

2006

Red morningglory (*Ipomoea coccinea* L.) biology and management in sugarcane

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RED MORNINGGLORY (*IPOMOEA COCCINEA* L.) BIOLOGY AND MANAGEMENT IN
SUGARCANE

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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August 2006

ACKNOWLEDGEMENTS

I would like to thank God for giving me the ability to pursue this degree. I am also very grateful God has blessed me with the best family and friends I could ever hope for.

To my wife Beth, thank you for your love and support. We have been through a lot in just two short years of marriage and two Ph.D. programs. Here is to the rest of our lives together and our new business.

I would like to thank my parents, Kirk and Helen Jones. You have always supported me in everything I have done in more ways than I can count. Your influence in my life is what has contributed to my success and all that I have accomplished. I hope that one day my children will look up to me as much as I look up to both of you.

Dr. Jim Griffin, I want to thank you for allowing me to be part of your program. Your guidance and assistance over the past few years is greatly appreciated. I especially want to thank you for your friendship. I also want to thank Dr. Eric Webster for being a part of my graduate committee, a friend, and for planting the seed in my head that lead to the inception of 1 Weed Ph.D. (my business venture). To the rest of my graduate committee, Drs. Donnie Miller, Ben Legendre, Ed Bush and Charles Graham, thank you for your time, guidance, and support.

To Dr. Jeff Ellis, Dr. Jonathan Seibert, and Luke Etheredge, all of whom I have shared responsibilities as co-Research Associates, I have learned both what and what not to do by working with you. Jonathan and Luke, I want to express my appreciation for your assistance in conducting my research. To Wilson Judice, I thank you for your help, friendship, and insight from a farmer's perspective regarding the sugarcane industry. I would also like to express my appreciation to the rice weed science group, Chris Leon, Chris Mudge, Matt Griffin, Wei

Zhang, Sunny Bottoms, Justin Hensley, and Kristy Pellerin. To the many student workers I have had the pleasure of working with during my time as a Research Associate, Christie Thomas, Lindsay Thomas, Kelly Patrick, Joey Boudreaux, John Hebert, and Matt Gravois, without your help I could not have done my job or completed my degree.

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ABSTRACT

In field research conducted over two years, red morningglory control 35 days after treatment (DAT) was at least 90 % with atrazine at 3.36 kg ai/ha, diuron plus hexazinone at 1.57 + 0.44 kg ai/ha, flumioxazin at 0.14 kg ai/ha, sulfentrazone at 0.21 kg ai/ha, and metribuzin at 2.52 kg ai/ha. At 49 DAT, atrazine at 4.48 kg/ha provided only 70 % control, which was equivalent to that for diuron plus hexazinone and flumioxazin. Sulfentrazone at 0.21 kg/ha controlled red morningglory at least 93 % 49 DAT and by 77 DAT control was 78 %. From June through October, red morningglory seedling emergence was compared for no tillage and tillage treatments. Seedling emergence was equal for the tillage treatments in July, but more seedlings emerged in August and September where plots were tilled. Total seedling emergence for the growing season was 129 plants/m² for the no tillage treatment and 195 plants/m² where plots were tilled. Seed population in soil from June through October for the treatments decreased an average of 34.7%.

When grown under 30 and 50 % shade, red morningglory seedling emergence decreased around 8% compared with full sun. Increasing shade to 70 and 90 % decreased seedling emergence around 40 %. Shade did not affect red morningglory height, but biomass per plant under 90 % shade decreased 48 %. Red morningglory produced more leaf area per plant under a shade environment. In the sugarcane (*Saccharum* spp. hybrids) and weed competition study, red morningglory infestation in November, based on the degree of wrapping of sugarcane stalks, was 24 % when plots were maintained weed free until late June and allowed to re-infest thereafter, but was no more than 9% when weeds were allowed to re-infest in July and August. In November, re-infestation was around 8% where plots were weedy until June or July and red morningglory was removed at that point, but weeds were not present in November for the

August removal treatments. For the various weed removal treatments, sugarcane and sugar yield were equivalent to the season long weed free control, but yields were reduced around 27 % when red morningglory competed with sugarcane season long.

CHAPTER 1

INTRODUCTION

Sugarcane (*Saccharum* spp. hybrids) is a tropical crop grown only in Florida, Louisiana, and Texas in the continental U.S., and is a major commodity in two of those states. In 2004 in Louisiana, sugarcane was grown on 186,865 ha with an average yield of 6,196 kg sugar/ha (Anonymous 2005). The average gross farm value of this product is around 359 million dollars, which ranks sugarcane as the number one agronomic crop in Louisiana. Sugarcane in Louisiana is grown as a perennial with three to five annual harvests made from a single, vegetatively propagated planting. During the entire crop cycle, the row tops are relatively undisturbed which contributes to weed proliferation. The major weed problems in sugarcane in Louisiana are the annual grasses, itchgrass [*Rottboellia cochinchinensis* (Lour.) W.D. Clayton], broadleaf signalgrass [*Brachiaria platyphylla* (Griseb.) Nash], and browntop panicum (*Panicum fasciculatum* Sw.); the perennial grasses, johnsongrass [*Sorghum halepense* (L.) Pers.] and bermudagrass [*Cynodon dactylon* (L.) Pers.]; annual morningglories (*Ipomoea* spp.); and nutsedges (*Cyperus* spp.) (Webster 2000).

Preemergence (PRE) herbicides are commonly used in sugarcane to control weeds throughout the long growing season. Herbicide is applied at planting in August and September to allow establishment of the crop, to prevent perennial weeds from reestablishing, and to control winter weeds. In the spring (March and April), herbicide is usually banded over the row to control winter weeds and to provide residual control of summer weeds. Along with the spring herbicide application, one to three inter-row cultivations are performed to remove weeds from the row middles and to facilitate fertilizer application. At layby in May, the final cultivation is performed and herbicide is applied broadcast under the crop canopy. The desire is that the

layby application of herbicide will control weeds until the crop is harvested from late September until December. However, a late-season application of herbicide is often made to control vines and to facilitate crop harvest.

In Louisiana, morningglory species, referred to as tie-vines by sugarcane producers, include ivyleaf morningglory [*Ipomoea hederacea* (L.) Jacq], entireleaf morningglory (*Ipomoea hederacea* var. *integriuscula* Gray), pitted morningglory (*Ipomoea lacunosa* L.), smallflower morningglory [*Jacquemontia tamnifolia* (L.) Griseb.], and red morningglory (*Ipomoea coccinea* L.).

Morningglory seed germinate over a wide range of temperatures (Cole and Coats 1973; Egley 1990; Gomes et al. 1978; Hardcastle 1978). In Louisiana, morningglory emergence is most prevalent after the layby cultivation (Viator et al. 2002b). Although several species of morningglory are present in Louisiana sugarcane fields, red morningglory is particularly problematic. Hardcastle (1978) in a laboratory study reported red morningglory germination was favored by 144 h of 20 to 30 C temperature. In Louisiana soil temperature in this range would occur at the time when layby tillage and layby herbicides are applied in sugarcane (Viator 2001).

Red morningglory is both the most common and troublesome broadleaf weed in Louisiana sugarcane (Webster 2000). Red morningglory, a member of the Convolvulaceae family, is a twining annual weed that was introduced into the U.S. and is native of tropical America (Radford et al. 1968). Primary distribution of red morningglory in the U.S. is in the coastal plain and piedmont of the southeast to Texas, but can be found as far north as Michigan and New York. Radford et al. (1968) describes red morningglory with glabrous, ovate somewhat angular leaves that are entire or rarely lobed. Red morningglory has a solitary peduncle with 8 to 9 mm glabrous sepals. (Rogers and Oliver 1982). The corolla color of red morningglory is

scarlet to orange-red. Red morningglory seeds are commonly three to four mm long and shaped like an orange wedge (Red morningglory is also referred to as: Mexican morningglory, redstar, scarlet morningglory, starglory, wooly tidestromia, *Quamoclit coccinea*, and *Ipomoea hederifolia* (Anonymous 2004).

Season-long red morningglory competition with sugarcane has reduced sugar yield as much as 30 % (Millhollon 1988). Germination and emergence of morningglory is most prevalent after the layby cultivation where climbing and wrapping of sugarcane stalks reduce the number of millable stalks per hectare (Millhollon 1988; Thakar and Singh 1954). Ivyleaf morningglory decreased sugarcane yield 20 to 25 %, mainly from physical hindrance of plant growth and harvestability (Thakar and Singh 1954). Even more troublesome is reduced harvest efficiency, where manual removal of morningglory from the mechanical harvester may be necessary.

In Louisiana in the mid-1990's, as much as 75% of the hectareage received an atrazine application in the spring or at layby to control morningglory (Rogers et al. 1996). The use atrazine was based on economics and the ability to provide soil residual control. Millhollon (1988) observed 84% control of red morningglory 60 d after treatment (DAT) with 1.8 kg ai/ha atrazine applied PRE in the first year of a two year study. In the second year of the study, red morningglory was controlled 88 to 93 % with atrazine 90 DAT. In this study atrazine was applied in mid-June, which was the standard practice at the time in sugarcane. In recent years, however, growers have reported red morningglory control failures with atrazine applied at layby in early to mid-May (Griffin et al. 2000). Viator et al. (2002a) showed that control failures were not a result of atrazine resistance through an altered triazine binding site. Application of atrazine at 1.68 kg/ha controlled red morningglory 74 and 96 % 45 DAT depending on location in the first year, but control was 71 and 83 % the second year (Viator et

al. 2002b). The reduced control of morningglory was attributed to shift to the sugarcane variety LCP 85-384 and change in cultural practices in Louisiana where layby herbicide application is made early to mid-May as opposed to early to mid-June (Viator et al. 2002a). With the earlier application of herbicide, longer residual control from atrazine into the growing season would be expected. Other factors such as rainfall and soil type will also affect persistence of soil-applied herbicides.

Other herbicides labeled for morningglory control in sugarcane include diuron, metribuzin, terbacil, sulfentrazone, and hexazinone plus diuron. Diuron PRE at 1.68 kg ai/ha controlled red morningglory 53 % 60 DAT and increasing the diuron rate to 2.24 kg/ha increased control to 76 % (Millhollon 1988). Viator et al. (2002b) showed diuron at 3.36 kg/ha controlled red morningglory 83 to 99 % 45 DAT in one year, but only 73 to 75 % in another. In the same study, sulfentrazone at 0.14, 0.28, or 0.42 kg ai/ha controlled red morningglory at least 94 % in one year, but no more than 80 % the next year. Red morningglory control with terbacil at 0.84 kg ai/ha or metribuzin at 1.12 kg ai/ha was 92 and 96 %, respectively, the first year but was 30 and 60 % respectively, the second year. The difference in control between years was attributed to when activating rainfall was received and also to soil pH and organic matter.

To facilitate harvest late season application of 2,4-D or a 2,4-D/dicamba prepackaged mixture is often needed to control morningglory. Siebert et al. (2004) reported complete control of 30 and 60 cm red morningglory with 2,4-D at 0.53 to 1.59 kg ai/ha 21 DAT. A prepackaged mixture of 2,4-D plus dicamba at a rate as low as 0.2 + 0.07 kg ai/ha controlled red morningglory at least 92 % 21 DAT. Control of 30 and 60-cm red morningglory with a postemergence application of atrazine at 2.23 kg/ha, flumioxazin at 0.05 kg ai/ha, sulfentrazone at 0.26 kg/ha, or carfentrazone at 0.02 kg ai/ha was at least 98 % 7 DAT. Control of 1.8-m red

morningglory in 2001 with 2,4-D (1.06 or 1.59 kg/ha), 2,4-D/dicamba premix (0.8/0.28 kg/ha), or 2,4-D plus 2,4-D/dicamba premix (0.53 plus 0.2/0.07 or 0.53 plus 0.4/0.14) was 100 % 28 DAT, while in the second year control with the same treatments 28 DAT was no more than 87 %. Differences in control between years were attributed to more vigorous and robust plants the second year.

Directed application of atrazine at 4.47 kg/ha and sulfentrazone at 0.35 kg/ha to the lower third of 1.8 m tall red morningglory was at least 96 % 28 DAT, while flumioxazin at 0.14 kg/ha provided only 74% control (Siebert et al. 2004). When this experiment was repeated a second year, red morningglory control with directed applications of atrazine, sulfentrazone, and flumioxazin was no more than 77 %.

In sugarcane fields in Louisiana red morningglory is observed to germinate throughout the growing season even in late season when heavy shading by the crop canopy has occurred. Information, however, is not available on red morningglory seedling emergence and seasonal growth as affected by light. Research has been conducted, however, with other species. Murdock et al. (1986) showed decreased pitted morningglory dry weight as soybean [*Glycine max* (L.) Merr.] row spacing decreased from 91 to 30 cm due to more rapid shading with the closer row spacing. Norsworthy (2004) showed that pitted morningglory emergence was not influenced by soybean canopy formation, but sicklepod [*Senna obtusifolia* (L.) Irwin & Barneby] and common cocklebur (*Xanthium strumarium* L.) emergence were reduced as much as 68 and 33 %, respectively. In a greenhouse study, field bindweed (*Convolvulus arvensis* L.) leaf area and flower production decreased as light intensity decreased (Dall'Armellina and Zimdahl 1988). Dry matter of field bindweed shoots grown from seed declined as light level decreased.

Giant foxtail (*Setaria faberi* Herm.) seed weight and above ground dry weight decreased linearly with increasing shade intensity (Knake 1972). Decreases were attributed to fewer leaves, stems, and fruiting structures per plant. Shading also affected giant foxtail internode length, but not the number of nodes per plant. Results of this research showed that giant foxtail can not survive in a 95 % or greater shade environment. This research also highlights the importance of crop canopy in reducing weed competition.

