2006

Echinochloa polystachya management in Louisiana rice

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ECHINOCHLOA POLYSTACHYA MANAGEMENT IN LOUISIANA RICE

A Dissertation

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

in

The Department of Agronomy and Environmental Management

By
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B.S., Mississippi State University, 1999
M.S., Mississippi State University, 2003
May 2006

ACKNOWLEDGEMENTS

Completing a Ph.D. program is a rigorous undertaking that has required my full dedication. Without the support, advice, and help of many colleagues and friends, this goal could not have been completed. My time at Louisiana State University has been a rewarding experience enriched with experiencing a new culture and developing new friendships.

I would like to thank my parents, Mike and Dolly Jo Griffin, and my sister, Emily Griffin, for their continued support throughout my graduate career. My mother's personal struggle with multiple myeloma has been a true inspiration.

I owe a debt of gratitude to Dr. Eric P. Webster for granting me the opportunity to pursue my graduate career at LSU. His guidance and support during this time have always been welcomed. While working in his program, I have been privileged with the opportunity to travel and explore much of south Louisiana.

I would also like to thank the Louisiana State University AgCenter, the Department of Agronomy and Environmental Management, and the Louisiana Rice Research Board for the opportunity, support, guidance, and financial funding that I have received.

I would like to acknowledge Dr. Jim Griffin for his guidance and friendship over the past three years. As part of my graduate committee, his attention to detail and weed science expertise have been tremendous resources. Besides experiencing life in the Mississippi delta and attending Mississippi State University, we both share the same appreciation for old four wheel drives.

I am also thankful to the other members of my graduate committee, Dr. Michael Wascom, Dr. Steven Linscombe, Dr. Steven Kelly, and Dr. Charles Sasser for their expertise and cross-disciplinary coordination.

I would like to personally acknowledge many of the people that contributed their time and advice to the completion of my project. I would like to extend my appreciation to Dr. Wei Zhang, Dr. Chris Leon, Chris Mudge, Sunny Bottoms, Justin Hensley, John Sonnier, Dr. Ronald Levy, Michael Fruge, and Nicholas Rasmussen. I would like to thank Brian Leonards, who allowed me to conduct my field experiments on his land. I would also like to mention my fellow graduate students Curtis Jones, Luke Etheredge, and Wilson Judice who have shown me the challenging aspects of sugarcane production. I would also like to thank the members of the Rice Research Station for their involvement in my research from planting through harvest each year.

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ABSTRACT

E. polystachya introduced at stand densities (SD) of 10,000 through 70,000 stolon segments/ha produced 5.4 to 6 stolons/introduced segment; however, 130,000 through 520,000 SD produced 1.4 to 2.1 stolons per introduced segment indicating increased intra- and inter-specific competition. Stolon production was greater than 160,000 plants/ha with 30,000 through 520,000 SD. The 520,000 SD produced a total stolon length of 318 km/ha and no difference was observed for the 260,000 SD. Total node production was 290,000 nodes/ha with an average of 29 nodes/introduced segment in the 10,000 SD and 5.4 to 9.8 nodes/introduced segment with 70,000 or greater SD indicating greater inter- and intra-specific competition. Total biomass indicated similar trends with increasing densities.

In a depth of emergence study, *E. polystachya* shoot emergence was 31, 63, and 44% for stolons planted at the 0, 1.3, and 2.5 cm depth, respectively. Shoot emergence was 25% for 5 cm depth, which was similar to the 0 and 2.5 cm depth.

In a greenhouse study, glyphosate controlled *E. polystachya* 91% and control was 65 to 78% for all herbicides evaluated. When treated with glyphosate, biomass production was 19% of the nontreated *E. polystachya*.

Two studies evaluated herbicides labeled for *Echinochloa crus-galli* (L.) Beauv. control in rice for activity on *E. polystachya*. The first study included: 448 g/ha clomazone PRE, 448 g/ha clomazone plus 420 g ai/ha quinclorac delayed PRE, 448 g ai/ha pendimethalin plus 420 g/ha quinclorac DPRE, 70 g/ha imazethapyr at EPOST, and 175 g ai/ha mesotrione PRE. Each PRE herbicide was followed by 315 g/ha cyhalofop POST. The second study included: 208 g ai/ha cyhalofop EPOST fb 315 g/ha cyhalofop LPOST, 22 g ai/ha bispyribac EPOST fb 22 g/ha bispyribac LPOST, 66 g ai/ha fenoxaprop EPOST fb 86 g/ha fenoxaprop LPOST, 70 g ai/ha imazethapyr EPOST fb 70 g/ha imazethapyr LPOST and 50 g ai/ha penoxsulam MPOST. Each POST program was assessed with

and without 448 g ai/ha clomazone PRE. In the first study, clomazone, imazethapyr, and pendimethalin plus quinclorac controlled *E. polystachya* 78 to 80%. In the second study, treatments including cyhalofop, imazethapyr, and penoxsulam controlled *E. polystachya* 76 to 84%.

CHAPTER 1

LITERATURE REVIEW

In Louisiana, rice (*Oryza sativa* L.) is an important grain crop with several challenging production problems. In 2004, there were 218,000 planted ha of rice with cash sales of $223,898,000 in Louisiana (USDA NASS 2006). Louisiana rice acreage in 2005 was 208,000 ha with Acadia, Jefferson Davis, and Vermilion Parishes planting the most ha (LSUA 2006). The subtropical environment in Louisiana not only allows for beneficial rice growing conditions (LOSC 2006), but also provides an acceptable climate to a wide range of weed species. Producers use integrated weed management programs that are best accomplished through the use of cultural, mechanical, and chemical practices in order to increase rice yields and attain higher economic returns (Jordan and Sanders 1999).

Rice tolerates low oxygen (hypoxic) conditions better than most weeds; thus, flooding has traditionally been used as an effective method of cultural control for many weed species including red rice, an economically important weed genetically identical to rice (Helms 1994). Flooding is also used for land leveling, tillage, and crawfish production (Jordan and Sanders 1999; Linscombe et al. 1999). Water-seeding, which is direct broadcasting dry or pre-soaked seed into flooded fields, is the predominant method of rice seeding used in Louisiana (Linscombe et al. 1999; Seaman 1983). Nitrogen is the most limiting nutrient in rice production in the United States; therefore pre as well as post flood applications of nitrogen-containing fertilizers are common (Helms and Slaton 1996; Linscombe et al. 1999; Miller and Street 2000; Walker and Street 2003). These production practices; however, may promote the spread of weeds that thrive in high nutrient, continuously flooded conditions.

The use of a conventional grain drill to plant rice in rows 15 to 20 cm apart into soil that has previously been prepared by disking or harrowing is referred to as drill- or dry-seeding (Mikkelsen and Datta 1991; Slaton and Cartright 2001). A delayed-flood production system postpones permanent flood establishment until rice is 15 to 20 cm in height (Walker and Street 2003). Intermittent surface irrigation is used to facilitate the growth of rice before permanent flood is established (Slaton and Cartright 2001). Drill-seeding and utilizing a delayed-flood production system may be an alternative weed management tool to water-seeding which may be suitable for the spread of weeds that thrive in continuously flooded conditions.

Echinochloa polystachya [(Kunth) A.S. Hitchc.] is a C_4 perennial grass found in the United States in Florida, Louisiana, Texas, and Puerto Rico (USDA NRCS 2005). It is referred to as: aleman grass, carib grass, creeping river grass, German grass, mudflat-millet, or river grass (Stutzenbaker 1999; USDA NRCS 2005). This weed had only been observed in Plaquemines Parish, Louisiana prior to 1993 (Thomas and Allen 1993).

E. polystachya has recently been identified in approximately 5,000 to 6,000 ha of rice in south Louisiana and is known locally as Habetz grass, referring to the owner of the farm where it was discovered, perennial barnyardgrass, or water bermuda (Saichuk 2003). This species is considered a weed in Australia, Argentina, Mexico, India, Hawaii, and Zaire (Csurhes and Edwards 1998; Holm 1979). *E. polystachya* has been reported to grow in rice fields in Central and South America where it suppresses rice and other weeds (Csurhes and Edwards 1998). However, no results from evaluating the control of *E. polystachya* in rice have been published.

E. polystachya was introduced as a forage at trial planting sites in northern and western Australia where it is becoming naturalized (Smith 1995). This weed has been labeled a priority threat in Australia because of its ability to spread over the northern region of the country which has a tropical climate and an abundance of continuously flooded pastures (Csurhes and Edwards 1998). Humphries et al. (1991) listed *E. polystachya* as one of

Australia's most important environmental weeds and recommended control and review of current non-native spp. introductions. Introduction of non-native plants such as *E. polystachya* can have varying ecological consequences. The introduced grass, *Ammophila arenaria* (L.) Link. is believed to have changed the topography of sand dunes in North America (Barbour and Johnson 1977). In Ireland, the introduced spp. *Rhododendrum ponticum* L. is believed to inhibit regenergation of native woodland plants by creating shade and producing an impenetrable litter layer (Usher 1987).

E. polystachya is a semi-aquatic macrophyte that roots in the littoral sediments of water bodies and forms dense meadows with its prolific perennial growth (Pizzaro 1999). Piedade et al. (1991) reported that the life cycle of *E. polystachya* in the Amazon floodplain is regulated by a seasonal flooding and receding water cycle. Seasonal precipitation differences in the Amazon region cause water level fluctuations resulting in aquatic and terrestrial phases of the weed (Junk et al. 1989). During the terrestrial phase, *E. polystachya* forms new shoots at the nodes of decaying stems (Morrison et. al. 2000). After the onset of the aquatic phase, the plant grows upward at a rate which allows it to remain above the fluctuating water level (Pompeo et al. 2001). At the end of the aquatic phase when the water recedes, the stems dry and new shoots appear at the nodes. *E. polystachya* is well suited for survival in flooded, anaerobic conditions, having a large proportion of aerenchyma tissue, large and hollow stolons, and advantitious roots (Baruch 1994). Sand-Jensen and Borum (1983) reported that there are many physical-chemical variables that affect *E. polystachya* when growth patterns are examined in a fluctuating habitat such as the Amazon floodplain and that it is usually not possible to pinpoint a single regulating growth factor.

Growth of the weed is prolific in areas of high fertility and moist soils with an annual rainfall which exceeds 800 mm (Csurhes and Edwards 1998). Southern Louisiana has similar environmental conditions to tropical and subtropical locations where the plant thrives (LOSC 2006). Cultural practices of rice production in Louisiana as previously discussed include using flooding for weed control during the growing season and keeping those areas flooded after harvest for aid in red rice control (Jordan and Sanders 1999). This environment could be suitable to the growth patterns and survivability of *E. polystachya* as described in previous publications (Morrison et al. 2000; Junk et al. 1989; Pompeo et al. 1999; Baruch 1994).

During initial flooding conditions like those found in the Amazon floodplain, *E. polystachya* has been found to sequester high amounts of nutrients (Piedade et al. 1997). It has been shown to greatly increase stolon biomass and root production under flooded conditions (Baruch and Marida 1995). Both CO_2 uptake and water use efficiency of *E. polystachya* have been found to be comparable with corn (*Zea mays* L.) production in warm temperate conditions (Morrison et al. 2000), and the stem section of *E. polystachya* has been found to contain and load the principal nutrient (C, N, and P) stock of the plant (Pompeo et al. 1999). The mean rate of dry-matter production per unit of solar radiation intercepted by *E. polystachya* is approximately 2.3 g/MJ, an efficiency close to the considered maximum for C_4 plant species (Piedade et al. 1991). The highly competitive qualities of *E. polystachya* allow it to act as a nitrogen sink and exhibit toxic qualities following terms of drought conditions when used as a cattle forage. In the state of Paraiba, northeastern Brazil, an outbreak of nitrate poisoning was attributed to *E. polystachya*. (Medeiros et al. 2003).

It is interesting to note that some perennial grasses are favorable in rice production. In Columbia, palisadegrass [*Brachiaria brizantha* (Hochst. ex A. Rich) Stapf] and signalgrass (*B. decumbens* Stapf) are sown with highly competitive rice varieties to establish a pasture which suppress weeds and provide grazing after the rice is harvested (Fischer et al. 2001). However, these perennial grasses can reduce rice yield when planted with less competitive rice varieties.

It has been stated that barnyardgrass *Echinochloa crus-galli* (L.) Beauv. and junglerice *Echinochloa colona* (L.) Link. are the most important weeds of rice worldwide (Holm et al. 1977; Valverde et al. 2001), so a genetically similar spp. may pose a significant threat to rice production. The variability of barnyardgrass competition is attributed to many factors including germination and emergence that starts at rice planting and extends through midseason (Maun and Barrett 1986; Ogg and Dawson 1984), rapid growth and development (Maun and Barrett 1986), and competition for space and nutrients (Mitich 1990). Smith (1988) reported that barnyardgrass threshold levels were heavily influenced by nitrogen fertility. *E. polystachya* development and competition may also be reliant on nitrogen fertilizer and permanent flood (Morrison et al. 2000; Piedade 1991; Sand-Jensen and Morrison 1991. These conditions exist in current Louisiana rice production and may provide excellent growing conditions for *E. polystachya*.

In a drill-seeded, delayed-flood production system, four to six weeks may elapse between planting and permanent flood establishment; therefore, herbicide applications are warranted (Jordan and Sanders 1999). *Echinochloa* spp. are the most common weeds in Louisiana rice (Webster 2004), so attention has been devoted to developing herbicide programs for control of these species (Jordan and Sanders 1999). Similarity with control options of barnyardgrass, junglerice, and *E. polystachya* may exist due to the genetic background of the weeds. Herbicide programs that are already in use in Louisiana for barnyardgrass control should be evaluated for possible activity on *E. polystachya.*

Preemergence (PRE) herbicides have been used successfully in rice production for weed control. Clomazone, recently labeled for use in rice, reduces or prevents accumulation of plastid pigments, producing plants with a bleached appearance (Duke et al. 1991). It has been shown to control barnyardgrass 90 and 83% at 7 and 35 days after PRE application, respectively (Webster et al. 1999). Other research has shown 100% control of barnyardgrass 14 days after application with 280 g/ha clomazone applied preplant incorporated or preemergence (Westberg et al. 1989).

