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Evaluation of pyroxasulfone in corn (Zea mays L.) and soybean (Glycine max L. Merr.) weed management programs

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EVALUATION OF PYROXASULFONE IN CORN (*ZEA MAYS* L.) AND SOYBEAN (*GLYCINE MAX* L. MERR.) WEED MANAGEMENT PROGRAMS

A Thesis

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

in

The School of Plant, Environmental, and Soil Sciences

by
Jon Marshall Hardwick
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TABLE OF CONTENTS

ABSTRACT

Research was conducted to evaluate corn (*Zea mays* L.) and soybean (*Glycine max* L. Merr.) injury and weed control with pyroxasulfone applied preemergence (PRE) and postemergence (POST). In corn, pyroxasulfone applied both PRE at 150 g/ha and POST at 60 g/ha with glyphosate controlled barnyardgrass, Palmer amaranth, sicklepod, prickly sida, browntop millet, ivyleaf morningglory, and entireleaf morningglory 90 to 99% 30 days after the POST application. Weed control was no greater than when pyroxasulfone at 150 g/ha was applied only PRE. Control of barnyardgrass, Palmer amaranth, smooth pigweed, and browntop millet was greater for pyroxasulfone PRE compared with atrazine PRE and lower corn yield was observed for the atrazine treatment. In a second corn study, pyroxasulfone applied alone PRE controlled barnyardgrass, smooth pigweed, Palmer amaranth, hophornbeam copperleaf, sicklepod, ivyleaf morningglory, pitted morningglory, and prickly sida 83 to 100% 66 days after application. Equivalent weed control was obtained for pyroxasulfone plus atrazine and atrazine plus *S*-metolachlor applied PRE. Corn yield was lower when pyroxasulfone was applied only PRE compared with pyroxasulfone plus atrazine PRE and atrazine plus *S*-metolachlor PRE.

Soybean injury was observed when pyroxasulfone was applied at 60 to 300 g/ha, and at 10 days after application, injury was 2 to 5% when applied PRE and 15 to 21% when applied POST. Injury consisted of crinkling of leaflet surface, irregular leaflet margins, indentation of leaflet tips, and a drooping of leaf petioles (POST application only). Soybean yield was not negatively affected by pyroxasulfone regardless of application timing. In a second soybean study, pyroxasulfone applied alone PRE at 150 g/ha controlled, browntop millet an average of 99%, barnyardgrass 75%, hophornbeam copperleaf 99%, ivyleaf morningglory 86%, hemp sesbania 98%, sicklepod 95% and pitted morningglory 73% around 30 days after treatment. Compared with pyroxasulfone applied alone PRE at 150 g/ha, weed control was not improved when pyroxasulfone was applied PRE with saflufenacil, flumioxazin, fluthicet-methyl, or chlorimuron ethyl plus flumioxazin plus thifensulfuron methyl. Crop safety, consistency in weed control, and flexibility in application timing with pyroxasulfone suggests that it should have a fit in corn and soybean weed management programs in the mid-south.

CHAPTER 1
INTRODUCTION

In 2011, the total gross farm-gate value for the agriculture industry in Louisiana was $6.1 billion; $3.8 billion of which was from plant enterprises (Anonymous 2012A). Many of the rural communities in the state rely heavily on the agriculture industry for employment. With the commodity prices remaining at high levels, the future for agriculture is promising. Corn (*Zea mays* L.*)* and soybean (*Glycine max* L. Merr.*)* are major crops grown in Louisiana primary due to attractive market price. According to USDA, 2008, 2009, 2010, 2011, and 2012 average for the price of corn and soybean has been $0.20 and $0.41 per kilogram, respectively (USDA, 2013). However, the drought in the Midwest in 2012 created a corn and soybean shortage, boosting their respective prices an average of $0.27 and $0.54 per kilogram.

CORN PRODUCTION IN LOUISIANA

Depending on weather conditions, corn planting is initiated in late February to early March and typically harvested in mid-July to August. From 2008 to 2012 in Louisiana, an average of 220,243 hectares were harvested per year, yielding 9106 kg/ha (USDA, 2009, 2010, 2011, 2012, 2013). Weeds are a major factor affecting corn growth and yield. In many weed management programs in corn, the weakness is the lack of early season control (Scroggs et al. 2006). Weed interference in corn is most critical from emergence through the 6- to 8-leaf stage or four to six weeks after emergence (Scroggs et al. 2006). The most common weeds in corn in Louisiana include barnyardgrass (*Echinochloa crus-galli* L. Beauv), browntop millet (*Urochloa ramosa* L. Nguyen), hemp sesbania [*Sesbania exaltata* (Raf.) Rydb. Ex. A. W. Hill], hophornbeam copperleaf (*Acalypha ostryifolia* Riddell), johnsongrass [*Sorghum halepense* (L.) R. Br.], morningglories (*Ipomoea* spp.), Palmer amaranth (*Amaranthus palmeri* S.Wats), prickly sida (*Sida spinosa* L.), and sicklepod [*Senna obtusifolia* (L.) H.S. Irwin & Barneby].