In a greenhouse study Patterson (1982a) showed that shading of 40% or more reduced shoot number, leaf area, total dry weight, and tuber number of both yellow nutsedge (*Cyperus esculentus* L.) and purple nutsedge (*Cyperus rotundus* L.). The two nutsedge species showed no difference in shade tolerance. In another study with yellow nutsedge Keeley and Thullen (1978) found the average number of shoots and tubers and dry matter also decreased with decreasing light intensity. As sunlight was reduced yellow nutsedge flower production decreased and was eliminated with less than 70% of full sunlight. Santos et al. (1997) showed that at 20 % shading yellow nutsedge was less affected than purple nutsedge when comparing shoot and tuber number, dry weight, and plant height. For shoot and tuber dry weight, both species responded linearly to increasing shade level.

In greenhouse studies, shading reduced height, dry matter accumulation, leaf production, leaf area, and reproductive development of showy croton (*Crotalaria spectabilis* Roth) (Patterson 1982b). Shading of showy croton increased the partitioning of plant biomass into leaves and away from stems. Velvetleaf (*Abutilon theophrasti* Medik.) leaf and branch number, plant biomass, and seed number decreased linearly with increasing shade (Bello et al. 1995). In contrast, velvetleaf seed weight increased with increasing shade.

Dry matter production of seedling and established silverleaf nightshade (*Solanum elaeagnifolium* Cav.) decreased with increased shading (Boyd and Murray 1982). Seedling plants did not flower when exposed to 63 % or greater shade, while established plants did not flower when grown under 92 % shade. Leaves of silverleaf nightshade grown under 92 % shade contained 35 % less chlorophyll per unit leaf area compared with unshaded plants. Leaf area increased with increasing shade, however, leaf weight per unit area decreased because leaf thickness was affected.

This thesis was conducted to address the biology and control of red morningglory in sugarcane in Louisiana. The efficacy of herbicides with soil residual and foliar activity was evaluated. Additionally, emergence of red morningglory seedlings as effected by tillage and shading was evaluated. Changes in shade provided by several sugarcane varieties across the growing season was determined for use in predicting red morningglory seasonal emergence patterns and the need for implementation of weed control measures.

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CHAPTER 2

RESIDUAL CONTROL OF RED MORNINGGLORY (*IPOMOEA COCCINEA*) WITH HERBICIDES APPLIED PREEMERGENCE AND POSTEMERGENCE

Introduction

In 2004 in Louisiana, sugarcane was grown on 186,860 ha with an average yield of 2,310 kg sugar/ha. (Anonymous 2005). Sugarcane in Louisiana is grown as a perennial with three to five annual harvests made from a single, vegetatively propagated planting. During the entire crop cycle, the row tops are relatively undisturbed which contributes to weed proliferation.

Preemergence (PRE) herbicides are commonly used in Louisiana to control weeds throughout the long growing season. Herbicides applied when sugarcane is planted in August and September prevent perennial summer weeds from reestablishing and control winter weeds. In March, herbicide is usually banded over the row to control emerged winter weeds and to provide residual control as sugarcane initiates growth following the winter dormant period. One to three inter-row cultivations are performed to remove weeds from the row middles and to facilitate fertilizer application. At layby in May, the final cultivation is performed and herbicide is applied broadcast under the crop canopy. The desire is that the layby herbicide control weeds until the crop is harvested from late September until December. However, a lateseason application of herbicide is often made to control morningglory and to facilitate crop harvest.

In Louisiana, morningglory species, referred to as tie-vines by sugarcane producers, include ivyleaf morningglory [*Ipomoea hederacea* (L.) Jacq], entireleaf morningglory (*Ipomoea hederacea* var. *integriuscula* Gray), pitted morningglory (*Ipomoea lacunosa* L.), smallflower morningglory [*Jacquemontia tamnifolia* (L.) Griseb.], and red morningglory (*Ipomoea coccinea*

L.). Morningglory seeds can germinate over a wide range of temperatures (Cole and Coats 1973; Egley 1990; Gomes et al. 1978; Hardcastle 1978). In Louisiana, morningglory emergence is most prevalent following the layby cultivation in May (Viator 2002b). Although several species of morningglory are present in Louisiana sugarcane fields, red morningglory is both the most common and troublesome species (Webster 2000). Hardcastle (1978) in a laboratory study reported red morningglory germination was favored by 144 h of 20 to 30 C temperatures. In Louisiana these soil temperature levels would occur at the time when layby herbicides are applied in sugarcane following cultivation (Viator 2001).

Season-long red morningglory competition with sugarcane has reduced sugar yields 24 to 30 % (Millhollon 1988). Germination and emergence of morningglory after the layby cultivation resulted in climbing and wrapping of sugarcane stalks and reduction in the number of millable stalks per hectare (Millhollon 1988; Thakar and Singh 1954). Ivyleaf morningglory has decreased sugarcane yield 20 to 25 %, mainly from physical hindrance of plant growth (Thakar and Singh 1954) and decreased harvest efficiency from having to manually remove morningglory vines from the mechanical harvester.

In Louisiana in the mid-1990's, as much as 75% of the hectareage received an atrazine application in March or in late May/early June to control morningglory (Rogers et al. 1996). The choice to use atrazine was based on economics and the need for extended soil residual control and because few alternative herbicides were available. Millhollon (1988) reported 84% control of red morningglory 60 d after treatment (DAT) with 1.8 kg ai/ha atrazine applied PRE in the first year of a two-year study. In the second year of the study, atrazine controlled red morningglory 88 to 93 % 90 DAT. In recent years, however, growers have reported variable control of red morningglory with atrazine applied in May at layby and in some cases control

failures have occurred (Griffin et al. 2000). Atrazine at 1.68 kg/ha controlled red morningglory 74 and 96 % 45 DAT depending on location in the first year, but control was 71 and 83 % the second year (Viator et al. 2002b). Variation in control observed with atrazine is not a result of atrazine resistance through an altered triazine binding site (Viator et al. 2002a). Rather, reduced control of morningglory with atrazine has been attributed to changes in sugarcane cultural practices where cultivation at layby followed by herbicide application is performed in early to mid-May as opposed to early to mid-June. With the earlier application of atrazine residual activity is decreased with high temperature and rainfall along with the longer time period until harvest is initiated in September. Field studies have shown that red morningglory can emerge from May through September and plants can thrive even under a heavy sugarcane canopy (Jones et al. 2006).

Other herbicides labeled for morningglory control in sugarcane in Louisiana include diuron, hexazinone, metribuzin, terbacil, and sulfentrazone. Morningglory control with these herbicides has been somewhat variable and control is directly related to soil conditions at application (cloddy or smooth seedbed) and when activating rainfall is received (Viator et al. 2002b). When soil applied herbicides at layby are not effective in providing long term residual control of morningglory in sugarcane, 2,4-D is often applied postemergence (POST) in late season to facilitate harvest. Siebert et al. (2004) reported complete control of 30 and 60 cm red morningglory with 2,4-D at 0.53 kg ai/ha 21 DAT. A prepackaged mixture of 2,4-D plus dicamba at a rate as low as 0.2 plus 0.07 kg ai/ha controlled red morningglory at least 92 % 21 DAT.

Another effective late season treatment for red morningglory is a POST directed application of herbicide. Atrazine at 4.47 kg/ha and sulfentrazone at 0.35 kg/ha as a directed application to

1.8 m tall red morningglory provided at least 96 % 28 DAT, while flumioxazin at 0.14 kg/ha provided only 74 % control. These herbicide treatments, however, provided no more than 77 % red morningglory control in the second year. In developing effective red morningglory control programs in sugarcane it would be most desirable for a herbicide to have both soil and foliar activity. Additionally and more importantly is that the herbicide provide residual control late into the growing season to prevent wrapping and climbing of stalks by morningglory plants which create harvest efficiency problems. The restriction in use of 2,4-D and because of drift concerns along with the added cost of aerial application would make a soil applied herbicide with long residual activity extremely valuable in a sugarcane production system. Objectives of this research were to evaluate soil and foliar applied herbicides at various rates for residual control of red morningglory and to develop morningglory control programs for use in sugarcane.

Materials and Methods

Experiments to evaluate residual control of red morningglory with herbicides applied PRE and POST were conducted near Port Allen, LA, in West Baton Rouge Parish in a fallowed sugarcane field. The soil type was a Commerce silt loam (fine-silty, mixed, superactive, nonacid, thermic Fluvaquentic Endoaquepts) with 1.8 % organic matter and a pH of 6.5. All herbicide applications were made with a tractor mounted compressed air sprayer calibrated to deliver 140 L/ha at a pressure of 179 kPa. Each experiment was conducted as a randomized complete block with 4 replications. Plot size was 3.1 by 4.6 m.

POST Study. Experiments were conducted in 2003 and 2004 to evaluate red morningglory control with herbicides that could be applied in sugarcane after the layby cultivation. Treatments evaluated included atrazine at 2.24 and 3.36 kg ai/ha; carfentrazone-ethyl at 0.009,

0.018, 0.026, and 0.035 kg ai/ha; a premix of diuron plus hexazinone at 1.05 + 0.30, 1.57 + 0.44, and 2.10 + 0.59 kg ai/ha; flumioxazin at 0.14 and 0.29 kg ai/ha; hexazinone at 0.56 kg/ha; pyraflufen-ethyl at 0.007 and 0.015 kg ai/ha; sulfentrazone 0.32 and 0.42 kg ai/ha; and trifloxysulfuron-sodium 0.016 kg ai/ha. Crop oil concentrate was added to atrazine, diuron plus hexazinone, and pyraflufen-ethyl treatments at 1% (v/v). Nonionic surfactant was added to carfentrazone-ethyl, flumioxazin, sulfentrazone, and trifloxysulfuron-sodium treatments at 0.25 % (v/v). Of the herbicides evaluated atrazine, diuron, hexazinone, flumioxazin, sulfentrazone, and trifloxysulfuron-sodium would have both PRE and POST activity whereas carfentrazone and pyraflufen-ethyl would have only POST activity. Herbicides were applied on July 21, 2003, and July 28, 2004, to 38 to 76 cm red morningglory. Visual control of red morningglory was determined 10 and 28 DAT based on a scale of 0 to 100 % with 0 = no control and 100 = all plants present at application dead and no new plants emerged. The 10 DAT rating would be reflective of POST activity of the herbicides and the 28 DAT rating would be reflective of both the initial POST control and any regrowth that may have occurred combined with the soil residual activity on weeds emerging after the application. At application soil was moist and rainfall was received within 10 d after application both years.

PRE Residual Study. Experiments were conducted in 2004 and 2005 to evaluate residual control of red morningglory with PRE herbicides typically used after the layby cultivation in sugarcane. Treatments included atrazine at 1.12, 2.24, 3.36 and 4.48 kg/ha; a premix of diuron plus hexazinone at 1.05 + 0.30, 1.57 + 0.44, and 2.10 + 0.59 kg/ha; flumioxazin at 0.07, 0.14, 0.21 and 0.29 kg/ha; sulfentrazone at 0.16, 0.21, 0.26, 0.32, 0.37, and 0.42 kg/ha; and metribuzin at 1.68 and 2.52 kg ai/ha. Visual control of red morningglory was determined 35, 49, 63, and 77 DAT (\pm 3 d) based on a scale of 0 to 100% with 0 = no control and 100 =

no plants emerged. At each rating date, glufosinate at 0.37 kg ai/ha was applied to the entire experimental area. Glufosinate provided complete control of all weeds thereby allowing for residual effects of the herbicides to be determined out to 77 DAT. Soil was tilled 1 to 2 days prior to application to represent a layby cultivation in sugarcane. At application soil was moist and rainfall to activate the PRE herbicides was received within 7 d after application both years.

Trifluralin/Sulfentrazone PPI/PRE Residual Study. Experiments were conducted in 2004 and 2005 to evaluate residual control of red mornigg glory with sulfentrazone soil incorporated and applied to soil surface. Treatments included trifluralin at 2.24 kg ai/ha preplant incorporated (PPI) once using a field cultivator; trifluralin at 2.24 kg/ha plus sulfentrazone at 0.21, 0.26, 0.35, and 0.42 kg/ha PPI; trifluralin at 2.24 kg/ha PPI followed by sulfentrazone at 0.21, 0.26, 0.35, and 0.42 kg/ha PRE applied to the soil surface; and sulfentrazone at 0.21, 0.26, 0.35, and 0.42 kg/ha PRE applied to a tilled seedbed. Treatments were selected because trifluralin is widely used for grass control at the layby cultivation in sugarcane. The addition of sulfentrazone would save an extra trip across the field. Visual control of red morningglory was determined 35, 49, 63, and 77 DAT (± 3 d) based on a scale of 0 to 100% with 0% = no control and 100 % = no plants emerged. As also indicated for the PRE study, after each rating date, glufosinate at 0.37 kg/ha was applied to the entire experimental area to allow for determination of residual control. At application soil was moist and rainfall to activate the PRE herbicides was received within 7 d after application both years.

Data for all studies were subjected to the Mixed Procedure in SAS¹. Years, replications (nested within years), and all interactions containing either of these effects were considered random effects (Carmer et al. 1989). All other variables were considered fixed effects.

¹SAS institute. 2003. SAS User's Guide: Statistics. Version 9.1. SAS Institute. Cary, NC.

Considering years as environmental or random effects permit inferences about treatments to be made over a range of environments (Carmer et al. 1989; Hager et al. 2003). Least square means were calculated and mean separation was performed using Fisher's protected LSD at $P \leq 0.05$. Letter groupings were converted using the PDMIX800 macro in SAS (Saxton 1998). In the PRE study and in the trifluralin/sulfentrazone PPI\PRE residual study each treatment was also subjected to repeated measures data analysis to compare weed control response over time.