Pendimethalin, a dinitroanaline, and quinclorac, a quinoline carboxylic acid, are also PRE herbicides used for barnyardgrass control (Vencill 2002b; Vencill 2002c). When substituted for multiple applications of 3.8 kg ai/ha propanil, a postemergence (POST) herbicide used for barnyardgrass control, pendimethalin applied PRE at 0.75 to 1.5 kg ai/ha reduced junglerice pressure and improved rice yield (Valverde et al. 2001). Previous research has shown that quinclorac controls barnyardgrass and is used to control propanil-resistant junglerice (Vasilakoglou et al. 2000). A combination of pendimethalin plus quinclorac at 1.1 and 0.42 kg ai/ha, respectively, applied delayed preemergence controlled barnyardgrass 81% at permanent flood establishment (Jordan et al. 1998). Use of a PRE herbicide may provide control of *E. polystachya,* and could be implemented in a herbicide program with the addition of a postemergence herbicide to enhance control.

The development of herbicide resistant rice has increased weed control efficacy during the growing season by providing additional control options. Imidazolinone-resistant (IR) rice allows the use of imidazolinone herbicides for weed control (Croughan 1994). Imazethapyr[1] and imazamox[2] are the imidazolinone herbicides targeted for use with tolerant rice lines (Dillon et al. 1999). Barnyardgrass control of 90% has been reported with imidazolinone herbicides applied PRE in an IR rice production system (Liscano et al. 1999; Masson et al. 2001). Control of barnyardgrass with imazethapyr applied

[1] Newpath® herbicide label. BASF Corporation, 26 Davis Drive, Research Triangle Park, NC 27709.

[2] Beyond® herbicide label. BASF Corporation, 26 Davis Drive, Research Triangle Park, NC 27709.

postemergence has varied. Control has been shown to be at least 89% at 28 days after application (Masson et al. 2001); however, control of 49 and 74% at 28 days after application was reported by Noldin et al. 1998. Therefore, with the activity of imazethapyr on barnyardgrass when applied PRE and POST it may also have activity on *E. polystachya* in an IR rice production system.

Several POST herbicides are currently labeled to control grasses in Louisiana rice production that may be useful in controlling *E. polystachya*. Cyhalofop and fenoxaprop, aryloxphenoxy propionates, are POST herbicides that have been found to control barnyardgrass. Cyhalofop has been reported to control barnyardgrass at least 88% when applied early as well as late postemergence at 200 g/ha (Ntanos et al. 2000). Fenoxaprop applied at 170 g/ha has been shown to control 5- to 12-cm barnyardgrass at least 83% (Carey et al. 1992).

Bispyribac and penoxsulam, both broad spectrum broadleaf herbicides which inhibit acetolactate synthase (ALS) enzyme, have activity on *Echinochloa* spp (Schmidt et al. 1999, Lassiter et al. 2004). Bispyribac applied mid- to late-POST at 20 to 23 g ai/ha has been shown to control barnyardgrass 98%; however, when applied late POST to three-tiller barnyardgrass, control was reduced to 70% (Williams 1999). Dillon et al. (2004) reported that bispyribac at 29 g/ha provided 80% control of barnyardgrass when applied 1 week after permanent flood establishment. Penoxsulam is a broad-spectrum triazolopyrimidine sulfonamide herbicide developed for weed control in rice (Lassiter et al. 2004). Barnyardgrass control with penoxsulam has been reported to be at least 99% at 21 days after application applied alone and following a PRE application of clomazone (Ottis et al. 2004).

Other herbicides have also been used to control barnyardgrass. Molinate, a thiocarbamate which inhibits lipid synthesis, propanil, an amide that inhibits photosynthesis at photosystem II, and quinclorac, a quinoline carboxylic acid that affects auxin activity have been extensively used to control barnyardgras (Baltazar and Smith 1994; Ntanos et al. 2000; Smith 1974). However, research has shown that these herbicides have little activity on *E. polystachya* (Griffin et al. 2004; Lassiter et al. 2002).

The use of nonselective herbicides for burndown prior to planting may be a management option as well. Glyphosate is a foliar-applied, nonselective herbicide used for burndown and POST applications in glyphosate-resistant transgenic crops (James and Krattiger 1996; Henry et al. 2003). Glyphosate applied at 560 g ae/ha has been reported to control barnyardgrass 88% (Norris et al. 2001). Glufosinate is a nonselective phosphorylated amino acid that controls many grass and broadleaf weeds (Vencill 2002a). Lanclos et al. reported 92% control of barnyardgrass 14 DAT with 840 g ai/ha glufosinate applied at the three- to four-leaf rice stage. With development of herbicide-resistant rice varieties, use of nonselective herbicides within the growing season may be a management option in the future.

Tillage has been used successfully to control other weeds such as redvine [*Brunnichia ovata* (Walt.) Shinners](Reddy 2000; Reddy 2005) and may be an option to control *E. polystachya*. Hsiao and Huang (1989) reported that knotgrass (*Paspalum distichum* L.), a perennial grass, when planted in single node segments in increasing soil depth, decreased emergence from 70 to 35% as soil depth was increased from 2.5 to 20 cm, respectively. Oxygen deficiency and lack of light have been suggested as causes of reduction in emergence of perennial grass in increasing soil depths (Hsiao and Huang 1989; Okuma et al. 1983). However, Huang et al. (1987) reported that cultivation or disking may eradicate young seedlings of perennial grasses; however, cutting shoots and rhizomes into small pieces may help to vegetatively propagate a perennial grass spp. Combining tillage with herbicide applications to enhance control may be another management option for *E. polystachya*.

Management difficulty of *E. polystachya* with herbicides may exist. Bruff et al. (1996) reported difficulty controlling johnsongrass, a common perennial grass weed in Louisiana. Because of growing characteristics of johnsongrass, removal or damage to the foliage of the plant does not control it because of the viability of buds present on rhizomes that are capable of reproducing the plant (McWhorter 1961). Foliar-applied herbicides have been found to be effective; however, they do not control rhizome regrowth because they are not translocated into rhizomes in sufficient quantities (Banks and Tripp 1983; McWhorter 1972; Obrigawitch et al. 1990). *E. polystachya* has prolific stolon and rhizome production and this weed may exhibit similar control problems compared with johnsongrass (Csurhes and Edwards 1998).

The highly competitive qualities of *E. polystachya* could potentially reduce rice yield when significant populations of the weed exist. Growing conditions and cultural practices in Louisiana rice production which mimic the native range of *E. polystachya* in the Amazon floodplain may advance the spread of this weed. Genetic similarities to barnyardgrass, a problematic weed in Louisiana rice, further the interest in controlling this new weed. The objectives of this research were:

1. To determine response of *E. polystachya* introduced at varying densities with rice.
2. To determine if burial depth affects emergence of *E. polystachya* stem segments.
3. To determine what herbicides control *E. polystachya* and reduce fresh weight biomass.
4. To evaluate current herbicide programs for baryardgrass control in rice for management of *E. polystachya*.

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CHAPTER 2

ECOLOGY AND CONTROL OF *ECHINOCHLOA POLYSTACHYA* IN LOUISIANA

Introduction

Echinochloa polystachya (Kunth) A.S. Hitchc. is a C_4 perennial grass typical of marshes and shoreline areas of rivers and lakes in South America (Pizzaro 1999). This spp. is found as far north as Florida, Louisiana, and Texas and is commonly referred to as: aleman grass, carib grass, creeping river grass, German grass, mudflat-millet, or river grass (Stutzenbaker 1999; USDA NRCS 2005). Prior to 1993 in Louisiana, this weed had only been observed in Plaquemines Parish but has recently been identified in southwest Louisiana and is known locally as perennial barnyardgrass, water bermuda, or Habetz grass (Saichuk 2003; Thomas and Allen 1993). It is estimated to infest approximately 5,000 to 6,000 ha of rice production (Saichuk 2003).

E. polystachya is a semi-aquatic macrophyte that roots in the littoral sediments of water bodies and forms dense meadows with its prolific perennial growth (Pizzaro 1999). Piedade et al. (1991) reported that the life cycle of *E. polystachya* in the Amazon floodplain is regulated by a seasonal flooding and receding water cycle. Seasonal precipitation differences in the Amazon region cause these water level fluctuations resulting in aquatic and terrestrial phases of this spp. (Junk et al. 1989). During the terrestrial phase, *E. polystachya* forms new shoots at the nodes of decaying stems (Morrison et. al. 2000). After the onset of the aquatic phase, the plant grows upward at a rate which allows it to remain above the fluctuating water level (Pompeo et al. 2001). At the end of the aquatic phase when the water recedes, the stems dry and new shoots appear from the decaying stems. *E. polystachya* is well suited for survival in these flooded, anaerobic conditions, having a large proportion of aerenchyma tissue, large and hollow stolons, and advantageous roots (Baruch 1994). Sand-Jensen and Borum (1991) reported that there are many physical-chemical variables that affect *E.*

polystachya growth patterns in a fluctuating habitat such as the Amazon floodplain and it is usually not possible to identify a single regulating growth factor.

Growth of the weed is prolific in areas with high fertility and moist soils and an annual rainfall greater than 800 mm (Csurhes and Edwards 1998). South Louisiana has similar environmental conditions to tropical and subtropical locations where the plant thrives (LOSC 2006). Cultural practices in Louisiana rice production include flooding for weed control during the growing season and keeping those areas flooded after harvest for aid in red rice control and tillage (Jordan and Sanders 1999). Nitrogen is the most limiting nutrient in rice production in the United States; therefore pre as well as post flood applications of nitrogen-containing fertilizers are common (Helms and Slaton 1996; Linscombe et al. 1999; Miller and Street 2000; Walker and Street 2003). This environment is suitable to the growth patterns and survivability of *E. polystachya* as described in previous publications (Baruch 1994; Junk et al. 1989; Morrison et al. 2000; Pompeo et al. 1999).

During initial flooding conditions like those found in the Amazon floodplain, *E. polystachya* has been found to sequester high amounts of nutrients (Piedade et al. 1997). It has been shown to greatly increase stolon biomass and root production under flooded conditions (Baruch and Marida 1995). Both CO_2 uptake and water use efficiency of *E. polystachya* have been found to be comparable with corn (*Zea mays* L.) in warm temperate conditions (Morrison et al. 2000). The stem section of *E. polystachya* has been found to contain and load the principal nutrient stock of C, N, and P (Pompeo et al. 1999). The rate of dry-matter production per unit of solar radiation intercepted by *E. polystachya* has been found to be 2.3 g/MJ, an efficiency close to the maximum for C_4 plant species (Piedade et al. 1991). The highly competitive qualities of *E. polystachya* allow it to act as a nitrogen sink and cause nitrate and nitrite poisoning in cattle when used as forage following extended periods of drought (Medeiros et al. 2003). In the state of Paraiba, northeastern Brazil, an outbreak of nitrate poisoning in cattle was attributed to ingesting *E. polystachya*.

Genetic similarities to barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.], a problematic weed in rice, further the interest in collecting information about the biology and control of this weed. Barnyardgrass and junglerice [*Echinochloa colona* (L.) Link.] have been described as the most important weeds of rice worldwide (Holm et al. 1977; Valverde et al. 2001). *Echinochloa spp.* are the most common weeds in Louisiana rice (Webster 2004); so a genetically similar species may pose an additional threat to rice production.

The highly competitive qualities of *E. polystachya* could potentially reduce rice yield or cause problems with tillage and machine harvest where significant populations of the weed exist. *E. polystachya* is considered a weed in Argentina, Mexico, India, Hawaii, and Zaire (Csurhes and Edwards 1998; Holm 1977). However, no studies evaluating the control of *E. polystachya* in rice have been published. Genetic similarities to barnyardgrass further the interest in controlling this weed in rice. The goal of this research is to observe *E. polystachya* growth and emergence as well as evaluate potential herbicides for management.

Materials and Methods

In Field Growth of *E. polystachya* with Rice. A field study was conducted in two locations in 2005 near Crowley, Louisiana to determine in field growth of varying densities of introduced *E. polystachya* stolon segments with rice. Soil was a Crowley silt loam (fine montmorillonitic, thermic Typic Albaqualf) with 1.4% organic matter and pH 5.5. Seedbed preparation consisted of fall and spring disking and two passes in opposite directions with a two-way bed conditioner equipped with rolling baskets and S-tine harrows set to operate at depth of 6 cm. The study area was laser-leveled to a slope of 0.25% in the fall following initial disking. 'CL-161' rice was drill-seeded on 15-cm rows with a grain drill at a rate of 78 kg/ha. Plot size was 1.5 by 5.2 m^2. The initial experiment was established on April 22, 2005 and the second experiment was established in an adjacent field on April 23, 2005.

E. polystachya was grown in 70 by 140 by 12-cm plastic containers prior to study initiation and allowed to grow to a length of 110- to 125-cm. At 60-cm from the rooting sections, stolons consisting of an individual node were trimmed to a length of 7-cm. The node was in the center of the stem segment. After rice seeding, the area was surface irrigated to a level of 1.5-cm then drained and *E. polystachya* was introduced at seven segment densities (SD): 0, 1, 3, 7, 13, 26, and 52 stolons/m^2 which corresponds to 0, 10,000, 30,000, 70,000, 130,000, 260,000, and 520,000 segments/ha, respectively. Stauber et al. (1991) found that rice straw yield decreased as barnyardgrass density increased from 0 to 200,000 plants/ha; *E. polystachya* evaluated densities were based around this value.

The experimental design was a randomized complete block with four replications. Patterns of stem segment introductions were predetermined by marked polypropylene ropes in order to guarantee proper plant density and equal spacing. The stem segments were oriented vertically and placed into the soil so that the node was covered by approximately one- to two-cm of soil and approximately two cm of the stem was exposed.