Standard weed control programs for corn consist of preplant burndown, preemergence, and postemergence applications (Anonymous 2012B). Preplant weed management targets emerged winter weeds to include Italian ryegrass (*Lolium perenne* L. spp. *multiflorum* (Lam) Husnot), which can be extremely competitive with young corn (Larson 2013). Paraquat and glyphosate are widely used as preplant herbicide and in some cases are mixed with other herbicides to increase initial weed control or to provide residual control. The goal is to have a weedfree seedbed at planting to promote corn seed germination and rapid early season growth. Removal of weeds can also eliminate habitat for damaging insects such as cutworms (*Agrotis* spp.) (Schultz 2012).

Roundup Ready, Liberty Link, and Clearfield corn are three herbicide-resistant technologies available in Louisiana, with Roundup Ready being the most popular (Scroggs et al. 2006). Growers may select to apply a PRE herbicide at planting followed by glyphosate (Roundup Ready), glufosinate (Liberty Link), or a imidazolinone/sulfonylurea herbicide (Clearfield). Other herbicides may be added or applied at a later date based on grower preference. Weed control programs can be quite variable depending on weed problems, soil types, growing conditions.

SOYBEAN PRODUCTION IN LOUISIANA

Soybeans are adaptable to the different soil types and climatic conditions found in Louisiana (Shipp 2003). The majority of soybean cultivars grown in Louisiana represent the Maturity groups III and IV (indeterminate) and V and VI (determinate). Producers typically begin planting soybeans in mid-April and harvest in September. From 2008 to 2012, an average of 405,263 hectares per year was harvested, yielding 2624 kg/ha per year (USDA 2009, 2010, 2011, 2012,2013). Currently, soybean is the number one crop in Louisiana in terms of hectares harvested (USDA, 2013).

Like corn, weeds can also limit production of soybeans. The same weeds important in corn production are also prevalent in soybean and because of the later planting date for soybean, weed infestation can often be greater. Other weed problems in soybean include wild poinsettia (*Euphorbia hererophylla* L.), redweed (*Melochia corchorifolia* L.), eclipta (*Eclipta prostrate* L.), cutleaf groundcherry (*Physalis angulata* L.), Texasweed [*Caperonia palustris* (L.) St. Hil.], smell melon (*Cucumis melo* L.), red rice (*Oryza sativa* L.), itchgrass [*Rottboellia cochinchinensis* (Lour.) W. D. Clayton] and nutsedge (*Cyperus* spp.). Severity of these weeds varies depending on region of the state and the specific crop grown in rotation with soybean. The majority of soybean cultivars grown in the state are glyphosate resistant cultivars. Because of issues with glyphosate-resistant Palmer amaranth some acreage is planted with glufosinate resistant cultivars.

Standard weed control programs in soybean consist of a preplant, preemergence, and postemergence applications (Anonymous 2012B), and like corn, herbicides used can vary depending on weed spectrum, grower preference, and economics.

In both corn and soybean, a weakness in weed control programs is the length of residual activity of herbicides. It would be desirable in both corn and soybean that soil applied herbicides have excellent crop tolerance, be broad spectrum and long residual, and possess some level of postemergence activity. Although atrazine can be very effective in corn, it is also susceptible to the limitations described and registration by EPA has been in question.

PYROXASULFONE INTRODUCTION

Pyroxasulfone (3-[5-(difluoromethoxy)-1-methyl-3- (trifluoromethyl)pyrazol-4-ylmethylsulfonyl]-4, 5-dihydro-5, 5-dimethyl-1, 2-oxazole) is a new herbicide discovered by Kumiai Chemical Industry (Anonymous 2011). Pyroxasulfone is in the Isoxazoline chemical family (WSSA Group 15). Licensing agreements will allow marketing of pyroxasulfone alone as Zidua® through BASF; pyroxasulfone plus flumioxazin as Fierce® through Valent; and pyroxasulfone plus fluthiacet-methyl as Anthem™ through FMC. Crop use will be dependent on the specific product.

Yoshitaka et al. (2011) reported the mode of action of pyroxasulfone as an inhibitor of very-long-chain fatty acid elongase (VLCFAE). Research in the United States and Japan has determined that this herbicide provides good control of grass and broadleaf weed species with excellent selectivity in corn, wheat (*Triticum sp.*), soybean, and other crops (Tanetani et al. 2009). VLCFAE-inhibiting herbicides, classified also in the K3 group by Herbicide Resistance Action Committee (HRAC), inhibit shoot elongation during seed germination and seedling development (Tanetani et al. 2009). Specifically, pyroxasulfone inhibits the elongation steps in fatty acid synthesis from C18:0 to C20:0, C20:0 to C22:0, C22:0 to C24:0, C24:0 to C26:0, and C26:0 to C28:0 catalyzed by VLCFA elongases (Tanetani et al. 2011). Inhibiting multiple steps within the biosynthetic pathway of VLCFAs in plants may help reduce weed resistance development associated with this mode of action. In Australia, however, repeated use of pyroxasulfone at sub-optimal doses led to rapid herbicide resistance evolution in rigid ryegrass (*Lolium rigidum* Gaudin), a cross-pollinated grass species (Busi et al. 2011).

Pyroxasulfone is currently being evaluated for PRE and POST use in soybean, corn, wheat, and other crops such as sunflower (*Helianthus annuus*), cotton (*Gossypium* spp.), and potato (*Solanum tuberosum*) (Anonymous, 2011B). Kurtz et al. (2009) reported activity on grass and broadleaf weeds when pyroxasulfone was applied early preplant (EPP) through EPOST. Pyroxasulfone can be applied alone or mixed with other herbicides to broaden the spectrum of weed control (Anonymous 2011B).