Results and Discussion

POST Study. The standard treatment for morningglory control in sugarcane is atrazine. The ability of atrazine to provide control of emerged morningglory and also to provide soil residual activity would aid in reducing weed regrowth and reinfestation. Red morningglory was controlled 78 and 84 % 10 DAT with atrazine at 2.24 and 3.36 kg/ha, respectively (Table 2.1). Equivalent red morningglory control to that of atrazine at 3.36 kg/ha was obtained 10 DAT with carfentrazone-ethyl at 0.026 and 0.035 kg/ha; and with diuron plus hexazinone; flumioxazin; and sulfentrazone at all rates evaluated. When compared with atrazine at 2.24 kg/ha, red morningglory control 10 DAT was greater for carfentrazone at 0.035 kg/ha, diuron plus hexazinone at 1.57 + 0.44 kg/ha and 2.10 + 0.59 kg/ha, and flumioxazin and sulfentrazone at both rates, and control with these treatments was 88 to 94 %. Carfentrazone-ethyl at 0.009 kg/ha, hexazinone at 0.56 kg/ha, pyraflufen-ethyl at 0.007 and 0.015, and trifloxysulfur sodium at 0.016 kg/ha controlled red morningglory 10 DAT no more than 66 %. Of the herbicides evaluated, weed response to rate was most apparent with carfentrazone-ethyl where red morningglory control 10 DAT increased from 24 to 88 % as rate increased from 0.009 to 0.035 kg/ha.

Table 2.1. Red morningglory control with postemergence herbicides 10 and 28 d after treatment (DAT).^a

Herbicide ^b	Rate	10 DAT	28 DAT
	kg ai/ha	%	
Atrazine	2.24	78 de ^c	79 d
Atrazine	3.36	84 bcd	92 abc
Carfentrazone-ethyl	0.009	24 h	44 hi
Carfentrazone-ethyl	0.018	74 ef	54 fg
Carfentrazone-ethyl	0.026	80 cde	66 e
Carfentrazone-ethyl	0.035	88 abc	80 d
Diuron + hexazinone	1.05 + 0.30	84 bcd	85 cd
Diuron + hexazinone	1.57 + 0.44	92 ab	95 ab
Diuron + hexazinone	2.10 + 0.59	93 ab	97 a
Flumioxazin	0.14	89 abc	87 bcd
Flumioxazin	0.29	91 ab	91 abc
Hexazinone	0.56	66 f	63 ef
Pyraflufen-ethyl	0.007	38 g	34 i
Pyraflufen-ethyl	0.015	65 f	52 gh
Sulfentrazone	0.32	93 ab	87 bcd
Sulfentrazone	0.42	94 a	89 abcd
Trifloxysulfuron-sodium	0.016	43 g	58 efg

^aHerbicide treatments were applied July 21, 2003 and July 28, 2004, when weeds were 38 to 76 cm in height. Rainfall was received within 10 d after application both years.

^bCrop oil concentrate was added to atrazine, diuron plus hexazinone, and pyraflufen-ethyl treatments at 1% (v/v). Nonionic surfactant was added to carfentrazone-ethyl, flumioxazin, hexazinone, sulfentrazone, and trifloxysulfuron-sodium treatments at 0.25 % (v/v).

^cMeans within a column followed by the same letter are not significantly different using Fisher's protected LSD ($P \leq 0.05$).

At 28 DAT atrazine at 3.36 kg/ha controlled red morningglory 92 % which was greater than the 79% control with 2.24 kg/ha (Table 2.1). Red morningglory control 28 DAT was equivalent to that observed with atrazine at 3.36 kg/ha for all rates of diuron plus hexazinone, flumioxazin, and sulfentrazone. Compared with atrazine at 2.24 kg/ha red morningglory control was greater for diuron plus hexazinone at 1.57 plus 0.44 and 2.10 plus 0.59 kg/ha. Red morningglory control increased as carfentrazone-ethyl rate increased and at 0.035 kg/ha red morningglory was controlled 80% 28 DAT. Control of red morningglory 28 DAT was no more than 66 % with carfentrazone-ethyl at 0.009, 0.018, and 0.026 kg/ha, hexazinone at 0.56 kg/ha, pyraflufen-ethyl at 0.007 and 0.015 kg/ha, and trifloxysulfuron-sodium at 0.016 kg/ha.

In this study none of the herbicide treatments provided greater red morningglory control than atrazine at 3.36 kg/ha 28 DAT. However, where atrazine rate was reduced to 2.24 kg/ha the higher rates of diuron plus hexazinone and the highest rate of flumioxazin were more effective in controlling red morningglory. In this study weed control ratings were not made past 28 DAT and long term residual control with the herbicides could not be evaluated. Other research has shown excellent POST control of red morningglory with atrazine and sulfentrazone (Siebert et al. 2004). The advantage of using atrazine, diuron plus hexazinone, flumioxazin, and sulfentrazone over carfentrazone-ethyl or pyraflufen-ethyl would be the additional soil residual activity that could be expected when herbicides are applied POST.

PRE Residual Study. This study allowed for the comparison of residual control of red morningglory with soil applied herbicides out to 77 DAT. Glufosinate applied at each rating date completely eliminated red morningglory competition to allow for residual control ratings to be made. Red morningglory control 35 DAT was at least 90% with atrazine at 3.36 and 4.48 kg/ha; diuron plus hexazinone at 1.57 + 0.44 and 2.10 + 0.59 kg/ha; flumioxazin at 0.14,

0.21, and 0.29 kg/ha; sulfentrazone at 0.21, 0.26, 0.32, 0.37, and 0.42 kg/ha; and metribuzin at 2.52 kg/ha (Table 2.2). Red morningglory control 35 DAT increased when atrazine rate increased from 1.12 to 2.24 kg/ha (78 to 88 %), when diuron plus hexazinone rate increased from 1.05 + 0.30 to 1.57 + 0.44 kg/ha (84 to 94 %), and when flumioxazin rate increased from 0.07 to 0.14 kg/ha (63 to 92%). Increasing sulfentrazone rate from 0.16 to 0.21 kg/ha increased red morningglory control from 87 to 96%.

By 49 DAT red morningglory control with atrazine at the highest rate was only 70 % and control for all atrazine rates was less than that observed 35 DAT (Table 2.2). Diuron plus hexazinone at the two lowest rates and flumioxazin at the two highest rates controlled red morningglory equivalent to atrazine, but control with metribuzin was less than that for atrazine. In contrast, sulfentrazone at 0.21 to 0.42 kg/ha controlled red morningglory at least 93 % 49 DAT and control was unchanged from the earlier rating. None of the other herbicide treatments controlled red morningglory equal to that of sulfentrazone at 0.21 kg/ha and only diuron plus hexazinone at 1.57 + 0.44 and 2.10 + 0.59 kg/ha controlled red morningglory equivalent to that of sulfentrazone at 0.16 kg/ha (80 %)

By 63 DAT red morningglory was controlled no more than 53 % with atrazine and for the highest rate of atrazine, control was less than what was observed 49 DAT (Table 2.2). Diuron plus hexazinone at all rates and flumioxazin at the three highest rates controlled red morningglory equivalent to that of atrazine at 4.48 kg/ha (53 %). Red morningglory control was no more than 41 % with metribuzin. For all rates of diuron plus hexazinone and metribuzin, control at 63 DAT was less than that observed 49 DAT. For sulfentrazone at 0.21 kg/ha and higher, red morningglory was controlled at least 83 %, and for the low rate of sulfentrazone (0.16 kg/ha) red morningglory control was 69 % and greater than for all other treatments except

Table 2.2. Red morningglory residual control with preemergence herbicides 35, 49, 63, and 77 d after treatment (DAT).^a

Herbicide	Rate	35 DAT	49 DAT	63 DAT	77 DAT
		%			
Atrazine	1.12	78 f A _b	49 ef B	46 ef BC	27 fg C
Atrazine	2.24	88 cde A	69 d B	50 de C	30 efg D
Atrazine	3.36	92 abcd A	69 d B	53 cde BC	44 cd C
Atrazine	4.48	90 abcde A	70 d B	53 cde C	39 cde C
Diuron plus hexazinone	1.05 + 0.30	84 ef A	70 d A	54 cd B	39 cde C
Diuron plus hexazinone	1.57 + 0.44	94 abcd A	76 bcd B	59 c C	43 cd D
Diuron plus hexazinone	2.10 + 0.59	96 abc A	79 bc B	61 bc C	46 c D
Flumioxazin	0.07	63 g A	44 f AB	39 fg B	26 fg B
Flumioxazin	0.14	92 abcde A	55 e B	45 efg BC	36 def C
Flumioxazin	0.21	93 abcd A	68 d B	56 cd BC	43 cd C
Flumioxazin	0.29	96 ab A	71 cd B	61 bc B	46 c C
Sulfentrazone	0.16	87 de A	80 b A	69 b B	64 b B
Sulfentrazone	0.21	96 abc A	94 a A	83 a B	78 a B
Sulfentrazone	0.26	97 a A	94 a A	84 a B	78 a C
Sulfentrazone	0.32	97 a A	94 a A	84 a B	78 a B
Sulfentrazone	0.37	98 a A	93 a A	84 a B	80 a B
Sulfentrazone	0.42	98 a A	94 a A	88 a B	82 a C
Metribuzin	1.68	89 bcde A	55 e B	37 g C	26 g D
Metribuzin	2.52	94 abcd A	54 e B	41 fg C	27 fg D

^aHerbicide treatments were applied June 10, 2004 and May 25, 2005, to soil that had been tilled 1 to 2 d earlier to represent a layby cultivation in sugarcane. Rainfall for activation of herbicides was received within 7 d after application both years. After each rating, glufosinate at 0.37 kg ai/ha was applied to control emerged red morningglory and to allow for residual effects of the herbicide treatments to be determined.

^bMeans within a column followed by the same lowercase letter are not significantly different using Fisher's protected LSD ($P \leq 0.05$). Means within a row followed by the same uppercase letter are not significantly different using Fisher's protected LSD ($P \leq 0.05$).

the highest rates of diuron plus hexazinone and flumioxazin. Even though red morningglory control decreased at 63 DAT for all rates of sulfentrazone compared with 49 DAT control was still around 85 % 63 DAT for the higher rates. Red morningglory control with sulfentrazone is impressive considering that none of the other treatments provided more than 61 % control and that atrazine controlled morningglory no more than 53 %.

At 77 DAT red morningglory control was 78 to 80 % when sulfentrazone was applied at 0.21 kg/ha and higher. The low rate of sulfentrazone controlled red morningglory 64 % and no other treatment provided more than 46 % control. For most rates of sulfentrazone, red morningglory control at 77 DAT was unchanged compared with 63 DAT. However when compared with 49 DAT, red morningglory control had decreased 12 to 16 percentage points for the sulfentrazone rates. For the highest rate of atrazine, diuron plus hexazinone, flumioxazin, and metribuzin red morningglory control ranged from 27 to 46 %.

A limitation in previous research has been the ability to evaluate long term residual control (greater than 28 d) with soil applied herbicides because weeds not initially controlled can restrict emergence and growth of new weeds. This factor was eliminated in this research through use of glufosinate which provided POST control of red morningglory without the soil activity to interfere with evaluation of herbicide treatments. This research shows that in areas with severe red morningglory infestations application of at least 0.21 kg/ha sulfentrazone can provide control of around 80 % for as long as 77 d. Sulfentrazone rate higher than 0.21 kg/ha, however, may be needed on soils with high clay content and organic matter². Atrazine has been widely used as a soil applied treatment for morningglory control in sugarcane. In this study atrazine at 4.48 kg/ha (a rate around four times higher than that used in corn) (Anonymous

²Spartan label. FMC Corporation, Agricultural Products Group. Philadelphia, PA 19103

2006) controlled red morningglory 90 % 35 DAT but only 70 % 49 DAT, clearly showing that long term residual control should not be expected. Even with the label restriction on rate of atrazine in corn, a single application of atrazine in sugarcane in Louisiana can be as high as 4.48 kg/ha (Anonymous 2006). An alternative method to best utilize atrazine for red morningglory control in sugarcane would be to delay application until later in the growing season to take advantage of the 35 d effective control period. The POST activity of atrazine on red morningglory would be advantageous in situations when application is delayed.

Another advantage of atrazine is that it can be applied over the top of sugarcane. Based on current labels, diuron plus hexazinone, flumioxazin, and sulfentrazone would have to be applied as a directed treatment preferably after sugarcane is jointing to avoid crop injury. Later applications of these herbicides, like atrazine, would also extend red morningglory control later into the growing season which would be advantageous. Research has shown that red morningglory seeds can germinate and emerge from May through September and plants can thrive under a 90 % shade environment, which can be expected in a sugarcane crop in Louisiana into July (Jones et al. 2006).

