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Nealley's Sprangletop (Leptochloa nealleyi Vasey) Management and Interference in Rice Production

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NEALLEY'S SPRANGLETOP (*LEPTOCHLOA NEALLEYI* VASEY) MANAGEMENT AND INTERFERENCE IN RICE PRODUCTION

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Abstract

A glasshouse study was conducted on the Louisiana State University campus in Baton Rouge to evaluate herbicide activity on Nealley's sprangletop. Herbicides were applied to Nealley's sprangletop plants in the one-two tiller stage with height of 20-30 cm. Nealley's sprangletop control, leaf number, height, tiller number, and fresh weight biomass were evaluated. Nealley's sprangletop treated with glyphosate, quizalofop, fenoxaprop, and clethodim was controlled 89 to 99%.

A field study was conducted at the LSU AgCenter Rice Research Station (RRS) and a grower location (GL) to evaluate herbicide rates and timings for control of Nealley's sprangletop in drill-seeded rice. Herbicide treatments were cyhalofop at 271, 314, and 417 g ai ha^{-1} and fenoxaprop at 66, 86, and 122 g ai ha^{-1} applied pre- or post-flood, propanil at 3360 g ai ha^{-1} applied pre-flood, and propanil plus thiobencarb at 5040 g ai ha^{-1} applied pre-flood. Cyhalofop increased control of Nealley's sprangletop compared with control observed with propanil plus thiobencarb. Nealley's sprangletop treated with fenoxaprop at 86 or 122 g ha^{-1} pre-flood resulted in increased control of Nealley's sprangletop over propanil or propanil plus thiobencarb.

Field studies were conducted at the RRS and a GL on drill-seeded rice to evaluate removal timings of Nealley's sprangletop and the impact on rice yield. Fenoxaprop was applied at 122 g ha^{-1} at 7, 14, 21, 28, 35, and 42 days after emergence (DAE). Rice from the 7 DAE removal yielded 1910 kg ha^{-1} more than the nontreated. Delaying the initial herbicide application from 7 to 42 DAE caused a rice yield loss of 1790 kg ha^{-1} with a net loss of \$460 ha^{-1}, or \$13 ha^{-1} loss per day.

Field studies were conducted at the RRS and a GL in drill-seeded rice to evaluate Nealley's sprangletop infestation densities in rice and the impact on rice yield. Analysis indicated significance for Nealley's sprangletop density on rice yield where the linear effects of density were

significant ($P < 0.0064$). Based on economic evaluations, Nealley's sprangletop at densities of 5 to 10 plants m^{2} are sufficient threshold levels for treatment.

Chapter 1

Introduction

In order to maximize rice (*Oryza sativa* L.) yields and achieve the highest economical return, producers use integrated weed management programs that are best accomplished through the use of cultural, mechanical, and chemical practices (Jordan and Sanders 1999). In 2012, approximately 116 million hectares of 158 million total hectares of farm land received an application of a herbicide (USDA 2012). Herbicides are critical for achieving optimal yield and maximum profit. Ashton and Monaco (1991) estimated farmers spend 3.6 billion dollars annually for chemical weed control; however, 16 years later Gianessi and Reigner (2007) report and estimated annual herbicide costs of 7 billion dollars.

There are several weeds in Louisiana rice cropping systems that can reduce yield and lower net returns. There are a number of troublesome grass and broadleaf weeds that exist in the rice culture in Louisiana (Braverman 1995). The most commonly encountered rice weeds include alligatorweed [*Alternanthera philoxeroides* (Mart.) Griseb.], Amazon sprangletop [*Leptochloa panicoides* (J. Presl) A.S. Hitchc.], barnyardgrass [*Echinochloa crus-galli* (L.) Beauv], broadleaf signalgrass [*Urochloa platyphylla* (Munro ex C. Wright) R.D. Webster], ducksalad [*Heteranthera limosa* (Sw.) Willd], hemp sesbania [*Sesbania herbacea* (Mill.) McVaugh], Indian jointvetch (*Aeschynomene indica* L.), junglerice [*Echinochloa colona* (L.) Link], red rice (*Oryza sativa* L.), rice flatsedge (*Cyperus iria* L.), spreading dayflower (*Commelina diffusa* Burm. f.), Texasweed [*Caperonia palustris* (L.) St. Hil.], and yellow nutsedge (*Cyperus esculentus* L.). Red rice is one of the most troublesome weeds of cultivated rice in the southern United States (Webster 2004; Noldin et al. 1999).

Nealley's sprangletop (*Leptochloa nealleyi* Vasey) is a monocot in the poaceae family with first known taxonomic description of Nealley's sprangletop in 1885 (Hitchcock 1903, 1950). This weed has been present along roadsides and ditches in south Louisiana, Texas, and Mexico, but has recently adapted to flooded environments similar to that of production rice (Bergeron et al. 2015).

Nealley's sprangletop may have gone unnoticed in Louisiana rice production due to the close resemblance to vaseygrass (*Paspalum urvillei* Steud.). This weed can be identified in several different ways. At the seedling stage, Nealley's sprangletop has sparse pubescence at the base of the stem unlike other sprangletop species commonly found in rice fields. This weed also has a fringed membranous ligule similar to Amazon sprangletop, which is commonly found in mid-south rice production. Nealley's sprangletop is erect and robust with flat culms mostly 1- to 1.5-m tall (Hitchcock 1950). Nealley's sprangletop is simple or sparingly branching at the base, with glabrous or slightly glabrous sheaths. At maturity, Nealley's sprangletop produces a panicle-like seedhead 25- to 50-cm in length with 50- to 75-racemes, 2- to 4-cm long. Nealley's sprangletop seed are obtuse and 1- to 1.5-mm long, which are highly viable at maturity (Bergeron et al. 2015).

Nealley's sprangletop has been observed to adapt to flooded conditions and become a widespread weed problem in the rice growing regions of Louisiana and Texas (Eric P. Webster, LSU Extension Weed Scientist, personal communication). Smith (1983) referenced Nealley's sprangletop infestations in rice; however, no research has been published concerning this plant as a weed in rice production. Nealley's sprangletop has been observed surviving through the winter months, and regrows during the summer months, indicating a potential perennial growth habit. Due to mild winters in south Louisiana, Nealley's sprangletop may have perennial characteristics (Eric Webster, LSU Extension Weed Scientist, personal communication). Often, a burndown application is required in the spring to assist in the management of this weed, and it is often important to control vegetation in a reduced or no-till system prior to planting (Stougaard et al. 1984). Planting into a field clear of vegetation can provide economic and agronomic advantages to the grower.

Advances in weed control technology have played an essential role in the development of the rice industry (Ashton and Monaco 1991). Imidazolinone-resistant (IR) rice, which was developed in 1993, offers an opportunity to effectively control red rice with little effect on the crop (Croughan 1994). The herbicides labeled for use in IR rice are imazethapyr (Newpath® herbicide label, BASF Corporation, Research Triangle Park, NC) and imazamox (Beyond® herbicide label, BASF Corporation, Research Triangle Park, NC) which are in the imidazolinone herbicide family (Wepplo 1991). These two herbicides have activity on red rice, barnyardgrass, broadleaf signalgrass, and several *Cyperus* spp. found in rice production (Webster 2016); however, when weeds such as hemp sesbania and Indian jointvetch are present other herbicides must be used to achieve acceptable control. In 2016, approximately 60% of the rice acreage in Louisiana was planted in IR lines or hybrids (Harrell 2016). In 2002, 2.6% of the rice acreage in Louisiana was planted with IR rice, and this was the first commercial use of this technology in the state (Saichuk 2002). By 2011, 76% of the rice grown in Louisiana was IR rice (Saichuk 2011). The increasing amount of Nealley's sprangletop in rice fields may be due to the widespread adoption of IR rice production systems (Eric P. Webster, LSU Extension Weed Scientist, personal communication). Research in Louisiana shows this group of herbicides causes a reduction in Nealley's sprangletop height, but surviving plants produce excessive tillering and this results in a more difficult grass to control (Webster et al. 2016).

In the early 1990s, 98% of the rice acreage was treated with at least one application of propanil each year (Carey et al. 1995). Smith (1975) reported propanil at 4480 g ai ha^{-1} applied alone controlled Amazon sprangletop 87%. Smith and Khodayari (1985) observed 62% control of bearded sprangletop [*Leptochloa fusca* (L.) Kunth var. *fascicularis* (Lam.) N. Snow] with propanil at 4480 g ha^{-1}, but with the addition of thiobencarb at 3400 g ai ha^{-1}, 91% control was achieved. Webster (2016) suggests propanil is weak on Nealley's sprangletop and will only provide suppression of this weed.

Stauber et al. (1991) conducted research on effective herbicides for the control of Amazon sprangletop and bearded sprangletop. Fenoxaprop (Whip® 360 herbicide label, Bayer Crop Protection LLC, Greensboro, NC) at 117 g ha^{-1} controlled Amazon and bearded sprangletop 90%. Although rice is initially injured slightly with fenoxaprop treatments, yields were usually not negatively impacted. In the mid-2000s, fenoxaprop was reformulated with isoxadifen (Ricestar® HT herbicide label, Bayer Crop Protection LLC, Greensboro, NC) to effectively safen rice from the negative impact often observed with fenoxaprop without the addition of isoxadifen (Buehring et al. 2006). Research conducted at LSU shows fenoxaprop is the most effective in crop herbicide for managing Nealley's sprangletop (Webster 2016).

Fenoxaprop and cyhalofop (Clincher® SF herbicide label, Dow AgroSciences LLC, Indianapolis, IN) are foliar applied herbicides in the chemical family aryloxyphenoxy propionate (Shaner 2014). Herbicides in this family inhibit the enzyme acetyl-CoA carboxylase (ACCase), the enzyme catalyzing the first committed step in de novo fatty acid synthesis (Burton et al. 1989). Essentially, these herbicides block the production of phospholipids used in building new cell membranes required for cell growth.

Fenoxaprop was first used in soybean, due to broadleaf plants having a natural tolerance (Shaner 2014). Fenoxaprop is only effective on grass weeds, but natural tolerance in rice appears to be due to a less sensitive ACCase enzyme (Stoltenberg 1989). Fenoxaprop is applied as an ethyl-ester form and is rapidly de-esterfied once absorbed into the plant tissue into the herbicidal active form fenoxaprop acid. Initially fenoxaprop affects young actively growing tissue, with a cessation of growth soon after treatment.

Leaf chlorosis occurs in susceptible plants 7- to 10-days after treatment followed by necrosis 7- to 10-days later.

In Louisiana, ACCase resistant Amazon sprangletop has been documented in rice (Heap 2009). Research has shown these particular biotypes are resistant to cyhalofop and fenoxaprop. In Thailand, Chinese sprangletop (*Leptochloa chinensis* L. Nees) has been documented as ACCase resistant in a field that received an application of fenoxaprop 8 years consecutively (Maneechote et al. 2005). Relying on one chemical family can eventually select for tolerance, therefore; it is important to evaluate multiple herbicides for control of Nealley's sprangletop to avoid overuse and prevent weed resistance (Eric P. Webster, LSU Extension Weed Scientist, personal communication).

Competitiveness of Nealley's sprangletop could potentially reduce rice yield as seen in previous studies with other sprangletop species. Interference of Amazon sprangletop (Smith 1975) and bearded sprangletop (Smith 1983) with rice reduced rice yield, grain quality, milling yield, and rice seed germination. Season long interference from Amazon sprangletop at 50- to 200-panicles m^2 and bearded sprangletop at 108 plants m^2 reduced rice yields up to 36%. Smith (1983) evaluated the impact of bearded sprangletop densities on rice yield, and reported densities of bearded sprangletop at 11- to 108-plants m^2 reduced grain yields from 9 to 36%. Bearded sprangletop at 1 plant m^2 reduced grain yield 21 kg ha^{-1}, and rice yields were reduced 10 and 50% from bearded sprangletop densities of 30 and 148 plants m^2, respectively (Smith 1983, 1988). Densities of 15- to 30-plants m^2 would be sufficient threshold levels to require control practices for bearded sprangletop.