Rate of pyroxasulfone have been tested for various soil types with rate ranges of 94 to 157, 125 to 188, and 157 to 220 g ai/ha for coarse, medium, and fine texture soils, respectively (Harden et al. 2011). In a study conducted using six soils from Australia ranging from loamy sand to clay, average half-life was 26.6, 10.9, and 15.8 days for pyroxasulfone, dimethenamid, and metolachlor, respectively (Shaner et al. 2012). Mueller et al. (2011) reported that in dry conditions (67% less annual rainfall), when pyroxasulfone was applied at 209, 250, and 332 g/ha, corn yield and broadleaf signalgrass [*Urochloa platyphylla* (Nash) R. D. Webster] control were significantly higher than when pyroxasulfone was applied at 125 and 166 g/ha. Average binding constant across the soils ranged from 0.7 for pyroxasulfone to 2.1 for metolachlor.

Research indicates that pyroxasulfone, with its flexible application timings and length of residual weed control, will provide an effective alternative for many problematic weeds including *Setaria* spp. and glyphosate-resistant *Amaranthus* spp. (Harden et al. 2011). Yamaji and Honda (2011) reported in medium texture soils, Palmer amaranth control with pyroxasulfone for up to six to eight weeks of control at the lower end of the recommended use range (60-180 g/ha); an additional one to two weeks was obtained at higher use rate (240-300 g/ha). Both susceptible and diclofop resistant Italian ryegrass [*Lolium multiflorum* L. ssp. *Multiflorum* (Lam.) Husnot] was controlled 86% or more with pyroxasulfone at 60 g/ha applied PRE or at 2 to 3 leaf stage (Wallace et al. 2011). Kurtz (2011) reported 96% Italian ryegrass control with pyroxasulfone compared with 68% control for pendimethalin. Pyroxasulfone, however, may not provide complete control common lambsquarters (*Chenopodium album* L.) and giant ragweed (*Ambrosia trifida* L.) (Harden et al. 2011).

Following a fall application of pyroxasulfone at 209 g/ha, broadleaf signalgrass (*Urochloa* platyphylla (Nash.) R.D. Webster) and velvetleaf (*Abutilon theophrasti* Medik.) were controlled 197 days after treatment (DAT) as much as 85 and 77%, respectively, compared to 57 and 10%, respectively, with s-metolachlor (Kurtz 2011).

Ligenfelter and Curran (2012) reported comparable weed control when pyroxasulfone was applied at rates up to eight times lower than s-metolachlor. Pyroxasulfone applied PRE at 146 g/ha controlled giant foxtail (*Setaria faberi* Herrm.), common lambsquarters (*Chenopodium album* L.), velvetleaf, common ragweed (*Ambrosia artemisiifolia* L.), and smooth pigweed (*Amaranthus hybridus* L.) 86 to 91%. Compared with s-metolachlor, pyroxasulfone provided similar annual grass control but greater control of annual broadleaf weeds.

Soybean treated with pyroxasulfone yielded 3028 kg/ha compared to 2624 kg/ha for treatments that did not include pyroxasulfone (Kurtz 2011). In Nebraska, optimum corn yield was obtained with pyroxasulfone at 195 g/ha and corn injury was not observed (Knezevic et al. 2009).

Although not a new mode of action, pyroxasulfone may represent an improvement over other herbicides within WSSA Group 15 by delivering higher unit activity and spectrum of control (Anonymous 2013). EPA granted registration for use in corn and soybean in 2012 and 2013, respectively. Research presented in this thesis focused on pyroxasulfone application timing and rate in corn and soybean in respect to crop injury and weed control. Additionally, weed control programs that included pyroxasulfone were compared with standard herbicide programs.

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CHAPTER 2

CORN RESPONSE AND WEED CONTROL WITH PYROXASULFONE APPLIED PREEMERGENCE AND POSTEMERGENCE

INTRODUCTION

The triazine herbicide, atrazine, is one of the most widely used pesticides in North America (Solomon et al. 1996). Atrazine is used both preemergence (PRE) and postemergence (POST) in corn (*Zea mays* L.) and provides control of grass and broadleaf weeds. Because atrazine does not adsorb strongly to soil particles, the potential for runoff and groundwater contamination is possible (Anonymous 1993). Atrazine has been found in both surface and ground water in North America, and aquatic ecological effects are of concern (Solomon et al. 1996). Trace amounts of atrazine have been found in drinking water samples from surface water sources in Louisiana and Iowa and in groundwater samples from Pennsylvania, Iowa, Nebraska, Wisconsin, and Maryland (Anonymous 1993). Because of the uncertainty in the future registration of atrazine there continues to be an interest in the development of herbicides as alternatives to atrazine.