Trifluralin/Sulfentrazone PPI/PRE Residual Study. Red morningglory control was no more than 29 % when trifluralin was applied alone PPI (Table 2.3). At 35 DAT, red morningglory control was at least 95 % when sulfentrazone (0.21 to 0.42 kg/ha) was applied PRE either alone or following trifluralin. When sulfentrazone at 0.21 kg/ha was incorporated with trifluralin, however, red morningglory control was decreased to 89 %. At 49 DAT, red morningglory control when sulfentrazone at 0.21 kg/ha was applied PRE alone or following trifluralin was 90 and 93 %, respectively, but when sulfentrazone at 0.21 kg/ha was incorporated

Table 2.3. Red morningglory control with trifluralin and sulfentrazone applied as preemergence treatments alone, in combination, and sequentially at 35, 49, 63, and 77 d after treatment (DAT).^a

Treatment	Rate kg ai/ha	Timing ^b	%			
			35 DAT	49 DAT	63 DAT	77 DAT
Trifluralin	2.24	PPI	29 d _{Ac}	28 f AB	27 f AB	19 d B
Trifluralin + sulfentrazone	2.24 + 0.21	PPI	89 c A	84 e A	73 e B	68 c B
Trifluralin + sulfentrazone	2.24 + 0.28	PPI	92 bc A	87 de A	80 cd B	79 ab B
Trifluralin + sulfentrazone	2.24 + 0.35	PPI	94 ab A	88 cde A	78 de B	78 ab B
Trifluralin + sulfentrazone	2.24 + 0.42	PPI	95 ab A	92 abc A	84 bc B	84 ab B
Trifluralin fb sulfentrazone	2.24 fb 0.21	PPI fb PRE	97 ab A	93 ab A	83 bcd B	77 b B
Trifluralin fb sulfentrazone	2.24 fb 0.28	PPI fb PRE	97 ab A	92 abc AB	83 bc BC	77 b C
Trifluralin fb sulfentrazone	2.24 fb 0.35	PPI fb PRE	97 a A	92 abc AB	87 ab B	79 ab C
Trifluralin fb sulfentrazone	2.24 fb 0.42	PPI fb PRE	97 a A	94 a AB	90 a B	84 ab C
Sulfentrazone	0.21	PRE	97 ab A	90 abcd AB	84 bc BC	79 ab C
Sulfentrazone	0.28	PRE	95 ab A	89 bcd AB	83 bc BC	82 ab C
Sulfentrazone	0.35	PRE	96 ab A	92 abc A	86 ab B	79 ab C
Sulfentrazone	0.42	PRE	96 ab A	92 abc AB	88 ab BC	86 a C

^aHerbicide treatments were applied on June 10, 2004 and May 25, 2005. Rainfall for activation of herbicides was received within 7 d after application both years. After each rating, glufosinate at 0.37 kg ai/ha was applied to control emerged red morningglory and to allow for residual effects of the herbicide treatments to be determined.

^bTiming treatments consisted of trifluralin alone or with sulfentrazone applied preplant incorporated (PPI), trifluralin PPI followed by (fb) sulfentrazone preemergence (PRE), and sulfentrazone applied PRE. PPI treatments were incorporated using a field cultivator. PRE treatments were applied to the soil surface of a tilled seedbed on the same day as the PPI treatments.

^cMeans within a column followed by the same lowercase letter are not significantly different using Fisher's protected LSD ($P \leq 0.05$). Means within a row followed by the same uppercase letter are not significantly different using Fisher's protected LSD ($P \leq 0.05$).

control decreased to 84 %. When sulfentrazone at higher rates was incorporated red morningglory control in most cases was equivalent to PRE applications. For the individual herbicide treatments red morningglory control did not change from 35 to 49 DAT. This same response was also observed in the PRE residual study (Table 2.2). Additionally, red morningglory control did not change for individual rates of sulfentrazone applied PRE either alone or following trifluralin.

At 63 DAT red morningglory control with sulfentrazone applied PRE was 83 to 90 % and for only the lowest rate of sulfentrazone incorporated with trifluralin was weed control less than the same rate applied PRE (73 vs. around 84%) (Table 2.3). In most cases red morningglory control with sulfentrazone applied PRE was not increased as rate increased from 0.21 to 0.42 kg/ha. A decrease in weed control with sulfentrazone at 0.21 kg/ha incorporated with trifluralin compared with a PRE application of sulfentrazone was also observed 77 DAT (68 vs. around 78 %), but differences in weed control related to method of application were not noted for other rates of sulfentrazone. In most cases weed control with individual sulfentrazone treatments did not change from 63 to 77 DAT, but for all treatments control was less than what was observed 35 DAT. For the PPI treatments with sulfentrazone control at 63 and 77 DAT was less than what was observed 49 DAT.

Trifluralin is commonly used in sugarcane to control grass weeds. It would be desirable if morningglory is a problem to apply sulfentrazone with the trifluralin to save a trip over the field. This study shows that if sulfentrazone at 0.21 kg/ha is to be incorporated with trifluralin, red morningglory control would be sacrificed if compared with the same rate applied to the soil surface. A sulfentrazone rate of at least 0.28 kg/ha would be needed to maximize red morningglory control when herbicide is incorporated.

In sugarcane, control of red morningglory is critical to prevent climbing and wrapping of sugarcane plants and subsequent decrease in yield and harvest efficiency. Ideally, herbicides used to control morningglory should have PRE and POST activity and should have excellent crop safety. The capability to apply herbicides over the top of sugarcane would increase versatility and weed control options. Atrazine offers all these benefits, but length of residual control of red morningglory under Louisiana conditions is limited to around five weeks and is rate dependent. For atrazine to be most effective application should be delayed until later in the growing season (4 to 6 weeks after the layby cultivation in May) when both foliar and soil residual activity could be appreciated. Current label restrictions would limit the use of diuron plus hexazinone, flumioxazin, sulfentrazone, and trifloxysulfuron-sodium to POST directed application. Sulfentrazone provided longer residual red morningglory control than atrazine and the other alternative herbicides and would have a fit when either incorporated at the layby cultivation with trifluralin or when applied to the soil surface after cultivation.

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CHAPTER 3

RED MORNINGGLORY (*IPOMOEA COCCINEA*) RESPONSE TO TILLAGE AND SHADE

Introduction

In 2004 in Louisiana, sugarcane was grown on 186,860 ha with an average yield of 6,196 kg sugar/ha (Anonymous 2005). Sugarcane is grown as a perennial with three to five annual harvests made from a single, vegetatively propagated planting. During the entire crop cycle, the row tops are relatively undisturbed which contributes to weed proliferation. Both grasses and broadleaf weeds are problematic in sugarcane. Especially troublesome are morningglory. In Louisiana, morningglory species include ivyleaf morningglory [*Ipomoea hederacea* (L.) Jacq], entireleaf morningglory (*Ipomoea hederacea* var. *integriuscula* Gray), pitted morningglory (*Ipomoea lacunosa* L.), smallflower morningglory [*Jacquemontia tamnifolia* (L.) Griseb.], and red morningglory (*Ipomoea coccinea* L.). Red morningglory is both the most common and troublesome broadleaf weed in Louisiana sugarcane (Webster 2000). Season-long red morningglory competition with sugarcane has reduced sugar yields 24 to 30 % (Millhollon 1988). Germination and emergence of morningglories after the layby cultivation result in climbing and wrapping of sugarcane stalks reducing the number of millable stalks per hectare.

Morningglory seeds germinate over a wide range of temperatures (Cole and Coats 1973; Egley 1990; Gomes et al. 1978; Hardcastle 1978). Hardcastle (1978) in a laboratory study reported red morningglory germination was favored by 144 h of 20 to 30 C temperatures. In Louisiana these soil temperature levels would occur when layby tillage in sugarcane is performed in May (Viator et al. 2002). Tillage stimulates germination of weed seeds by aerating soil and repositioning seeds closer to the soil surface where conditions are more

favorable to germination (Eagley 1986). In sugarcane, tillage is usually accompanied by a flush of new weed seedlings. The extent that seedlings develop and compete with sugarcane is dependent on rainfall, effectiveness of soil applied herbicides, and competition from the sugarcane crop.

Sugarcane is a rapidly growing crop often growing as much as 2.5 cm per d during the hottest part of the growing season (B. Legendre, personal communication). Rapid shading of row middles by sugarcane plants is essential to aid in weed control late in the season when herbicides become ineffective. It is not uncommon for red morningglory to germinate late in the growing season under a heavy crop canopy.

The fact that red morningglory emerges late into the growing season in sugarcane in Louisiana suggests that it may be somewhat shade tolerant. Murdock et al. (1986) reported decreased pitted morningglory emergence and dry weight as soybean [*Glycine max (L.) Merr.*] row spacing decreased from 91 to 30 cm due to more rapid shading with the closer row spacing. Norsworthy (2004) reported that pitted morningglory emergence was not influenced by soybean canopy formation, but sicklepod [*Senna obtusifolia (L.) Irwin and Barneby*] and common cocklebur (*Xanthium strumarium L.*) emergence were reduced as much as 68 and 33 %, respectively. Giant foxtail (*Setaria faberi Herrm.*) seed weight and above ground dry weight decreased linearly with increasing shade intensity (Knake 1972). Decreases were attributed to fewer leaves, stems, and fruiting structures per plant. Shading also affected giant foxtail internode length, but not the number of nodes per plant. Giant foxtail was unable to survive in a 95 % or greater shade environment, again emphasizing the importance of crop canopy in reducing weed competition.

Research to address weed response to shade has been conducted with field bindweed (*Convolvulus arvensis L.*) (Dall'Armellina and Zimdahl 1988), yellow (*Cyperus esculentus L.*)

and purple nutsedge (*Cyperus rotundus* L.) (Keeley and Thullen 1978; Patterson 1982a; Santos et al. 1997), showy croton (*Crotalaria spectabilis* Roth) (Patterson 1982b), velvetleaf (*Abutilon theophrasti* Medik.) (Bello et al. 1995), and silverleaf nightshade (*Solanum elaeagnifolium* Cav.) (Boyd and Murray 1982). Shading has affected shoot number, plant height, leaf and stem dry weight, leaf area, chlorophyll content per unit leaf area, and reproductive development. This research was conducted to evaluate the effect of tillage and shade on red morningglory seedling emergence and growth. Photosynthetically active radiation (PAR) at ground level in the row middle for four sugarcane varieties was measured to relate changes in shading provided by the sugarcane canopy to potential for red morningglory competition. Results from this research would be directly applicable to the development of effective and season long weed control programs.

Materials and Methods

Field research was conducted near Port Allen, LA, in West Baton Rouge Parish in a fallowed sugarcane field with a natural red morningglory infestation to evaluate response to tillage and shade. The soil type was a Commerce silt loam (fine-silty, mixed, superactive, nonacid, thermic Fluvaquentic Endoaquepts) with 1.8 % organic matter and a pH of 6.5.

Tillage Study. For the tillage study a completely randomized design was used and experiments were conducted in 2001, 2002, and 2004. Three areas, each 9.1 by 9.1 m, were used to compare red morningglory emergence following weed removal by tillage or chemical treatment (no tillage). Red morningglory emergence was determined from 10 sub-plots measuring 0.28 m² and selected at random in each treatment in July, August, and September in 2001, 2002, and 2004. Experiments were initiated in June each year with tillage of the entire treatment area. After seedlings were counted in July, August, and September weeds were

removed using a rotary tiller set a depth of 10.2 cm or chemically using glufosinate at 0.37 kg ai/ha and for both treatments complete control of emerged seedlings was obtained. Additionally, bulb planters were used to take soil core samples 6.4 cm in diameter and 10.2 cm in depth from each subplot within the two tillage treatments and in a season long undisturbed control at initiation of the study each year in June and at completion of the study in October. In the season long undisturbed control flowering and seed production occurred and seeds were visible on the soil surface in October. For all treatments soil core samples were taken with minimal disturbance of the soil and care was taken in the undisturbed control to collect seed present on the soil surface. Soil core samples were placed between two 18 mesh (1 mm openings) testing sieves and soil was washed from the sample and red morningglory seeds were counted. Only seeds that were full and hard to the touch were considered in the counts. No attempt was made to evaluate seed germination or viability.

Shade Study. For the shade study the experimental design was a randomized complete block with four replications and four experiments per year were conducted in 2001, 2002, and 2004. Shading was achieved by use of 0.6 by 0.6 by 0.6-m wooden structures covered with black polypropylene fabric³ used as shading material. Intensities of shade were 0, 30, 50, 70, and 90% (100, 70, 50, 30, or 10% of full sun light). Shade intensities expressed as PAR with the polypropylene fabric were confirmed within three percent using an AccuPAR Linear PAR Ceptometer⁴. To initiate the study, the experimental area was tilled to a 10.2 cm depth with a rotary tiller. Data including red morningglory seedling emergence, plant height, total above ground biomass, leaf and stem weight per plant, and leaf area per plant were collected 20 to 41 d after each tillage operation and when red morningglory plants in the 0% shade treatment

³DeWitt Company, 905 S. Kings Highway, Sikeston, MO 63801

⁴Decagon Devices, Inc., 950 NE Nelson Court, Pullman, WA 99163

reached three to six leaf. Data were collected for the individual experiments on June 21, July 21, August 11, and September 21, 2001; June 19, July 16, August 14, and September 5, 2002; and July 15, August 11, September 27 and November 1, 2004. Leaf area was measured using a LI-Cor LI-3100 area meter⁵. Data were averaged across the three years and four experiments within each year and data are expressed as a percent of no shade (full sun) treatment. For the no shade (full sunlight) treatment seedling emergence, plant height, total above ground biomass, biomass per plant, leaf weight per plant, stem weight per plant, leaf area, and leaf weight:leaf area ratio averaged 20 plants per shade enclosure (92/m²), 9.94 cm, 4.9 g, 0.24 g, 0.15 g, 0.09 g, 31.5 cm², and 0.0048 g/cm², respectively.

In both the tillage and shade studies data were subjected to the Mixed Procedure in SAS⁶. Each year/experiment was considered an environment sampled at random as suggested by Carmer et al. (1989). Environment, replications (nested within environment), and all interactions containing either of these effects were considered random effects. All other variables were considered fixed effects. Considering years as environmental or random effects permit inferences about treatments to be made over a range of environments (Carmer et al. 1989; Hager et al. 2003). Least square means were calculated and mean separation was performed using Fisher's protected LSD at P_u 0.05. Letter groupings were converted using the PDMIX800 macro in SAS (Saxton 1998).