A 6-cm permanent flood was established when rice maturity reached five-leaves to one-tiller and was maintained until 2 wk prior to harvest. Soil fertility management consisted of 280 kg/ha of 8-24-24 fertilizer pre-plant and 280 kg/ha 46-0-0 urea nitrogen prior to permanent flood establishment. Standard agronomic practices were employed during the growing season to maximize yield. Herbicide treatments consisting of 420 g ai/ha quinclorac and 53 g ai/ha halosulfuron were applied at the two- to three-leaf rice stage to maintain the area weed-free other than *E. polystachya*. Treatments were applied using a CO_2-pressurized backpack sprayer calibrated to deliver a volume of 140 L/ha at 193 kPa.

E. polystachya growth parameters were determined by measuring the number of stolons, stolons produced by planting density, and total stolon length at 50 and 100 days after planting (DAP) at the one- to two-tiller and physiological maturity rice stage, respectively. Additionally, individual node number, fresh weight biomass, and fresh weight biomass by planting density were recorded at 100 DAP. Rice stand count was taken at 50 DAP by counting the number of rice plants in 46 cm of row length. Rice height was also determined at 50 and 100 DAP by measuring from the base of the plant to the tip of the tallest leaf and extended panicle, respectively.

Data was subjected to the Mixed procedure of SAS with location used as a random factor (SAS 2003). Location, replication (nested within location), and all interactions containing either of these effects were considered random effects; growth parameters were considered fixed effects. Type III statistics were used to test all possible effects of fixed factor (growth parameter) and least square means were used for mean separation at a 5% probability level ($p \leq 0.05$). Tables were constructed for appropriate interactions.

Depth of Emergence of *E. polystachya*. A greenhouse study was conducted in 2003 and 2005 at Louisiana State University in Baton Rouge to evaluate *E. polystachya* emergence in response to increasing soil depth. A completely randomized design with eight replications was used. The greenhouse was maintained at a day-night temperature of 30:25 ± 5 C and relative humidity of 60 ± 10%. A sterilized Commerce silt loam (fine-silty, mixed, superactive, nonacid, thermic Aeric Fluvaquent) soil with less than 0.1% organic matter, 80% sand, 6% silt, 14% clay, and pH 7.0 was used. The soil was thoroughly mixed with 8-24-24 fertilizer to simulate a preplant application of rate of 280 kg/ha used in rice production.

Sections of PVC pipe, approximately 7.5 cm in diameter and 35 cm in length attached to a 13 by 13 by 0.5 cm plexiglass base were used in the study. A 1.25 cm hole was drilled into each plexiglass bases to allow for sub-irrigation and drainage. Holes, approximately 1.25-cm in diameter, were drilled at 1.3-, 2.5-, 5.0-, 10.0-, and 20.0-cm from a 2.5-cm indicator mark, located below the top of the pipe for stolon insertion. A 1.3-cm cork was placed in the hole to prevent soil loss during soil fill of tubes. A circular piece of filter paper 7.5-cm in diameter (Whatman #1)[3] was added to the bottom of each tube to prevent soil loss and allow water movement under the simulated aquatic conditions.

E. polystachya was grown and harvested as previously described. Stolons were trimmed to a length of 7-cm and were weighed prior to insertion into tubes. Soil was added to each tube and compacted by tapping the plexiglass base on a hard surface three times to insure that each tube was filled completely. Each tube was filled to the 2.5 cm indicator line at the open end of the tube with 1990 g of soil. After filling and compacting the soil, the corks were removed, a 1-cm wooden dowel was used to form an entrance hole into the soil, and a 0.5 to 0.6-g stolon was inserted. After insertion, the corks were replaced in the tube, the tube was tapped twice on a hard surface to allow for soil/stolon contact. The tubes were sub-irrigated and after visual confirmation of irrigation, the tubes were allowed to drain for 24 hours and weighed for field capacity. Four random tubes in the study were weighed every 3 d to insure soil water content was within 20% of field capacity.

Visual ratings were taken every day for 28 d to evaluate emergence. Emergence was defined as a shoot emerging from the soil line. At the end of the 28 d, the stolons that did not emerge were removed from the tubes and

[3] Whatman® filter papers, Whatman International Ltd., Maidstone, U.K.

planted in 12- by 10-cm pots at a depth of 1.2-cm. Emergence was recorded for the next 28 d.

Data was subjected to the GLIMMIX procedure of SAS. A series of paired T-tests were used to compare the emergence difference between the soil depths evaluated. Type III statistics were used to test the effect of the factor depth and least square means were used for mean separation at P=0.05. Tables were constructed for interactions present.

Herbicide Evaluation for *E. polystachya* Management. A greenhouse study was conducted in 2005 at Louisiana State University in Baton Rouge to determine herbicide efficacy for the control of *E. polystachya.* The experimental design was a completely randomized design with four replications. The study was repeated. The greenhouse conditions and soil used was the same as previously described.

E. polystachya was grown as previously described. At 60-cm from the rooting sections, stolons consisting of an individual node were trimmed to a length of 7-cm. Twelve stolon segments, arranged in three rows of four stolons were planted in 30- by 20- by 15-cm containers. The stem segments were oriented vertically and placed into the soil so that the node was covered and the stem was slightly exposed. *E. polystachya* was allowed to grow for 21 days to the two- to four-leaf stage.

Treatments were applied to *E. polystachya* at the two- to four-leaf stage with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L/ha at 193 Kpa. Herbicide treatments were: bispyribac[4] at 22 g ai/ha, cyhalofop[5] at 314 g ai/ha, fenoxaprop/S[6] at 86 g ai/ha, fenoxaprop/S at 46 g/ha plus

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[4] Regiment™ herbicide label. Valent Corp. Walnut Creek, CA 94596.
[5] Clincher® SF herbicide label. Dow AgroScience. Indianapolis, IN 46268.
[6] Ricestar® herbicide label. Bayer CropScience. P.O. Box 12014, 2 T.W. Alexander Dr. Research Triangle Park, NC 27709.

fenoxaprop[7] at 40 g ai/ha, glufosinate[8] at 497 g ai/ha, glyphosate[9] at 1260 g ae/ha, imazethapyr[10] at 70 g ai/ha, penoxsulam[11] at 50 g ai/ha, propanil[12] at 3364 g ai/ha, and quinclorac[13] at 560 g/ha. A nontreated was added for comparison. Visual control ratings were taken at 14 and 28 DAP. Fresh weight was measured by randomly clipping three individual *E. polystachya* plants at the soil line from each of the four replications at 14 and 28 DAP.

Data was subjected to the Mixed procedure of SAS with experiment used as a random factor. Experiment, replication (nested within experiment), and all interactions containing either of these effects were considered random effects; visual injury and weight were considered fixed effects. Type III statistics were used to test all possible effects of fixed factors (visual injury or weight) and least square means were used for mean separation at P=0.05. Tables were constructed for interactions present.

Results and Discussion

In Field Growth of *E. polystachya* with Rice. The main effects of total stolon number, stolon number:planted density ratio, and total stolon length were detected at both 50 and 100 DAP, fresh weight biomass, fresh weight biomass:planted density ratio, and total node number main effects were detected at 100 DAP; therefore tables were developed for these interactions (Table 2.1 and Table 2.2). The average rice height at rice maturity was 35 cm and rice stand at 50 DAP was 115 plants/m^2 with no difference among introduced

[7] Whip® 360 herbicide label. Bayer CropScience. P.O. Box 12014, 2 T.W. Alexander Dr. Research Triangle Park, NC 27709.

[8] Liberty® herbicide label. Bayer CropScience. P.O. Box 12014, 2 T.W. Alexander Dr. Research Triangle Park, NC 27709.

[9] Roundup WeatherMax® herbicide label. Monsanto Co. St. Louis, MO 63167.

[10] Newpath® herbicide label. BASF Corporation, 26 Davis Dr., Research Triangle Park, NC 27709.

[11] Grasp® herbicide label. Dow AgroScience. Indianapolis, IN 46268.

[12] Stam® M4 herbicide label. Dow AgroScience. Indianapolis, IN 46268.

[13] Facet® 75DF herbicide label. BASF Corp, 26 Davis Dr., Research Triangle Park, NC 27709.

Table 2.1. *Echinochloa polystachya* stolon production and length at 50 days after planting in drill-seeded imidazolinone-resistant rice near Crowley, Louisiana in 2005[a].

E. polystachya	50 days after planting		
planted density	Total stolon production	Stolons:Planted density	Total stolon length
Stolon segment/ha	#/ha		Km/ha
10,000	10,000 d	1.0 a	4 b
30,000	20,000 cd	0.63 ab	8 b
70,000	30,000 cd	0.30 b	8 b
130,000	40,000 b	0.28 b	17 ab
260,000	70,000 b	0.20 b	21 ab
520,000	100,000 a	0.15 b	33 a

[a] Studies planted in separate but adjacent fields on April 22, 2005.

Table 2.2. *Echinochloa polystachya* stolon production,length, number of nodes, and biomass produced at 100 days after planting in drill-seeded imidazolinone-resistant rice near Crowley, Louisiana in 2005[a,b,c].

E. polystachya	100 days after planting						
planted density	Stolons	Stolons:PD	Stolon length	Nodes	Nodes:PD	Biomass	Biomass/PD
Segments/ha	#/ha		— Km/ha —	— #/ha —		Kg/ha	— g —
10,000	60,000 c	6.0 a	15 c	290,000 c	29 a	130 c	16 a
30,000	160,000 bc	5.4 a	30 c	530,000 c	17.5 b	300 bc	10 b
70,000	380,000 b	5.4 a	92 bc	690,000 bc	9.8 bc	380 bc	5.5 bc
130,000	270,000 b	2.1 b	150 bc	900,000 bc	6.8 c	410 bc	3.1 c
260,000	400,000 b	1.5 b	217 ab	1,540,000 b	5.9 c	750 b	2.9 c
520,000	760,000 a	1.4 b	318 a	2,800,000 a	5.4 c	1,270 a	2.4 c

[a] Studies planted in separate but adjacent fields on April 22, 2005.
[b] DAP, days after planting; PD, planted density.
[c] Fresh weight biomass.

E. polystachya density observed (data is not shown). Rice was not harvested due to lodging and heavy late season red rice infestation.

Stolon sampling at 50 DAP was conducted immediately prior to nitrogen fertilization and permanent flood establishment. Only stolons that had visually emerged from the introduced stolons were counted. Some of the introduced stolons that had not visually emerged above the soil line at this time had developed root systems below ground and emerged after the onset of the permanent flood. This is similar to observations in the Amazon floodplain (Pompeo et al. 2001).

At 50 DAP, the highest number of emerged *E. polystachya* stolons was 100,000 stolons/ha and was collected from the 520,000 PD (Table 2.1). The most critical period for competition between rice and weeds is when rice is in the vegetative stage and it is during this growth stage that yield components of the rice plant are differentiated (Bayer 1991). Smith (1968) reported that barnyardgrass populations at 108,000 plants/ha decreased rice yield by at least 25%; similar *E. polystachya* densities existing during this period may also decrease yield.

Stolon emergence from individually introduced nodes were higher at the two lowest introduced densities, 10,000 and 30,000 SD with 1 and 0.63 stolons produced per introduced segment, respectively. The higher densities evaluated produced 0.15 to 0.3 stolons per introduced segment. This may indicate some intraspecific competition for light, nutrients, and water among individual *E. polystachya* plants. However, it is difficult to determine how E. polystachya growth is determined in this fluctuating habitat (Baruch 1994; Sand-Jensen and Borum 1991). Total stolon length was 17 to 33 Km/ha for the 130,000 through 520,000 stolon/ha planted density.

At 100 DAP, the introduced densities of 10,000 through 70,000 stolons/ha produced 5.4 to 6 stolons per introduced segment, but 130,000 through 520,000 SD produced 1.4 to 2.1 stolons per introduced segment (Table 2.2). This may be due to increased competition with rice and other *E. polystachya* plants. Norris et al. (2000) reported that information on weed density in relation to a crop is required if yield loss predictions due to competition can be developed for a particular weed spp. Prolific *E. polystachya* growth yielded stolon production that was greater than 160,000 plants/ha with the 30,000 through 520,000 SD (Table 2.2), barnyardgrass at 108,000 plants/ha has been reported to decrease rice yield by at least 25% (Smith 1968; Smith 1988). Total stolon length was 318 km/ha for the 520,000 SD and was similar for the 260,000 SD.

The variability of barnyardgrass competition is attributed to many factors including germination and emergence that starts at rice planting and extends through midseason (Maun and Barrett 1986; Ogg and Dawson 1984), rapid growth and development (Maun and Barrett 1986), and competition for space and nutrients (Mitich 1990). Smith (1988) reported that barnyardgrass threshold levels were heavily influenced by nitrogen fertility. *E. polystachya* development and competition may also be reliant on nitrogen fertilization and permanent flood establishment (Morrison et al. 2000; Piedade 1991; Sand-Jensen and Morrison 1991.

This study demonstrates the effectiveness of *E. polystachya* to reproduce vegetatively in a drill-seeded rice production system from single-node stolon segments. Shallow tillage or tillage under moist conditions may allow *E. polystachya* stolons to be introduced in numbers exceeding those evaluated in this study. At the lowest introduced density, 10,000 stolons/ha, individual node production was 290,000 nodes/ha with a total of 29 nodes produced for every single node segment introduced. Introduced densities of 70,000 stolons/ha or greater produced 5.4 to 9.8 nodes/introduced segment. As with total stolon production, this may indicate intraspecific *E. polystachya* competition or interspecific competition with rice. In a production situation where high numbers of introduced stolons are distributed, the competitive advantage may overwhelm rice; therefore, management decisions must be made to minimize favorable conditions for this weed.

E. polystachya is considered among the most productive plant species in the world, producing from 80,000 to 100,000 kg/ha in established monotypic stands located in the Amazon basin (Piedade et al. 1991; Junk and Piedade 1993). The highest biomass production recorded in this study was 1,270 kg/ha (Table 2.1); however, conditions found in its native range in the Amazon river basin may assist in its prolific growth. *E. polystachya* biomass was 16 g/introduced segment for the lowest introduced density, 10,000 SD and was 2.4 through 5.5 g/introduced stolon for the 70,000 through 520,000 SD.