Carey et al. (1994) evaluated interference duration of bearded sprangletop in rice. Bearded sprangletop densities of 50 plants m^2 were removed from rice plots at 21, 35, 42, 56, 70, and 130 days after planting (DAP). Grain yields decreased as bearded sprangletop interference duration increased; durations of bearded sprangletop interference of greater than 56 DAP decreased rice yield more than 2296 kg ha^{-1}. Interference of bearded sprangletop at 130 DAP reduced yields 50%. By determining the effects of Nealley's sprangletop on mid-south rice this will allow a producer to determine if enacting a control measure will prove to be an economical benefit.

Nealley’s sprangletop control is achievable in a conventional or IR rice production system by employing a weed management program that has activity on Nealley’s sprangletop. An overwintered Nealley's sprangletop plant is very difficult to control and will require tillage to prevent this plant from re-growing the following growing season (Bergeron et al. 2015). A program approach with a spring preplant burndown herbicide application, and residual herbicides along with an in crop application of fenoxaprop will be needed to manage this weed. Current research shows this herbicide to be the most effective for in crop Nealley's sprangletop control (Bergeron et al. 2015).

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Chapter 2

Herbicide Evaluations for Nealley's Sprangletop Control

Introduction

New and emerging weeds in agricultural crops can often cause a management problem. Research evaluating methods for weed control is essential in developing an overall program approach for management. Nealley’s sprangletop (*Leptochloa nealleyi* Vasey) is a monocot in the poaceae family (Hitchcock 1950). This weed has been present along roadsides and ditches in south Louisiana, Texas, and Mexico, but has recently adapted to flooded environments similar to that of production rice (*Oryza sativa* L.) (Bergeron et al. 2015). Nealley’s sprangletop has been observed to adapt to flooded conditions and become a widespread weed problem in the rice growing regions of Louisiana and Texas (Eric P. Webster, LSU Extension Weed Scientist, personal communication). Smith (1983) referenced Nealley’s sprangletop infestations in southern rice production; however, no research has been published on the management of this weed in rice.

The first known taxonomic description of Nealley's sprangletop was in 1885 (Hitchcock 1903). Nealley's sprangletop is a summer annual clump grass found predominately in marshes along the coast of Louisiana and Texas (Bergeron et al. 2015). Nealley’s sprangletop has been observed surviving through the winter months, and regrows during the summer months, indicating a potential perennial growth habit. Due to mild winters in south Louisiana, Nealley’s sprangletop may have perennial characteristics (Eric Webster, LSU Extension Weed Scientist, personal communication). Often, a burndown application is required in the spring to assist in the management of this weed, and it is often important to control vegetation in a reduced or no-till system prior to planting (Stougaard et al. 1984). Planting into a field clear of vegetation can provide economic and agronomic advantages to the grower.

It is important to correctly identify Nealley's sprangletop in order to select the appropriate weed management program (Webster 2014). This weed can be identified in several different ways. At the seedling stage, Nealley’s sprangletop has sparse pubescence at the base of the stem unlike other sprangletop species commonly found in rice fields. This grass also has a fringed membranous ligule similar to Amazon sprangletop [*Leptochloa panicoides* (J. Presl) A.S. Hitchc.], which is commonly found in mid-south rice production. Nealley’s sprangletop is erect and robust with flat culms mostly 1- to 1.5-m tall (Hitchcock 1950). Nealley’s sprangletop is simple or sparingly branching at the base, with glabrous or slightly glabrous sheaths. At maturity, Nealley's sprangletop produces a panicle-like seedhead 25- to 50-cm in length with several racemes 2- to 4-cm long. Nealley’s sprangletop seed are obtuse and 1- to 1.5-mm long. This weed is a high seed producer with high seed viability at maturity (Bergeron et al. 2015).

Amazon sprangletop and bearded sprangletop [*Leptochloa fusca* (L.) Kunth var. *fascicularis* (Lam.) N. Snow] became more problematic in rice with the development of quinclorac (Jordan 1997). It is believed that the widespread adoption of the imidazolinone-resistance (IR) rice (Clearfield® rice, BASF Corporation, Research Triangle Park, NC) in the mid-south further caused the proliferation of Amazon and bearded sprangletop, but it may also be the reason for the expansion of Nealley’s sprangletop as a weed in rice (Bergeron et al. 2015). The herbicides labeled for use in IR rice are imazethapyr (Newpath® herbicide label, BASF Corporation, Research Triangle Park, NC) and imazamox (Beyond® herbicide label, BASF Corporation, Research Triangle Park, NC) which are in the imidazolinone herbicide family (Wepplo 1991). Imidazolinone herbicides cause excessive tillering and have little activity on Nealley's sprangletop (Webster et al. 2016).

Many herbicides have activity on weeds, but understanding the most effective herbicide for Nealley's sprangletop control is important for managing this weed and optimizing rice yield. This study was conducted with common rice herbicides that have activity on grass weed species. As well as commonly used preplant burndown herbicides. The estimated lost potential from weeds in crops worldwide is 34% (Oerke 2006). Ashton and Monaco (1991) estimated farmers spend 3.6 billion dollars annually for chemical weed control; however, 16 years later Gianessi and Reigner (2007) reported and estimated annual herbicide cost of 7 billion dollars. This study is an important first step in understanding chemical control options for this new weed in rice and allowing a foundation for conducting field trials. The objective of this study was to determine which herbicide could be employed to control Nealley's sprangletop in a burndown situation or during the production of a rice crop.

Materials and Methods

A study was conducted in September 2014, October 2014, November 2015, and March 2016 in a glasshouse on the Louisiana State University campus in Baton Rouge, Louisiana to determine which herbicides have activity on Nealley's sprangletop. This study was conducted four times. Nealley's sprangletop seed was collected from various grower locations in Acadia Parish and planted into commercial potting soil (Jiffy Mix Grower’s Choice, Jiffy Products of America, Inc., Lorain, OH) in seed flats with fifty 2.5- by 2.5-cm cells. When the Nealley's sprangletop plants reached the two- to three-leaf growth stage, the seedlings were then transplanted into 6- by 10-cm Ray Leach cone-tainers™ (Stuewe & Sons, Inc., 31933 Rolland Dr., Tangent, OR) filled with the same potting soil. The cones containing Nealley's sprangletop plants were placed in trays and then subsurfaced irrigated in 40.6- by 40.6- by 40.6-cm plastic containers filled with 67 L of water. The water level was maintained for the duration of the study. Urea fertilizer, 46-0-0, was added to the water at 280 kg ha^{-1} after transferring the plants. The experimental design was completely randomized with nine replications. Herbicide applications were applied when the Nealley's sprangletop plants reached the one- to two-tiller stage with an approximate height of 20- to 30-cm. Herbicides applied are listed in, Table 2.1. Each herbicide application was applied with a CO_2-pressurized backpack sprayer calibrated at 145 kPa to deliver 140 L ha^{-1} of solution. Prior to application, the plants were removed from the glasshouse and placed outside for 2 hours prior to and after herbicide application to allow the plants to acclimate to the outside environment and allow the spray to thoroughly dry after application.

Nealley's sprangletop control was evaluated at 5, 10, 14, 21, and 28 days after treatment (DAT). Visual weed control was evaluated on a scale of 0 to 100%, 0 = no injury or control and 100 = complete plant death. Nealley's sprangletop leaf number, height, and tiller number were evaluated at 0, 5, 10, 14, 21, and 28 DAT. Height of each individual plant was measured, from base of plant to the tip of the tallest leaf. At harvest, 28 DAT, immediately after final plant evaluation the Nealley's sprangletop plants were removed from the soil and thoroughly rinsed. After rinsing, the above ground plant material was separated from the below ground portion and the fresh weight of each was obtained.

Data for this study were analyzed using mix procedure of SAS (release 9.4, SAS Institute, Cary, NC). Runs, two runs in 2014, one run in 2015 and one run in 2016, replications (nested within treatments), and all interactions containing either of these effects were considered random effects. Herbicide and DAT were considered fixed effects. All evaluations were analyzed as repeated measures. Considering year or combination of year as random effects permits inferences about treatments over a range of environments (Carmer et al. 1989; Hager et al. 2003). Type III statistics were used to test all possible effects of fixed factors (application timing by rate by rating date) and Tukey's test was used for mean separation at the 5% probability level ($p \leq 0.05$).

Table 2.1. Herbicide information for all products used in experiment.[abc]

Herbicide common name	Herbicide trade name	Rate	Manufacturer
		g ai ha^{-1}	
Bispyribac	Regiment	28	Valent U.S.A. Corporation, Walnut Creek, CA
Clethodim	Select	150	Valent U.S.A. Corporation, Walnut Creek, CA
Cyhalofop	Clincher SF	314	Dow AgroSciences LLC, Indianapolis, IN
Fenoxaprop	Ricestar HT	122	Bayer Crop Protection LLC, Greensboro, NC
Florpyrauxifen	Loyant	30	Dow AgroSciences LLC, Indianapolis, IN
Glufosinate	Liberty	450	Bayer Crop Protection LLC, Greensboro, NC
Glyphosate	Roundup	840	Monsanto Co., St. Louis, MO
Imazamox	Beyond	44	BASF Corporation, Research Triangle Park, NC
Imazethapyr	Newpath	105	BASF Corporation, Research Triangle Park, NC
Penoxsulam	Grasp SC	40	Dow AgroSciences LLC, Indianapolis, IN
Propanil	Stam M4	4480	RiceCo LLC, Memphis, TN
Propanil + thiobencarb	RiceBeaux	6720	RiceCo LLC, Memphis, TN
Quinclorac	Facet L	420	BASF Corporation, Research Triangle Park, NC
Quizalofop	Assure II	120 or 185	Dupont Crop Protection, Wilmington, DE
Thiobencarb	Bolero	4480	Valent U.S.A. Corporation, Walnut Creek, CA

[a]Treatments consisting of imazamox, thiobencarb, cyhalofop, quinclorac, penoxsulam, imazethapyr, fenoxaprop, clethodim, and quizalofop contained a crop oil concentrate at 1% v/v (Agri-dex®, Helena Chemical Co., Collierville, TN).

[b]Florpyrauxifen treatment contained a methylated seed oil at 0.5% v/v (Soysurf Xtra, Sanders®, Cleveland, MS).

[c]Bispyribac treatment contained a spray adjuvant (Dyne-A-Pak®, Helena Chemical Company, Collierville, TN).

Results and Discussion

A herbicide by rating date interaction occurred for control of Nealley's sprangletop (Table 2.2). Two herbicides were evaluated with synthetic auxin mode of action with activity on grasses, quinclorac (Shaner 2014) and florpyrauxifen (Perry et al. 2015). Nealley's sprangletop treated with quinclorac at 420 g ha^{-1} resulted in 0 to 10% control across all rating dates. Jordan (1997) reported a quinclorac plus propanil co-application was necessary for control of Amazon sprangletop due to the lack of activity from quinclorac applied alone. Florpyrauxifen applied at 30 g ha^{-1} resulted in 53% control of Nealley's sprangletop at 28 DAT. This herbicide has both grass and broadleaf activity, and florpyrauxifen is in a new structural class of synthetic auxins in the arylpicolinate family (Weimer et al. 2015).

A major issue with Nealley's sprangletop in south Louisiana rice production is the propensity of the weed to have a more perennial growth habit compared with the annual life cycle as described by taxonomists (Hitchcock 1903, 1950). Two herbicides commonly used as burndown herbicides in reduced tillage rice production systems were evaluated on seedling Nealley's sprangletop. Nealley's sprangletop treated with glufosinate at 450 g ha^{-1} resulted in 67% control at 5 DAT (Table 2.2). The rapid, initial activity on Nealley's sprangletop with glufosinate is similar to that reported by Steckel et al. (1997) when applying glufosinate on barnyardgrass. Control of Nealley's sprangletop treated with glufosinate increased to 77% control at 14 DAT, but control decreased as the Nealley's sprangletop began to outgrow the herbicide activity. At 14, 21, and 28 DAT, Nealley's sprangletop treated with glyphosate at 840 g ha^{-1} resulted in control 86, 94, and 99%, respectively. This data indicates that glyphosate can be used as a valuable tool when determining a spring burndown application to manage Nealley's sprangletop prior to planting rice.