In conjunction with the shade study, changes in light penetration into sugarcane canopy for the varieties 'LCP 85-384', 'L 97-128', 'HoCP 96-540', and 'Ho 95-988' were measured in 2005 at St. Gabriel Research Station in St. Gabriel, LA. A completely randomized design with three replications was used. PAR was measured with an AccuPAR Linear PAR Ceptometer⁴ in

⁵ LI-COR Biosciences, 4421 Superior Street, Lincoln, NE 68504-0425

⁶ SAS institute. 2003. SAS User's Guide: Statistics. Version 9.1. SAS Institute. Cary, NC.

each plot and 10 subsamples were taken. Data were subjected to ANOVA and means separated using Fisher's protected LSD.

Results and Discussion

Tillage Study. Red morningglory emergence on the July, August, and September sampling dates represented the number of seedlings present around 4 weeks after plots were either tilled or not tilled. For the no tillage treatment, glufosinate was applied and all weeds, as for the tillage treatment, were eliminated without affecting weed reinfestation. On the July sampling date red morningglory emergence was equal whether soil was tilled or not tilled and emergence averaged 69.1 plants/m² (Table 3.1). In August, weed emergence was 50.8 % greater when plots were tilled 4 weeks earlier as compared with plots that had not been tilled. For the September sampling date only 15.1 plants/m² emerged in the no tillage plots, 74.0 % less than when plots were tilled. Total season emergence was 128.5 plants/m² in the no tillage plots compared with 194.4 plants/m², a 1.5 fold increase where plots were tilled.

For the tillage treatment red morningglory emergence across the growing season did not change (Table 3.1). This was probably due to aeration of soil and repositioning of weed seeds with tillage operations which stimulated seed germination and seedling emergence. The decrease in red morningglory emergence as the season progressed for the no tillage treatment and the greater separation between tillage treatments for the September sampling date was probably due to soil compaction from lack of tillage and the fact that most seeds that could germinate had already germinated earlier in the season.

Soil samples were collected in June when the study was initiated and in October when the study was terminated. The decrease in seed population would be directly related to the number of seedling that had emerged across the growing season as well as seeds that may have

Table 3.1. Red morningglory seedling emergence from June through September as influenced by tillage.^a

Treatment ^b	Sampling date			
	July	August	September	Total
	no./m ²			
No tillage	68.9 _{ac}	44.5 _b	15.1 _c	128.5 ^{*c}
Tillage	69.2 _a	67.1 _a	58.1 _{ab}	194.4

^aExperiments were conducted in 2001, 2002, and 2004. In June of each year experimental areas were tilled using a rotary tiller set at a depth of 10.2 cm.

^bFor the no tillage treatment glufosinate at 0.37 kg ai/ha was used to eliminate weeds after data were collected each month. For the tillage treatment soil was tilled after data were collected each month using a rotary tiller set at a depth of 10.2 cm.

^cMeans within rows and columns followed by the same letter are not significantly different using Fisher's protected LSD ($P \leq 0.05$). An asterisk (*) indicates that total seedling emergence was different for the tillage treatments.

deteriorated. In the season long undisturbed control red morningglory flowered and set seed. In October, seeds were visible on the soil surface in the undisturbed control. When the study was initiated seed population was not different among the tillage treatments and the area designated as the undisturbed control and seed population averaged 4.2 seeds/core (Table 3.2). In October the seed bank had decreased 37.5 % for the no tillage treatment and 31.8 % for the tilled treatment. In contrast, seed population in the undisturbed control increased 1.4 fold across the growing season. The soil seed population in October was equal for the tillage treatments and averaged 54.2% less than the undisturbed control. Strahan et al. (1999) reported that for itchgrass (*Rottboellia cochinchinensis L.*), another major weed problem in Louisiana sugarcane, frequent tillage during a single summer fallow period reduced the seed population in the soil by approximately 95 %. A no tillage fallow program where herbicide was used to kill emerged itchgrass periodically throughout the summer fallow period was as effective in reducing the seed reservoir of seed as was frequent tillage. In a multi-state study, spring soil disturbance either had no effect or soil disturbance reduced total seedling emergence compared with undisturbed soils and the response was weed species and location dependent (Myers et al. 2005).

In the present study results show, regardless of whether soil was tilled or not tilled, a significant reduction in red morningglory seed population in the soil occurred from June through October. However, for the experimental site used in this study a significant population of red morningglory seeds was still present at the end of the growing season. The significant reduction in seedling emergence in September when plots were not tilled suggests that elimination of tillage can affect red morningglory seedling emergence and may provide a cultural control method to help in management of red morningglory in sugarcane. Research has

Table 3.2. Number of red morningglory seeds in soil core samples collected at initiation of the study in June and at completion in October.^a

Treatment ^b	Sampling date	
	June	October
	no./soil core sample	
No tillage	4.0 _{bc}	2.5 _d
Tillage	4.4 _b	3.0 _{cd}
Season long undisturbed	4.2 _b	6.0 _a

^aExperiments were conducted in 2001, 2002, and 2004. In June of each year experimental areas were tilled using a rotary tiller set at a depth of 10.2 cm. Soil core samples were 6.4 cm in diameter and 10.2 cm in depth.

^bFor the no tillage treatment glufosinate at 0.37 kg ai/ha was used to eliminate weeds every four weeks across the growing season. For the tillage treatment soil was tilled every four weeks across the growing season using a rotary tiller set at a depth of 10.2 cm.

^cMeans within rows and columns followed by the same letter are not significantly different using Fisher's protected LSD ($P \geq 0.05$).

shown positive economic benefit to eliminating tillage operations in sugarcane without sacrificing crop yield (Wilson et al. 2006).

Shade Study. For the shade study data were collected 20 to 41 d after each tillage operation and when red morningglory plants in the no shade (full sun) treatment reached three to six leaf. Data are expressed as a percent of the no shade treatment and represent an average across three years with four experiments conducted each year. Emergence of red morningglory decreased 5 and 8% for the 30 and 50 % shade treatments, respectively, compared with full sun (Table 3.3). Increasing shade to 70 and 90% decreased seedling emergence 37 and 43%, respectively.

Norsworthy (2004) reported that pitted morningglory emergence was not influenced by shading in soybean planted in narrow and wide row spacings compared with a non-crop treatment. Murdock et al. (1986), however, reported decreased pitted morningglory emergence and dry weight in soybean planted in closer row spacings. In the present study shade, however, did not affect height of red morningglory. Variability in height observed among plants within each treatment contributed to the inability to detect significant differences. Total above ground biomass under 50, 70, and 90 % shade decreased 19, 35, and 58 %, respectively, compared with full sun (Table 3.3). When expressed on a per plant basis above ground biomass decreased 27 % under 70 % shade and 48 % under 90 % shade. For giant foxtail above ground dry weight decreased linearly with increasing shade intensity (Knake 1972). Decreases were attributed to fewer leaves, stems, and fruiting structures per plant. Shading also affected giant foxtail internode length, but not the number of nodes per plant.

In the present study as shade increased fewer plants emerged and produced less biomass (Table 3.3). Of interest is how the reduced biomass was partitioned into leaves and stems. Leaf weight per plant was reduced when compared with full sunlight only for the 90 % shade

Table 3.3. Influence of shade on red morningglory seedling emergence, plant height, total above ground biomass, and above ground biomass per plant expressed as percent of no shade (full sun) treatment.^a

Shade level	Seedling emergence	Plant height	Total above ground biomass	Above ground biomass per plant
%		% full		
0	100 ^{ab}	100 a	100 a	100 a
30	95 b	127 a	90 ab	92 a
50	92 b	135 a	81 bc	87 a
70	63 c	119 a	65 c	73 b
90	57 c	124 a	42 d	52 c

^aExperiments were conducted in 2001, 2002, and 2004. Data collected 20 to 41 days after tillage and installation of shade enclosures when red morningglory plants in full sun reached 3- to 6-leaf stage. Data averaged across three years and four experiments within each year. For the no shade (full sunlight) treatment seedling emergence, plant height, total above ground biomass, and biomass per plant averaged 20 per shade enclosure (92/m²), 9.94 cm, 4.9 g, and 0.24 g, respectively.

^bMeans within each column followed by the same letter are not significantly different using Fisher's protected LSD (P \leq 0.05).

treatment (48 % reduction) (Table 3.4). Stem weight per red morningglory plant was reduced for both the 70 and 90 % shade treatments (31 and 50 % reduction, respectively). Leaf area per plant, however, increased under all shade environments (19 to 48% increase compared with full sun). Under 90 % shade, leaf area per plant was less than for 30 % shade but equal to the 50 and 70% shade treatments. Additionally, the leaf weight:leaf area ratio was less for all shade treatments compared with full sun. The ratio was less for the 90 % shade treatment compared with 30, 50, or 70 % shade. This showed that under shade, red morningglory plants produced leaves with less weight but with greater leaf area. Leaf thickness and density could come into play here but those variables were not measured.

Results show that red morningglory deprived of sunlight is capable of partitioning growth into leaves rather than stems. Increased partitioning of plant biomass into leaves and away from stems has also been reported for showy crotalaria (Patterson 1982b). Boyd and Murray (1982) reported silverleaf nightshade had increased leaf area when shade was increased, however, leaf weight per unit area decreased because leaf thickness was affected.

Results show that as shade increased fewer red morningglory plants with less weight were present. However, plants grown in 90 % shade, compared with plants in full sun, produced more leaf area increasing the potential for photosynthetic activity allowing plants to survive. The ability of red morningglory to germinate and emerge under a 90 % shade environment emphasizes the importance of rapid crop canopy development. This research was conducted with the intent to relate the response of red morningglory to shade to what could happen under a sugarcane canopy. Sugarcane in Louisiana because of the short growing season must grow and accumulate sugar rapidly to be adaptable. During the grand growth stage, between late June (when sugarcane internode elongation begins) and September, sugarcane can grow in excess of

Table 3.4. Influence of shade on red morningglory leaf and stem weight per plant, leaf area per plant, and leaf weight:leaf area ratio expressed as percent of no shade (full sun) treatment.^a

Shade level	Leaf weight per plant	Stem weight per plant	Leaf area per plant	Leaf weight:leaf area
%	% full			
0	100 a	100 a	100 c	100 a
30	89 a	97 a	148 a	62 b
50	80 ab	93 ab	133 ab	61 b
70	77 ab	69 bc	131 ab	59 b
90	52 b	50 c	119 b	46 c

^aExperiments were conducted in 2001, 2002, and 2004. Data collected 20 to 41 days after tillage and installation of shade enclosures when red morningglory plants in full sun reached 3-to 6-leaf stage. Data averaged across three years and four experiments within each year. For the no shade (full sunlight) treatment leaf weight per plant, stem weight per plant, leaf area, and leaf weight:leaf area ratio averaged 0.15 g, 0.09 g, 31.5 cm², and 0.0048 g/cm², respectively.

^bMeans within each column followed by the same letter are not significantly different using Fisher's protected LSD (P \geq 0.05).

2.5 cm per day (B. Legendre personal communication). Varieties that produce a high population of stalks per hectare with leaves less upright in growth habit would be expected to be more competitive with weeds in respect to shading. Most weeds in Louisiana sugarcane are shade intolerant and herbicide programs combined with rapid sugarcane growth result in excellent late season control. With red morningglory, however, research shows that plants are shade tolerant. Of interest therefore would be how the shade environment changes within the sugarcane canopy and how this might vary depending on variety.

Sugarcane varieties, LCP 85-384, L 97-128, HoCP 96-540, and Ho 95-988 did not differ in regard to PAR in the row middle at ground level for any of the sampling dates (Table 3.5). On June 13, PAR for the varieties averaged 48 % and decreased to an average of 24 % on July 6 and 9% on July 21. Using the red morningglory response data to shade it would be expected that plants would be capable of emerging and growing into late July and August underneath a sugarcane canopy. To exacerbate the problem soil applied herbicide such as atrazine applied in May would be effective on red morningglory for only around five weeks (Jones et al. 2006). If red morningglory pressure is high, germination and emergence late in the growing season and subsequent climbing and wrapping of sugarcane stalks would be expected. Findings further emphasize the need to develop weed control programs for red morningglory that increase residual activity of soil applied herbicides and extend weed control into August.

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Table 3.5. Photosynthetically active radiation (PAR) at ground level for four sugarcane varieties grown in Louisiana.^a

Sugarcane Variety	Sampling date		
	June 13	July 6	July 21
	% PAR		
LCP 85-384	46	27	7
L 97-128	48	15	6
HoCP 96-540	64	27	9
Ho 95-988	32	26	12
Average	48a ^b	24b	9c

^aExperiments were conducted in 2005 at the Sugarcane Research Station, St. Gabriel, LA. PAR measured with an AccuPAR Linear PAR Ceptometer using 10 subsamples in each plot and expressed as % of full sunlight.

^bVariety means followed by the same letter are not significantly different using Fisher's protected LSD ($P \leq 0.05$).

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CHAPTER 4

RED MORNINGGLORY (*IPOMOEA COCCINEA*) CONTROL AND COMPETITION IN SUGARCANE

Introduction

Sugarcane (*Saccharum* spp. hybrids) is a tropical crop grown only in Florida, Louisiana, and Texas in the continental U.S. In 2004, sugarcane was grown in Louisiana on 186,865 ha with an average yield of 6,196 kg sugar/ha (Anonymous 2005). Sugarcane in Louisiana is grown as a perennial, with three to five annual harvests made from a single, vegetatively propagated planting. The row tops are relatively undisturbed during the entire crop cycle, which contributes to weed proliferation.