Pyroxasulfone, a new herbicide in the isoxazoline chemical family (Weed Science Society of America Group 15) (Senseman 2007) was discovered by Kumiai Chemical Industry. Yoshitaka et al. (2011) reported the mode of action of pyroxasulfone as an inhibitor of very-long-chain fatty acid elongase (VLCFAE). Herbicides with this mode of action are also classified in the K3 group by the Herbicide Resistance Action Committee (HRAC) (Senseman 2007). By inhibiting VLCFAE, pyroxasulfone affects shoot elongation during seed germination and seedling development (Tanetani et al. 2009). Licensing agreements will allow the marketing of pyroxasulfone alone as Zidua® through BASF for use in corn and soybean (*Glycine max* L. Pers.)

and also as pyroxasulfone plus flumioxazin as Fierce® through Valent and pyroxasulfone plus fluthiacet-methyl as Anthem™ through FMC for use in soybean. Pyroxasulfone has been evaluated on various soil types when applied both PRE and POST (Harden et al. 2011). Rate ranges are 94 to 157, 125 to 188, and 157 to 220 g ai/ha on coarse, medium, and fine texture soils, respectively. Knezevic et al. (2009) reported that rates of 200 to 300 g/ha on soils up to 3% organic matter will control most grasses weeds and certain broadleaf weeds for approximately 4 to 6 weeks.

In a study conducted using six soils from Australia ranging from loamy sand to clay, average half-life was 26.6, 10.9, and 15.8 days for pyroxasulfone, dimethenamid, and metolachlor, respectively (Shaner et al. 2012). Average binding constant across the soils ranged from 0.7 for pyroxasulfone to 2.1 for metolachlor. Solubility of pyroxasulfone is low (3.1 mg/L) (Anonymous 2004). Water solubility for atrazine is 33 mg/L and is 488 mg/L for metolachlor (Senseman 2007). Yamaji and Honda (2011) in a plant-back study on medium textured soil reported up to 8 weeks of weed control for pyroxasulfone at 125 g/ha and an additional 1 to 2 weeks of control when applied at 188 g/ha. Pyroxasulfone applied in Fall controlled broadleaf signalgrass 85% 197 days after treatment (DAT) compared with 57% for *S*-metolachlor; velvetleaf (*Abutilon theophrasti* Medik.) control was 77% for pyroxasulfone and 10% for *S*-metolachlor (Kurtz et al. 2011).

Lingenfelter and Curran (2012) found that pyroxasulfone applied PRE at 145 g/ha provided late season control of 86 to 91% for giant foxtail (*Setaria faberi* Herrm.), common lambsquarters (*Chenopodium album* L.), velvetleaf, common ragweed (*Ambrosia artemisiifolia* L.), and smooth pigweed (*Amaranthus hybridus* L.). Although pyroxsulfone rate was eight times less than that of *S*-metolachlor, annual grass control for the herbicides was equivalent; broadleaf weed control was greater for pyroxasulfone. Corn was not injured with pyroxasulfone. Jha et al. (2012) reported no injury or yield reduction in corn with pyroxasulfone applied PRE at 300 g/ha. Pyroxasulfone PRE at 166, 209, and 250 g/ha provided equivalent control of kochia (*Kochia scoparia* L. Schrad.) 4 months after planting in corn, but a higher rate was required for wild buckwheat (*Polgonum convolvulus* L.) control (King and Garcia 2008).

In Louisiana, rainfall and warm weather promote emergence of weeds throughout the growing season and subsequent competition with crops. With glyphosate becoming the primary herbicide used in most row crops in the mid-south, glyphosate-resistant weeds have become a problem, which has required the use of alternative herbicides and technologies. The main weakness in many weed management programs in Louisiana is the lack of early season weed control. Research indicates that weed interference with corn is most critical from emergence through the 6- to 8-leaf stage or four to six weeks after emergence (Stephenson and Bond 2012). Pyroxasulfone, with its potential long residual activity (Kurtz et al. 2009, 2011; Shaner et al. 2012; Yamaji and Honda 2011) and its spectrum of weed control (Harden et al. 2011; Kurtz et al. 2009 and 2012; Lingenfelter and Curran 2012), could offer a viable alternative for weed control in corn.

The objectives of this research were to evaluate corn injury and weed control with pyroxasulfone and atrazine applied PRE and POST alone and in combination and to compare pyroxasulfone PRE and POST weed control programs with commercially available programs.

MATERIALS AND METHODS

PYROXASULFONE AND ATRAZINE PRE AND POST STUDY. Experiments were conducted in 2011 and 2012 at the Dean Lee Research and Extension Center at Alexandria, LA, and in 2012 at the Ben Hur Research Farm in Baton Rouge, LA. The soil in Alexandria was a Coushatta silt loam (fine-silty, mixed, superactive, thermic Fluventic Entrudept) with 2.3% organic matter (OM) and pH of 8. In Baton Rouge, the soil was a Mhoon silty clay loam (fine-silty, mixed, nonacid, thermic Typic Flauaquent) with 1.9% OM and pH of 6.3. 'Pioneer 2023 HR' corn was planted in Alexandria in 2011 and 'Pioneer 31P42' was planted at both locations in 2012. Both years at Alexandria, corn was planted March 28 at a rate of 75,000 seed per hectare. For Baton Rouge in 2012, corn was planted April 10 at a rate of around 75,000 seed per hectare. Plot size in Alexandria consisted of four 0.97 m rows, 9.1 m long both years and four 0.97 m rows, 7.6 m long in Baton Rouge in 2012. In Alexandria herbicide treatments were applied to all four rows and at Baton Rouge, only the two inside rows were treated.