Table 2.2. Effects of herbicides on control of Nealley's sprangletop plants 5, 10, 14, 21, and 28 days after treatment (DAT), at Louisiana State University Baton Rouge, Louisiana, averaged over 4 runs.[ab]

		Control[c] (DAT)				
Herbicide[d]	Rate	5	10	14	21	28
	g ai ha^{-1}	%				
Synthetic Auxin						
Florpyrauxifen	30	48 de	62 b-d	64 b-d	53 cd	53 cd
Quinclorac	420	0 f	0 f	0 f	3 f	10 ef
Burndown						
Glufosinate	450	67 bc	74 ab	77 ab	75 ab	64 b-d
Glyphosate	840	15 ef	56 cd	86 ab	94 ab	99 a
Contact						
Propanil	4480	52 cd	58 cd	61 b-d	45 de	45 de
Propanil + thiobencarb	6720	49 de	58 cd	53 cd	32 e	31 e
Thiobencarb	4480	20 ef	23 ef	15 ef	13 ef	29 ef
ALS						
Bispyribac	28	5 f	9 ef	7 f	9 ef	13 ef
Imazamox	44	4 f	18 ef	20 ef	14 ef	25 ef
Imazethapyr	105	5 f	15 ef	15 ef	17 ef	26 ef
Penoxsulam	40	0 f	0 f	0 f	0 f	0 f
ACCase						
Clethodim	150	16 ef	69 bc	78 ab	89 ab	89 ab
Cyhalofop	314	7 ef	31 e	43 de	58 cd	63 b-d
Fenoxaprop	122	19 ef	91 ab	96 ab	99 a	99 a
Quizalofop	120	14 ef	86 ab	99 a	99 a	99 a
Quizalofop	185	20 ef	90 ab	96 ab	99 a	99 a

[a]Means followed by the same letter do not significantly differ at P=0.05 using Tukey's test.

[b]Runs conducted in September 2014, October 2015, November 2015, and March 2016.

[c]Control was measured using a scale of 0 (no control) to 100 (complete control) based on visual symptoms.

[d]Herbicides grouped by mode of action: Synthetic Auxin, herbicides with auxin activity, Burndown, herbicides used as burndown, Contact, herbicides with post-emergence contact activity, Acetolactase Synthase (ALS) inhibitor, Acetyl CoA Carboxylase (ACCase) inhibitor.

In the early 1990s, 98% of the rice acreage was treated with at least one application of propanil each year (Carey et al. 1995). Smith (1975) reported propanil at 4480 g ai ha^{-1} applied alone controlled Amazon sprangletop 87%. In this study, the highest control of Nealley's sprangletop observed with a single application of propanil was 61% at 14 DAT (Table 2.2). Nealley's sprangletop treated with propanil plus thiobencarb at 6720 g ha^{-1} or thiobencarb at 4480 g ha^{-1} alone achieved 31 and 29% control, respectively. Smith (1988) reported 87 to 94% control of bearded sprangletop after an application of thiobencarb at 4500 g ai ha^{-1}. These data indicate contact herbicides containing propanil and/or thiobencarb are not as active on Nealley's sprangletop compared with Amazon or bearded sprangletop.

All ALS herbicides evaluated controlled Nealley's sprangletop from 0 to 26% across all rating dates (Table 2.2). The control observed did not differ to control observed from quinclorac. All of these ALS herbicides are used in rice production to control barnyardgrass and other troublesome species; however, these herbicides have little to no activity on Amazon sprangletop (Webster 2016).

Several ACCase herbicides were evaluated for activity on Nealley's sprangletop (Table 2.2). Nealley's sprangletop treated with quizalofop at 120 and 185 g ha^{-1}, fenoxaprop at 122 g ha^{-1}, and clethodim at 150 g ha^{-1} resulted in 89 to 99% control. Currently, quizalofop is labeled in soybeans [*Glycine max* (L.) Merr.] and has shown to provide 90% control of red rice and other perennial and annual grasses (Askew et al. 2000). The Provisia™ Rice System (BASF Corporation, Research Triangle Park, NC), is a new herbicide resistant rice, and quizalofop is the target herbicide to be used in this system (Youmans et al. 2016; Rustom et al. 2016; Webster et al. 2015). Quizalofop has activity on Nealley's sprangletop and this herbicide will be a useful tool in management of this weed. Clethodim is labeled for use in soybeans and cotton (*Gossypium hirsutum* L.) and is often used as a spring application to manage annual ryegrass [*Lolium perenne* L. subsp. *multiflorum* (Lam.) Husnot] (Jordan et al. 2001). Ryegrass control greater than 95% was reported with clethodim at 140, 210, or 280 g ha^{-1}. This herbicide also has activity on Nealley's sprangletop and can potentially be utilized in soybean or cotton weed control programs where this weed can be a problem. At 28 DAT, cyhalofop at 314 g ha^{-1} resulted in 63% control of Nealley's sprangletop. Buehring et al. (2006) reported no difference in Amazon sprangletop control with fenoxaprop or cyhalofop; however, these data indicate fenoxaprop is more active on Nealley's sprangletop. Yokohama et al. (2001) reported that fenoxaprop applications resulted in 95 to 97% control of Chinese sprangletop [*Leptochloa chinensis* (L.) Nees].

A herbicide by rating date interaction occurred when evaluating the number of leaves on Nealley's sprangletop (Table 2.3). Nealley's sprangletop plants averaged 8- to 12-leaves per plant prior to application. At all evaluation dates, Nealley's sprangletop treated with florpyrauxifen, quinclorac, and all ALS herbicides resulted in no difference in the number of leaves per plant compared with the nontreated. At 28 DAT, Nealley's sprangletop treated with glyphosate and glufosinate resulted in 3- and 13-leaves per plant, respectively, compared with the nontreated with 33-leaves per plant. Applications of clethodim, cyhalofop, fenoxaprop, and quizalofop reduced the number of Nealley's sprangletop leaves to 11 or less per plant at 28 DAT. These leaf number data also support the control observed from the herbicides evaluated (Table 2.2).

A herbicide by rating date interaction also occurred in number of tillers per Nealley's sprangletop plant (Table 2.4). All ALS herbicides evaluated on Nealley's sprangletop resulted in 11- to 13-tillers per plant compared with the nontreated with 10 tillers per plant. Hensley et al. (2012) evaluated imazethapyr drift on conventional rice varieties and found excessive tillering occurring on recovering rice plants. Nealley's

Table 2.3. Effects of herbicides on leaf number of Nealley's sprangletop plants 0, 5, 10, 14, 21, and 28 days after treatment (DAT), at Louisiana State University Baton Rouge, Louisiana, averaged over 4 runs.[ab]

		Leaf Number (DAT)					
Herbicide[c]	Rate	0	5	10	14	21	28
	g ai ha^{-1}			#			
Nontreated		9 c	15 bc	22 bc	25 ab	29 ab	33 ab
Synthetic Auxin							
Florpyrauxifen	30	11 bc	11 bc	10 c	12 bc	16 bc	18 bc
Quinclorac	420	12 bc	19 bc	27 ab	32 ab	33 ab	37 ab
Burndown							
Glufosinate	450	10 bc	8 c	2 c	2 c	9 c	13 bc
Glyphosate	840	12 bc	13 bc	5 c	2 c	4 c	3 c
Contact							
Propanil	4480	11 bc	10 bc	5 c	6 c	11 bc	15 bc
Propanil + thiobencarb	6720	11 bc	10 bc	5 c	8 c	13 bc	17 bc
Thiobencarb	4480	11 bc	15 bc	19 bc	24 b	25 ab	29 ab
ALS							
Bispyribac	28	8 c	14 bc	20 bc	25 ab	30 ab	32 ab
Imazamox	44	11 bc	15 bc	23 b	32 ab	36 ab	36 ab
Imazethapyr	105	11 bc	13 bc	23 b	29 ab	31 ab	33 ab
Penoxsulam	40	12 bc	20 bc	28 ab	33 ab	38 a	39 a
ACCase							
Clethodim	150	10 bc	11 bc	4 c	4 c	5 c	5 c
Cyhalofop	314	12 bc	14 bc	9 c	9 c	9 c	11 bc
Fenoxaprop	122	11 bc	13 bc	2 c	1 c	1 c	1 c
Quizalofop	120	12 bc	14 bc	5 c	4 c	4 c	4 c
Quizalofop	185	13 bc	14 bc	2 c	1 c	1 c	1 c

[a]Means followed by the same letter do not significantly differ at P=0.05 using Tukey's test.

[b]Runs conducted in September 2014, October 2015, November 2015, and March 2016.

[c]Herbicides grouped by mode of action: Synthetic Auxin, herbicides with auxin activity, Burndown, herbicides used as burndown, Contact, herbicides with post-emergence contact activity, Acetolactase Synthase (ALS) inhibitor, Acetyl CoA Carboxylase (ACCase) inhibitor.

Table 2.4. Effects of herbicides on tiller number of Nealley's sprangletop plants 0, 5, 10, 14, 21, and 28 days after treatment (DAT), at Louisiana State University Baton Rouge, Louisiana, averaged over 4 runs.[ab]

		Tiller Number (DAT)					
Herbicide[c]	Rate	0	5	10	14	21	28
	g ai ha^{-1}	#					
Nontreated		2 c	3 c	7 bc	8 bc	8 bc	10 ab
Synthetic Auxin							
Florpyrauxifen	30	3 c	4 bc	3 c	3 c	5 bc	6 bc
Quinclorac	420	3 c	5 bc	9 ab	10 ab	9 ab	13 a
Burndown							
Glufosinate	450	3 c	2 c	1 c	1 c	2 c	4 bc
Glyphosate	840	3 c	4 bc	2 c	1 c	1 c	1 c
Contact							
Propanil	4480	3 c	2 c	2 c	2 c	3 c	5 bc
Propanil + thiobencarb	6720	3 c	2 c	2 c	2 c	3 c	6 bc
Thiobencarb	4480	3 c	3 c	7 bc	7 bc	8 bc	9 ab
ALS							
Bispyribac	28	2 c	3 c	6 bc	7 bc	9 ab	11 ab
Imazamox	44	3 c	5 bc	9 ab	10 ab	11 ab	12 ab
Imazethapyr	105	3 c	3 c	9 ab	10 ab	11 ab	11 ab
Penoxsulam	40	3 c	5 bc	9 ab	9 ab	9 ab	13 a
ACCase							
Clethodim	150	3 c	3 c	2 c	2 c	2 c	2 c
Cyhalofop	314	4 bc	4 bc	3 c	3 c	3 c	2 c
Fenoxaprop	122	3 c	3 c	1 c	0 c	0 c	0 c
Quizalofop	120	4 bc	4 bc	1 c	1 c	1 c	1 c
Quizalofop	185	4 bc	4 bc	1 c	0 bc	0 c	0 c

[a]Means followed by the same letter do not significantly differ at P=0.05 using Tukey’s test.

[b]Runs conducted in September 2014, October 2015, November 2015, and March 2016.

[c]Herbicides grouped by mode of action: Synthetic Auxin, herbicides with auxin activity, Burndown, herbicides used as burndown, Contact, herbicides with post-emergence contact activity, Acetolactase Synthase (ALS) inhibitor, Acetyl CoA Carboxylase (ACCase) inhibitor.

sprangletop treated with ACCase herbicides resulted in 0- to 3-tillers per plant. After application, desiccation of tillers occurred as well as no new tiller production. Maneechote et al. (2005) reduced Chinese sprangletop tillers up to 90% with applications of fenoxaprop. Milligan et al. (1999) observed reductions of purple moor-grass [*Molinia caerulea* (L.) Moench] tillers when applying quizalofop at 150 g ha^{-1}. These tiller number data also support the control observed from the herbicides evaluated (Table 2.2).