During a production cycle, *E. polystachya* emerges from developed rootstock and takes advantage of the high nutrient load as well as suspended sediments during the Amazon flood period (Junk and Piedade 1993). A comparable situation with rice production which employs flooding and heavy fertilizer usage as a favorable habitat exists; however, in this study, delayed flood production practices as well as the use of single-node stolons for propagation may have given the rice crop a competitive advantage over *E. polystachya*.

Depth of Emergence of *E. polystachya*. Depth of burial impacted emergence of *E. polystachya* stolons (Table 2.3). The highest shoot emergence was 63% for stolons planted at the 1.3 cm depth. Similar emergence was recorded at the 0 and 2.5 cm level with 31 and 44% emergence, respectively. Shoot emergence was 25% for 5 cm burial depth, which had similar emergence to the 0 and 2.5 cm planting depth. There was no emergence for the 10 and 20 cm burial depths. Stolons that had not emerged at 28 DAP were recoverd, replanted at 1.3 cm depth, and resulted in 19% emergence (data is not shown). Hsiao and

Table 2.3. Percent emergence of *Echinochloa polystachya* stolons planted at various depths in 2003 at Louisiana State University located in Baton Rouge[a,b,c].

	Burial depth (cm)					Average
Burial depth (cm)	1.3	2.5	5	10	20	emergence
						—— % ——
0	0.5361	0.1166	0.7457	<0.0001	<0.0001	31 ab
1.3		0.6738	0.0284	<0.0001	<0.0001	63 a
2.5			0.0644	<0.0001	<0.0001	44 ab
5				<0.0001	<0.0001	25 b
10					1.000	0 c
20					–	0 c

[a] Emergence/depth of burial significant at P=0.05.
[b] Emergence recorded for 28 d.
[c] Stem segments that had not emerged at 28 d were replanted at 1.3-cm and resulted in 19% germination.

Huang (1989) reported that knotgrass (*Paspalum distichum* L.), a perennial grass, when planted in single node segments in increasing soil depth, decreased emergence from 70 to 35% as soil depth was increased from 2.5 to 20 cm, respectively. Oxygen deficiency and lack of light have been suggested as causes of reduction in emergence of perennial grass in increasing soil depths (Hsiao and Huang 1989; Okuma et al. 1983). Tillage has been used successfully to control other weeds such as redvine [*Brunnichia ovata* (Walt.) Shinners] and may be an option to control *E. polystachya* (Reddy 2000; Reddy 2005). However, Huang et al. (1987) reported that cultivation or disking may eradicate young seedlings of *P. distichum*; however, cutting shoots and rhizomes into small pieces may help to propagate the spp.

Herbicide Evaluation for *E. polystachya* Management. A herbicide treatment by DAT interaction was detected for visual control as well as fresh weight biomass; therefore, data are presented separately for each DAT (Table 2.4).

At 14 DAT, glyphosate and glufosinate had the highest visual control of *E. polystachya* with 89 and 78%, respectively (Table 2.4). Imazethapyr, penoxsulam, and fenoxaprop/S controlled the weed 49 to 61%; however, some of the herbicides may not have fully expressed control at this time. At 28 DAT, glyphosate controlled *E. polystachya* 91%. Glufosinate, cyhalofop, imazethapyr, fenoxaprop/S, and penoxsulam controlled the weed 65 to 78%.

Little control data exists for *E. polystachya*; therefore, reduction in fresh weight biomass can reinforce the observed visual control ratings. Glyphosate, glufosinate, cyhalofop, imazethapyr, fenoxaprop/S, fenoxaprop/S plus fenoxaprop, and penoxsulam had the highest biomass reduction at both 14 and 28 DAT (Table 2.4). Final biomass reduction at 28 DAT was 19 to 37% of the nontreated with these herbicides. Cyhalofop, fenoxaprop/S, and penoxsulam are currently labeled for use in rice, and imazethapyr is labeled for use in imidazoline-resistant rice. Producers have herbicide options for managing this weed in imidazolinone-resistant or conventional rice.

Table 2.4. Greenhouse evaluation of herbicide treatments for visual control and fresh weight biomass production of *Echinochloa polystachya* conducted in 2005 at Louisiana State University in Baton Rouge, Louisiana[a,b,c,d,e]

Herbicide	Rate	Visual control		Fresh weight	
		14 DAT	28 DAT	14 DAT	28 DAT
	g ai/ha	%		% nontreated	
bispyribac	28	36 de	54 d	93 bc	61 bc
cyhalofop	314	44 cde	65 bcd	57 ab	37 ab
fenoxaprop/S	86	51 bc	65 bcd	52 a	33 ab
fenoxaprop/S +	46	46 cd	56 cd	75 abc	36 ab
fenoxaprop	40				
glufosinate	497	78 a	78 b	54 ab	28 ab
glyphosate	1260	89 a	91 a	41 a	19 a
imazethapyr	70	61 b	68 bc	54 ab	32 ab
penoxsulam	50	49 bcd	76 b	74 abc	34 ab
propanil	3364	31 ef	20 e	92 bc	75 cd
quinclorac	560	26 f	16 e	109 c	124 e

[a] Crop oil concentrate, trade name Agri-dex®, Helena Chemical Co., 225 Schilling boulevard, Suite 300, Collierville, TN 38017 at 2.5% (v/v) used with cyhalofop and penoxsulam and at 1% (v/v) used with imazethapyr and quinclorac. An organo-silicon surfactant, trade name Kinetic®, Helena Chemical Co. at 0.125% (v/v) was used with bispyribac.

[b] Fenoxaprop/S designates fenoxaprop formulated with a safener. Sold under trade name Ricestar HT®, Bayer CropScience, 2 T.W. Alexander Drive, Research Triangle Park, North Carolina 27709. Fenoxapop designates fenoxaprop formulated without a safener. Sold under trade name Whip® 360, Bayer CropScience.

[c] Means in a column followed by the same letter do not significantly differ at P=0.05.

(continued)

(Table 2.4 continued)

[d] DAT, days after herbicide treatment; % nontreated, fresh sample weight expressed as a percent of nontreated sample.

[e] Nontreated *E. polystachya* biomass was: 0.659 and 1.91 g for 14 and 28 DAT, respectively.

Multiple applications of these herbicides or potentially the addition of a preemergnece herbicide may be necessary for complete control (Eleftherohorinos and Dhima 2002; Griffin et al. 2004; Ottis et al. 2003).

Glyphosate is a nonselective herbicide considered to be efficacious on a number of grass and broadleaf weeds (Ellis and Griffin 2002; Jordan et al. 1997). Glyphosate has been reported to control barnyardgrass as well as knotgrass, a perennial grass with similar growing characteristics to *E. polystachya* (De Datta et al. 1979; Norris et al. 2001). Glufosinate is another nonselective herbicide that has been shown to control baryardgrass [*Echinochloa crus-galli* (L.) Beauv.], genetically similar *to E. polystachya* at least 91% at 28 DAT (Lanclos et al. 2002). Glyphosate and glufosinate are not currently labeled for use in rice; however, burndown prior to planting may be a management option.

Quinclorac was the only herbicide treatment that resulted in an augmentation of the nontreated fresh weight with 124% of the nontreated. Keller and Van Volkenburgh (1997) and Pignocchi et al. (2003) reported auxin-induced inhanced growth of tobacco (*Nicotiana tabacum* L. cv Xanthi) from [mu]M [alpha]-naphthalene acetic acid and [mu]M indole-3-acetic acid. Quinclorac is used as a PRE or POST herbicide to control barnyardgrass (Vencill 2002); however, quinclorac tolerant barnyardgrass has been identified in rice (Lopez-Martinez et al. 1997). Several factors can be involved in the differential tolerance of weed species to a particular herbicide (Zawierucha and Penner 2000). Some of these factors include differences in herbicide uptake, translocation, metabolism, and spray retention which may have been demonstrated by *E. polystachya* (Anderson 1996; Hess 1987; Wanamarta and Penner 1989).

In conclusion, *E. polystachya* may not demonstrate impressive prolific biomass production within a single, drill-seeded rice crop compared with growth observed in the Amazon floodplain. However, *E. polystachya* is capable of reproducing from a single-node stolon segment into potentially problematic densities (Table 2.1 and Table 2.2). The data reported in this study could be useful in identifying potential problematic population densities of *E. polystachya* so management decisions could be implemented. Even though rice height or stand was not affected in this study, populations of *E. polystachya* that are allowed to survive may affect ratoon rice crops or crawfish production where continuous flooding of production areas is used. Significant populations of this weed that interfere with agriculture production not only from a competition standpoint but also as a mechanical nuisance may warrant a shift from these production practices.

The results of the depth of burial study indicate that burial depth of stolons has an effect on emergence of *E. polystachya* stolons; therefore, deep tillage may be a management option (Table 4.3). Care should be taken to assure that tillage is performed that maximizes *E. polystachya* destruction. Tillage that is conducted at an ineffective depth or under flooded conditions, which is commonly used for land leveling in south Louisiana, may promote the spread of *E. polystachya*. The use of tillage may impact other environmental concerns (Alm et al. 2000); however, if this spp. is allowed to thrive declining rice yield and mechanical obstruction may be observed.

Glyphosate had the highest control of *E. polystachya* with 91%; however, several other herbicides such as cyhalofop, fenoxaprop/S, imazethapyr, and penoxsulam that are labeled for use in rice controlled *E. polystachya* 65 to 76% (Table 4.3). These herbicides may be used in management decisions regarding *E. polystachya* as well as other problematic weeds. Future research could include evaluations of sequential applications of these herbicides or the addition of a preemergence herbicide with residual activity. Glyphosate and glufosinate are not currently labeled for use in rice; however, with development of glufosinate- or glyphosate-resistant rice, these two herbicides may be an option for controlling *E. polystachya* other than as a burndown application. De Datta et al. (1979) reported control of knotgrass with glyphosate used with and without tillage as a burndown option for minimum and no till rice grown in the Phillipines. Employing a combination of herbicides and tillage can potentially be used to manage *E. polystachya*.

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CHAPTER 3

MANAGEMENT OF *ECHINOCHLOA POLYSTCHYA* IN DRILL-SEEDED RICE (*ORYZA SATIVA*)

Introduction

In Louisiana, rice (*Oryza sativa* L.) producers integrate weed management programs with cultural, mechanical, and chemical methods to maximize yields (Jordan and Sanders 1999). Water-seeding, which is direct broadcasting dry or pre-soaked seed into flooded fields, is the predominant method of rice seeding used in Louisiana (Linscombe et al. 1999; Seaman 1983). Rice tolerates low oxygen (hypoxic) conditions better than most weeds; thus, flooding has traditionally been used as an effective method of cultural control for many weed species including red rice, an economically important weed genetically identical to rice (Helms 1994). In addition, flooding is used for land leveling, tillage, and crawfish production (Jordan and Sanders 1999; Linscombe et al. 1999); however, these practices may promote the spread of weeds that thrive in continuously flooded conditions.

The use of a conventional grain drill to plant rice in rows 15 to 20 cm apart into soil that has previously been prepared by disking or harrowing is referred to as drill- or dry-seeding (Mikkelsen and Datta 1991; Slaton and Cartright 2001). A delayed-flood production system postpones permanent flood establishment until rice is 15 to 20 cm in height (Walker and Street 2003). Intermittent surface irrigation is used to facilitate the growth of rice before permanent flood is established (Slaton and Cartright 2001). Drill-seeding and utilizing a delayed-flood production system may be an alternative weed management tool to water-seeding which can be suitable for the spread of weeds that thrive in continuously flooded conditions.

Echinochloa polystachya (Kunth) A.S. Hitchc. is a C_4 perennial grass found in Florida, Louisiana, Texas, and Puerto Rico (Stutzenbaker 1999; USDA 2005; USDA NRCS 2005). The subtropical environment in Louisiana not only allows for favorable rice growing conditions, but also provides an acceptable climate to a wide range of grass species, including *E. polystachya* (Allen 1980; LOSC 2005). This weed has been found to be quickly spreading through the rice-producing parishes of the state due to its ability to reproduce vegetatively by cut stolons and rhizomes which are transported by tillage practices and movement of the contaminated equipment (Strahan 2003). *E. polystachya* thrives in flooded conditions such as those found in Louisiana rice production, having the ability to remain above fluctuating water levels found in its native terrain of the Amazon basin (Pompeo et al. 2001).

In a drill-seeded, delayed-flood production system, four to six weeks may elapse between planting and permanent flood establishment; therefore, herbicide applications are warranted (Jordan and Sanders 1999). *Echinochloa spp.* are the most common weeds in Louisiana rice (Webster 2004), so attention has been devoted to developing herbicide programs for control of these weeds (Jordan and Sanders 1999). Similarity with control options of barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] and junglerice [*Echinochloa colona* (L.) Link] may exist for *E. polystachya* due to the genetic background of these plants.

Preemergence (PRE) herbicides have been used successfully in rice production for weed control (Eleftherohorinos and Dhima 2002; Valverde et al. 2001; Zhang et al. 2005). Clomazone[14], labeled for use in rice, reduces or prevents accumulation of plastid pigments, producing plants with a bleached appearance (Duke et al. 1991). Clomazone has been shown to control barnyardgrass 90 and 83% at 7 and 35 days after PRE application, respectively (Webster et al. 1999). Westberg et al. (1989) reported 100% control of

[14] Command® 3ME herbicide label. FMC Corporation, Agricultural Products Group, Philadelphia, PA 19103.

barnyardgrass 14 days after treatment (DAT) with 280 g ai/ha clomazone applied PRE.