At both locations, the experimental design was a randomized complete block with a factorial arrangement of treatments. Treatments were replicated four times. Factor A consisted of PRE herbicide treatments applied PRE and included: no PRE herbicide, pyroxasulfone at 150 g/ha, atrazine at 1120 g ai/ha, and pyroxasulfone at 150 g/ha plus atrazine at 1120 g/ha. Factor B consisted of POST herbicide treatments and included: no POST herbicide, pyroxasulfone at 60 g/ha plus glyphosate at 860 g ae/ha, atrazine at 1120 g/ha plus glyphosate at 860 g/ha, and pyroxasulfone at 60 g/ha plus atrazine at 1120 g/ha plus glyphosate at 860 g/ha. Postemergence herbicide treatments were applied at vegetative growth stage 4 (V4) April 25, 2011 and April 20, 2012 at Alexandria and May 1, 2012 at Baton

Rouge. Treatments in Alexandria were applied with a tractor-mounted sprayer calibrated to deliver 140 L/ha at 255 kPa in 2011 and 140 L/ha spray volume and 303 kPa pressure in 2012. Treatments in Baton Rouge in 2012 were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L/ha spray volume and 193 kPa pressure. Weeds at Alexandria included barnyardgrass [*Echinochloa crus-galli* (L.) Beauv], browntop millet [*Urochloa ramosa* (L.) Nguyen], Palmer amaranth (*Amaranthus palmeri* S. Wats), sicklepod [*Senna obtusifolia* (L.) H.S. Irwin & Barneby], ivyleaf (*Ipomoea hederacea* Jacq.), and entireleaf morningglory (*Ipomoea hederacea* var. *integriuscula*). Weeds at Baton Rouge included barnyardgrass, smooth pigweed (*Amaranthus hybridus* L.), pitted morningglory (*Ipomoea lacunosa* L.), and prickly sida (*Sida spinosa* L.). When POST herbicides were applied at both locations weeds were no more than 5 cm in height.

Prior to POST herbicide application and 12 and 20 days after PRE (DAPRE) application at each location, barnyardgrass, Palmer amaranth, and smooth pigweed control and corn injury were rated based on a scale of 0 to 100% with 0 = no weed control/no crop injury and 100 = complete weed control/crop death. Using the same rating scale, control of barnyardgrass, Palmer amaranth, sicklepod, and smooth pigweed were rated 7, 30, and 118 days after POST (DAPOST) herbicide application; pitted morningglory and prickly sida 30 and 118 DAPOST; and browntop millet, ivyleaf morningglory, and entireleaf morningglory 7, 30, and 125 DAPOST. Corn Injury was rated when weed control data were collected.

At corn maturity, the two center rows of each plot for each experiment were mechanically harvested with a plot combine in mid to late August. Corn grain yield was adjusted to 15% moisture.

PYROXASULFONE VS. STANDARD HERBICIDE PROGRAMS STUDY. Experiments were conducted in 2012 at the Dean Lee Research and Extension Center in Alexandria, LA, and at the Ben Hur Research Farm in Baton Rouge, LA. Soil type, corn cultivar, seeding rate and planting date, and plot size at each location in 2012 were the same as described for the previous study. At both locations, the experimental design was a randomized complete block with four replications and 10 treatments. Treatments with only PRE herbicides included pyroxasulfone at 150 g/ha; pyroxasulfone at 120 g/ha plus saflufenacil at 50 g ai/ha; pyroxasulfone at 120 g/ha plus saflufenacil at 50 g/ha plus dimethenamid-P at 440 g ai/ha; pyroxasulfone at 120 g/ha plus atrazine at 1680 g/ha; atrazine at 1830 g/ha plus S-metolachlor at 1420 g/ha; and atrazine at 1475 g/ha plus *S*-metolachlor at 1475 g/ha plus mesotrione at 190 g ai/ha. At both locations, PRE herbicide treatments were applied PRE (March 28 at Alexandria and April 10 at Baton Rouge).

Postemergence treatments included pyroxasulfone at 120 g/ha plus atrazine at 1680 g/ha plus glyphosate at 860 g/ha; *S*-metolachlor at 1050 g/ha plus mesotrione at 105 g/ha plus atrazine at 1120 g/ha plus glyphosate at 1050 g/ha; and atrazine at 1680 g/ha plus glyphosate at 860 g/ha. A nontreated control was included for comparison. Postemergence herbicide treatments were applied at V4 on April 20 at Alexandria and on May 2 at Baton Rouge. The sprayer, spray volume, and spray pressure used at each location in 2012 were the same as described for the previous study.

Weeds at Alexandria included barnyardgrass, browntop millet, Palmer amaranth, sicklepod, ivyleaf morningglory, and hophornbeam copperleaf (*Acalypha ostryifolia* Riddell). Weeds at Baton Rouge included barnyardgrass, smooth pigweed, pitted morningglory, prickly sida, and hemp sesbania (*Sesbania exaltata* Raf. Cory). When POST herbicides were applied at both locations, weeds were no more than 5 cm in height. Prior to POST herbicide application and 12 DAPRE application, barnyardgrass, browntop millet, smooth pigweed, Palmer amaranth, sicklepod, and ivyleaf morningglory control and corn injury were rated based on the scale described previously. Barnyardgrass and smooth pigweed control were also rated 20 DAPRE. Control of barnyardgrass, smooth pigweed, Palmer amaranth, hophornbeam copperleaf, sicklepod, and ivyleaf morningglory were rated 7 and 42 DAPOST. Pitted morningglory and prickly sida were rated 28 and 42 DAPOST. In addition, barnyardgrass, smooth pigweed, pitted morningglory, prickly sida, and hemp sesbania were rated 116 DAPOST. At maturity, corn yield was determined at both locations as described previously.