A herbicide by rating date interaction occurred in height of Nealley's sprangletop plants. A great deal of variability occurred with plant height through the duration of this study. Herbicide effects on Nealley's sprangletop height were arranged as actual data (Table 2.5) and based on the percentage of the nontreated (Table 2.6). At 28 DAT, fenoxaprop reduced the height of Nealley's sprangletop plants compared with the nontreated (Table 2.5). Pornprom et al. (2006) recorded a height reduction of Chinese sprangletop treated with fenoxaprop. Nealley's sprangletop treated with quinclorac or penoxsulam resulted in heights of 60- and 63-cm, respectively, compared with the nontreated at 59-cm. Applications of quizalofop, fenoxaprop, clethodim, glufosinate, and glyphosate on Nealley's sprangletop resulted in height of 50% of the nontreated (Table 2.6).

A herbicide by treatment interaction occurred for fresh weight of Nealley's sprangletop plants at 28 DAT. Herbicide impacts on Nealley's sprangletop fresh weight were arranged as actual data and based on the percentage of the nontreated (Table 2.7). Glyphosate, clethodim, fenoxaprop, and quizalofop were the only herbicides that reduced fresh weight biomass compared with the nontreated (Table 2.7). Nealley's sprangletop treated with quinclorac and penoxsulam had a fresh weight 141 to 160% of the nontreated. Applications of glyphosate, clethodim, fenoxaprop, and quizalofop resulted in Nealley's sprangletop fresh weights 15% of the nontreated.

Table 2.5. Effects of herbicides on height of Nealley's sprangletop plants 0, 5, 10, 14, 21, and 28 days after treatment (DAT), at Louisiana State University Baton Rouge, Louisiana, averaged over 4 runs.[ab]

Herbicide[c]	Rate	Height (DAT)					
		0	5	10	14	21	28
	g ai ha^{-1}	cm					
Nontreated		27 bc	32 bc	37 bc	40 bc	50 ab	59 ab
Synthetic Auxin							
Florpyrauxifen	30	26 bc	30 bc	29 bc	29 bc	29 bc	34 bc
Quinclorac	420	28 bc	35 bc	40 bc	44 ab	52 ab	60 ab
Burndown							
Glufosinate	450	30 bc	32 bc	21 c	22 bc	27 bc	27 bc
Glyphosate	840	28 bc	30 bc	23 bc	17 c	24 bc	25 bc
Contact							
Propanil	4480	29 bc	30 bc	26 bc	28 bc	30 bc	36 bc
Propanil + thiobencarb	6720	28 bc	29 bc	25 bc	27 bc	29 bc	36 bc
Thiobencarb	4480	26 bc	32 bc	36 bc	39 bc	46 ab	51 ab
ALS							
Bispyribac	28	25 bc	29 bc	33 bc	37 bc	49 ab	52 ab
Imazamox	44	29 bc	32 bc	32 bc	32 bc	39 bc	46 ab
Imazethapyr	105	27 bc	29 bc	28 bc	30 bc	37 bc	42 bc
Penoxsulam	40	29 bc	36 bc	42 ab	47 ab	56 ab	63 a
ACCase							
Clethodim	150	25 bc	28 bc	19 c	17 c	23 bc	24 bc
Cyhalofop	314	27 bc	29 bc	29 bc	28 bc	29 bc	30 bc
Fenoxaprop	122	26 bc	28 bc	11 c	10 c	18 c	19 c
Quizalofop	120	29 bc	31 bc	29 bc	29 bc	28 bc	29 bc
Quizalofop	185	28 bc	30 bc	16 c	16 c	21 c	22 bc

[a]Means followed by the same letter do not significantly differ at P=0.05 using Tukey’s test.
[b]Runs conducted in September 2014, October 2015, November 2015, and March 2016.
[c]Herbicides grouped by mode of action: Synthetic Auxin, herbicides with auxin activity, Burndown, herbicides used as burndown, Contact, herbicides with post-emergence contact activity, Acetolactase Synthase (ALS) inhibitor, Acetyl CoA Carboxylase (ACCase) inhibitor.

Table 2.6. Effects of herbicides on height of Nealley's sprangletop plants 0, 5, 10, 14, 21, and 28 days after treatment (DAT), at Louisiana State University Baton Rouge, Louisiana, averaged over 4 runs.[a]

		Height (DAT)					
Herbicide[b]	Rate	0	5	10	14	21	28
	g ai ha^{-1}	% of nontreated					
Synthetic Auxin							
Florpyrauxifen	30	100	94	78	73	58	58
Quinclorac	420	93	109	108	110	104	102
Burndown							
Glufosinate	450	107	100	57	55	54	46
Glyphosate	840	112	94	62	43	48	42
Contact							
Propanil	4480	107	94	70	70	60	61
Propanil + thiobencarb	6720	97	91	68	68	58	61
Thiobencarb	4480	90	100	97	98	92	86
ALS							
Bispyribac	28	89	91	89	93	98	88
Imazamox	44	107	100	86	80	78	78
Imazethapyr	105	104	91	76	75	74	71
Penoxsulam	40	107	113	114	30	112	107
ACCase							
Clethodim	150	89	88	51	43	46	41
Cyhalofop	314	96	91	78	70	58	51
Fenoxaprop	122	104	88	30	25	36	32
Quizalofop	120	112	97	78	73	56	49
Quizalofop	185	97	94	43	40	42	37

[a]Runs conducted in September 2014, October 2015, November 2015, and March 2016.

[b]Herbicides grouped by mode of action: Synthetic Auxin, herbicides with auxin activity, Burndown, herbicides used as burndown, Contact, herbicides with post-emergence contact activity, Acetolactase Synthase (ALS) inhibitor, Acetyl CoA Carboxylase (ACCase) inhibitor.

Table 2.7. Effects of herbicides on fresh weight of Nealley's sprangletop plants 28 days after treatment (DAT), at Louisiana State University Baton Rouge, Louisiana, averaged over 4 runs.[ab]

Herbicide[c]	Rate	Fresh Weight	
	g ai ha^{-1}	g	% of nontreated
Nontreated		11.1 a-d	
Synthetic Auxin			
Florpyrauxifen	30	3.9 c-e	35
Quinclorac	420	15.7 ab	141
Burndown			
Glufosinate	450	1.9 c-e	17
Glyphosate	840	1.2 e	11
Contact			
Propanil	4480	3.5 c-e	32
Propanil + thiobencarb	6720	3.9 c-e	35
Thiobencarb	4480	10.4 a-e	94
ALS			
Bispyribac	28	11.1 a-c	100
Imazamox	44	9.7 a-e	87
Imazethapyr	105	8.8 a-e	79
Penoxsulam	40	17.8 a	160
ACCase			
Clethodim	150	1.3 e	12
Cyhalofop	314	2.8 c-e	25
Fenoxaprop	122	1.4 e	13
Quizalofop	120	0.5 e	5
Quizalofop	185	1.3 e	12

[a]Means followed by the same letter do not significantly differ at P=0.05 using Tukey’s test.

[b]Runs conducted in September 2014, October 2015, November 2015, and March 2016.

[c]Herbicides grouped by mode of action: Synthetic Auxin, herbicides with auxin activity, Burndown, herbicides used as burndown, Contact, herbicides with post-emergence contact activity, Acetolactase Synthase (ALS) inhibitor, Acetyl CoA Carboxylase (ACCase) inhibitor.

Minton et al. (1989) evaluated fresh weight of barnyardgrass treated with fenoxaprop, clethodim, and quizalofop, and observed a reduction of fresh weight compared with the nontreated. These fresh weight biomass data also support control observed with the herbicides evaluated (Table 2.2).

In conclusion, this glasshouse study will play an important role in setting a foundation for future Nealley's sprangletop management and research. Quinclorac, penoxsulam, and bispyribac provided little to no control when applied on Nealley's sprangletop. Grichar (2011) and Stauber et al. (1991) observed little to no control of bearded sprangletop when treated with quinclorac. For an infestation of Nealley's sprangletop in rice, a spring burndown application prior to planting may be necessary for proper management of this weed. A glyphosate application on Nealley's sprangletop achieved the highest control of burndown herbicides evaluated, with 99% control at 28 DAT. Although Levy et al. (2006) observed at least 87% control of Amazon sprangletop when treated with imazethapyr, this research indicates that imazethapyr and imazamox suppresses Nealley's sprangletop, at best, and the adoption of the IR rice system may further explain the reason for the expansion of this weed in mid-south rice production (Eric P. Webster, LSU Extension Weed Scientist, personal communication). Clethodim and quizalofop applications resulted in 89 and 99% control of Nealley's sprangletop, respectively. Although these herbicides are not currently labeled in rice, this research can be useful when evaluating control methods for Nealley's sprangletop in broadleaf crops such as cotton or soybean or as herbicides in a burndown system. The adoption of these herbicides for Nealley's sprangletop control in a program could further prolong the life of herbicide resistant crops and aid in resistance management. Fenoxaprop is currently the best option for controlling Nealley's sprangletop in season rice production. Stauber et al. (1991) observed greater than 85% control of bearded sprangletop when treated with fenoxaprop. Carlson et al. (2011) evaluated controlling weeds in rice at multiple timings and determined weed pressure, even over a short period of time, can decrease rice yield. Similar to other grasses, early removal of Nealley's sprangletop may optimize rough rice yields. Employing an overall strategy for Nealley's sprangletop management can help reduce an infestation; which includes, tillage, burndown applications, and in crop herbicide application.

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Chapter 3

Evaluation of Cyhalofop and Fenoxaprop for Sprangletop Control

Introduction

Advances in weed control technology have played an essential role in the development of the rice (*Oryza sativa* L.) industry (Ashton and Monaco 1991). Imidazolinone-resistant (IR) rice (Clearfield® rice, BASF Corporation, Research Triangle Park, NC), which was first developed in 1993, offers an opportunity to effectively control red rice (*Oryza sativa* L.) with no negative impact on the crop (Croughan 1994). The herbicides labeled for use in IR rice are imazethapyr (Newpath® herbicide label, BASF Corporation, Research Triangle Park, NC) and imazamox (Beyond® herbicide label, BASF Corporation, Research Triangle Park, NC) which are in the imidazolinone herbicide family (Wepplo 1991).

In 2016, approximately 60% of the rice acreage in Louisiana was planted in IR lines or hybrids (Harrell 2016). The two herbicides labeled for use in IR rice have activity on red rice, barnyardgrass [*Echinochloa crus-galli* (L.) Beauv], broadleaf signalgrass [*Urochloa platyphylla* (Munro ex C. Wright) R. D. Webster], and several *Cyperus* spp. found in rice production (Webster 2016); however, when weeds such as hemp sesbania [*Sesbania herbacea* (Mill.) McVaugh] and Indian jointvetch (*Aeschynomene indica* L.) are present other herbicides must be used to achieve acceptable control.

Another weed that has been expanding in Louisiana rice production is Nealley's sprangletop (*Leptochloa nealleyi* Vasey). Webster et al. (2016) observed little activity with imidazolinone herbicides on Nealley's sprangletop. Due to lack of activity with these herbicides, the increasing amount of Nealley's sprangletop in rice fields may be due to the widespread adoption of IR rice (Eric P. Webster, LSU Extension Weed Scientist, personal communication).

Nealley's sprangletop is a monocot in the poaceae family (Hitchcock 1950). The first known taxonomic description of Nealley's sprangletop was in 1885 (Hitchcock 1903). This weed has been present along roadsides and ditches in south Louisiana, Texas, and Mexico, but has recently adapted to flooded environments similar to that of production rice (Bergeron et al. 2015). Nealley's sprangletop has been observed surviving through the winter months in south Louisiana, and regrows during the summer months, indicating a potential perennial growth habit. In order to select the appropriate weed management program for Nealley's sprangletop correct identification is important (Webster 2014).