In Louisiana, morningglory emergence is most prevalent after the layby cultivation (Viator et al. 2002b). Although several species of morningglory are present in Louisiana sugarcane fields, red morningglory is particularly problematic. Red morningglory is both the most common and troublesome broadleaf weed in Louisiana sugarcane (Webster 2000). Season-long red morningglory competition with sugarcane has reduced sugar yields as much as 24 to 30 % (Millhollon 1988). Germination and emergence of morningglory is most prevalent after the layby cultivation where climbing and wrapping of sugarcane stalks reduce the number of millable stalks per hectare (Millhollon 1988; Thakar and Singh 1954). Ivyleaf morningglory decreased sugarcane yield 20 to 25 %, mainly from physical hindrance of plant growth and harvestability (Thakar and Singh 1954). Even more troublesome is reduced harvest efficiency, where manual removal of morningglory from the mechanical harvester may be necessary.

In Louisiana in the mid-1990's, as much as 75% of the hectareage received an atrazine application in the spring or at layby to control morningglory (Rogers et al. 1996). The use of atrazine was based on economics and the ability to provide soil residual control. Millhollon (1988) observed 84% control of red morningglory 60 d after treatment (DAT) with 1.8 kg ai/ha atrazine applied PRE in the first year of a two year study. In the second year of the study, red morningglory was controlled 88 to 93 % with atrazine 90 DAT. In this study, atrazine was applied in mid-June, which was standard practice in sugarcane at the time. In recent years, however, growers have reported red morningglory control failures with atrazine applied at layby in early to mid-May (Griffin et al. 2000). Viator et al. (2002a) showed that control failures were not a result of atrazine resistance through an altered triazine binding site. Application of atrazine at 1.68 kg/ha controlled red morningglory 74 and 96 % 45 DAT depending on location in the first year, but control was 71 and 83 % the second year (Viator et al. 2002b). The reduced control of morningglory was attributed to a shift to the sugarcane variety LCP 85-384 and a change in cultural practices in Louisiana, where layby herbicide application is made early to mid-May as opposed to early to mid-June (Viator et al. 2002a). With the earlier application of herbicide, longer residual control from atrazine into the growing season would be expected

Other herbicides labeled for morningglory control in sugarcane include diuron, metribuzin, terbacil, sulfentrazone, and hexazinone plus diuron. Diuron PRE at 1.68 kg ai/ha controlled red mornigglory 53 % 60 DAT and increasing the diuron rate to 2.24 kg/ha increased control to 76% (Millhollon 1988). Viator et al. (2002b) showed diuron at 3.36 kg/ha controlled red morningglory 83 to 99 % 45 DAT in one year, but only 73 to

75 % in another. In the same study, sulfentrazone at 0.14, 0.28, or 0.42 kg ai/ha controlled red morningglory at least 94 % in one year, but no more than 80 % the next year. Red morningglory control with terbacil at 0.84 kg ai/ha or metribuzin at 1.12 kg ai/ha was 92 and 96%, respectively, the first year but was 30 and 60%, respectively, the second year. The difference in control between years was attributed to the timing of activating rainfall, soil pH, and organic matter.

This research was conducted to evaluate control programs for red morningglory that involve herbicides applied at the layby cultivation in May and delayed application of herbicides to extend the residual control period. Additionally, the effect of red morningglory competition on sugarcane growth and yield were evaluated.

Materials and Methods

Experiments were conducted in 2005 near Port Allen, LA, in West Baton Rouge Parish and near White Castle, LA, in Iberville Parish in sugarcane fields with natural infestation of red morningglory. The soil type in West Baton Rouge Parish was a Commerce silt loam (fine-silty, mixed, superactive, nonacid, thermic Fluvaquentic Endoaquepts) with 1.8 % organic matter and a pH of 6.5. The soil type in Iberville Parish was a Commerce silty clay loam (Fine-silty, mixed, superactive, nonacid, thermic Fluvaquentic Endoaquepts) with 1.3 % organic matter and a pH of 6.3. Each experiment was conducted as a randomized complete block with 4 replications. Plot size was 5.5 (3 rows) by 15.2 m. Applications were not made and data were not recorded at the Iberville Parish location after August 11 due to sever lodging of the sugarcane crop.

Red Morningglory Control Study. To initiate the study, the entire experimental area was treated with 2,4-D at 1.12 kg ae/ha on May 25, 2005 to kill emerged red morningglory and complete control was obtained. Layby application was made on May 26, 2005, the first

delayed layby application (DL1) was made on June 23, 2005, and the second delayed layby application (DL2) was made on July 21, 2005. Herbicide treatments applied at the traditional layby timing on May 26 consisted of pendimethalin at 2.78 kg ai/ha plus atrazine at 2.24 or 3.36 kg ai/ha, pendimethalin at 2.78 kg/ha plus sulfentrazone at 0.35 or 0.42 kg ai/ha, and pendimethalin at 2.78 kg/ha alone directed under the sugarcane to the row middles. For the DL1 timing, herbicide application was delayed until June 23 and followed pendimethalin at 2.78 kg/ha on May 26. Treatments for DL1 timing included atrazine at 2.24 and 3.36 kg/ha, sulfentrazone at 0.35 and 0.42 kg/ha, and flumioxazin at 0.14 and 0.28 kg ai/ha. Morningglory present at the application ranged from 2 to 25 cm. For this application herbicide was directed under sugarcane to the row middles. For the DL2 timing, herbicide application was delayed until July 21 and treatments included paraquat at 0.63 kg ai/ha plus atrazine at 2.24 kg/ha and paraquat at 0.63 kg/ha plus sulfentrazone at 0.35 kg/ha. These treatments were directed to the lower 76 cm of the sugarcane stalks and morningglory present at application ranged from 2 to 160 cm. All applications were made with a CO₂ backpack sprayer calibrated to deliver 93.5 l/ha. Surfactant was added to all DL1 and DL2 applications at 0.25 % v/v.

Visual control of red morningglory was determined on June 23, July 21, and August 11. The June 23 rating represents 28 days after the layby application. The July 21 rating represents 56 days after the layby application and 28 days after the DL1 application. The August 11 rating represents 77 days after the layby application, 49 days after the DL1 application, and 21 days after the DL2 application. The ratings scale for weed control ranged from 0 to 100%, with 0 = no control and 100 = all plants present at application dead and no new plants emerged. To provide an estimate of the degree of infestation by red morningglory as affected by the herbicide timing treatments, ratings for stalk wrapping (SW) were made for

each plot based on a scale of 0 to 10, with 0 = no stalks wrapped by red morningglory and 10 = all stalks wrapped to some degree with red morningglory. Another rating was made for each plot to estimate percent of stalk wrapping (PSW) by red morningglory and was based on a scale of 0 to 10, with at 0 = no stalks wrapped and 10 = the whole stalk was wrapped based on an average for all stalks in each plot. These two ratings summed and divided by 20 and expressed as a percent would formulate a percent red morningglory infestation level (IL) where a maximum rating of 10 for each individual rating would correspond to 100%, meaning that all stalks in the plot were wrapped to the top of the crop canopy.

Sugarcane stalk population and height were determined in August only for the West Baton Rouge Parish site. Stalk height was measured from the soil surface to the collar of the youngest leaf on five randomly selected stalks. Plots were hand harvested in early November and ten randomly selected stalks were weighed to determine average stalk weight. Stalk samples were then crushed and the juice was extracted for analysis of theoretical recoverable sugar using standard methodology (Chen and Chou 1993). Sugar yield was calculated by multiplying theoretical recoverable sugar by sugarcane yield⁷.

Red Morningglory Competition Study. To initiate the competition study, the entire experimental area was treated with 2,4-D at 1.12 kg ae/ha on May 25, 2005 to kill emerged weeds and complete control was obtained. Experiments were initiated on May 26. Duration of interference treatments included weed infestation in plots until June 23, until July 21, until August 11, or until August 25, after which plots were maintained weed free for the remainder of the growing season. For the weed free maintenance treatments, plots were maintained weed free

⁷Sugar content of stalks derived from theoretical recoverable sugar expressed as kilograms of sugar per 1,000 kg of sugarcane.

until June 23, until July 21, until August 11, and until August 25, after which red morningglory was allowed to naturally reinfest plots. Season long weed free and season long weedy controls were included for comparison. Atrazine at 2.24 kg/ha, 2,4-D at 0.8 kg/ha plus dicamba at 0.28 kg ai/ha, and hand weeding were used in the season long weed free control and in the duration of interference treatments after the specified dates. For the weed free maintenance treatments, plots were maintained weed free until the specified dates using only 2,4-D plus dicamba and hand weeding. Data collected included infestation by red morningglory at both locations using the ratings scale previously described, and sugarcane height, sugarcane stalk population, and sugarcane and sugar yield at the Port Allen location as described previously.

Data for both studies were subjected to the Mixed Procedure in SAS⁸. Location, replications (nested within location), and all interactions containing either of these effects were considered random effects (Carmer et al. 1989). All other variables were considered fixed effects. Considering locations as environmental or random effects permit inferences about treatments to be made over a range of environments (Carmer et al. 1989; Hager et al. 2003). Least square means were calculated and mean separation was performed using Fisher's protected LSD at $P \leq 0.05$. Letter groupings were converted using the PDMIX800 macro in SAS (Saxton 1998).

Results and Discussion

Red Morningglory Control Study. On June 23, 28 DAT, the pendimethalin plus atrazine or sulfentrazone treatments applied at layby controlled red morningglory at least 94% (Table 4.1). However, on July 21, 56 DAT pendimethalin plus atrazine at 2.24 kg/ha controlled red morningglory 86 % which was less than the 91 to 95 % control with atrazine at 3.36 kg/ha and sulfentrazone at 0.35 and 0.42 kg/ha. Pendimethalin followed by (fb) atrazine, sulfentrazone, or

⁸ SAS institute. 2003. SAS User's Guide: Statistics. Version 9.1. SAS Institute. Cary, NC.

flumioxazin at DL1 provided at least 94% control of red morningglory on July 21, 28 DAT. On August 11 control of red morningglory was no more than 53 % when pendimethalin plus atrazine was applied at layby compared with around 93 % control when pendimethalin was applied with sulfentrazone at the same timing. Delaying application of sulfentrazone following pendimethalin did not change red morningglory control compared with the combination of the two herbicides applied earlier. When atrazine application was delayed following pendimethalin, red morningglory was controlled around 75 % on August 11 and control was greater than when atrazine was applied earlier with pendimethalin. Other research has shown that atrazine will provide residual control of red morningglory for around 35 days whereas sulfentrazone can provide control out to 77 days (Jones et al. 2006). Red morningglory control was no more than 39 % on August 11, 21 DAT when paraquat was applied as a directed treatment with atrazine or sulfentrazone. The poor control was due to lack of coverage of red morningglory foliage which had begun to wrap sugarcane stalks. Neither paraquat nor sulfentrazone are labeled for overtop application to sugarcane at that time during the growing season. It would be expected that weed control would have been excellent for both grass and broadleaf weeds if herbicide had been applied overtop and foliage had been contacted (Anonymous 2006).

Red morningglory infestation was determined by making a SW rating of 0 to 10 and a PSW ratings of 0 to 10 and using these numbers to calculate a red morningglory IL where a value of 100 % would mean that all stalks in the plot were wrapped with morningglory to the top of the crop canopy. On June 23, for the pendimethalin plus atrazine or sulfentrazone treatments applied at layby in May, red morningglory had not emerged and by July 21 red morningglory infestation level was no more than 7 and equal for the treatments (Table 4.2). However, by August 11, 77 DAT, morningglory had wrapped stalks where atrazine was applied at layby and the infestation

Table 4.1. Red morningglory control in sugarcane with herbicide treatments applied at layby and as delayed layby applications.^a

Treatment	Rate	Timing	June 23 ^b	July 21	August 11
	kg ai/ha		-----	% -----	
Pendimethalin + atrazine	2.78 + 2.24	Layby	94 a ^c	86 b	48 de
Pendimethalin + atrazine	2.78 + 3.36	Layby	95 a	91 a	53 d
Pendimethalin + sulfentrazone	2.78 + 0.35	Layby	95 a	94 a	93 a
Pendimethalin + sulfentrazone	2.78 + 0.42	Layby	95 a	95 a	94 a
Pendimethalin fb atrazine	2.78 fb 2.24	Layby fb DL1	0 b	95 a	71 c
Pendimethalin fb atrazine	2.78 fb 3.36	Layby fb DL1	0 b	95 a	76 bc
Pendimethalin fb sulfentrazone	2.78 fb 0.35	Layby fb DL1	0 b	95 a	95 a
Pendimethalin fb sulfentrazone	2.78 fb 0.42	Layby fb DL1	0 b	95 a	95 a
Pendimethalin fb flumioxazin	2.78 fb 0.14	Layby fb DL1	0 b	94 a	71 c
Pendimethalin fb flumioxazin	2.78 fb 0.28	Layby fb DL1	0 b	95 a	85 ab
Paraquat + atrazine	0.63 + 2.24	DL2	0 b	0 c	38 e
Paraquat + sulfentrazone	0.63 + 0.35	DL2	0 b	0 c	39 e

^a Experiments were conducted in 2005 near Port Allen and White Castle, LA. Layby application was made on May 26, 2005, the first delayed layby application (DL1) was made on June 23, 2005, and the second delayed layby application (DL2) was made on July 21 2005. The abbreviation “fb” represents followed by.

^b The June 23 rating date represents 28 days after the layby application. The July 21 rating represents 56 days after the layby application and 28 days after the DL1 application. The August 11 rating represents 77 days after the layby application, 49 days after the DL1 application, and 21 days after the DL2 application.