Pendimethalin[15], a dinitroanaline, and quinclorac[16], a quinoline carboxylic acid, are two PRE herbicides used for barnyardgrass control (Vencill 2002a; Vencill 2002b). When substituted for multiple applications of 3.8 kg ai/ha propanil[17], a postemergence (POST) herbicide used for barnyardgrass control, pendimethalin applied delayed PRE (DPRE) at 0.75 to 1.5 kg ai/ha reduced junglerice pressure and improved rice yield (Valverde et al. 2001). Vasilakoglou et al. (2000) reported that quinclorac controls barnyardgrass and is used to control propanil-resistant junglerice. A combination of pendimethalin plus quinclorac at 1.1 and 0.42 kg ai/ha, respectively, applied DPRE controlled barnyardgrass 81% at permanent flood establishment (Jordan et al. 1998).

The development of herbicide resistant rice allows the use of imidazolinone herbicides for weed control on resistant cultivars (Croughan 1994). Imazethapyr[18] and imazamox[19] are the imidazolinone herbicides labeled for use with imidazolinone-resistant (IR) rice. Barnyardgrass control of 90% has been reported with imidazolinone herbicides applied PRE in an IR rice production system (Masson et al. 2001). Pellerin and Webster (2004) reported 97% barnyardgrass control 49 days after treatment (DAT) with two applications of imazethapyr at 70 g ai/ha.

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[15] Prowl® 3.3 EC herbicide label. BASF Corporation, 26 Davis Drive, Research Triangle Park, NC 27709.

[16] Facet® 75DF herbicide label. BASF Corp, 26 Davis Dr., Research Triangle Park, NC 27709.

[17] Stam® M4 herbicide label. Dow AgroScience. Indianopolis, IN 46268.

[18] Newpath® herbicide label. BASF Corporation, 26 Davis Drive, Research Triangle Park, NC 27709.

[19] Beyond® herbicide label. BASF Corporation, 26 Davis Drive, Research Triangle Park, NC 27709.

Mesotrione[20], a herbicide in the triketone family, is a selective herbicide that can be applied PRE and POST for control of broadleaf and grass weeds in corn (*Zea mays* L.) through inhibition of the enzyme *p*-hydroxyphenylpyruvate dioxygenase (EC 1.13.11.27) (Mitchell et al. 2001; Norris et al. 1998; Stephenson et al. 2004). Ohmes et al. (2000) reported at least 65% control of barnyardgrass with mesotrione PRE in corn. Although not labeled for use in rice, mesotrione is of interest because of activity on barnyardgrass.

Due to the lapse in time before permanent flood establishment in a drill-seeded, delayed-flood production system, residual herbicides may not always provide complete control of weeds and require a POST herbicide application (Jordan and Sanders 1999). Cyhalofop[21], an aryloxphenoxy propionate, is a POST herbicide that has been found to control barnyardgrass. Cyhalofop has been reported to control barnyardgrass at least 88% when applied early POST (EPOST) and late POST (LPOST) at 200 g ai/ha (Ntanos et al. 2000). Griffin et al. (2004a) reported 94% barnyardgrass control 16 DAT with 280 followed by (fb) 314 g/ha of cyhalofop applied POST. A total herbicide program with a PRE herbicide fb a POST application of cyhalofop may be an additional management tool for *E. polystachya,* and could be implemented in a management program.

The rapid spread and growing characteristics of *E. polystachya* could potentially reduce rice yield and cause production difficulty where significant populations of the weed exist. The goal of this research is to evaluate current total weed control programs and cultural practices in Louisiana rice for the management and control of *E. polystachya*.

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[20] Callisto® herbicide label. Syngenta Corporation, 2200 Concord Pike, P.O. Box 8353, Wilmington, DE 19803-8353.

[21] Clincher® SF herbicide label. Dow AgroScience. Indianopolis, IN 46268.

Materials and Methods

A field study was conducted in 2004 and 2005 near Crowley, Louisiana to determine the most effective barnyardgrass herbicide program for control of *E. polystachya.* Soil was a Crowley silt loam (fine montmorillonitic, thermic Typic Albaqualf) with 1.4% organic matter and pH 5.5. Seedbed preparation consisted of fall and spring disking and two passes in opposite directions with a two-way bed conditioner equipped with rolling baskets and S-tine harrows set to operate at depth of 6-cm. The study area was laser-leveled to a slope of 0.25% in both years in the fall following initial disking.

Plots consisted of eight 19-cm spaced rows, 5 m long. 'CL-161' rice was drill-seeded at 112 kg/ha on May 16 and April 9 in 2004 and 2005, respectively. The entire study area was surface irrigated immediately after seeding, at the two- to three-leaf rice stage, and at the three- to four-leaf rice stage. A 6-cm permanent flood was established when rice was at four- to five-leaf stage. Soil fertility management consisted of 280 kg/ha of 8-24-24 ($N-P_2O_5-K_2O$) fertilizer preplant and 280 kg/ha of 46-0-0 ($N-P_2O_5-K_2O$) urea immediately before permanent flood establishment. Standard agronomic and pest management practices were implemented throughout the growing season.

Segments of *E. polystachya* stolons were grown in 70 by 140 by 12-cm plastic containers in a Commerce silt loam (fine-silty, mixed, superactive, nonacid, thermic Aeric Fluvaquents) soil with less than 0.1% organic matter, 80% sand, 6% silt, 14% clay with a pH 7.0. The soil was thoroughly mixed with 7-21-21 fertilizer to simulate a preplant incorporated application rate of 280 kg/ha used in rice production. These stolon segments were grown prior to establishing the field study and were allowed to grow to a length of 110- to 125-cm.

At approximately 60 cm from the rooting sections, stem segments consisting of an individual node were trimmed to a length of 7-cm. After rice seeding and initial surface irrigation, *E. polystachya* was introduced at a density of three segments/m^2 or 3,000 segments/ha. The stem segments were oriented vertically and placed into the soil so that the node was covered by one- to two-cm of soil and the stem was slightly exposed.

The experimental design was a randomized complete block with four replications consisting of six herbicide programs. PRE treatments were applied before rice and *E. polystachya* emerged through the soil, DPRE treatments were applied approximately four days after planting and prior to rice and *E. polystachya* emergence, POST treatments were applied at the three- to four-leaf rice stage and two- to five-leaf *E. polystachya* stage. Herbicide programs included: 448 g/ha clomazone applied PRE, 448 g/ha clomazone plus 420 g/ha quinclorac applied PRE, 448 g ai/ha pendimethalin plus 420 g/ha quinclorac applied DPRE, 70 g/ha imazethapyr applied PRE, and 175 g ai/ha mesotrione applied PRE. Each herbicide application was followed by a POST application of 314 g/ha cyhalofop. Research has shown that molinate and propanil are not effective in controlling *E. polystachya* (Griffin et al. 2004b; Lassiter et al. 2002) and therefore were not included in the herbicide programs evaluated. Herbicide treatments were applied using a CO_2-pressurized backpack sprayer calibrated to deliver a volume of 140 L/ha at 193 kPa.

E. polystachya and barnyardgrass control were visually estimated 7 DAT and continued weekly until 49 DAT on a scale of 0 to 100%, where 0 = no injury and 100 = plant death. Rice plant height was measured from the soil surface to the tip of the extended panicle immediately prior to harvest. Rough rice grain yield was determined by harvesting the four center rows of each plot with a small-plot combine. Grain yield was corrected to 12% moisture.

Data were subjected to the mixed procedure of SAS with year used as a random factor (SAS 2003). Years, replication (nested within years), and all interactions containing either of these effects were considered random effects; herbicide program and DAT were considered fixed effects. Considering year or combination of year as random effects permits inferences about herbicide programs over a range of environments (Carmer et al. 1989; Hager et al. 2003). DAT was considered a repeated measures variable, which allowed comparisons across DAT and the change in control over time (Blouin et al. 2004). A study with a repeated measures variable is a type of factorial experiment, with treatment and time as the two factors. The objectives of repeated measures data analysis are to examine and compare response trends over time (Littell et al. 1998), in this case the control of *E. polystachya* throughout the growing season. Type III statistics were used to test all possible effects of fixed factors (herbicide program or DAT) and least square means were used for mean separation at a 5% probability level ($p \leq 0.05$). Tables were constructed for interactions present.

Results and Discussion

Barnyardgrass. No herbicide program by DAT interaction was observed for barnyardgrass control (Table 3.1). Herbicide program and DAT main effects were detected; therefore, data are presented separately by herbicide program averaged over DAT (Table 3.2) and by DAT averaged over herbicide program (Table 3.3).

Averaged over 7 to 49 DAT, all of the herbicide programs controlled barnyardgrass at least 87% (Table 3.2). Averaged over herbicide program, barnyardgrass control was 91 to 93% from 28 to 42 DAT; however, control at all DAT was at least 85% for all rating dates (Table 3.3). Because of neighboring field trials with late POST applications as well as delaying

Table 3.1. Statistical parameters for barnyardgrass and *Echinochloa polystachya* control to herbicide programs at different rating dates (DAT) in drill-seeded imidazolinone-resistant rice near Crowley, Louisiana in 2004 and 2005[a].

	barnyardgrass		*E. polystachya*	
Effect	F value	Pr>F	F value	Pr>F
herbicide program	3.93	0.012	12.07	<0.001
DAT	21.33	<0.001	16.13	<0.001
herbicide program*DAT	0.50	NS	1.52	NS

[a]Data were analyzed using Mixed procedure of SAS with year used as a random factor. Years, replication (nested within years), and all interactions containing either of these effects were considered random effects; herbicide program and DAT were considered fixed effects. Type III statistics were used to test all possible effects of herbicide program and DAT.

Table 3.2. Evaluation of herbicide programs containing different preemergence herbicides followed by cyhalofop POST for control of barnyardgrass and *Echinochloa polystachya*, the impacts on rice plant height at harvest, and rough rice yield in drill-seeded imidazolinone-resistant rice near Crowley, Louisiana in 2004 and 2005, averaged over rating date[a,b,c,d,e].

Herbicide programs	Rate	Timing	Control		Rice	Rice
			barnyardgrass	*E. polystachya*	height	yield
	g ai ha		— % —		— cm —	kg/ha
clomazone fb	448	PRE	89 a	80 a	90 a	3980 b
cyhalofop	314	POST				
clomazone +	448	PRE	89 a	72 b	90 a	4190 b
quinclorac fb	420	PRE				
cyhalofop	314	POST				
imazethapyr fb	70	PRE	89 a	81 a	89 a	5560 a
cyhalofop	314	POST				
mesotrione fb	175	PRE	87 b	72 b	89 a	4310 b
cyhalofop	314	POST				
pendimethalin +	1120	DPRE	88 ab	78 a	92 a	4460 b
quinclorac fb	420	DPRE				
cyhalofop	314	POST				
nontreated			0	0	81 b	1950 c

(continued

(Table 3.2 continued)

[a] Crop oil concentrate, trade name Agri-dex®, Helena Chemical Co., 225 Schilling boulevard, Suite 300, Collierville, TN 38017 at 2.5% (v/v) used with cyhalofop and at 1% (v/v) used with pendimethalin plus quinclorac.

[b] Abbreviations: DPRE, applied just before rice and *E. polystachya* emergence; fb, followed by; POST, postemergence, applied at the three- to four-leaf rice stage and two- to five-leaf *E. polystachya* stage; PRE, preemergence, applied before rice and *E. polystachya* emerged through the soil.

[c] Means in a column followed by the same letter do not significantly differ at P=0.05.

[d] Rice height at harvest.

[e] Visual ratings were taken 7 d after POST herbicide application and continued weekly until 49 days after application.

Table 3.3. Response of barnyardgrass and *Echinochloa polystachya* to herbicide programs containing different preemergence herbicides followed by cyhalofop POST at different rating dates (DAT) in drill-seeded imidazolinone-resistant rice near Crowley, Louisiana in 2004 and 2005, averaged over herbicide program[a,b].

	Control	
DAT	barnyardgrass	*E. polystachya*
	%	
7	85 d	80 a
14	86 cd	81 a
21	87 cd	79 a
28	93 a	82 a
35	91 ab	78 a
42	91 ab	71 b
49	89 bc	67 b

[a] Preemergence herbicide programs included: 448 g/ha clomazone PRE, 448 g/ha clomazone plus 420 g ai/ha quinclorac PRE, 70 g/ha imazethapyr PRE, 175 g ai/ha mesotrione PRE, and 1120 g ai/ha pendimethalin plus 420 g/ha quinclorac DPRE. Each preemergence herbicide application was followed by a MPOST application of 314 g/ha cyhalofop.

[b] Means in a column followed by the same letter do not significantly differ at P=0.05.

flood for aid in control of *E. polystachya*, permanent flood was not established until 14 and 21 DAT in 2004 and 2005; respectively, use of flood waters may not have fully benefited early-season barnyardgrass control which was 85 to 87% from 7 to 21 DAT.

Echinochloa polystachya. No herbicide program by DAT interaction was observed for *E. polystachya* control (Table 3.1). Herbicide program and DAT main effects were detected; therefore, data are presented separately by herbicide program averaged over DAT (Table 3.2) and by DAT averaged over herbicide program (Table 3.3).

The herbicide programs that contained a single application of clomazone or imazethapyr applied PRE, or pendimethalin plus quinclorac applied DPRE controlled *E. polystachya* 78 to 81% (Table 3.2). Control was 72% for programs containing mesotrione or clomazone plus quinclorac applied PRE. The combination of clomazone and quinclorac PRE fb cyhalofop POST controlled *E. polystachya* 72% while clomazone PRE fb cyahlofop POST contolled the weed 80%. This control difference may be due to control of other weeds found in the test area which were competing with *E. polystachya* for light, nutrients and water and this would allow *E. polystachya* to thrive under a less competitive environment (Radosevich et al. 1997). DiTomaso (2000) reported that a weed species can be replaced by another equally undesirable species insensitive to a particular herbicide. Quinclorac[22] is labeled for use on broadleaf, sedge, and annual grass weeds which were infesting these areas.