At the seedling stage, Nealley's sprangletop has sparse pubescence at the base of the stem unlike other sprangletop species commonly found in rice fields. This grass also has a fringed membranous ligule similar to Amazon sprangletop [*Leptochloa panicoides* (J. Presl) A.S. Hitchc.], which is commonly found in mid-south rice production. Nealley's sprangletop is erect and robust with flat culms from 1- to 1.5-m tall (Hitchcock 1950). Nealley's sprangletop is simple or sparingly branching at the base, with glabrous or slightly glabrous sheaths. At maturity, Nealley's sprangletop produces a panicle-like seedhead 25- to 50-cm in length with several racemes 2- to 4-cm long. Nealley's sprangletop seed are obtuse and 1- to 1.5-mm long, and the plant produces a high number of seed with significant viability at maturity (Bergeron et al. 2015).

Amazon sprangletop is commonly found in mid-south rice production. This weed is a tufted, erect summer annual reaching heights of 1- to 1.5-m tall (Bryson and DeFelice 2009), and is commonly found in cultivated fields, roadsides, ditches, and marshes. Amazon spangletop has a glabrous leaf sheath and blade, flat smooth leaves, and a long, fringed membranous ligule. At maturity, Amazon sprangletop produces an erect, spreading panicle 12- to 30-cm in length and seeds 3- to 5-mm long.

Stauber et al. (1991) conducted research on effective herbicides for the control of Amazon sprangletop and bearded sprangletop. Fenoxaprop (Whip® 360 herbicide label, Bayer Crop Protection LLC, Greensboro, NC) at 117 g ha^{-1} controlled Amazon and bearded sprangletop 90%. Although rice is initially injured slightly with fenoxaprop treatments, yields are usually not negatively impacted. In the mid-2000s, fenoxaprop was reformulated with isoxadifen to effectively safen rice from the negative impact often observed with fenoxaprop (Buehring et al. 2006). Research conducted at LSU shows fenoxaprop is the most effective in crop herbicide for managing Nealley's sprangletop (Webster 2016).

Fenoxaprop (Ricestar® HT herbicide label, Bayer Crop Protection LLC, Greensboro, NC) and cyhalofop (Clincher® SF herbicide label, Dow AgroSciences LLC, Indianapolis, IN) are foliar applied herbicides in the chemical family aryloxyphenoxy propionate (Shaner 2014). Herbicides in this family inhibit the enzyme acetyl-CoA carboxylase (ACCase), the enzyme catalyzing the first committed step in de novo fatty acid synthesis (Burton et al. 1989). Essentially, these herbicides block the production of phospholipids used in building new cell membranes required for cell growth.

Fenoxaprop was first used in soybean, due to broadleaf plants having a natural resistance (Shaner 2014). Fenoxaprop is only effective on grass weeds, but natural tolerance in rice appears to be due to a less sensitive ACCase enzyme (Stoltenberg 1989). Fenoxaprop is applied as an ethyl-ester form and is rapidly de-esterfied once absorbed into the plant tissue into the herbicidal active form fenoxaprop acid. Initially fenoxaprop affects young actively growing tissue, with a cessation of growth soon after treatment. Leaf chlorosis occurs in susceptible plants 7- to 10-days after treatment followed by necrosis after another 7- to 10-days.

Cyhalofop was first labeled for use in rice in 1996. Rice tolerance to cyhalofop is due to rapid metabolism of the herbicide due to the herbicidally inactive form diacid (Stoltenberg 1989). Initially, cyhalofop affects young actively growing tissue within sensitive plants, with a cessation of growth soon after treatment. Leaf chlorosis begins 3- to 7-days after application leading to necrosis and plant death within 2- to 3-weeks.

For many years, cyhalofop and fenoxaprop have been used for grass control in mid-south rice production. Acceptable control of Amazon sprangletop has been observed with both herbicides. With this in mind, this study was established to evaluate cyhalofop and fenoxaprop at multiple rates and timings for management of Nealley's sprangletop. The effects of these herbicides will also be compared with standard herbicides used to manage Amazon sprangletop in Louisiana (Webster 2016). The two comparison herbicides evaluated were propanil (RiceShot® herbicide label, RiceCo LLC, Memphis, TN) and propanil plus thiobencarb (RiceBeaux® herbicide label, RiceCo LLC, Memphis, TN). Data from this study can be used when evaluating an in crop herbicide to incorporate in an overall management program for Nealley's sprangletop.

Materials and Methods

A field study was conducted at the Louisiana State University Agricultural Center H. Rouse Caffey Rice Research Station (RRS) near Crowley, LA in 2014, 2015, and 2016 on a Crowley silt loam soil (fine smectic, thermic Typic Albaqualfs) with a pH of 6.4 and 1.4% organic matter. Field preparation consisted of a fall and spring disking followed by two passes in opposite directions with a two-way bed conditioner equipped with rolling baskets and S-tine harrows set at a 6-cm depth. Before planting, Nealley's sprangletop seed was collected from various locations in Acadia Parish, Louisiana and mechanically spread over the entire study area at 30 kg ha^{-1}.

This study was repeated in 2015 at a grower location near Estherwood, LA on a Kaplan silt loam soil (fine smectic, thermic Aeric Chromic Vertic Epiaqualfs) with a pH of 6.2 and 2.5% organic matter. Field preparation was conducted similar to at the RRS. A natural population of Nealley's sprangletop existed at this location with no additional overseeding required.

The long grain rice cultivar ‘CL-151’ was drill-seeded in 18-cm rows at a planting rate of 67 kg ha^{-1} on April 01, 2014. ‘CL-111’ was drill-seeded on March 25, 2015 at the grower location, March 30, 2015 and April 6, 2016 at the RRS. CL-151 and CL-111 are imidazolinone-resistant rice lines with similar maturity dates and yields (Steve Linscombe, LSU Rice Breeder, personal communication). Twenty-four hours after planting, the area was surface irrigated to a level of 2.5-cm and drained. A permanent flood of 10-cm was established when the rice reached the five-leaf to one-tiller stage and was maintained until 2 weeks prior to harvest.

The experimental design was a randomized complete block replicated four times. Herbicide treatments consisted of cyhalofop at 271, 314, and 417 g ai ha^{-1} applied pre-flood, 24-hours prior to permanent flood establishment and post-flood, 24-hours after permanent flood establishment, fenoxaprop at 66, 86, and 122 g ai ha^{-1} applied pre-flood and post-flood, propanil at 3360 g ai ha^{-1} applied pre-flood, and propanil plus thiobencarb at 5040 g ai ha^{-1} applied pre-flood. A nontreated, propanil, and propanil plus thiobencarb were added as comparison treatments. A crop oil concentrate (COC) (Agri-Dex® label, Helena Chemical Company, Collierville, TN) at 1% v/v was added in each herbicide application except applications containing propanil. Previous research indicated quinclorac plus halosulfuron had no activity on Nealley's sprangletop (Bergeron et al. 2015); therefore, quinclorac at 420 g ai ha^{-1} plus halosulfuron at 53 g ai ha^{-1} was applied delayed preemergence (DPRE) to the entire plot area, to control grass, sedge, and broadleaf weeds. Each herbicide application was applied with a CO_2-pressurized backpack sprayer calibrated at 145 kPa to deliver 140 L ha^{-1} of solution.

At the pre-flood herbicide application timing, Nealley's sprangletop and Amazon sprangletop was four leaf- to one-tiller and approximately 10- to

20-cm in height. At the post-flood timing, Nealley's sprangletop and Amazon sprangletop was one- to two-tiller and approximately 18- to 25-cm.

Nealley's sprangletop and Amazon sprangletop visual control ratings were taken 7, 21, and 35 days after treatment (DAT). Visual weed control was evaluated on a scale of 0 to 100%, 0 = no injury or control and 100 = complete plant death. Immediately prior to harvest, rice plant heights were taken from four rice plants per plot from the soil surface to tip of the extended panicle. The center four rows, a 0.75- by 6-m strip of rice, was harvested with a Mitsubishi® VM3 (Mitsubishi Corporation, 3-1, Marunouchi 2-chome, Chiyoda-ky, Tokyo, Japan) rice harvester on July 30, 2015 at the RRS and August 4, 2015 at the grower location. Rough rice yield was not obtained in 2014 due to lodging and in 2016 due to flooding and lodging from 41.5-cm rainfall August 12 and 13, 2016.

All data were arranged as repeated measures and subjected to the mix procedure of SAS (release 9.4, SAS Institute, Cary, NC). Replications were nested within year, cyhalofop and fenoxaprop application timings and rates, as well as applications of propanil and propanil plus thiobencarb, were the treatments, plots within each block were the experimental units for the treatments, and 7, 21, and 35 DAT were the repeated measure effects in time for Nealley's sprangletop and Amazon sprangletop control. Herbicide treatment and evaluation timing were considered fixed effects. The random effects for the model were year, replications within year, and plots. Considering year or combination of year as random effects permits inferences about treatments over a range of environments (Carmer et al. 1989; Hager et al. 2003). Type III statistics were used to test all possible effects of fixed factors (herbicide treatment by rating date) and Tukey's test was used for mean separation at the 5% probability level ($p \leq 0.05$).

Results and Discussion

A herbicide treatment by rating date interaction occurred for Nealley's sprangletop; therefore, a table for this interaction was constructed (Table 3.1). At 35 DAT, regardless of rate or timing Nealley's sprangletop treated with cyhalofop resulted in increased control compared with Nealley's sprangletop treated with propanil plus thiobencarb. Maneechote et al. (2005) reduced Chinese sprangletop populations up to 90% when treated with cyhalofop or fenoxaprop. Nealley's sprangletop treated with fenoxaprop at 86 or 122 g ha^{-1} pre-flood resulted in higher control of Nealley's sprangletop than propanil or propanil plus thiobencarb at 35 DAT. Stauber et al. (1991) observed no difference in bearded sprangletop control with an application of fenoxaprop or propanil.

A herbicide treatment by rating date interaction occurred for Amazon sprangletop control; therefore, a table for this interaction was constructed (Table 3.1). At 21 DAT, fenoxaprop applied post-flood at 66, 86, or 122 g ha^{-1} controlled Amazon sprangletop 72, 75, and 74%, respectively, with no difference compared with propanil or propanil plus thiobencarb treated Amazon sprangletop; however, cyhalofop applied at 271 g ha^{-1} pre-flood resulted in 88% control of Amazon sprangletop, compared with an application of propanil plus thiobencarb which resulted in 73% control at 21 DAT. Prashant et al. (2010) observed increased barnyardgrass control after a cyhalofop application post-flood compared with a pre-flood application; however, no differences in herbicide timing were observed in this study. Regardless of herbicide or timing no differences were observed in rice height at harvest (data not shown). Snipes and Street (1987) observed no rice height differences at harvest after an application of fenoxaprop when applied before tillering.

Rough rice yields were recorded at both locations in 2015. Rough rice yields were arranged as actual data and based on the percentage of the

Table 3.1. Effects of cyhalofop, fenoxaprop, and comparison treatments on Nealley's sprangletop and Amazon sprangletop 7, 21, and 35 days after treatment (DAT), 2014 through 2016 at multiple locations.[abcd]

			Control[f] (DAT)					
			Nealley's Sprangletop			Amazon Sprangletop		
Herbicide	Rate	Timing[e]	7	21	35	7	21	35
	g ai ha^{-1}				%			
Cyhalofop	271	PREFLOOD	85 a-c	85 a-c	86 ab	88 a	88 a	84 a-f
Cyhalofop	271	POSTFLOOD	80 a-e	83 a-e	87 ab	82 a-f	86 a-d	82 a-f
Cyhalofop	314	PREFLOOD	86 ab	84 a-d	88 ab	87 a-c	85 a-e	84 a-f
Cyhalofop	314	POSTFLOOD	81 a-e	84 a-d	85 a-c	81 a-f	82 a-f	82 a-f
Cyhalofop	417	PREFLOOD	86 ab	85 a-c	90 a	82 a-f	86 a-d	84 a-f
Cyhalofop	417	POSTFLOOD	80 a-e	85 a-c	89 ab	82 a-f	83 a-f	83 a-f
Fenoxaprop	66	PREFLOOD	86 ab	85 a-c	83 a-e	88 a	80 a-f	84 a-f
Fenoxaprop	66	POSTFLOOD	82 a-e	84 a-d	79 b-e	77 a-f	72 f	73 f
Fenoxaprop	86	PREFLOOD	87 ab	86 ab	86 ab	89 a	83 a-f	84 a-f
Fenoxaprop	86	POSTFLOOD	81 a-e	84 a-d	83 a-e	80 a-f	75 c-f	75 c-f
Fenoxaprop	122	PREFLOOD	84 a-d	85 a-c	86 ab	87 a-c	83 a-f	84 a-f
Fenoxaprop	122	POSTFLOOD	82 a-e	82 a-e	82 a-e	78 a-f	74 d-f	80 a-f
Propanil	3360	PREFLOOD	82 a-e	79 b-e	75 c-e	80 a-f	75 c-f	76 a-f
Propanil + thiobencarb	5040	PREFLOOD	80 a-e	73 e	73 e	78 a-f	73 f	73 f

[a]Analysis of Nealley's sprangletop and Amazon sprangletop control were performed as repeated measures at 7, 21, and 35 days after treatment.

