, with 91 to 99% control across all evaluation dates compared with 61 to 76% following glufosinate alone (Table 3.3). Askew et al. (2000) noted that single graminicide applications were inadequate for control of red rice populations while sequential applications reduced populations and improved control. When herbicide applications where delayed to 31 cm timing, sequential applications of glufosinate alone provided no more than 77% control (Table 3.3). However, sequential applications of glufosinate plus clethodim or quizalofop resulted in 86 or 98% control of Nealley's sprangletop 21 DAT, respectively (Table 3.3). This justifies the need for a graminicide to be co-applied with glufosinate to effectively control Nealley's sprangletop. Nealley's sprangletop biomass was reduced in all treatments regardless of weed size at initial application (Table 3.3). Treatments resulting in less than acceptable control, 35 and 43% at 28 DAT, were still able to reduce
biomass by at least 73 and 85%, respectively (Table 3.3). While treatments with Nealley's sprangletop control above 90% 28 DAT reduced biomass as much as 99% (Table 3.3).

These data provide important information in determining strategies for Nealley's sprangletop management in soybean. Glyphosate and mixtures of glyphosate plus clethodim or quizalofop controlled Nealley's sprangletop 97 to 99% when applied to 10 cm stage. When treatments were delayed to larger weed size, sequential applications were required. Data indicates that glufosinate is not a stand-alone product to control Nealley's sprangletop. Culpepper et al. (2000) stated that glyphosate alone was more effective on all grass species than glufosinate alone. Poor grass control by a single application of glufosinate can be overcome with the addition of a graminicide when applied to 10 cm Nealley's sprangletop. However, when applications are delayed to larger weed size, sequential applications of glufosinate plus graminicide are required. Bergeron (2017) shows 89 and 99% control of Nealley's sprangletop with clethodim and quizalofop, respectively. This supports our data that an addition of either herbicide with glufosinate increases grass control. Regardless of broad spectrum herbicide, Nealley's sprangletop was more efficiently controlled when applications began at 10 cm. Early removal of Nealley's sprangletop should occur to avoid multiple in-season herbicide applications.

**Literature Cited**

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CHAPTER 4
SUMMARY

Trials were conducted to evaluate growth characteristics and control strategies for Nealley's sprangletop (*Leptochloa nealleyi* Vasey). Field and greenhouse studies were conducted across two years 2016 and 2017 on the Dean Lee Research and Extension Center near Alexandria, Louisiana. Trials were designed to evaluate early season growth and control of Nealley's sprangletop to provide useful information when soybean infestations occur. Potential growth and control can be elucidated from these trials.

Growth characteristics of Nealley's sprangletop were evaluated in a study. Factors include Amazon or Nealley's sprangletop and destructive harvest intervals of 2, 4, 6 wk after emergence (WAE). Amazon sprangletop was included for comparison. Nealley's sprangletop undergoes a more drastic height increase 212 to 742 mm, 4 to 6 WAE than Amazon sprangletop 377 to 612 mm in the same time frame. Averaged across harvest interval, tiller number of Nealley’s sprangletop was approximately 50% less than Amazon sprangletop, 11 compared to 21, respectively. Nealley’s sprangletop produced significantly less leaves compared to Amazon sprangletop, 81 compared to 138, respectively. The greater amount of tiller and leaf production for Amazon compared to Nealley's sprangletop may indicate that Amazon sprangletop displays more robust growth. Nealley's sprangletop reached a maximum LAR of 52.2 cm² g⁻¹ and Amazon sprangletop LAR was 91.5 cm² g⁻¹ 4 WAE, which may indicate less photosynthetic capacity for Nealley's sprangletop. This suggests the allocation of resources to leaf production was greatest for the plants 4 WAE. Amazon sprangletop NAR was greater than Nealley’s sprangletop 4 to 6 WAE.
with 30 g cm$^{-2}$ d$^{-1}$ compared to 12.9 g cm$^{-2}$ d$^{-1}$, respectively, indicating more efficient use of photosynthates by existing leaf matter. There were no differences for RGR between the two species, however SLA, a major contributor to RGR, did differ. Amazon sprangletop SLA was 157.2 cm$^{2}$ g$^{-1}$ which was greater than Nealley's sprangletop at 112.9 cm$^{2}$ g$^{-1}$ when averaged across harvest interval. Even though greater SLA for Amazon sprangletop implies that more leaf area is available for photosynthesis, which is supported by greater leaf number and LAE, these differences may not have been great enough to influence RGR differences between the two species. Regardless of species, the greatest SLR was 1.9 g g$^{-1}$ and occurred 6 WAE. This indicates that stems and reproductive tissues are enlarging resulting in less resource partitioning to leaves. Also, the lowest SLR coincided with the highest LAR harvest interval 4 WAE harvest interval, indicating the period in which plant growth is most rapid regardless of species. There were no differences between Amazon and Nealley’s sprangletop SLW, which takes into account nitrogen status, light accumulation, and other stresses to predict overall canopy function. This data indicates a competitive advantage of Amazon sprangletop to be greater than that of Nealley’s sprangletop.