Averaged across herbicide programs, *E. polystachya* control was 78 to 82% at 7 to 35 DAT (Table 3.3). This control was probably due to increased activity of the herbicides applied to small two- to five-leaf *E. polystachya* plants and the combined effects of PRE applications which may have provided initial control or suppression followed by the POST application of cyhalofop

[22] Facet® 75DF herbicide label. BASF Corporation. 26 Davis Drive, Research Triangle Park, NC 27709.

which provided more activity on *E. polystachya*. Control of *E. polystachya* decreased to 71 and 67%; respectively, at 42 and 49 DAT. This reduced control was probably due to *E. polystachya* regrowth late in the growing season. Early ratings reflected bleaching and leaf chlorsis from herbicides applied PRE or DPRE and leaf chlorosis from the cyhalofop application applied POST; however, new shoots emerged late in the season from lower nodes of surviving *E. polystachya*. It has been reported that reserve nonstructural carbohydrates have been correlated to regrowth of perennial grasses damaged by mowing or herbicide applications (Gonzales et al. 1989; Johnson et al. 2002).

Baruch and Merida (1995) stated *E. polystachya* has the ability to greatly increase stolon biomass and root production once under flooded conditions. This may account for late-season recovery of the weed after permanent flood establishment. Pompeo et al. (2001) reported similar growing characteristics of *E. polystachya*; the ability to grow upwards at a rate which allows it to remain above fluctuating water levels. Physiologically, *E. polystachya* possess a large proportion of aerenchyma tissue, large and hollow stolons, as well as advantageous roots that make the weed well suited for survival in flooded conditions (Baruch 1994). The establishment of a permanent flood after POST applications may not have affected *E. polystachya* control at later rating dates. Regrowth and physiological characteristics of the weed allow it to flourish under flooded conditions.

Rice Response. Rice heights at harvest were 89 to 92 cm for all herbicide treated rice; nontreated rice height was 81 cm (Table 3.2).

The producer locations used in this study were infested with red rice. Only one herbicide program that was evaluated contained an imazethapyr application, which is labeled for red rice control. Herbicide programs that include imazethapyr applications have been reported to effectively control red rice (Avila et al. 2005; Pellerin et al. 2004; Steele et al. 2002). Rice yield has been reduced 86 to 88% by red rice competition (Kwon et al. 1991; Smith 1988). In this study, rice treated with imazethapyr yielded 5560 kg/ha (Table 3.2). Rice yields were reduced to 3980 to 4460 kg/ha when no imazethapyr PRE application occurred and this low yield was probably due to a heavy red rice infestation rather than *E. polystachya* interference.

In conclusion, barnyardgrass was controlled in the drill-seeded, delayed-flood production system with the herbicide programs evaluated in this study. *E. polystachya* was controlled at least 78% with herbicide programs containing clomazone or imazethapyr applied PRE, and pendimethalin plus quinclorac applied DPRE. Producers have the choice of using conventional or IR rice production systems to manage *E. polystachya*; allowing weed control decisions to be made for other spp. present such as red rice. The herbicide programs in this study were applied to *E. polystachya* stolons and two- to five-leaf plants, so application timing may be important when attempting to manage this weed. *E. polystachya* control was higher at 7 to 35 DAT; however, at 42 and 49 DAT, control decreased to 71 and 67%, respectively. This indicates the plant may have recovered from the initial response from the herbicide programs. Management decisions with the herbicide programs evaluated in this study may not provide total control of *E. polystachya*, but the ability to manage the weed at a level that does not negatively impact yield.

E. polystachya control may not have affected rice height or yield, but populations of this weed that are allowed to survive and propagate could impact future rice production. A ratoon rice crop could be impacted through competition for light, water, and nutrients and harvest efficiency may be reduced. Rotation into crawfish production may be affected as well by late season regrowth or infestations of this weed after rice harvest. Because of the prolific nature of *E. polystachya*, production decisions in regard to management will have to be made not only to address short-term goals in the current crop cycle but also to address the long-term survivability of this weed. Management options of *E. polystachya* that may be of interest are crop rotation that would allow the use of alternate herbicides or implementation of a fallow system where tillage and extended dry periods unsuitable for growth of this weed could be utilized.

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CHAPTER 4

POSTEMERGENCE HERIBICIDE PROGRAMS FOR MANAGING *ECHINOCHLOA POLYSTACHYA*

Introduction

In Louisiana, rice (*Oryza sativa* L.) is an important grain crop with several challenging production problems. In 2003, cash sales of rice in Louisiana were $165,575,000 and represented 8.3% of the total cash receipts from agricultural commodity sales (USDA 2006). Louisiana rice in 2004 was 216,200 ha with Acadia, Jefferson Davis, and Vermilion Parishes with the most production (Anonymous 2006). The subtropical environment in Louisiana not only allows for beneficial rice growing conditions, but also provides an acceptable climate to a wide range of grass species (Allen 1980; LOSC 2006). Producers use integrated weed management programs that are best accomplished through the use of cultural, mechanical, and chemical practices in order to increase rice yields and attain higher economic returns (Jordan and Sanders 1999).

Echinochloa polystachya (Kunth) A.S. Hitchc. is a C_4 perennial grass found in Florida, Louisiana, Texas, and Puerto Rico (USDA NRCS 2006). It is also referred to as: aleman grass, carib grass, creeping river grass, German grass, mudflat-millet, or river grass (Stutzenbaker 1999; USDA 2006). This weed had only been observed in Plaquemines Parish, Louisiana prior to 1993 (Thomas and Allen 1993).

Growth of this weed is prolific in areas of moist, high fertility soils with an annual rainfall which exceeds 800 mm (Csurhes and Edwards 1998). In southern Louisiana where the weed has been identified, the annual rainfall is 1400 to 1600 mm (LOSC 2006). Cultural practices in Louisiana rice production include using pinpoint flooding for weed control during the growing season and keeping those areas flooded after harvest for aid in red rice management (Jordan and Sanders 1999). This environment could be conducive for the growth patterns and survivability of *E. polystachya* as described in previous publications (Baruch 1994; Junk et al. 1989; Morrison et al. 2000; Pompeo et al. 1999). Strahan (2003) reported that *E. polystachya*, which can reproduce vegetatively by stolon and rhizome segments, was rapidly spreading in rice production areas in Louisiana due to tillage practices and movement of contaminated equipment.

Bruff et al. (1996) reported difficulty in control of johnsongrass, a common perennial grass weed in Louisiana. Because of growing characteristics of johnsongrass, removal or damage to the foliage of the plant does not control it because of the viability of buds present on rhizomes that are capable of reproducing the plant (McWhorter 1961). Foliar-applied herbicides have been found to be effective; however, they often do not control rhizome regrowth because they are not translocated into rhizomes in sufficient quantities (Banks and Tripp 1983; McWhorter 1972; Obrigawitch et al. 1990). *E. polystachya* has prolific stolon and rhizome production and this weed may exhibit similar control problems compared with Johnsongrass (Csurhes and Edwards 1998).

It has been stated that barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] and junglerice [*Echinochloa colona* (L.) Link.] are the most important weeds of rice worldwide (Holm et al. 1977; Valverde et al. 2001), so a genetically similar spp. may pose a significant threat to rice production. *Echinochloa spp.* are the most common weeds in Louisiana rice (Webster 2004), so attention has been devoted to developing herbicide programs for control of these weeds (Jordan and Sanders 1999). Similarity with control options of barnyardgrass and junglerice, may exist for *E. polystachya* due to the genetic background of these plants.

Several postemergence (POST) herbicides are currently labeled to control barnyargrass in Louisiana rice production that may be useful in controlling *E. polystachya*. Cyhalofop[23] and fenoxaprop[24], aryloxphenoxy propionates, are POST herbicides that have been found to control barnyardgrass. Cyhalofop has been reported to control barnyardgrass at least 88% when applied early POST (EPOST) as well as late POST (LPOST) at 200 g ai/ha (Ntanos et al. 2000). Fenoxaprop applied at 170 g ai/ha has been reported to control 5- to 12-cm barnyardgrass at least 83% (Carey et al. 1992).

Bispyribac[25] and penoxsulam[26] are both broad spectrum herbicides which inhibit acetolactate synthase, (ALS E.C. 2.2.1.6), enzyme that have activity on targeted *Echinochloa* spp (Lassiter et al. 2004; NC-IUBMB 2005; Schmidt et al. 1999). Bispyribac applied mid POST (MPOST) to LPOST at 200 to 230 g ai/ha has been shown to control barnyardgrass 98%; however, when applied LPOST to three-tiller barnyardgrass, control was reduced to 70% (Williams 1999). Dillon et al. (2004) reported that bispyribac at 29 g/ha provided 80% control of barnyardgrass when applied 1 week after permanent flood establishment. Penoxsulam is a new broad-spectrum triazolopyrimidine sulfonamide herbicide labeled for weed control in rice (Lassiter et al. 2004). Barnyardgrass control with penoxsulam has been reported to be at least 99% at 21 days after treatment (DAT) applied alone and following a preemergence (PRE) application of clomazone[27] (Ottis et al. 2004).

The development of herbicide resistant rice has increased weed control efficacy during the growing season by providing additional control options. Imidazolinone-resistant (IR) rice allows the use of imidazolinone herbicides

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[23] Clincher® SF herbicide label. Dow AgroScience. Indianopolis, IN 46268.

[24] Ricestar® herbicide label. Bayer CropScience. P.O. Box 12014, 2 T.W. Alexander Dr. Research Triangle Park, NC 27709.

[25] Regiment™ herbicide label. Valent Corp. Walnut Creek, CA 94596.

[26] Grasp® herbicide label. Dow AgroScience. Indianopolis, IN 46268.

[27] Command® 3ME herbicide label. FMC Corporation, Agricultural Products Group, Philadelphia, PA 19103.

for weed control (Croughan 1994). Imazethapyr[28] and imazamox[29] are the imidazolinone herbicides labeled for use with IR rice lines. Barnyardgrass control of 90% has been reported with imidazolinone herbicides applied PRE in an IR rice production system (Liscano et al. 1999; Masson et al. 2001). Pellerin and Webster (2004) reported 97% barnyardgrass control with sequential applications of imazethapyr at 70 g ai/ha in drill-seeded IR rice. Control has been shown to be at least 89% at 28 DAT (Masson et al. 2001); however, Noldin et al. (1998) reported 49 and 74% barynardgrass control in 1993 and 1994, respectively, at 28 DAT. Masson and Webster (2001) reported that other herbicides may not be necessary for control of barnyardgrass in an IR rice production system due to the activity of imazethapyr on this weed. Therefore, imazethapyr may have activity on *E. polystachya* when applied PRE or POST in an IR rice production system.

Clomazone is a PRE herbicide that reduces or prevents accumulation of plastid pigments which produces plants with a bleached appearance (Duke et al. 1991). Westberg et al. (1989) reported 100% control of barnyardgrass 14 DAT with 280 g/ha clomazone applied preplant incorporated or PRE in soybean [*Glycine max* L. (Merr.)]. It has been shown to control barnyardgrass in rice 90 and 83% at 7 and 35 DAT, respectively (Webster et al. 1999).

Other herbicides have also been used to control barnyardgrass. Molinate[30], a thiocarbamate which inhibits lipid synthesis, propanil[31], an amide that inhibits photosynthesis at photosystem II, and quinclorac[32], a carboxylic acid that acts as a synthetic auxin have been extensively used to

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[28] Newpath® herbicide label. BASF Corporation, 26 Davis Drive, Research Triangle Park, NC 27709.

[29] Beyond® herbicide label. BASF Corporation, 26 Davis Drive, Research Triangle Park, NC 27709.

[30] Ordram® 15-GM herbicide label. Syngenta Crop Protection. Greensboro, NC 27409.

[31] Stam® M4 herbicide label. Dow AgroScience. Indianapolis, IN 46268.

[32] Facet® 75DF herbicide label. BASF Corp, 26 Davis Dr., Research Triangle Park, NC 27709.

control barnyardgras (Baltazar and Smith 1994; Ntanos et al. 2000; Smith 1974). However, research has shown that these herbicides have little activity on *E. polystachya* (Griffin et al. 2004; Lassiter et al. 2002).

The highly competitive qualities of *E. polystachya* could potentially reduce rice yield where significant populations of the weed exist. Genetic similarities to barnyardgrass further the interest in controlling this weed in rice. The goal of this research is to evaluate current weed control programs and cultural practices targeted to barnyardgrass in Louisiana rice for management of *E. polystachya*.

Materials and Methods

A field study was conducted from 2004 to 2005 near Crowley, Louisiana to determine the most effective POST barnyardgrass herbicide program for control of *E. polystachya.* Soil was a Crowley silt loam (fine montmorillonitic, thermic Typic Albaqualf) with 1.4% organic matter and pH 5.5. Seedbed preparation consisted of fall and spring disking and two passes in opposite directions with a two-way bed conditioner equipped with rolling baskets and S-tine harrows set to operate at depth of 6-cm. The study area was laser-leveled to a slope of 0.25% in both years in the fall following initial disking.

Plots consisted of eight 19-cm spaced rows, 5 m long. 'CL-161' rice was drill-seeded at 112 kg/ha on May 16 and April 9 in 2004 and 2005, respectively. The entire study area was surface irrigated immediately after seeding, at the two- to three-leaf rice stage, and at the three- to four-leaf rice stage. A 6-cm permanent flood was established when rice was at four- to five-leaf stage. Soil fertility management consisted of 280 kg/ha of 8-24-24 (N-P_2O_5-K_2O) fertilizer preplant and 280 kg/ha of 46-0-0 (N-P_2O_5-K_2O) urea immediately before permanent flood establishment. Standard agronomic and pest management practices were implemented throughout the growing season.

Segments of *E. polystachya* stolons were grown in 70 by 140 by 12-cm plastic containers in a Commerce silt loam (fine-silty, mixed, superactive, nonacid, thermic Aeric Fluvaquents) soil with less than 0.1% organic matter, 80% sand, 6% silt, 14% clay with a pH 7.0. The soil was thoroughly mixed with 8-24-24 fertilizer to simulate a preplant incorporated application rate of 280 kg/ha used in rice production. These stolon segments were grown prior to establishing the field study and were allowed to grow to a length of 110- to 125-cm. At approximately 60 cm from the rooting sections, stem segments consisting of an individual node were trimmed to a length of 7-cm. After rice seeding and initial surface irrigation, *E. polystachya* was introduced at a density into individual plots of three stem segments/m^2. The stem segments were oriented vertically and placed into the soil so that the node was covered by one- to two-cm of soil and the stem was slightly exposed.