STATISTICAL ANALYSIS. Data collected for experiments conducted in Alexandria and Baton Rouge for each study were subjected to an ANOVA by SAS Proc. Mixed (SAS/STAT Version 6, SAS Institute, Cary, NC). For individual weeds, the number of experiments, where the weed was present, varied depending on location and year. Years, locations, year by location, and replications nested within year by location were considered random effects (Blouin et al. 2011). Preemergence and postemergence herbicide treatments were considered fixed effects. Considering location as random effects permits inferences about treatments to be made over a range of environments (Carmer et al. 1989). Least square means were calculated and mean separation ($P \leq 0.05$) was produced using PDMIX800 in SAS, which is a macro for converting mean separation output to letter groupings (Saxton et al. 1998).

RESULTS AND DISCUSSION

PYROXASULFONE AND ATRAZINE PRE AND POST STUDY. Prior to POST herbicide application, pyroxasulfone alone and pyroxasulfone plus atrazine PRE controlled barnyardgrass, Palmer amaranth, and smooth pigweed 96 to 100% 12 and 20 DAPRE herbicide application (Table 2.1). Barnyardgrass and Palmer amaranth control 12 and 20 DAPRE application of atrazine alone was 81 to 86% and less than for the pyroxasulfone and pyroxasulfone plus atrazine treatments. For smooth pigweed, control with atrazine PRE was 97% at 12 days and 63% at 20 days after application. Control of smooth pigweed was equal to that of pyroxasulfone and pyroxasulfone plus atrazine at 12 days, but was less at 20 days. Injury to corn was not observed with any of the PRE treatments.

The pyroxasulfone, atrazine, and pyroxasulfone plus atrazine PRE treatments were followed POST by either no herbicide or pyroxasulfone, atrazine, or pyroxasulfone plus atrazine, each in combination with glyphosate. Corn injury was not observed for any of the POST treatments. After pyroxasulfone and pyroxasulfone plus atrazine were applied PRE without a POST (30 days after POST herbicides were applied to other treatments), control at 50 days after pyroxasulfone and pyroxasulfone plus atrazine were applied PRE was 83 and 88% for barnyardgrass and 90 and 92% for Palmer amaranth (Table 2.2). Geier et al. (2006) reported Palmer amaranth control over two years in conventional corn of 80 and 88% with pyroxasulfone applied PRE at 166 g/ha and 100 and 96% with pyroxasulfone plus atrazine; green foxtail (*Setaria viridis* L. Beauv.) was controlled 98% with pyroxasulfone and 93% with pyroxasulfone plus atrazine. In the present study control of barnyardgrass and Palmer

Table 2.1. Barnyardgrass, Palmer amaranth, and smooth pigweed control 12 and 20 days with pyroxasulfone and atrazine applied preemergence.

Preemergence treatment	Rate	Barnyardgrass		Palmer amaranth		Smooth pigweed	
		12 DAPRE	20 DAPRE	12 DAPRE	20 DAPRE	12 DAPRE	20 DAPRE
	g ai/ha			%			
Pyroxasulfone	150	98 a[1]	98 a	98 a	98 a	100 a	96 a
Atrazine	1120	86 b	81 b	86 b	81 b	97 b	63 b
Pyroxasulfone + atrazine	150 + 1120	98 a	98 a	98 a	98 a	100 a	99 a

[1] Means within each column followed by the same letter are not significantly different at $P \leq 0.05$.

amaranth with pyroxasulfone and pyroxasulfone plus atrazine 50 DAPRE was greater than for Palmer atrazine alone (21% for barnyardgrass and 31% for Palmer amaranth). In contrast, sicklepod control 50 days after pyroxasulfone, atrazine, and pyroxasulfone plus atrazine were applied PRE was equivalent (79 to 98%); numerically, control was lowest for pyroxasulfone alone. At 140 days after only PRE herbicides were applied (118 days after POST herbicides were applied to other treatments), pyroxasulfone PRE alone controlled barnyardgrass 76%, Palmer amaranth 90%, and sicklepod 78%. Control of these weeds was not improved when atrazine was applied alone or with pyroxasulfone PRE compared with pyroxasulfone applied alone. When PRE herbicide was not applied, control 30 days after POST application of pyroxasulfone plus glyphosate, atrazine plus glyphosate, and pyroxasulfone plus atrazine plus glyphosate was 87 to 91% for barnyardgrass, 91 to 95% for Palmer amaranth, and 86 to 93% for sicklepod (Table 2.2). Differences in weed control among the herbicides were not observed 118 DAPOST. When pyroxasulfone, atrazine, or pyroxasulfone plus atrazine PRE were followed by pyroxasulfone, atrazine, or pyroxasulfone plus atrazine plus glyphosate POST, control of barnyardgrass, Palmer amaranth, and sicklepod 30 and 118 DAPOST was in most cases no

Table 2.2. Barnyardgrass, Palmer amaranth, and sicklepod control with pyroxasulfone and atrazine applied preemergence (PRE) and followed by (fb) pyroxasulfone, atrazine, and glyphosate applied postemergence (POST).