Trials were conducted two years to assess control of Nealley’s sprangletop with two broad spectrum herbicides glyphosate 1120 g ae ha$^{-1}$ or glufosinate 594 g ai ha$^{-1}$, applied alone or in combination with clethodim 102 g ai ha$^{-1}$ or quizalo fop 93 g ai ha$^{-1}$. Glyphosate- and glufosinate-based treatments were evaluated in separate studies. All herbicide treatments were applied once or sequentially with the second application occurring 28 d after the initial application. Initial applications of all
treatments were applied to either 10 or 31 cm Nealley's sprangletop. When Nealley's sprangletop was treated with glyphosate-based applications, beginning at 10 cm, neither the addition of graminicides or sequential applications increased control with all treatments providing greater than 94% control 28 DAT. When treatments were delayed to 31 cm Nealley's sprangletop, the addition of graminicides increased control from 45% with glyphosate alone to 98 and 94% 28 DAT with the addition of clethodim and quizalofop, respectively. Glufosinate applied alone provided poor control of Nealley’s sprangletop when applied to 10 or 31 cm timings. Quizalofop co-applied with glufosinate to 10 cm Nealley's sprangletop resulted in 95% control 28 DAT, however was ineffective at 31 cm timing with 77% control 28 DAT with a single application. Clethodim or quizalofop co-applied with glufosinate in sequential applications resulted in 86 and 98% control 21 DAT compared to 77% by glufosinate alone at 31 cm Nealley's sprangletop.

In conclusion, optimum timing to control Nealley's sprangletop is when this weed species is small. The comparative growth data indicates that by 4 WAE Nealley’s sprangletop undergoes robust growth and can quickly become a major competitor. To further reinforce the importance of early control, both glyphosate and glufosinate studies indicate that Nealley's sprangletop is easier to control at 10 cm size compared to 31 cm. Additionally, glyphosate provides excellent control of Nealley’s sprangletop with a single application when control is implemented early in weed growth. When Nealley's sprangletop is allowed to grow and mature, sequential treatments and co-application with clethodim and quizalofop are
required to provide effective control. When glufosinate is selected to control Nealley’s sprangletop, control strategies require early season applications with the addition of a graminicide. If treatments are delayed to a larger weed size, sequential applications of glufosinate co-applied with quizalofop are required.
APPENDIX
SUPPLEMENTAL DATA FOR CHAPTER 2

Appendix 2.1. Plant height, tiller count, leaf count, leaf area ratio (LAR), net assimilation rate (NAR), relative growth rate (RGR), stem leaf ratio (SLR), and specific leaf weight (SLW) of two sprangletop species grown at Alexandria, LA in 2016 and 2017.\(^a\)

<table>
<thead>
<tr>
<th>Species</th>
<th>Plant Height</th>
<th>Tiller Count</th>
<th>Leaf Count</th>
<th>LAR</th>
<th>NAR</th>
<th>RGR</th>
<th>SLA</th>
<th>SLR</th>
<th>SLW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amazon sprangletop</td>
<td>360.5 a</td>
<td>21 a</td>
<td>138 a</td>
<td>69.5 a</td>
<td>15.7 a</td>
<td>0.27 a</td>
<td>157.2 a</td>
<td>1.5 a</td>
<td>0.04 a</td>
</tr>
<tr>
<td>Nealley's sprangletop</td>
<td>339.8 a</td>
<td>11 b</td>
<td>81 b</td>
<td>44.3 b</td>
<td>6.5 b</td>
<td>0.26 a</td>
<td>112.9 b</td>
<td>1.5 a</td>
<td>0.02 a</td>
</tr>
</tbody>
</table>

\(^a\) Data pooled over harvest interval. Means followed by the same letter for each parameter are not significantly different according to Tukey's honest significant difference test at \(P \leq 0.05\).
Appendix 2.2. Plant height, tiller count, leaf number, leaf area ratio (LAR), net assimilation rate (NAR), relative growth rate (RGR), and specific leaf area (SLA) of two sprangletop species at three harvest intervals grown at Alexandria, LA in 2016 and 2017.  