[b]Means followed by the same letter do not significantly differ at P=0.05 using Tukey's test.

[c]Crop oil concentrate, trade name Agri-dex®, Helena Chemical Co., Collierville, TN at 1% (v/v) was used with all treatments not containing propanil.

[d]Locations: Crowley, Louisiana and Estherwood, Louisiana.

[e]PREFLOOD application applied 24 hours prior to permanent flood, POSTFLOOD application applied 24 hours after establishment of permanent flood.

[f]Control was measured using a scale of 0 (no control) to 100 (complete control) based on visual symptoms.

nontreated (Table 3.2). Rice treated pre-flood with cyhalofop at 417 g ha^{-1} yielded 6360 kg ha^{-1}, compared with the nontreated at 4570 kg ha^{-1}. However, this application of cyhalofop is above labeled rate for use in rice. Ntanos et al. (2000) observed an increase in rice yield with rice treated with cyhalofop compared with the nontreated. Rice treated with fenoxaprop applied pre-flood at 66 or 86 g ha^{-1} and postflood at 86 g ha^{-1} resulted in higher yields, compared with the nontreated. Snipes and Street (1987) observed

Table 3.2. Rough rice yields of rice treated with cyhalofop, fenoxaprop, and comparison treatments, averaged over multiple locations.[abc]

Herbicide	Rate	Timing[d]	Yield	
	g ai ha^{-1}		kg/ha	% of nontreated
Cyhalofop	271	PREFLOOD	5500 a-c	120
Cyhalofop	271	POSTFLOOD	5420 a-c	119
Cyhalofop	314	PREFLOOD	5250 a-c	115
Cyhalofop	314	POSTFLOOD	5180 a-c	113
Cyhalofop	417	PREFLOOD	6360 a	139
Cyhalofop	417	POSTFLOOD	5540 a-c	121
Fenoxaprop	66	PREFLOOD	5890 ab	129
Fenoxaprop	66	POSTFLOOD	5820 a-c	127
Fenoxaprop	86	PREFLOOD	5850 ab	128
Fenoxaprop	86	POSTFLOOD	5870 ab	128
Fenoxaprop	122	PREFLOOD	5480 a-c	120
Fenoxaprop	122	POSTFLOOD	5760 a-c	126
Propanil	3360	PREFLOOD	5370 a-c	118
Propanil + thiobencarb	5040	PREFLOOD	6110 a	134
Nontreated			4570 c	

[a]Means followed by the same letter do not significantly differ at P=0.05 using Tukey's test.

[b]Crop oil concentrate, trade name Agri-dex®, Helena Chemical Co., Collierville, TN at 1% (v/v) was used with all treatments not containing propanil.

[c]Locations: Crowley, Louisiana and Estherwood, Louisiana.

[d]PREFLOOD application applied 24 hours prior to permanent flood, POSTFLOOD application applied 24 hours after establishment of permanent flood.

higher rice yields compared with the nontreated, after an application of fenoxaprop before the boot stage of rice. No differences occurred in yield when comparing pre-flood or post-flood applications with these herbicides. Although, Griffin and Baker (1990) observed yield reductions in rice treated with fenoxaprop applied post-flood compared with a pre-flood application.

In conclusion, these herbicides, rates, and timings had no effect on rice injury or rice height. Also, no differences occurred in weed control or rice yield when comparing herbicide timing. Cyhalofop or fenoxaprop controlled Nealley's and Amazon sprangletop greater than 71% across all rating dates. These results are similar to observations by Buehring et al. (2006) when evaluating Amazon sprangletop control with cyhalofop and fenoxaprop. Rice treated with cyhalofop at 417 g ha^{-1} pre-flood, fenoxaprop at 66 and 86 g ha^{-1} pre-flood, and fenoxaprop at 86 g ha^{-1} post-flood yielded 1280 to 1790 kg ha^{-1} higher than rice that received no herbicide treatment. Some differences were observed in the control of Nealley's sprangletop when treated with products containing propanil; however, no difference in yield was observed. This was probably due to a late infestation of hemp sesbania and rice flatsege that were not controlled with the DPRE quinclorac plus halosulfuron treatment, but were controlled by the propanil and propanil plus thiobencarb treatments causing yields to be similar. When managing an infestation of Nealley's sprangletop, an overall strategy should be employed; which includes tillage, burndown applications, and in crop herbicide application.

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Chapter 4

Impact of Nealley's Sprangletop on Rice

Introduction

Herbicides are critical for achieving optimal yield and maximizing profit. In 2012, approximately 116 million hectares of 158 million total hectares of farm land received an application of a herbicide (USDA 2012). In order to maximize rice (*Oryza sativa* L.) yields and achieve the highest economical return, producers use integrated weed management programs that are best accomplished through the use of cultural, mechanical, and chemical practices (Jordan and Sanders 1999). Ashton and Monaco (1991) estimated farmers spend 3.6 billion dollars annually for chemical weed control; however, 16 years later Gianessi and Reigner (2007) reported and estimated annual herbicide cost of 7 billion dollars.

Nealley’s sprangletop (*Leptochloa nealleyi* Vasey) is a monocot in the poaceae family with first known taxonomic description of Nealley's sprangletop in 1885 (Hitchcock 1903, 1950). This weed has been found predominately along roadsides and in drainage ditches in south Louisiana, Texas, and Mexico, but has recently adapted to flooded environments similar to that of production rice (Bergeron et al. 2015). Nealley’s sprangletop has been observed surviving through the winter months, and regrows during the summer months, indicating a potential perennial growth habit in South Louisiana and Texas. In order to select the appropriate weed management program for Nealley's sprangletop correct identification is important (Webster 2014).

At the seedling stage, Nealley’s sprangletop has sparse pubescence at the base of the stem unlike other sprangletop species commonly found in rice fields (Bergeron et al. 2015). This grass also has a fringed membranous ligule similar to Amazon sprangletop [*Leptochloa panicoides* (J. Presl) A.S. Hitchc.], which is commonly found in mid-south rice production. Nealley’s sprangletop is erect and robust with flat culms from 1- to 1.5-m tall (Hitchcock 1950). Nealley's sprangletop is simple or sparingly branching at the base, with glabrous or slightly glabrous sheaths. At maturity, Nealley's sprangletop produces a panicle-like seedhead 25- to 50-cm in length with 50- to 75-racemes, 2- to 4-cm long. Nealley's sprangletop seed are obtuse and 1- to 1.5-mm long. This weed produces a high number of seed with significant viability at maturity (Bergeron et al. 2015).

Competitiveness of Nealley's sprangletop could potentially reduce rice yield as seen in previous studies with other sprangletop species. Interference of Amazon sprangletop (Smith 1975) and bearded sprangletop (Smith 1983) with rice reduced rice yield, grain quality, milling yield, and rice seed germination. Season long interference from Amazon sprangletop at 50- to 200-panicles m^2 and bearded sprangletop at 108 plants m^2 reduced rice yields up to 36%. Smith (1983) evaluated the impact of bearded sprangletop [*Leptochloa fusca* (L.) Kunth var. *fascicularis* (Lam.) N. Snow] densities on rice yield, and reported densities of bearded sprangletop at 11- to 108-plants m^2 reduced grain yields from 9 to 36%. Bearded sprangletop at 1 plant m^2 reduced grain yield 21 kg ha^{-1}, and rice yields were reduced 10 and 50% from bearded sprangletop densities of 30 and 148 plants m^2, respectively (Smith 1983, 1988). Densities of 15- to 30-plants m^2 would be sufficient threshold levels to require control practices for bearded sprangletop.

Carey et al. (1994) evaluated interference duration of bearded sprangletop in rice. Bearded sprangletop densities of 50 plants m^2 were removed from rice plots at 21, 35, 42, 56, 70, and 130 days after planting (DAP). Grain yields decreased as bearded sprangletop interference duration increased; durations of bearded sprangletop interference of greater than 56 DAP decreased rice yield more than 2296 kg ha^{-1}. Interference of bearded sprangletop at 130 DAP reduced yields 50%. By determining the effects of Nealley's sprangletop on mid-south rice this will allow a producer to determine if enacting a control measure will prove to be an economical benefit.

Materials and Methods

Two field studies were conducted at the Louisiana State University Agricultural Center H. Rouse Caffey Rice Research Station (RRS) near Crowley, LA to determine the impact of Nealley's sprangletop on rice yield in 2014, 2015, and 2016 and in 2015 at a grower location near Estherwood, LA. The first study evaluated optimal removal timings of Nealley's sprangletop for optimizing rough rice yields. The second study evaluated Nealley's sprangletop populations in rice and the impact of Nealley's sprangletop densities on rice yield.

Nealley's Sprangletop Removal Study. The soil type at the RRS was a Crowley silt loam soil (fine smectic, thermic Typic Albaqualfs) with a pH of 6.4 and 1.4% organic matter. Field preparation consisted of a fall and spring disking followed by two passes in opposite directions with a two-way bed conditioner equipped with rolling baskets and S-tine harrows set at a 6 cm depth. Before planting, Nealley's sprangletop seed was collected from various locations in Acadia Parish, Louisiana and mechanically spread over the entire study area at 30 kg ha^{-1} resulting in 5- to 10-plants m^2. The soil type at the grower location was a Kaplan silt loam soil (fine smectic, thermic Aeric Chromic Vertic Epiaqualfs) with a pH of 6.2 and 2.5% organic matter. Field preparation was conducted as previously described at the RRS. A natural population of Nealley's sprangletop existed at this location with no additional overseeding required resulting in a density of 10- to 20-plants m^2.

The long grain rice cultivar 'CL-151' was drill-seeded in 18-cm rows at a planting rate of 67 kg ha^{-1} on April 01, 2014 at the RRS. 'CL-111' was drill-seeded on March 25, 2015 at the grower location, March 30, 2015 and April 6, 2016 at the RRS. CL-151 and CL-111 are imidazolinone-resistant rice lines with similar maturity dates and yields (Steve Linscombe, LSU Rice

Breeder, personal communication). Twenty-four hours after planting, the area was surface irrigated to a level of 2.5-cm and drained. A permanent flood of 10-cm was established when the rice reached the five-leaf to one-tiller stage and was maintained until 2 weeks prior to harvest.

The experimental design was a randomized complete block with four replications. Fenoxaprop (Ricestar® HT herbicide label, Bayer Crop Protection LLC, Greensboro, NC) is a recommended control measure for Nealley's sprangletop (Webster 2016), and was used to remove Nealley's sprangletop at pre-set intervals during the growing season. Fenoxaprop was applied at 122 g ai ha^{-1} at 7, 14, 21, 28, 35, and 42 days after emergence (DAE) on Nealley's sprangletop at one- to two-leaf, two- to three-leaf, two- to four-leaf, three- to five-leaf, one- to two-tiller, and two- to three-tiller, respectively. A weed-free plot was added by utilizing herbicide application, fenoxaprop at 122 g ha^{-1}, and hand-weeding as a comparison treatment. A nontreated was also added for comparison. Previous research indicated quinclorac plus halosulfuron had no activity on Nealley's sprangletop; therefore, quinclorac at 420 g ai ha^{-1} plus halosulfuron at 53 g ai ha^{-1} was applied delayed preemergence (DPRE), to control grass weeds, sedges, and broadleaf weeds in the entire research area. A crop oil concentrate (COC) (Agri-Dex® label, Helena Chemical Company, Collierville, TN) at 1% v/v was added to all applications. Each herbicide application was applied with a CO_2-pressurized backpack sprayer calibrated at 145 kPa to deliver 140 L ha^{-1} of solution.