^c Means within each column followed by the same letter are not significantly different using Fisher’s protected LSD ($P \leq 0.05$).

index was 39%, but morningglory were not present where sulfentrazone was applied at layby. Morningglory continued to infest plots where atrazine was applied with pendimethalin at layby and on November 9 the infestation level was around 55 % compared with no infestation where sulfentrazone was applied with pendimethalin at layby

Where atrazine followed pendimethalin, morningglory was present at time of atrazine application but plants were small (Table 4.2). Atrazine at both rates provided complete control of emerged plants and residual control was provided into July. However, by August 11 red morningglory infestation in the DL1 atrazine treatments was 11 and 4% for the 2.24 and 3.36 kg/ha rates, respectively. By November 9, red morningglory infestation was 23 % for the low rate of atrazine and 5% for the high rate. By delaying atrazine application residual control was obtained later into the growing season thereby extending the effective weed control period. Since red morningglory are capable of germinating and growing under a sugarcane canopy late into the growing season (Jones et al. 2006), delaying atrazine application would be preferred over the traditional application of atrazine at the layby cultivation in May. A different response, however, was observed with sulfentrazone. Whether sulfentrazone was applied with pendimethalin at layby or as a DL1 treatment after pendimethalin red morningglory control was excellent into November (Table 4.2). Sulfentrazone also provided excellent postemergence activity of emerged morningglory when application was delayed. For the DL1 applications herbicides were directed under the crop canopy to provide coverage of emerged weeds and to avoid direct contact with the whorl of the sugarcane plants and subsequent injury that can occur with sulfentrazone and flumioxazin, but not with atrazine. Flumioxazin applied as a DL1 treatment after pendimethalin provided excellent postemergence control of red morningglory as evidenced on July 21, 28 DAT (Table 4.1). However, by August 11 red morningglory had begun to reinfest plots and the

Table 4.2. Red morningglory infestation as influenced by herbicide treatments applied at layby and as delayed layby applications.^a

Treatment	Rate	Timing	June 23			July 21			August 11			November 9		
			SW _b	PSW _b	IL _b	SW	PSW	IL	SW	PSW	IL	SW	PSW	IL
	kg ai/ha													
Pendimethalin + atrazine	2.78 + 2.24	Layby	0 b _c	0 b	0 b	0.5 b	0.8 b	7 b	3.0 b	4.9 b	39 b	5.5 b	5.5 b	55 b
Pendimethalin + atrazine	2.78 + 3.36	Layby	0 b	0 b	0 b	0.3 b	0.3 b	3 b	3.0 b	4.6 b	39 b	5.8 b	5.8 b	58 b
Pendimethalin + sulfentrazone	2.78 + 0.35	Layby	0 b	0 b	0 b	0.0 b	0.0 b	0 b	0.0 c	0.0 d	0 e	0.0 e	0.0 d	0 e
Pendimethalin + sulfentrazone	2.78 + 0.42	Layby	0 b	0 b	0 b	0.0 b	0.0 b	0 b	0.0 c	0.0 d	0 e	0.0 e	0.0 d	0 e
Pendimethalin fb atrazine	2.78 fb 2.24	Layby fb DL1	1.3 a	2.0 a	17 a	0.0 b	0.0 b	0 b	0.6 c	1.6 d	11 d	1.3 cd	3.3 c	23 d
Pendimethalin fb atrazine	2.78 fb 3.36	Layby fb DL1	1.8 a	2.0 a	19 a	0.0 b	0.0 b	0 b	0.3 c	0.6 d	4 de	0.5 de	0.5 de	5 e
Pendimethalin fb sulfentrazone	2.78 fb 0.35	Layby fb DL1	2.0 a	2.5 a	23 a	0.0 b	0.0 b	0 b	0.0 c	0.0 d	0 e	0.0 e	0.0 d	0 e
Pendimethalin fb sulfentrazone	2.78 fb 0.42	Layby fb DL1	2.0 a	2.3 a	22 a	0.0 b	0.0 b	0 b	0.0 c	0.0 d	0 e	0.0 e	0.0 d	0 e
Pendimethalin fb flumioxazin	2.78 fb 0.14	Layby fb DL1	1.8 a	2.3 a	21 a	0.0 b	0.0 b	0 b	0.9 c	3.1 c	20 c	1.8 c	6.3 b	41 c
Pendimethalin fb flumioxazin	2.78 fb 0.28	Layby fb DL1	1.5 a	2.5 a	20 a	0.0 b	0.0 b	0 b	0.4 c	3.1 c	18 de	0.8de	2.3 cd	16 de
Paraquat + atrazine	0.63 + 2.24	DL2	1.8 a	1.8 a	18 a	3.5 a	7.0 a	53 a	6.8 a	8.5 a	77 a	10.0 a	10.0 a	100 a

(Table 4.2 cont.)

Paraquat + sulfentrazone	0.63 + 0.35	DL2	1.8 a	1.5 a	17 a	3.0 a	6.8	49 a	6.8 a	8.4 a	76 a	10.0 a	10.0a	100 a
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^aExperiments were conducted in 2005 near Port Allen and White Castle, LA. Layby application was made on May 26, 2005, the first delayed layby application (DL1) was made on June 23, 2005, and the second delayed layby application (DL2) was made on July 21 2005. The abbreviation “fb” represents followed by.

^bThe June 23 rating date represents 28 days after the layby application. The July 21 rating represents 56 days after the layby application and 28 days after the DL1 application. The August 11 rating represents 77 days after the layby application, 49 days after the DL1 application, and 21 days after the DL2 application. The degree of infestation by red morningglory was based on a stalk wrapping (SW) rating of 0 to 10 with 0 = no stalks wrapped by red morningglory and 10 = all stalks wrapped to some degree with red morningglory. Infestation was also based on a percent stalk wrapping (PSW) ratings of 0 to 10 with 0 = no stalks wrapped and 10 = the whole stalk wrapped based on an average for all stalks in each plot. These two ratings summed and divided by 20 and expressed as a percent would formulate a red morningglory infestation level (IL) where a maximum rating of 10 for each individual rating would correspond to 100%, meaning that all stalks in the plot were wrapped to the top of the crop canopy.

^cMeans within each column followed by the same letter are not significantly different using Fisher’s protected LSD (P \leq 0.05).

infestation was 20 and 18 % for flumioxazin at 0.14 and 0.28 kg/ha, respectively. The infestation level changed to 41 and 16 %, respectively, by November 9. As indicated earlier, red morningglory was not controlled when paraquat was applied as a directed treatment with atrazine or sulfentrazone (Table 4.1). For the two paraquat treatments the red morningglory infestation level continued to increase across the growing season changing from around 18 % on June 23 to around 50% on July 21 when the herbicide treatments were applied (Table 4.2). The growth of red morningglory was not hindered by the paraquat treatments and by November 9 red morningglory infestation was 100 % with all stalks in the plots wrapped with vines to the top of the crop canopy. As noted earlier, the poor control was due to lack of coverage of red morningglory foliage which had begun to wrap sugarcane stalks when herbicide was applied on July 21.

Sugarcane yield was determined only at the Port Allen location because of severe lodging at White Castle. Sugarcane height, stalk population, and sugarcane and sugar yield did not differ among the herbicide treatments when applied at layby on May 26 or when herbicides were delayed and applied on June 23 following pendimethalin at layby (Table 4.3). When herbicide application was delayed until July 21 sugarcane height was equivalent to the other treatments but sugarcane and sugar yield were reduced an average of 29.7 to 44.9 % and 43.4 to 53.3 %, respectively.

Red Morningglory Competition Study. For the season long weedy treatment, weed infestation changed from 14 to 48 % from June through August and by November was 89 % (Table 4.4). On August 23 red morningglory infestation would be reflective of weeds that had emerged for the weed free until June 23 and weed free until July 21 treatments. For these treatments on August 11, weed infestation was no more than 3%. However, by November 9 red morningglory

infestation was 24 % when weeds were allowed to reinfest after June 23 but only 8 to 9% when weeds were allowed to reinfest after July 21, August 11, or August 25. These results can be used to show how the length of residual activity from a soil applied herbicide might impact the degree of reinfestation. Results indicate even if herbicide prevents morningglory reinfestation into July and August that significant reemergence and growth can occur. Findings also suggest under heavy red morningglory infestation that if residual activity of herbicide is not season long, late season control options should be considered. In the previous study, sulfentrazone applied either with pendimethalin in late May or applied in late June following pendimethalin provided season long red morningglory control (Table 4.2).

The weedy treatments would represent a situation where soil herbicide is not applied at layby or when a herbicide has become ineffective and a late season overtop application of a herbicide would be used to eliminate red morningglory after plants have begun to climb sugarcane stalks. For the weedy until June 23 treatment plots had a 14 % infestation level when control measures were implemented and only 7% infestation in November. For the weedy until July 21 treatment plots had a 48 % infestation when control measures were implemented and only an 8% infestation was present in November. With the weedy until August 11 or August 25 treatments the infestation of red morningglory was around 50 % August 11 and no weeds were present in November. Of interest is how competition from red morningglory might affect sugarcane growth and yield. Comparing the season long weedy treatment to the season long weed free treatment at the Port Allen location, sugarcane height and population were equivalent (Table 4.5). This is not unexpected because the study was not initiated until May, at which time all red morningglory in the plots were killed. In May when the layby cultivation is made, sugarcane has produced the tillers that will be harvestable stalks and some of the older tillers will be jointing.

Table 4.3. Sugarcane height, stalk population, and yield and sugar yield as influenced by herbicide treatments applied at layby and as delayed layby applications.^a

Treatment	Rate	Timing	Sugarcane				
			Rate	height	Stalks	weight	Sugar/ha
	kg ai/ha		kg ai/ha	cm	1000/ha	1000 kg/ha	kg/ha
Pendimethalin + atrazine	2.78 + 2.24	Layby	2.78 + 2.24	184 a	92.4 a	54.3 a	6834 a
Pendimethalin + atrazine	2.78 + 3.36	Layby	2.78 + 3.36	172 a	87.4 a	49.1 a	6874 a
Pendimethalin + sulfentrazone	2.78 + 0.35	Layby	2.78 + 0.35	182 a	98.2 a	59.7 a	8136 a
Pendimethalin + sulfentrazone	2.78 + 0.42	Layby	2.78 + 0.42	185 a	87.9 a	51.9 a	6841 a
Pendimethalin fb atrazine	2.78 fb 2.24	Layby fb DL1	2.78 fb 2.24	192 a	90.1 a	58.5 a	7876 a
Pendimethalin fb atrazine	2.78 fb 3.36	Layby fb DL1	2.78 fb 3.36	192 a	87.9 a	56.4 a	7543 a
Pendimethalin fb sulfentrazone	2.78 fb 0.35	Layby fb DL1	2.78 fb 0.35	184 a	99.1 a	58.3 a	7787 a
Pendimethalin fb sulfentrazone	2.78 fb 0.42	Layby fb DL1	2.78 fb 0.42	185 a	91.9 a	56.0 a	7503 a
Pendimethalin fb flumioxazin	2.78 fb 0.14	Layby fb DL1	2.78 fb 0.14	186 a	97.3 a	62.6 a	8298 a
Pendimethalin fb flumioxazin	2.78 fb 0.28	Layby fb DL1	2.78 fb 0.28	185 a	94.1 a	58.9 a	7894 a
Paraquat + atrazine	0.63 + 2.24	DL2	0.63 + 2.24	167 a	81.3 a	36.9 b	4137 b
Paraquat + sulfentrazone	0.63 + 0.35	DL2	0.63 + 0.35	163 a	66.5 b	32.1 b	3596 b

^aExperiments were conducted in 2005 near Port Allen, LA. Layby application was made on May 26, 2005, the first delayed layby application (DL1) was made on June 23, 2005, and the second delayed layby application (DL2) was made on July 21 2005. An fb for the treatments designates that one herbicide was followed by another.

^bMeans within each column followed by the same letter are not significantly different using Fisher's protected LSD ($P \leq 0.05$).

Table 4.4. Weed infestation in sugarcane as influenced by red morningglory competition.^a

Treatment	June 23			July 21			August 11			November 9		
	SW ^b	PSW ^b	IL ^b	SW	PSW	IL	SW	PSW	IL	SW	PSW	IL
Weedy (season long)	1.3 a	1.5 a	14 a	3.3 a	5.3 a	43 a	4.3 a	5.3 a	48 a	8.5 a	9.3 a	89 a
Weed free (season long)	0.0 b	0.0 b	0 b	0.0 b	0.0 b	0 b	0.0 b	0.0 b	0 b	0.0 b	0.0 c	0c
Weed free until June 23	0.0 b	0.0 b	0 b	0.0 b	0.0 b	0 b	0.5 b	0.0 b	3 b	0.8 b	4.0 b	24 b
Weed free until July 21	0.0 b	0.0 b	0 b	0.0 b	0.0 b	0 b	0.3 b	0.0 b	2 b	0.3 b	1.5 bc	8 c
Weed free until August 11	0.0 b	0.0 b	0 b	0.0 b	0.0 b	0 b	0.0 b	0.0 b	0 b	0.3 b	1.3 bc	9 c
Weed free until August 25	0.0 b	0.0 b	0 b	0.0 b	0.0 b	0 b	0.0 b	0.0 b	0 b	0.3 b	1.5 bc	8 c
Weedy until June 23	1.3 a	1.5 a	14 a	0.0 b	0.0 b	0 b	0.0 b	0.0 b	0 b	0.5 b	0.8 bc	7 c
Weedy until July 21	1.5 a	1.5 a	15 a	3.5 a	6.0 a	48 a	0.0 b	6.0 a	0 b	0.3 b	1.3 bc	8 c
Weedy until August 11	1.5 a	1.8 a	17 a	3.0 a	6.0 a	45 a	4.0 a	6.0 a	50 a	0.0 b	0.0 c	0 c
Weedy until August 25	1.5 a	1.3 a	14 a	3.3 a	6.3 a	48 a	4.5 a	6.3 a	54 a	0.0 b	0.0 c	0 c

^aExperiments were conducted in 2005 near Port Allen and White Castle, LA. To initiate the study the entire experimental area was treated with 2,4-D at 1.12 kg ae/ha on May 25, 2005 to kill emerged weeds and complete control was obtained. Experiments were initiated on May 26. For the weed free maintenance treatments plots were maintained weed free until June 23, until July 21, until August 11, and until August 25 after which red morningglory was allowed to naturally reinfest plots. Duration of interference treatments included weed infestation in plots until June 23, until July 21, until August 11, or until August 25 after which plots were maintained weed free for the remainder of the growing season. Atrazine at 2.24 kg/ha, 2,4-D at 0.8 kg/ha plus dicamba at 0.28 kg ai/ha, and hand weeding were used in the season long weed free control and in the duration of interference treatments after the specified dates. For the weed free maintenance treatments plots were maintained weed free until the specified dates using only 2,4-D plus dicamba and hand weeding.