			Barnyardgrass[1]			Palmer amaranth[2]			Sicklepod[2]		
Herbicide treatment[3]	Timing	Rate	7 DAPOST	30 DAPOST	118 DAPOST	7 DAPOST	30 DAPOST	118 DAPOST	7 DAPOST	30 DAPOST	118 DAPOST
		g ai/ha	%								
Pyroxasulfone	PRE	150	92 abc[4]	83 a	76 a	92 abc	90 ab	90 a	97 ab	79 a	78 bc
Pyroxasulfone fb pyroxasulfone	PRE fb POST	150 fb 60	97 a	93 a	90 a	97 ab	93 ab	88 ab	99 a	91 a	73 c
Pyroxasulfone fb atrazine	PRE fb POST	150 fb 1120	98 a	91 a	84 a	98 a	93 ab	83 bc	99 a	82 a	73 c
Pyroxasulfone fb pyroxasulfone + atrazine	PRE fb POST	150 fb 60 + 1120	98 a	95 a	85 a	98 a	97 a	90 a	99 a	90 a	90 ab
Atrazine	PRE	1120	59 d	21 b	67 a	62 e	31 c	78 cd	83 c	98 a	93 ab
Atrazine fb pyroxasulfone	PRE fb POST	1120 fb 60	90 abc	89 a	69 a	91 bcd	88 ab	90 a	99 a	97 a	95 a
Atrazine fb atrazine	PRE fb POST	1120 fb 1120	90 abc	83 a	68 a	89 cd	84 b	73 d	97 ab	95 a	93 ab
Atrazine fb pyroxasulfone + atrazine	PRE fb POST	1120 fb 60 + 1120	87 bc	92a	80 a	89 cd	95 ab	88 ab	99 a	91 a	73 c
Pyroxasulfone + atrazine	PRE	150 + 1120	90 abc	88 a	76 a	92 abc	92 ab	88 ab	99 a	93 a	90 ab
Pyroxasulfone + atrazine fb pyroxasulfone	PRE fb POST	150 + 1120 fb 60	96 ab	85 a	87 a	96 ab	97 a	90 a	99 a	78 a	73 c
pyroxasulfone + atrazine fb atrazine	PRE fb POST	150 + 1120 fb 1120	97 a	94 a	83 a	97 ab	95 ab	85 ab	99 a	88 a	70 c
Pyroxasulfone + atrazine fb pyroxasulfone + atrazine	PRE fb POST	150 + 1120 fb 60 + 1120	97 a	95 a	81 a	97 ab	95 ab	90 a	99 a	92 a	93 ab
Pyroxasulfone	POST	60	91 abc	89 a	67 a	91 bcd	95 ab	85 ab	98 ab	91 a	93 ab
Atrazine	POST	1120	86 c	87 a	71 a	85 d	91 ab	83 bc	96 b	93 a	90 ab
Pyroxasulfone + atrazine	POST	60 + 1120	85 c	91 a	78 a	86 cd	91 ab	85 ab	96 b	86 a	83 abc

[1] Data for 7, 30, and 118 days after POST (DAPOST) application correspond to around 27, 50, and 140 days after preemergence (PRE) treatments were applied.

[2] Data correspond to around 27, 50, and 140 DAPRE treatments were applied.

[3] All POST herbicide treatments included glyphosate at 860 g ae/ha.

[4] Means within each column followed by the same letter are not significantly different at $P \leq 0.05$.

greater than when pyroxasulfone was applied only PRE or when pyroxasulfone plus glyphosate was applied only POST.

In Baton Rouge when POST herbicide was not applied, pyroxasulfone and pyroxasulfone plus atrazine controlled smooth pigweed 50 DAPRE application (30 days after POST herbicides were applied to other treatments) 81% compared with 20% for atrazine alone (Table 2.3). For pitted morningglory, however, control was 96% for atrazine alone and 88% for pyroxasulfone plus atrazine 50 days after PRE application, but was only 64% for pyroxasulfone alone. Prickly sida was controlled 88 to 98% 30 DAPRE and control was equivalent for pyroxasulfone, atrazine, and pyroxasulfone plus atrazine. When PRE herbicide was not applied, smooth pigweed, pitted morningglory, and prickly sida control 30 DAPOST application of pyroxasulfone plus glyphosate, atrazine plus glyphosate, and pyroxasulfone plus atrazine plus glyphosate was equivalent and averaged 100, 89, and 94%, respectively (Table 2.3). Differences in control were also not observed 118 DAPOST. For pyroxasulfone plus glyphosate, atrazine plus glyphosate, and pyroxasulfone plus atrazine plus glyphosate applied POST following either pyroxasulfone, atrazine, or pyroxasulfone plus atrazine PRE, control of smooth pigweed and pitted morningglory 30 DAPOST application was greater than when pyroxasulfone was applied only PRE; control was equivalent, however, to that of pyroxasulfone plus glyphosate applied POST. At 118 DAPOST, control of smooth pigweed, pitted morningglory, and prickly sida was equivalent regardless of PRE/POST herbicide program and control averaged 89, 78, and 86%, respectively.

Table 2.3. Smooth pigweed, pitted morningglory, and prickly sida control with pyroxasulfone and atrazine applied preemergence (PRE) and followed by (fb) pyroxasulfone, atrazine, and glyphosate applied postemergence (POST).