Immediately prior to harvest, rice plant heights were taken from four rice plants per plot from the soil surface to tip of the extended panicle. The center four rows, a 0.75 by 6 m strip of rice, was harvested with a Mitsubishi® VM3 (Mitsubishi Corporation, 3-1, Marunouchi 2-chome, Chiyoda-ky, Tokyo, Japan) rice harvester on August 13, 2014 and July 30, 2015 at the RRS and August 4, 2015 at the grower location. Rough rice yield was not obtained in 2016 due to flooding and lodging from 41.5-cm rainfall August 12 and 13, 2016.

Economic applications were based on the average long grain rough rice price for 2015, \$254 MT^{-1} (USDA 2016). Fenoxaprop was priced at \$48 L^{-1} and COC was priced at \$4 L^{-1}. The cost of an aerial application applied at 47 L ha^{-1} is \$15 ha^{-1} (Salassi et al. 2015). The total value of the product was calculated by multiplying average rough rice price by total rough rice yield. Net returns above fenoxaprop herbicide application costs were also analyzed, by subtracting the cost of herbicide, COC, and application from total product value.

All data were arranged as repeated measures and subjected to the mix procedure of SAS (release 9.4, SAS Institute, Cary, NC). Years, replication (nested within years), location, and all interactions containing either of these effects were considered random effects. Application timing was considered a fixed effect. Considering year or combination of year as random effects permits inferences about treatments over a range of environments (Carmer et al. 1989; Hager et al. 2003). Type III statistics were used to test all possible effects of fixed factors (application timings) and Tukey's test was used for mean separation at the 5% probability level ($p \leq 0.05$).

Nealley's Sprangletop Density Study. The research location land preparation was as previously described. However, in this study Nealley's sprangletop seed was planted 2 weeks prior to rice planting into commercial potting soil (Jiffy Mix Grower's Choice, Jiffy Products of America, Inc., Lorain, OH) in seed flats with 50- 2.5- by 2.5-cm cells. When the Nealley's sprangletop plants reached the three- to four-leaf growth stage, the seedlings were transplanted into two- to three-leaf rice field plots at 1, 3, 7, 13, and 26 plants m^2. The study area received an initial DPRE application of quinclorac plus halosulfuron as previously described and hand-weeding was used to maintain clean plots throughout the maturity of the rice.

Immediately prior to harvest, rice plant heights were taken from four rice plants per plot from the soil surface to tip of the extended panicle. Rice was harvested as previously described on August 13, 2014, July 30, 2015, and August 23, 2016 at the RRS. At harvest, Nealley's sprangletop plant survival counts were evaluated and recorded.

Data were subjected to PROC MIXED in SAS (release 9.4, SAS Institute, Cary, NC). The yield and height data were subjected to regression analysis to model the effects of Nealley's sprangletop density. The data were log transformed for better distribution and showed a linear relationship with density. Random coefficient effects included the intercepts and linear regression effects of density by replication within trial.

Results and Discussion

Nealley's Sprangletop Removal Study. No difference occurred for plant height at harvest when Nealley's sprangletop was allowed to compete with rice from 7 DAE to 35 DAE; however, a slight height reduction occurred for rice plants that competed with Nealley's sprangletop for 42 DAE (Table 4.1). Smith (1968) observed lower rice heights from increased barnyardgrass populations. Snipes and Street (1987) observed rice height reductions with later applications of fenoxaprop in rice, and this reduction may have been partially caused by the late application of the herbicide at 42 DAE.

Nealley's sprangletop removal at 7 and 14 DAE resulted in higher rice yield when compared with the nontreated (Table 4.1). Smith (1983) observed up to 36% reductions in rice yields with a season long infestation of bearded sprangletop in rice. The earliest removal timing, 7 DAE, yielded 1910 kg ha^{-1} more than the nontreated, and this was a 131% yield increase compared with the nontreated. Carlson et al. (2012) evaluated imazethapyr timings on IR rice and observed an increase in rice yield with earlier imazethapyr application. Similar, Chauhan and Johnson (2011) reported a 20% yield

Table 4.1 Rough rice yields from a single application of fenoxaprop 7 to 42 days after Nealley's sprangletop emergence, 2014 through 2016, over multiple locations.[abcdef]

Treatment	Size at treatment	Harvest height	Rough rice yield	Yield of nontreated
		—— cm ——	—— kg ha^{-1} ——	—— % ——
Nontreated		97 a	6090 d	100
7 DAE Removal	1- to 2-leaf	97 a	8000 a	131
14 DAE Removal	2- to 3-leaf	97 a	7020 bc	115
21 DAE Removal	2- to 4-leaf	97 a	6750 b-d	111
28 DAE Removal	3- to 5-leaf	96 ab	6890 b-d	113
35 DAE Removal	1- to 2-tiller	96 ab	6570 cd	108
42 DAE Removal	2- to 3-tiller	93 b	6210 cd	102
Weed Free		97 a	7620 ab	125

[a]Means followed by the same letter do not significantly differ at P=0.05 using Tukey’s test.
[b]Crop oil concentrate, trade name Agri-dex®, Helena Chemical Co., 225 Schilling Boulevard, Suite 300, Collierville, TN 38017 at 1% (v/v) was used with all treatments.
[c]Locations: Crowley, Louisiana and Estherwood, Louisiana.
[d]Fenoxaprop was applied at 122 g ai ha^{-1}.
[e]Weed free plot established by herbicide application and/or hand-weeding Nealley's sprangletop.
[f]Abbreviations: DAE, days after emergence of Nealley's sprangletop.

loss by delaying herbicide application 28 days after weed emergence. Rice maintained weed-free yielded 7620 kg ha^{-1} compared with 8000 kg ha^{-1} from the 7 DAE removal timing, some damage may have occurred to rice during hand weeding; however, no yield reduction was observed. By delaying herbicide application from 7 DAE to 42 DAE a yield loss of 1790 kg ha^{-1} was observed. Over the 35 day delay in application, rice yield loss was equivalent to 51 kg ha^{-1} per day from Nealley's sprangletop interference.

Table 4.2 contains economical returns based on the yields obtained in this study. The total product value is considering the average rice price in 2015, \$254 MT^{-1}. Removing Nealley's sprangletop 7 DAE resulted in a 126% increase in net returns over fenoxaprop costs compared with nontreated; resulting in a profit increase of \$395 ha^{-1}. Delaying herbicide application to 42 DAE resulted in a 4% loss of profit and \$65 ha^{-1} less return than nontreated rice, after factoring in herbicide cost. Carlson et al. (2012) observed a decrease in total product value when delaying imazethapyr

Table 4.2 Economical returns from a single application of fenoxaprop 7 to 42 days after Nealley's sprangletop emergence, 2014 through 2016, over multiple locations.[abcdfg]

Treatment	Total product value	Net returns above herbicide cost	Change in net returns[e]
		\$ ha^{-1}	
Nontreated	1540 d	1540	0
7 DAE Removal	2030 a	1935	+395 (126%)
14 DAE Removal	1780 bc	1685	+145 (109%)
21 DAE Removal	1710 b-d	1615	+75 (105%)
28 DAE Removal	1750 b-d	1655	+115 (107%)
35 DAE Removal	1670 cd	1575	+35 (102%)
42 DAE Removal	1570 cd	1475	-65 (-4%)

[a]Means followed by the same letter do not significantly differ at P=0.05 using Tukey’s test.

[b]Crop oil concentrate, trade name Agri-dex®, Helena Chemical Co., 225 Schilling Boulevard, Suite 300, Collierville, Tennessee 38017 at 1% (v/v) was used with all treatments.

[c]Locations: Crowley, Louisiana and Estherwood, Louisiana.

[d]Fenoxaprop was applied at 122 g ai ha^{-1}.

[e]Change in net returns compared to nontreated.

[f]Herbicide cost provided by Helena Chemical Co., 813 N. Jackson Avenue, Morse, Louisiana 70559.

[g]Abbreviations: DAE, days after emergence of Nealley's sprangletop.

herbicide application on rice to 42 DAE. With this research, delaying fenoxaprop application from 7 DAE to 42 DAE resulted in a net return loss of \$460 ha^{-1}. Over the 35 day delay in herbicide application profits were reduced at a rate of \$13 ha^{-1} per day. Early removal of Nealley's sprangletop is essential for optimizing rice yield and gaining maximum profit.

Nealley’s Sprangletop Density Study. Analysis indicated significance for Nealley's sprangletop density on rice yield where the linear effects of density (b = -0.00158) were significant ($P < 0.0064$). The effects of Nealley's sprangletop density on rice height (b = -0.00000284) were not significant ($P = 0.9900$). Chin (2001) observed decreases in rice yield with higher populations of red sprangletop (*Leptochloa chinensis* L. Nees). At Nealley's sprangletop densities of 1 to 26 plants m^2, rice yields were reduced 80 to 1930 kg ha^{-1}, compared with the nontreated (data not shown). Diarra et al. (1985) observed cultivated rice yield decreases with a heavy infestation of red rice. Based on \$85 ha^{-1} cost for fenoxaprop treatment and an average rough rice price of \$254 MT^{-1}, Nealley's sprangletop at densities of 5 plants m^2 or greater would be sufficient threshold levels to require weed management. Smith (1988) observed similar threshold levels when evaluating barnyardgrass densities in rice.

In conclusion, data from the removal study indicates that early control of Nealley's sprangletop will prevent season long competition from this weed with rice, which can result in higher yields and higher profits. Removal of Nealley's sprangletop 7 DAE increased rough rice yield 1910 kg ha^{-1} compared with rice from the nontreated. Delaying removal of Nealley's sprangletop 42 days after the weed emerges can result in profit loss of rice at \$460 ha^{-1}. Applying herbicides at 42 DAE to remove Nealley's sprangletop would result in a loss of profit due to higher application cost than profit gain compared with the nontreated. Competition from this weed on rice should be eliminated earlier than 14 DAE to maximize yield and increase profit.

Results from the density trial indicate that Nealley's sprangletop competes with rice resulting in reduced rice yield. Nealley's sprangletop populations of 26 plants m^2 can reduce rice yield by 1930 kg ha^{-1},when allowed to compete the entire growing season. This data also indicates that Nealley's sprangletop at a density of 1 plant m^2 reduced rice yield 80 kg ha^{-1}. Smith (1983) observed rice yield loss of 21 kg ha^{-1} when 1 plant m^2 of bearded sprangletop interfered with rice.

By determining the impact of Nealley's sprangletop on rice, the producer can determine when employing control practices will produce a favorable economic return. The value of crop and cost of control programs, which are subject to change, can be correlated with rice yield losses in fields with a known density of Nealley's sprangletop.

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Chapter 5

Summary

Nealley’s sprangletop (*Leptochloa nealleyi* Vasey) is a monocot in the poaceae family (Hitchcock 1950). This weed has been present along roadsides and ditches in south Louisiana, Texas, and Mexico, but has recently adapted to flooded environments similar to that of production rice (*Oryza sativa* L.) (Bergeron et al. 2015). This research was conducted to evaluate Nealley's sprangletop interference and management of this weed in drill-seeded rice. Results from this research can be used to develop a Nealley's sprangletop management program in rice.