<table>
<thead>
<tr>
<th>Harvest Interval</th>
<th>Plant Height</th>
<th>Tiller Count</th>
<th>Leaf Number</th>
<th>LAR</th>
<th>NAR</th>
<th>RGR</th>
<th>SLA</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 WAE</td>
<td>79 c</td>
<td>1 c</td>
<td>6 c</td>
<td>47.9 b</td>
<td></td>
<td></td>
<td>54.8 a</td>
</tr>
<tr>
<td>4 WAE</td>
<td>294 b</td>
<td>8 b</td>
<td>62 b</td>
<td>71.8 a</td>
<td>0.7 b</td>
<td>0.3 a</td>
<td>54.9 a</td>
</tr>
<tr>
<td>6 WAE</td>
<td>677 a</td>
<td>39 a</td>
<td>261 a</td>
<td>50.9 b</td>
<td>21.5 a</td>
<td>0.3 a</td>
<td>54.9 a</td>
</tr>
</tbody>
</table>

Data pooled over sprangletop species. Means followed by the same letter for each parameter are not significantly different according to Tukey’s honest significant difference test at P ≤ 0.05.

NAR and RGR were calculated over time from 2 to 4 WAE, and from 4 to 6 WAE. Since you cannot measure a plant prior to emergence changes from 0 to 2 WAE were not recorded.
Appendix 2.3. Relative growth rate (RGR), specific leaf area (SLA), stem-to-leaf ratio, and specific leaf weight (SLW) as influenced by the interaction of two sprangletop species and three harvest intervals grown at Alexandria, LA in 2016 and 2017.  

<table>
<thead>
<tr>
<th>Species</th>
<th>Harvest Interval</th>
<th>RGR</th>
<th>SLA</th>
<th>SLR</th>
<th>SLW</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g g⁻¹ d⁻¹</td>
<td>g cm⁻²</td>
<td>g g⁻¹</td>
<td>g cm⁻²</td>
<td></td>
</tr>
<tr>
<td>Amazon sprangletop</td>
<td>2 WAE</td>
<td>142.5 a</td>
<td>1.8 a</td>
<td>0.08 a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 WAE</td>
<td>0.3 a</td>
<td>174.8 a</td>
<td>0.94 a</td>
<td>0.01 a</td>
</tr>
<tr>
<td></td>
<td>6 WAE</td>
<td>0.3 a</td>
<td>154.3 a</td>
<td>1.7 a</td>
<td>0.01 a</td>
</tr>
<tr>
<td>Nealley’s sprangletop</td>
<td>2 WAE</td>
<td>75.9 b</td>
<td>1.3 a</td>
<td>0.03 a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 WAE</td>
<td>0.3 a</td>
<td>108.4 a</td>
<td>1.1 a</td>
<td>0.02 a</td>
</tr>
<tr>
<td></td>
<td>6 WAE</td>
<td>0.3 a</td>
<td>154.3 a</td>
<td>2.1 a</td>
<td>0.01 a</td>
</tr>
</tbody>
</table>

aData pooled over the interaction of species by harvest interval. Means followed by the same letter for each parameter are not significantly different according to Tukey’s honest significant difference test at P ≤ 0.05.

bRGR was calculated over time from 2 to 4 WAE, and from 4 to 6 WAE. Since you cannot measure a plant prior to emergence changes from 0 to 2 WAE were not recorded.
VITA

Trace Braxton Buck was born in Gates, NC, located in the northeast portion of the state. He grew up just south of the Virginia state line on a small family owned farm. He attended Gatesville elementary, Central middle, and Gates County High School in Gates, North Carolina. During that time he was involved in baseball, basketball, FFA, and other activities. Summer jobs outside of the family farm started at age 15, were he worked for Harrell Agronomic Services scouting crops and conducting soil sampling. As a junior in college he began to work as an undergraduate research assistant for Dr. Alan York assisting in day-to-day research duties.

He graduated with a B.S. in Science in 2016 from North Carolina State University. Upon graduation he moved to Alexandria, Louisiana to begin his graduate studies in Weed Science under the direction of Dr. Daniel O. Stephenson, IV and Dr. Eric P. Webster. He enrolled in the School of Plant, Environmental, and Soil Sciences at Louisiana State University in 2016 and is currently a candidate for the Master of Science degree with a focus in Weed Science.