^bThe degree of infestation by red morningglory was based on a stalk wrapping (SW) rating of 0 to 10 with 0 = no stalks wrapped by red morningglory and 10 = all stalks wrapped to some degree with red morningglory. Infestation was also based on a percent stalk wrapping (PSW) ratings of 0 to 10 with 0 = no stalks wrapped and 10 = the whole stalk wrapped based on an average for all stalks in each plot. These two ratings summed and divided by 20 and expressed as a percent would formulate a red morningglory infestation index where a maximum rating of 10 for each individual rating would correspond to 100%, meaning that all stalks in the plot were wrapped to the top of the crop canopy.

^cMeans within each column followed by the same letter are not significantly different using Fisher's protected LSD ($P \leq 0.05$).

Consequently, competition from weeds at this time should not decrease stalk population. However, weed competition could affect stalk diameter and weight which could affect yield. Comparing the season long weedy treatment to the season long weed free treatment, red morningglory competition reduced sugarcane yield and sugar yield around 27% (Table 4.5). Sugarcane and sugar yields did not differ among the treatments that were maintained weed free season long or maintained weed free for a specified period of time and allowed to reinfest, and for the weedy treatments where weeds were removed after competing with sugarcane for a specified time. In this study, sugarcane was hand harvested and yields are reflective of any harvest efficiency problems that might have occurred if plots had been harvested mechanically. Of interest is that in November for the weed free until June 23 treatment plots had a 24 % infestation level. It would be expected that for this treatment harvest efficiency would have been affected to include decreased speed of harvest due to wrapping of stalks with morningglory vines. Breakage of stalks due to wrapping may also affect the number of stalks placed in the loading wagon from the combine harvester. These factors, however, were not investigated in the present study. Field observation has been that in fields where wrapping of sugarcane stalks with red morningglory is extensive that no attempt is made to harvest the sugarcane, resulting in a 100 % yield reduction.

Findings from both the weed control and the competition studies substantiate the importance that red morningglory be controlled sometime during the growing season and that following the layby cultivation in May, timing of application is not as important as is the degree of control obtained. It would be most desirable that residual herbicide applied to the soil at the layby cultivation in May provide season long control. Sulfentrazone applied at 0.35 kg/ha in late May or June provided excellent season long control. Atrazine was more effective when application

Table 4.5. Sugarcane height and stalk population in August and yield and sugar yield as influenced by red morningglory competition.^a

Treatment	Sugarcane			
	Height	Stalk population	Sugarcane yield	Sugar yield
	cm	1000/ha	1000 kg/ha	kg/ha
Weedy (season long)	164 a	33.4 a	41.0 b	4984 b
Weed free (season long)	171 a	39.7 a	56.2 a	6864 a
Weed free until June 23	172 a	40.5 a	56.2 a	6885 a
Weed free until July 21	185 a	37.2 a	56.7 a	6740 a
Weed free until August 11	172 a	38.0 a	49.6 ab	6237 ab
Weed free until August 25	173 a	37.2 a	45.4 ab	5610 ab
Weedy until June 23	178 a	36.8 a	49.8 ab	5907 ab
Weedy until July 21	180 a	36.0 a	47.9 ab	6003 ab
Weedy until August 11	174 a	37.6 a	48.4 ab	6058 ab
Weedy until August 25	176 a	35.8 a	48.5 ab	5954 ab

^aExperiments were conducted in 2005 near Port Allen, LA. To initiate the study the entire experimental area was treated with 2,4-D at 1.12 kg ae/ha on May 25, 2005 to kill emerged weeds and complete control was obtained. Experiments were initiated on May 26. For the weed free maintenance treatments plots were maintained weed free until June 23, until July 21, until August 11, and until August 25 after which red morningglory was allowed to naturally reinfest plots. Duration of interference treatments included weed infestation in plots until June 23, until July 21, until August 11, or until August 25 after which plots were maintained weed free for the remainder of the growing season. Atrazine at 2.24 kg/ha, 2,4-D at 0.8 kg/ha plus dicamba at 0.28 kg ai/ha, and hand weeding were used in the season long weed free control and in the duration of interference treatments after the specified dates. For the weed free maintenance treatments plots were maintained weed free until the specified dates using only.

^bMeans within each column followed by the same letter are not significantly different using Fisher's protected LSD ($P \leq 0.05$).

was delayed until late June rather than late May, but regardless of the time of application significant reinfestation of red morningglory occurred late in the growing season. A delayed application of flumioxazin in late June, like atrazine, did not provide residual control later into the growing season. Directed application of paraquat with atrazine or sulfentrazone in late July was ineffective because vines had begun to climb sugarcane stalks and coverage was an issue. Directed application of these herbicides has been very effective in field situations when weeds are small and if vines are present, growers add 2,4-D to the herbicide mixture or select herbicides that can be applied overtop of sugarcane without causing injury. A common and effective practice in Louisiana to control red morningglory is to apply 2,4-D or 2,4-D plus dicamba in July or August (Siebert et al. 2004). Data from the present study suggest that late season application of an effective herbicide, such as 2,4-D, can maximize yield even under heavy morningglory pressure when weeds emerge following the layby cultivation in May and compete with sugarcane into July or August. Red morningglory competition from May until the end of the growing season can reduce sugarcane and sugar yield around 27 %. However, under heavy infestation where wrapping of stalks causes severe lodging, red morningglory competition can result in complete crop loss.

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CHAPTER 5

SUMMARY

Sugarcane (*Saccharum* spp. hybrids) is the number one agronomic crop in Louisiana. In Louisiana sugarcane, red morningglory is both the most common and troublesome broadleaf weed. Research was conducted from 2001 through 2005 to assess red morningglory control, biology, and the effect on sugarcane.

Atrazine has been widely used as a soil applied treatment for morningglory control in sugarcane. The ability of atrazine to provide control of emerged morningglory and also to provide soil residual activity can aid in reducing weed regrowth and reinfestation. In the postemergence (POST) study, none of the herbicide treatments provided greater red morningglory control than atrazine at 3.36 kg/ha 28 days after treatment (DAT). However, where atrazine rate was reduced to 2.24 kg/ha, the higher rates of diuron plus hexazinone and the highest rate of flumioxazin were more effective in controlling red morningglory. The advantage of using atrazine, diuron plus hexazinone, flumioxazin, and sulfentrazone over carfentrazone-ethyl or pyraflufen-ethyl would be the additional soil residual activity that could be expected when herbicides are applied POST.

A limitation in previous research has been the ability to evaluate long term residual control (greater than 28 d) with soil applied herbicides because weeds not initially controlled can restrict emergence and growth of new weeds. The preemergence (PRE) study allowed for the comparison of residual control of red morningglory with soil applied herbicides out to 77 DAT and eliminated this factor through use of glufosinate, which provided POST control of red morningglory without the soil activity to interfere with evaluation of herbicide treatments. This research shows that in areas with severe red morningglory infestations, application of at least 0.21

kg/ha sulfentrazone can provide control of around 80 % for as long as 77 d. Sulfentrazone rate higher than 0.21 kg/ha, however, may be necessary on soils with high clay content and organic matter. In this study, atrazine at 4.48 kg/ha controlled red morningglory 90 % 35 DAT but only 70 % 49 DAT, clearly showing that long term residual control should not be expected. To best utilize atrazine for red morningglory control in sugarcane, delay application until later in the growing season in order to take advantage of the 35 d effective control period. The POST activity of atrazine on red morningglory would be advantageous in situations when application is delayed.

Another advantage of atrazine is that it can be applied over the top of sugarcane. Based on current labels, diuron plus hexazinone, flumioxazin, and sulfentrazone would have to be applied as a directed treatment, preferably after sugarcane is jointing, to avoid crop injury. Later applications of herbicides, such as atrazine, would also extend red morningglory control later into the growing season, which would be advantageous.

Trifluralin is commonly used in sugarcane to control grass weeds. If morningglory is a problem, it would be desirable to apply sulfentrazone with the trifluralin to save a trip over the field. The trifluralin/sulfentrazone study shows that if sulfentrazone at 0.21 kg/ha is to be incorporated with trifluralin, red morningglory control would be sacrificed as compared with the same rate applied to the soil surface. A sulfentrazone rate of at least 0.28 kg/ha would be needed to maximize red morningglory control when herbicide is incorporated.

In sugarcane, control of red morningglory is critical to prevent climbing and wrapping of sugarcane plants and subsequent decrease in yield and harvest efficiency. Ideally, herbicides used to control morningglory should have PRE and POST activity and should have excellent crop safety. The capability to apply herbicides over the top of sugarcane would increase versatility and

weed control options. Atrazine offers all of these benefits, but length of residual control of red morningglory is limited to around five weeks and rate dependent given conditions in Louisiana . For atrazine to be most effective, application should be delayed until later in the growing season (4 to 6 weeks after the layby cultivation in May) when both foliar and soil residual activity could be appreciated. Current label restrictions would limit the use of diuron plus hexazinone, flumioxazin, sulfentrazone, and trifloxysulfuron-sodium to POST directed application. Sulfentrazone provided longer residual red morningglory control than atrazine or any of the alternative herbicides and would have a fit when either incorporated at the layby cultivation with trifluralin or when applied to the soil surface after cultivation.

In the tillage study, results show, regardless of whether soil was tilled or not tilled, a significant reduction in red morningglory seed population in the soil from June to October. However, for the experimental site used in this study, a significant population of red morningglory seeds was still present at the end of the growing season. The significant reduction in seedling emergence in September when plots were not tilled suggests that elimination of tillage can affect red morningglory seedling emergence and may provide a cultural control method to help in management of red morningglory in sugarcane.

Results of the shade study show that as shade increased fewer red morningglory plants with less weight were present. However, plants grown in 90% shade, compared with plants in full sun, produced more leaf area, increasing the potential for photosynthetic activity and allowing plants to survive. The ability of red morningglory to germinate and emerge under a 90 % shade environment emphasizes the importance of rapid crop canopy development. This research was conducted with the intent to relate the response

of red morningglory to shade to what could happen under a sugarcane canopy. Varieties that produce a high population of stalks per ha with leaves less upright in growth habit would be expected to be more competitive with weeds in respect to shading. Most weeds in Louisiana sugarcane are shade intolerant and herbicide programs combined with rapid sugarcane growth result in excellent late season control. With red morningglory, however, research shows that plants are shade tolerant. Of interest, therefore, would be how the shade environment changes within the sugarcane canopy and how this might vary depending on variety.

Sugarcane varieties, LCP 85-384, L 97-128, HoCP 96-540, and Ho 95-988 did not differ in regard to PAR in the row middle at ground level for any of the sampling dates. On June 13, PAR for the varieties averaged 48 % and decreased to an average of 24 % on July 6 and 9% on July 21. Using the red morningglory response data to shade it would be expected that plants would be capable of emerging and growing into late July and August underneath a sugarcane canopy. If red morningglory pressure is high, germination and emergence late in the growing season and subsequent climbing and wrapping of sugarcane stalks would be expected. Findings further emphasize the need to develop weed control programs for red morningglory that increase residual activity of soil applied herbicides and extend weed control into August.

Findings from both the weed control and competition studies substantiate the importance that red morningglory be controlled sometime during the growing season and that following the layby cultivation in May, timing of application is not as important as is the degree of control obtained. It would be most desirable that residual herbicide applied to the soil at the layby cultivation in May provide season long control. Sulfentrazone applied at 0.35 kg/ha in late May or June

provided excellent season long control. Atrazine was more effective when application was delayed until late June rather than late May, but regardless of the time of application significant reinfestation of red morningglory occurred late in the growing season. A delayed application of flumioxazin in late June, like atrazine, did not provide residual control later into the growing season. Directed application of paraquat with atrazine or sulfentrazone in late July was ineffective because vines had begun to climb sugarcane stalks and coverage was an issue. Directed application of these herbicides has been very effective in field situations when weeds are small and if vines are present, growers add 2,4-D to the herbicide mixture or select herbicides that can be applied overtop of sugarcane without causing injury. Data from the present study suggest that late season application of an effective herbicide, such as 2,4-D, can maximize yield even under heavy morningglory pressure when weeds emerge following the layby cultivation in May and compete with sugarcane into July or August. Red morningglory competition from May until the end of the growing season can reduce sugarcane and sugar yield around 27 %. However, under heavy infestation where wrapping of stalks causes severe lodging, red morningglory competition can result in complete crop loss.

VITA

Curtis Jones was born the son of Kirk and Helen Jones on November 20, 1973. He was reared in Tom Bean, Texas, and graduated from Tom Bean High School in 1992. Curtis went on to Texas A&M University to pursue his bachelor's (1996) and master's (1999) degree in agronomy. After completing his master's degree, Curtis was hired to work full-time, under Dr. James Griffin, as a Research Associate for in the LSU AgCenter in the area of weed science. While working full-time, Curtis took the necessary coursework to fulfill the requirements for a doctorate in weed science.