Research was conducted in September 2014, October 2014, November 2015, and March 2016 in a glasshouse on the Louisiana State University campus in Baton Rouge, Louisiana to determine which herbicides have activity on Nealley's sprangletop. This study was conducted four times. Herbicide applications were applied when the Nealley’s sprangletop plants reached the one- to two-tiller stage with an approximate height of 20- to 30-cm. All herbicides applied were known to have some grass activity. Nealley’s sprangletop control was evaluated at 5, 10, 14, 21, and 28 days after treatment (DAT). Nealley's sprangletop leaf number, height, and tiller number were evaluated at 0, 5, 10, 14, 21, and 28 DAT. At harvest, 28 DAT, immediately after final plant evaluation the Nealley's sprangletop plants were removed from the soil and thoroughly rinsed. After rinsing, the above ground plant material was separated from the below ground portion and the fresh weight of each was obtained.

Quinclorac, penoxsulam, and bispyribac provided little to no control when applied on Nealley's sprangletop. For an infestation of Nealley's sprangletop in rice, a spring burndown application prior to planting may be necessary for proper management of this weed. A glyphosate application on Nealley's sprangletop achieved the highest control of burndown herbicides evaluated, with 99% control at 28 DAT. This research indicates that imazethapyr and imazamox suppresses Nealley's sprangletop, at best, and the adoption of the IR rice system may further explain the reason for the expansion of this weed in mid-south rice production (Eric P. Webster, LSU Extension Weed Scientist, personal communication). Clethodim and quizalofop applications resulted in 89 and 99% control of Nealley's sprangletop, respectively. Although these herbicides are not currently labeled in rice, this research can be useful when evaluating control methods for Nealley's sprangletop in broadleaf crops such as cotton (*Gossypium hirsutum* L.) or soybean [*Glycine max* (L.) Merr.] or as herbicides in a burndown system. The adoption of these herbicides for Nealley's sprangletop control in a program could further prolong the life of herbicide resistant crops and aid in resistance management. Fenoxaprop is currently the best option for controlling Nealley's sprangletop in season rice production.

Research was conducted at the Louisiana State University Agricultural Center H. Rouse Caffey Rice Research Station (RRS) near Crowley, LA in 2014, 2015, and 2016 and in 2015 at a grower location near Estherwood, LA. This study evaluated herbicide rates and timings for control of Nealley's sprangletop. Herbicide treatments consisted of cyhalofop at 271, 314, and 417 g ai ha^{-1} applied pre-flood and post-flood, fenoxaprop at 66, 86, and 122 g ai ha^{-1} applied pre-flood and post-flood, propanil at 3360 g ai ha^{-1} applied pre-flood, and propanil plus thiobencarb at 5040 g ai ha^{-1} applied pre-flood. A nontreated, propanil, and propanil plus thiobencarb were added as comparison treatments. Nealley's sprangletop and Amazon sprangletop [*Leptochloa panicoides* (J. Presl) A.S. Hitchc.] visual control ratings were taken 7, 21, and 35 DAT. Immediately prior to harvest, rice plant heights were taken. The center four rows of rice were harvested with a rice harvester on July 30, 2015 at the RRS and August 4, 2015 at the grower location.

These herbicides, rates, and timings had no effect on rice crop injury or rice height. Also, no differences occurred in weed control or rice yield when comparing herbicide timing. Cyhalofop or fenoxaprop controlled Nealley's and Amazon sprangletop greater than 71% across all rating dates. Rice treated with cyhalofop at 417 g ha^{-1} pre-flood, fenoxaprop at 66 and 86 g ha^{-1} pre-flood, and fenoxaprop at 86 g ha^{-1} post-flood yielded 1280 to 1790 kg ha^{-1} higher than rice that received no herbicide treatment. Some differences were observed in the control of Nealley's sprangletop when treated with products containing propanil; however, no difference in yield was observed.

Research was conducted at the RRS in 2014, 2015, and 2016 and in 2015 at a grower location to determine the optimal removal timings of Nealley's sprangletop for optimizing rough rice yields. Fenoxaprop was applied at 122 g ai ha^{-1} at 7, 14, 21, 28, 35, and 42 days after emergence (DAE) on Nealley's sprangletop at one- to two-leaf, two- to three-leaf, two- to four-leaf, three- to five-leaf, one- to two-tiller, and two- to three-tiller, respectively. A weed-free plot was added by utilizing herbicide application, fenoxaprop at 122 g ha^{-1}, and hand-weeding for comparison purposes. Immediately prior to harvest, rice plant heights were taken from four rice plants per plot. The center four rows of rice were harvested with a rice harvester on August 13, 2014 and July 30, 2015 at the RRS and August 4, 2015 at the grower location.

No difference occurred for plant height at harvest when Nealley's sprangletop was allowed to compete with rice from 7 DAE to 35 DAE; however, a slight height reduction occurred for rice plants that competed with Nealley's sprangletop for 42 DAE. Nealley's sprangletop removal at 7 and 14 DAE resulted in higher rice yield when compared with the nontreated. The earliest removal timing, 7 DAE, yielded 1910 kg ha^{-1} more than the nontreated, and this amounts to a 131% yield increase compared with the nontreated. Rice maintained weed-free yielded 7620 kg ha^{-1} compared with 8000 kg ha^{-1} from the 7

DAE removal timing, some damage may have occurred to rice during hand weeding of the weed-free treatment. By delaying herbicide application from 7 DAE to 42 DAE a yield loss of 1790 kg ha^{-1} was observed. Over the 35 day delay in application, rice yield loss was equivalent to 51 kg ha^{-1} per day from Nealley's sprangletop competition.

The total product value is considering the average rice price in 2015, $254 MT. Removing Nealley's sprangletop 7 DAE resulted in a 126% increase in net return over fenoxaprop costs compared with nontreated; resulting in a profit increase of $395 ha^{-1}. Delaying herbicide application to 42 DAE resulted in a 4% loss of profit and $65 ha^{-1} less return than nontreated rice, after factoring in herbicide cost. Delaying herbicide application from 7 DAE to 42 DAE resulted in a net return loss of $460 ha^{-1}. Over the 35 day delay in herbicide application profits were reduced at a rate of $13 ha^{-1} per day. Early removal of Nealley's sprangletop is essential for optimizing rice yield and gaining maximum profit.

Research was conducted at the RRS in 2014, 2015, and 2016 to determine impacts of Nealley's sprangletop densities on rice yield. Nealley's sprangletop seedlings were transplanted into two- to three-leaf rice field plots at 1, 3, 7, 13, and 26 plants m^2 and allowed to compete until harvest. Immediately prior to harvest, rice plant heights were taken from four rice plants per plot. The center four rows of rice were harvested with a rice harvester on August 13, 2014 and July 30, 2015 at the RRS and August 4, 2015 at the grower location.

Results from the density trial indicate that Nealley's sprangletop competes with rice resulting in reduced rice yield. Nealley's sprangletop populations of 26 plants m^2 can reduce rice yield by 1930 kg ha^{-1} when allowed to compete the entire growing season. This data also indicates that Nealley's sprangletop at a density of 1 plant m^2 reduced rice yield 80 kg ha^{-1}.

In conclusion, the effectiveness of herbicides on Nealley's sprangletop is different compared with other species of sprangletop. Smith (1975) reported propanil at 4480 g ai ha^{-1} controlled Amazon sprangletop 87%. In the glasshouse study, the highest control of Nealley's sprangletop observed with propanil was 61%. Smith (1988) reported 87 to 94% control of bearded sprangletop [*Leptochloa fusca* (L.) Kunth var. *fascicularis* (Lam.) N. Snow] after an application of thiobencarb at 4500 g ai ha^{-1}. Nealley's sprangletop treated with thiobencarb at 4480 g ha^{-1} was controlled 29%. These data indicate contact herbicides containing propanil and/or thiobencarb are not as active on Nealley's sprangletop compared with Amazon or bearded sprangletop.

Levy et al. (2006) observed at least 87% control of Amazon sprangletop when treated with imazethapyr. This research indicates that imazethapyr and imazamox suppresses Nealley's sprangletop, at best, and the adoption of the IR rice system may further explain the reason for the expansion of this weed in mid-south rice production (Eric P. Webster, LSU Extension Weed Scientist, personal communication). For an infestation of Nealley's sprangletop in rice, a spring burndown application prior to planting may be necessary for proper management of this weed. A glyphosate application on Nealley's sprangletop achieved the highest control of burndown herbicides evaluated, with 99% control at 28 DAT.

Nealley's sprangletop treated with quizalofop at 120 and 185 g ha^{-1} resulted in 99% control. The Provisia™ Rice System (BASF Corporation, Research Triangle Park, NC), is a new herbicide resistant rice, and quizalofop is the target herbicide to be used in this system (Youmans et al. 2016; Rustom et al. 2016; Webster et al. 2015). Quizalofop has activity on Nealley's sprangletop and this herbicide will be a useful tool in management of this weed. Yokohama et al. (2001) reported that fenoxaprop applications resulted in 95 to 97% control of Chinese sprangletop [*Leptochloa chinensis* (L.) Nees], and this research indicates fenoxaprop at 122 g ai ha^{-1} controlled Nealley's sprangletop 99% at 28 DAT. Stauber et al. (1991) observed greater than 85% control of bearded sprangletop when treated with fenoxaprop. Fenoxaprop is currently the best option for controlling Nealley's sprangletop in season rice production.

When evaluating applications of cyhalofop and fenoxaprop pre-flood or post-flood, Nealley's and Amazon sprangletop control was greater than 71% across all rating dates. These results are similar to observations by Buehring et al. (2006) when evaluating Amazon sprangletop control with cyhalofop and fenoxaprop. Rice treated with cyhalofop at 417 g ha^{-1} pre-flood, fenoxaprop at 66 and 86 g ha^{-1} pre-flood, and fenoxaprop at 86 g ha^{-1} post-flood yielded 1280 to 1790 kg ha^{-1} higher than rice that received no herbicide treatment. No differences occurred in yield when comparing pre-flood or post-flood applications with these herbicides. Although, Griffin and Baker (1990) observed yield reductions in rice treated with fenoxaprop applied post-flood compared with a pre-flood application.

By determining the impact of Nealley's sprangletop on rice, the producer can determine when employing control practices will produce a favorable economic return. Carlson et al. (2011) evaluated controlling weeds in rice at multiple timings and determined weed pressure, even over a short period of time, can decrease rice yield. Similar, data from the removal study indicates that early control of Nealley's sprangletop will prevent season long competition from this weed with rice, which can result in higher yields and higher profits. Removal of Nealley's sprangletop 7 DAE increased rough rice yield 1910 kg ha^{-1} compared with rice from the nontreated. Delaying removal of Nealley's sprangletop 42 days after the weed emerges can result in a profit loss at \$460 ha^{-1}.

Chin (2001) observed decreases in rice yield with higher populations of red sprangletop (*Leptochloa chinensis* L. Nees). Nealley's sprangletop densities of 1 to 26 plants m^2 reduced rice yields 80 to 1930 kg ha^{-1}, compared with the nontreated. Based on \$85 ha^{-1} cost for fenoxaprop treatment and an average rough rice price of \$254 MT^{-1}, Nealley's sprangletop at densities of 5 plants m^2 or greater would be sufficient threshold levels to require weed management. Smith (1988) observed similar threshold levels when evaluating barnyardgrass densities in rice.

Employing an overall strategy for Nealley's sprangletop management can help reduce an infestation; which includes, tillage, burndown applications, and in crop herbicide application. These data indicate which herbicides should be incorporated into a management program when dealing with an infestation of Nealley's sprangletop, the impact this weed has on rice, and when employing control practices will produce favorable economic return. This data will play an essential role in current and future management of Nealley's sprangletop.

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Vita

Eric Allen Bergeron Jr is the son of Eric and Roxane Bergeron. He was born in September of 1992 in Crowley, Louisiana. He was raised in Basile, Louisiana until the age of 8 then moved to Morse, Louisiana. Eric attended Midland High School and graduated in 2010. He then enrolled at McNeese State University graduating *cum laude* in December 2013 with a Bachelor of Science degree in general agriculture. He then began his graduate career at Louisiana State University in the Department of Plant, Environmental and Soil Sciences under the direction of Dr. Eric Webster in 2014 and is currently a candidate for the degree of Master of Science in agronomy.