The experimental design was a randomized complete block with four replications consisting of 11 herbicide programs. PRE treatments were applied before rice and *E. polystachya* emerged through the soil, very early POST (VEPOST) treatments were applied at rice and *E. polystachya* emergence, at the one-leaf stage. Early POST (EPOST) treatments were applied at the one- to two-leaf rice and the three- to four-leaf *E. polystachya* stage. Mid POST (MPOST) treatments were applied at the three- to four-leaf rice and the three- to five-leaf *E. polystachya* stage. Late POST (LPOST) treatments were applied when rice was at the five-leaf to two-tiller stage and *E. polystachya* was at the six- to eight-leaf stage. Herbicide programs included: 22 g/ha bispyribac EPOST fb 22 g/ha bispyribac LPOST, 208 g/ha cyhalofop EPOST followed by (fb) 315 g/ha cyhalofop LPOST, 66 g/ha fenoxaprop EPOST fb 86 g/ha fenoxaprop LPOST, 70 g/ha imazethapyr EPOST fb 70 g/ha imazethapyr LPOST and 50 g/ha penoxsulam MPOST. Research has shown that molinate, propanil, and quinclorac are not effective in controlling *E. polystachya* (Griffin et al. 2004; Lassiter et al. 2002) and therefore were not included in the herbicide programs evaluated. Control obtained from each herbicide program was evaluated with and without 448 g/ha clomazone PRE. Herbicide treatments were applied using a CO_2-pressurized backpack sprayer delivering a volume of 140 L/ha at 193 kPa.

E. polystachya and barnyardgrass control were visually estimated 7 DAT and continued weekly through 49 DAT on a scale of 0 to 100%, where 0 = no injury and 100 = plant death. Rice plant height was measured from the soil surface to the tip of the extended panicle immediately prior to harvest. Rough rice grain yield was determined by harvesting the four center rows of each plot with a small-plot combine. Grain yield was corrected to 12% moisture.

Data were subjected to the mixed procedure of SAS with year used as a random factor (SAS 2003). Years, replication (nested within years), and all interactions containing either of these effects were considered random effects; herbicide program and DAT were considered fixed effects. Considering year or combination of year as random effects permits inferences about herbicide programs over a range of environments (Carmer et al. 1989; Hager et al. 2003). DAT was considered a repeated measures variable, which allowed comparisons across DAT and the change in control over time (Blouin et al. 2004). A study with a repeated measures variable is a type of factorial experiment, with treatment and time as the two factors. The objectives of repeated measures data analysis are to examine and compare response trends over time (Littell et al. 1998), in this case the control of *E. polystachya* throughout the growing season. Type III statistics were used to test all possible effects of fixed factors (herbicide program or DAT) and least square means were used for mean separation at a 5% probability level ($p \leq 0.05$). Tables were constructed for appropriate interactions.

Results and Discussion

Barnyardgrass. No herbicide program by DAT interaction was observed for barnyardgrass control (Table 4.1). Herbicide program and DAT main effects were detected; therefore data are presented separately by herbicide program averaged over DAT (Table 4.2) and by DAT averaged over herbicide program (Table 4.3).

All herbicide programs controlled barnyardgrass 87 to 91% with the exception of penoxsulam applied without a PRE application of clomazone which controlled barnyardgrass 78% (Table 4.2). Barnyardgrass control averaged across herbicide programs was 90 to 92% at 21 to 35 DAT; however, control at all DAT was at least 85% (Table 4.3). Ottis et al. (2004) previously reported 99% barnyardgrass control 21 DAT with penoxsulam, with and without the addition of a PRE herbicide. Unlike the other POST herbicides evaluated, penoxsulam can only be applied once per season[33]. The targeted barnyardgrass size for penoxsulam is up to 10 cm. Because the other herbicide programs contained LPOST applications and permanent flood was not established until 7 and 14 days after final POST application in 2004 and 2005; respectively, use of flood waters may not have benefited the penoxsulam program. Ogg and Dawson (1984) reported barnyardgrass usually emerges in late April to May and shows significant emergence into July so emergence may have occurred after the penoxsulam application thus reducing the activity of this herbicide on barnyardgrass.

***Echinochloa polystachya*.** No herbicide program by DAT interaction was observed for *E. polystachya* control (Table 4.1). Herbicide program and DAT main effects were detected; therefore data are presented separately by herbicide program averaged over DAT (Table 4.2) and by DAT averaged over herbicide program (Table 4.3).

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[33] Grasp® herbicide label. Dow AgroSciences, LLC 9330 Zionsville Road, Indianapolis, IN 46268.

Table 4.1. Statistical parameters for barnyardgrass and *Echinochloa polystachya* control to herbicide programs at different rating dates (DAT) in drill-seeded imidazolinone-resistant rice near Crowley, Louisiana in 2004 and 2005[a].

	barnyardgrass		*E. polystachya*	
Effect	F value	Pr>F	F value	Pr>F
herbicide program	18.01	<0.001	15.18	<0.001
DAT	22.53	<0.001	59.79	<0.001
herbicide program*DAT	1.09	NS	0.86	NS

[a]Data were analyzed using Mixed procedure of SAS with year used as a random factor. Years, replication (nested within years), and all interactions containing either of these effects were considered random effects; herbicide program and DAT were considered fixed effects. Type III statistics were used to test all possible effects of herbicide program and DAT.

Table 4.2. Evaluation of herbicide programs for the control of barnyardgrass and *Echinochloa polystachya* and the impacts on rice plant height at harvest and rough rice yield in drill-seeded imidazolinone-resistant rice near Crowley, Louisiana in 2004 and 2005[a,b,c,d,e].

Herbicide programs	Rate	Timing	Control: barnyardgrass	Control: *E. polystachya*	Rice ht	Yield
	g ai ha		%	%	cm	kg/ha^{-1}
bispyribac fb	22	EPOST	87 b	70 de	89 abc	2850 b
bispyribac	22	LPOST				
clomazone fb	448	PRE	89 ab	74 cd	91 ab	2900 b
bispyribac fb	22	EPOST				
bispyribac	22	LPOST				
clomazone fb	448	PRE	91 ab	85 a	91 ab	2850 b
cyhalofop fb	208	EPOST				
cyhalofop	314	LPOST				
clomazone fb	448	PRE	88 ab	70 de	88 abc	2970 b
fenoxaprop fb	66	EPOST				
fenoxaprop	86	LPOST				
clomazone fb	448	PRE	92 a	83 ab	93 a	5110 a
imazethapyr fb	70	VEPOST				
imazethapyr	70	MPOST				

(continued)

(Table 4.2 contined)

clomazone fb	448	PRE	89 ab	76 bcd	90 ab	3110 b
penoxsulam	50	MPOST				
cyhalofop fb	208	EPOST	91 ab	80 abc	88 abc	3260 b
cyhalofop	314	LPOST				
fenoxaprop fb	66	EPOST	88 ab	65 e	86 bc	3270 b
fenoxaprop	86	LPOST				
imazethapyr fb	70	VEPOST	91 ab	82 abc	91 ab	5230 a
imazethapyr	70	MPOST				
penoxsulam	50	MPOST	78 c	68 de	90 ab	2730 b
nontreated			0 f	0 f	82 c	1140 c

[a] Crop oil concentrate, trade name Agri-dex®, Helena Chemical Co., 225 Schilling boulevard, Suite 300, Collierville, TN 38017 at 2.5% (v/v) used with cyhalofop and penoxsulam and at 1% (v/v) used with imazethapyr. An organo-silicon surfactant, trade name Kinetic®, Helena Chemical Co. at 0.125% (v/v) was used with bispyribac.

[b] Means in a column followed by the same letter do not significantly differ at P=0.05.

[c] Abbreviations: PRE, preemergence; fb, followed by; EPOST, early postemergence, applied at the one- to two-leaf rice stage; LPOST, late postemergence, applied at the five-leaf to two-tiller rice stage; VEPOST, very-early postemergence, applied at one-leaf stage rice; MPOST, mid postemergence, applied at the three- to four-leaf rice stage.

[d] Rice height at harvest.

[e] Visual ratings were taken 7 d after POST herbicide application and continued weekly until 49 days after application.

Table 4.3. Response of barnyardgrass and *Echinochloa polystachya* to herbicide programs at different rating dates (DAT) in drill-seeded imidazolinone-resistant rice near Crowley, Louisiana in 2004 and 2005, averaged over herbicide program[a,b].

DAT	Control	
	barnyardgrass	*E. polystachya*
	%	
7	85 d	84 a
14	87 c	81 ab
21	92 a	84 a
28	90 ab	77 b
35	90 ab	70 c
42	88 bc	67 cd
49	87 c	63 d

[a] Herbicide programs included: 22 g ai/ha bispyribac EPOST fb 22 g/ha bispyribac LPOST; 208 g ai/ha cyhalofop EPOST fb 315 g/ha cyhalofop LPOST;; 66 g ai/ha fenoxaprop EPOST fb 86 g/ha fenoxaprop LPOST; 70 g ai/ha imazethapyr VEPOST fb 70 g/ha imazethapyr MPOST; and 50 g ai/ha penoxsulam MPOST. Each postemergence herbicide treatment was evaluated with and without 448 g ai/ha clomazone PRE.

[b] Means in a column followed by the same letter do not significantly differ at P=0.05.

The herbicide program that included clomazone PRE fb sequential POST cyhalofop applications controlled *E. polystachya* 85% (Table 4.2). Herbicide programs that had similar control included two POST cyhalofop applications as well as programs containing two applications of imazethapyr. Control was at least 65% for programs containing bispyribac, fenoxaprop, or penoxsulam; however, programs that included bispyribac and fenoxaprop contained two applications of each herbicide; respectively, while penoxsulam was only applied in a single MPOST application as previously discussed with barnyardgrass. Multiple POST applications probably increased control of the late emerging *E. polystachya*. Kim et al. (2005) reported an increased translocation and metabolism of cyhalofop compared with fenoxaprop which results in increased interruption of initial growth of barnyardgrass. Bispyribac and penoxsulam, both ALS-inhibiting herbicides, controlled *E. polystachya* 70 and 68%, respectively. Barnyardgrass is tolerant to some ALS-herbicides because it can rapidly metabolize the herbicides into inactive products (Neighbors and Privalle 1990). A genetically similar weed may show similar tolerance to this class of herbicide. Also, properties of the ALS enzyme for a particular weed can affect the selectivity of herbicides whose mode of action is inhibition of this enzyme (Carey et al. 1997). As previously mentioned, control with penoxsulam applied without a PRE application of clomazone may have been affected by delayed permanent flood.

Averaged across herbicide programs, *E. polystachya* control was 81 to 84% at 7 to 21 DAT (Table 4.3). This control was probably due to increased activity of the herbicides applied to small plant segments. At 28 DAT, control of *E. polystachya* decreased to 77% and at 49 DAT control was 63%. This indicates that regrowth occurred causing reduced control as the season progressed. Early ratings reflected bleaching from clomazone applications as well as initial leaf chlorosis or desiccation from POST herbicide applications.

Pompeo et al. (2001) described *E. polystachya* as having the ability to quickly grow upwards at a rate which allows it to remain above the fluctuating water levels of its native terrain. The establishment of a permanent flood after final herbicide applications may not have affected control at the later rating dates due to growth of the weed from plants that were not controlled and the natural ability of this weed to thrive in a flooded environment. *E. polystachya* is well suited for survival in flooded conditions, having a large proportion of aerenchyma tissue, large and hollow stolons, and advantageous roots (Baruch 1994). This weed has been shown to greatly increase stolon biomass and root production under flooded conditions (Baruch and Marida 1995).

Rice Response. Rice heights at harvest were 88 to 93 cm for all herbicide treated rice except fenoxaprop applied without clomazone PRE and the nontreated which were 86 and 82 cm, respectively (Table 4.2). The producer locations used in this study were infested with red rice. Only two herbicide programs that were evaluated contained applications of imazethapyr, which is labeled for red rice control.

Kwon et al. (1991) reported up to 86% reduction in rice yield by season-long red rice interference. Herbicide programs that include sequential imazethapyr applications have been reported to effectively control red rice. (Steele et al. 2002). In this research, rice treated with imazethapyr yielded 5110 to 5230 kg/ha^{-1} with and without the addition of clomazone PRE. Rice yields were reduced to 2730 to 3270 kg/ha^{-1} when the herbicide programs evaluated did not include an imazethapyr application and the low yield was probably due to a heavy red rice infestation rather than *E. polystachya* competition.

In conclusion, barnyardgrass was controlled with the herbicide programs evaluated in this study. *E. polystachya* was controlled with herbicide treatments containing applications of cyhalofop or imazethapyr, regardless of clomazone applied PRE. Producers have the choice of using conventional or IR rice production systems to control *E. polystachya*. Additionally, total POST herbicide programs can be used to control *E. polystachya*; however, herbicide application timing is very important when attempting to manage this weed. The addition of clomazone PRE may provide control of other weeds infesting the field. *E. polystachya* control was higher at 7 to 21 DAT, but control decreased to 63% at 49 DAT. This indicates the plant stolons may have recovered from the initial symptoms from the herbicide program selected. Even though *E. polystachya* control may not have affected rice height or yield, populations of this weed that are allowed to survive and propagate could impact future rice production. Ratoon rice crops, as well as rotation into crawfish production may be affected by late season regrowth or infestations of this weed after rice is harvested. The late season regrowth could impact the ratoon crop through competition for light, water, and nutrients and could have a major impact on harvest efficiency. Because of the prolific nature of *E. polystachya*, production decisions in regard to control will have to be made not only to address short-term infestations in the current crop cycle but also to address the long-term survivability of this weed.

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CHAPTER 5

SUMMARY

This research was undertaken to evaluate *Echinochloa polystachya* (Kunth) A.S. Hitch. ecology and management strategies in Louisiana rice (*Oryza sativa* L.). A field study was repeated in 2005 to evaluate *E. polystachya* response when introduced at varying densities in drill-seeded rice. Greenhouse experiments were conducted in 2003 and 2005 to evaluate potential herbicides for control of *E. polystachya* and to determine if soil depth affects *E. polystchya* stolon emergence. Field studies were established in 2004 and 2005 to evaluate current weed control programs in drill-seeded rice production systems for management of *E. polystachya*.

A field study was conducted in 2005 near Crowley, Louisiana to determine in-field response of introduced *E. polystachya* segments with rice. After rice seeding, the area was surface irrigated to a level of 1.5-cm then drained and *E. polystachya* was introduced at seven densities (SD): 0, 1, 3, 7, 13, 26, and 52 segments/m^2 which corresponds to 0, 10,000, 30,000, 70,000, 130,000 260,000, and 520,000 segments/ha, respectively. *E. polystachya* response was determined by measuring the number of stolons, stolons produced by planting density, and total stolon length at 50 and 100 days after planting (DAP) at the one- to two-tiller and physiological maturity rice stage, respectively. Additionally, node number, node number by introduced density, fresh weight biomass, and fresh weight biomass by introduced density were recorded at 100 DAP. Rice stand count was recorded at 50 DAP. Rice height was determined at 100 DAP by measuring from the base of the plant to the tip of the tallest leaf or extended panicle, respectively.

At 50 DAP, the highest number of emerged *E. polystachya* stolons was 100,000 stolons/ha and was collected from the 520,000 SD. Stolon emergence from individually introduced nodes were higher at the two lowest introduced densities, 10,000 and 30,000 SD with 1 and 0.63 stolons produced per introduced segment, respectively. The higher densities evaluated produced 0.15 to 0.3 stolons per introduced segment. This may indicate some intraspecific competition for light, nutrients, and water among individual *E. polystachya* plants. However, it is difficult to determine how *E. polystachya* growth is determined in a fluctuating habitat. Total stolon length was 17 to 33 Km/ha for the 130,000 through 520,000 stolon/ha planted density.

At 100 DAP, the introduced densities of 10,000 through 70,000 segments/ha produced 5.4 to 6 stolons per introduced segment, but 130,000 through 520,000 SD produced 1.4 to 2.1 stolons per introduced segment. This may be due to increased competition with rice and other *E. polystachya* plants. Prolific *E. polystachya* stolon production was greater than 160,000 plants/ha in the 30,000 through 520,000 SD. Total stolon length was 318 km/ha for the 520,000 SD and was similar for the 260,000 SD.

This study demonstrates the effectiveness of *E. polystachya* to reproduce vegetatively in a drill-seeded rice production system from single-node stolons. Shallow tillage or tillage under moist conditions may allow *E. polystachya* stolons to be introduced in numbers exceeding those evaluated in this study. At the lowest introduced density, 10,000 segments/ha, individual node production was at least 290,000 nodes/ha with a total of 29 nodes produced for every single node segment introduced. Introduced densities of 70,000 segments/ha or greater produced 5.4 to 9.8 nodes/introduced segment. As with total stolon production, this may indicate intraspecific *E. polystachya* competition or interspecific competition with rice. The highest biomass production recorded in this study was 1270 kg/ha; however, *E. polystachya* biomass is much greater in the native range of the Amazon river basin. *E. polystachya* biomass was 16 g/segment introduced for the lowest density of 10,000 SD, and was 2.4 through 5.5 g/segment introduced for the 70,000 through 520,000 SD. In a production situation where high numbers of introduced stolons are distributed, the competitive advantage may overwhelm rice; therefore, management decisions must be made to minimize favorable growing conditions for this weed.

The average rice height at rice maturity was 35 cm and rice stand at 50 DAP was 115 plants/m^2 with no difference among introduced *E. polystachya* density observed. Rice was not harvested due to lodging and heavy late season red rice infestation.

A greenhouse study was conducted in 2003 and 2005 to evaluate *E. polystachya* emergence in response to increasing soil depth. Soil depths of 1.3-, 2.5-, 5.0-, 10.0-, and 20.0-cm were evaluated. The highest shoot emergence was 63% for stolons planted at the 1.3 cm depth. Similar emergence was recorded at the 0 and 2.5 cm level with 31 and 44% emergence, respectively. Shoot emergence was 25% for 5 cm burial depth, which had similar emergence to the 0 and 2.5 cm planting depth. There was no emergence for the 10 and 20 cm burial depths. Tillage has been used to control other perennial weeds; however, cutting shoots and rhizomes into small pieces in moist, shallow conditions may help to propagate the spp rather than control it.

A greenhouse study was conducted in 2005 to evaluate herbicide efficacy for the control of *E. polystachya.* Treatments were applied to *E. polystachya* plants at the two- to four-leaf stage with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L/ha at 193 Kpa. Herbicide treatments were: bispyribac at 22 g ai/ha, cyhalofop at 314 g ai/ha, fenoxaprop/S (designates safened fenoxaprop) at 86 g ai/ha, fenoxaprop/S at 46 g/ha plus fenoxaprop at 40 g ai/ha, glufosinate at 497 g ai/ha, glyphosate at 1260 g ae/ha, imazethapyr at 70 g ai/ha, penoxsulam at 50 g ai/ha, propanil at 3364 g ai/ha, and quinclorac at 560 g ai/ha. A nontreated was added for comparison. Visual control ratings were taken at 14 and 28 days after treatment (DAT). *E. polystachya* fresh weight was measured by clipping three *E. polystachya* plants at the soil line from each of the four replications at 14 and 28 DAT.

At 14 DAT, the herbicide treatments that contained glyphosate or glufosinate resulted in the highest visual control of *E. polystachya* with 78 and 89%, respectively. Herbicide treatments that contained imazethapyr, penoxsulam, or fenoxaprop/S controlled the weed 49 to 61%; however, some of the herbicides may not have been fully expressed visually at this time. At 28 DAT, glyphosate controlled *E. polystachya* 91%. Treatments including glufosinate, cyhalofop, imazethapyr, fenoxaprop/S, or penoxsulam controlled the weed 65 to 78%.

Little control data exists for *E. polystachya* in rice; therefore, reduction in fresh weight biomass can reinforce the observed visual control ratings. Glyphosate, glufosinate, cyhalofop, imazethapyr, fenoxaprop/S, fenoxaprop/S plus fenoxaprop, and penoxsulam had the highest biomass reduction at both 14 and 28 DAT. Final biomass reduction at 28 DAT was 19 to 37% of the nontreated fresh weight with these herbicides. Cyhalofop, fenoxaprop, and penoxsulam are currently labeled for use in Louisiana rice production. Imazethapyr is labeled for use in imidazoline-resistant (IR) rice in Louisiana; therefore, producers have herbicide options for managing this weed in IR or conventional rice. Multiple applications of these herbicides or the addition of a preemergence herbicide may be necessary for complete control. Glyphosate and glufosinate are not currently labeled for use in rice; however, burndown prior to planting may be a management option. Quinclorac was the only herbicide treatment that resulted in an augmentation of the nontreated fresh weight with 124% of the nontreated.

Field studies were established in 2004 and 2005 to evaluate current weed control programs in drill-seeded rice production systems for management of *E. polystachya*. The first study was conducted near Crowley, Louisiana to evaluate herbicide programs for *E. polystachya* management. Herbicide programs included: 448 g ai/ha clomazone applied preemergence (PRE), 448 g/ha clomazone plus 420 g/ha quinclorac applied PRE, 70 g/ha imazethapyr applied

PRE, 175 g ai/ha mesotrione applied PRE, and 448 g ai/ha pendimethalin plus 420 g/ha quinclorac applied delayed PRE (DPRE). Each herbicide application was followed by (fb) a postemergence (POST) application of 314 g/ha cyhalofop. *E. polystachya* and barnyardgrass control were visually estimated 7 DAT and continued weekly until 49 DAT. Rice plant height just prior to harvest and rough rice grain yield data were collected.

Averaged over 7 to 49 DAT, all of the herbicide programs controlled barnyardgrass at least 87%. Averaged over herbicide program, barnyardgrass control was 91 to 93% from 28 to 42 DAT; however, control was at least 85% for all evaluation dates.

The herbicide programs that contained a single application of clomazone or imazethapyr applied PRE, or pendimethalin plus quinclorac applied DPRE controlled *E. polystachya* 78 to 81%. Control was 72% for programs containing mesotrione or clomazone plus quinclorac applied PRE. The combination of clomazone and quinclorac PRE fb cyhalofop POST controlled *E. polystachya* 72% while clomazone PRE fb cyahlofop POST contolled the weed 80%. Averaged across herbicide programs, *E. polystachya* control was 78 to 82% at 7 to 35 DAT. Control of *E. polystachya* decreased to 71 and 67%; respectively, at 42 and 49 DAT.

Rice heights at harvest were 89 to 92 cm for all herbicide treated rice; the nontreated rice height was 81 cm. In this study, rice treated with imazethapyr yielded 5560 kg/ha. Rice yields were reduced to 3980 to 4460 kg/ha when no imazethapyr applications were included and this low yield was probably due to heavy red rice infestation rather than *E. polystachya* interference.

Barnyardgrass was controlled in the drill-seeded, delayed-flood production system with the herbicide programs evaluated in this study. *E. polystachya* was controlled at least 78% with herbicide programs containing applications of clomazone or imazethapyr applied PRE, and pendimethalin plus quinclorac applied DPRE. Producers have the choice of using conventional or IR rice production systems to manage *E. polystachya*; allowing weed control decisions to be made for other spp. present such as red rice. Management decisions with the herbicide programs evaluated in this study may not provide total control of *E. polystachya*, but the ability to manage the weed at a level that does not negatively impact yield.

A field study was conducted near Crowley, Louisiana to evaluate current POST herbicide programs used with and without clomazone. Herbicide programs included: 208 g/ha cyhalofop early POST (EPOST) fb 315 g/ha cyhalofop late POST (LPOST), 22 g ai/ha bispyribac EPOST fb 22 g/ha bispyribac LPOST, 66 g/ha fenoxaprop/S EPOST fb 86 g/ha fenoxaprop/S LPOST, 70 g ai/ha imazethapyr EPOST fb 70 g/ha imazethapyr LPOST and 50 g/ha penoxsulam mid-POST (MPOST). Control obtained from each herbicide program was evaluated with and without 448 g ai/ha clomazone PRE.

All herbicide programs controlled barnyardgrass 87 to 91% with the exception of penoxsulam applied without a PRE application of clomazone which controlled barnyardgrass 78%. Barnyardgrass control averaged across herbicide programs was 90 to 92% at 21 to 35 DAT; however, control at all DAT was at least 85%.

The herbicide program that included clomazone PRE fb sequential POST cyhalofop applications controlled *E. polystachya* 85%. Herbicide programs that had similar control included two POST cyhalofop applications as well as programs containing two applications of imazethapyr. Control was at least 65% for programs containing bispyribac, fenoxaprop/S, or penoxsulam. Averaged across herbicide programs, *E. polystachya* control was 81 to 84% at 7 to 21 DAT. This control was probably due to increased activity of the herbicides applied to small plant segments. At 28 DAT, control of *E. polystachya* decreased to 77% and at 49 DAT control was 63%. This indicates that regrowth occurred causing reduced control as the season progressed.

Rice heights at harvest were 88 to 93 cm for all herbicide programs except fenoxaprop/S applied without a PRE application of clomazone and the nontreated which were 86 and 82 cm, respectively. Rice treated with imazethapyr yielded 5110 to 5230 kg/ha with and without the addition of clomazone PRE. Rice yields were reduced to 2730 to 3270 kg/ha when the herbicide programs evaluated did not include an imazethapyr application and the low yield was probably due to a heavy red rice infestation rather than *E. polystachya* competition.

Barnyardgrass was controlled with the herbicide programs evaluated in this study. *E. polystachya* was controlled with herbicide treatments containing applications of cyhalofop or imazethapyr, regardless of clomazone applied PRE. Total POST herbicide programs can be used to control *E. polystachya*; however, herbicide application timing is very important when attempting to manage this weed. The addition of clomazone PRE may provide control of other weeds infesting the field.

Even though *E. polystachya* control may not have affected rice height or yield, populations of this weed that are allowed to survive and propagate could impact future rice production. Ratoon rice crops, as well as rotation into crawfish production may be affected by late season regrowth or infestations of this weed after rice is harvested. The late season regrowth could impact the ratoon crop through competition for light, water, and nutrients and could have a major impact on harvest efficiency. Because of the prolific nature of *E. polystachya*, production decisions in regard to control will have to be made not only to address short-term infestations in the current crop cycle but also to address the long-term survivability of this weed.

VITA

Roy Matthew Griffin was born on July 13, 1976, in Cleveland, Mississippi. He attended elementary and high school at Bayou Academy and graduated with honors May 1995. Matt attended Mississippi State University in Starkville, Mississippi, where he completed a bachelor's degree in agricultural engineering, technology, and business in December 1999. In 1998 while still pursuing his bachelor's degree, he was a student worker for Dr. David Shaw, a research agronomist. After graduation, he continued his education by entering the Master of Science program at MSU as a Graduate Assistant for Dr. Shaw. He was active in the University Graduate Student Association, serving as a representative in 2001 for the Department of Plant and Soil Sciences. Matt graduated in May 2003 with a Master of Science in weed science and a minor in plant physiology. As a requirement of his graduate program, he wrote, submitted, and defended a thesis, entitled "Weed Control in Early-Maturing Soybean in the Mississippi Delta". Prior to completing the requirements of his master's degree, Matt accepted a Research Assistant position under Dr. Eric P. Webster in the Department of Agronomy and Environmental Management at Louisiana State University and began fulfilling the requirements for the Doctor of Philosophy degree. His research focused on perennial grass management in Louisiana rice.

During his graduate career, Matt was a member of numerous professional organizations and presented papers at each of the annual conferences of these organizaions. He was an active participant in the Southern Weed Science Society Weed Contest where he was a member of the third place team at Louisiana State University in 2003. Matt has authored or co-authored 54 abstracts and six annual research reports.