			Smooth pigweed[1]			Pitted morningglory[1]		Prickly sida[1]	
Herbicide treatment[2]	Timing	Rate	7 DAPOST	30 DAPOST	118 DAPOST	30 DAPOST	118 DAPOST	30 DAPOST	118 DAPOST
		g ai/ha	%						
Pyroxasulfone	PRE	150	76 b[3]	81 b	91 a	64 b	70 a	88 a	86 a
Pyroxasulfone fb pyroxasulfone	PRE fb POST	150 fb 60	100 a	100 a	88 a	94 a	74 a	99 a	93 a
Pyroxasulfone fb atrazine	PRE fb POST	150 fb 1120	100 a	99 a	86 a	92 a	79 a	98 a	91 a
Pyroxasulfone fb pyroxasulfone + atrazine	PRE fb POST	150 fb 60 + 1120	100 a	100 a	91 a	91 a	69 a	99 a	89 a
Atrazine	PRE	1120	26 c	20 c	94 a	96 a	85 a	98 a	80 a
Atrazine fb pyroxasulfone	PRE fb POST	1120 fb 60	95 a	100 a	88 a	86 a	79 a	90 a	75 a
Atrazine fb atrazine	PRE fb POST	1120 fb 1120	93 a	100 a	85 a	90 a	83 a	85 a	74 a
Atrazine fb pyroxasulfone + atrazine	PRE fb POST	1120 fb 60 + 1120	95 a	100 a	90 a	82 a	69 a	94 a	81 a
Pyroxasulfone + atrazine	PRE	150 + 1120	78 b	81 b	84 a	88 a	80 a	98 a	89 a
Pyroxasulfone + atrazine fb pyroxasulfone	PRE fb POST	150 + 1120 fb 60	100 a	100 a	91 a	85 a	70 a	96 a	94 a
pyroxasulfone + atrazine fb atrazine	PRE fb POST	150 + 1120 fb 1120	100 a	100 a	93 a	97 a	85 a	100 a	88 a
Pyroxasulfone + atrazine fb pyroxasulfone + atrazine	PRE fb POST	150 + 1120 fb 60 + 1120	100 a	100 a	90 a	89 a	76 a	100 a	93 a
Pyroxasulfone	POST	60	93 a	100 a	89 a	84 a	86 a	88 a	79 a
Atrazine	POST	1120	95 a	100 a	89 a	99 a	81 a	97 a	90 a
Pyroxasulfone + atrazine	POST	60 + 1120	95 a	100 a	89 a	83 a	76 a	97 a	85 a

[1] Data for 7, 30, and 118 days after POST (DAPOST) application correspond to around 27, 50, and 140 days after preemergence (PRE) treatments were applied.

[2] All POST herbicide treatments included glyphosate at 860 g ae/ha.

[3] Means within each column followed by the same letter are not significantly different at $P \leq 0.05$.

When POST herbicide was not applied, browntop millet control around 50 DAPRE (30 days after POST herbicides were applied to other treatments) for pyroxasulfone and pyroxasulfone plus atrazine was equivalent and averaged 91% (Table 2.4). In contrast, atrazine PRE controlled browntop millet 59%. When PRE herbicide was not applied, browntop millet control 30 DAPOST application of pyroxasulfone, atrazine, and pyroxasulfone plus atrazine along with glyphosate averaged 87%. For ivyleaf and entireleaf morningglory, control around 50 DAPRE was 89 to 99% when pyroxasulfone, atrazine, and pyroxasulfone plus atrazine were applied PRE without a POST application and when PRE herbicide was not applied and pyroxasulfone plus glyphosate, atrazine plus glyphosate, and pyroxasulfone plus atrazine plus glyphosate were applied POST. Browntop millet, ivyleaf morningglory, and entireleaf morningglory control 30 DAPOST application of pyroxasulfone plus glyphosate, atrazine plus glyphosate, and pyroxasulfone plus atrazine plus glyphosate following PRE application of pyroxasulfone, atrazine, and pyroxasulfone plus atrazine in most cases was no greater than when only pyroxasulfone was applied PRE or when only pyroxasulfone plus glyphosate was applied POST.

When pyroxasulfone and pyroxasulfone plus atrazine were applied PRE with no follow up POST treatment, corn yield averaged 10,910 kg/ha, 33% greater than when atrazine was applied only PRE (Table 2.5). When PRE herbicide was not applied and pyroxasulfone plus glyphosate, atrazine plus glyphosate, and pyroxasulfone plus atrazine plus glyphosate were applied POST, corn yield was equivalent and averaged 11,090 kg/ha. Yield for these treatments, however, was no greater than when pyroxasulfone and pyroxasulfone plus atrazine were

Table 2.4. Browntop millet, ivyleaf morningglory, and entireleaf morningglory control with pyroxasulfone and atrazine applied preemergence (PRE) and followed by (fb) pyroxasulfone, atrazine, and glyphosate postemergence (POST).

			Browntop millet[1]			Ivyleaf morningglory[1]			Entireleaf morningglory[1]		
Herbicide treatment[2]	Timing	Rate	7 DAPOST	30 DAPOST	125 DAPOST	7 DAPOST	30 DAPOST	125 DAPOST	7 DAPOST	30 DAPOST	125 DAPOST
		g ai/ha	%								
Pyroxasulfone	PRE	150	99 a[3]	92 abc	85 a	95 b	89 a	93 a	99 a	97 b	95 a
Pyroxasulfone fb pyroxasulfone	PRE fb POST	150 fb 60	99 a	97 a	78 a	99 a	90 a	95 a	99 a	97 b	95 a
Pyroxasulfone fb atrazine	PRE fb POST	150 fb 1120	99 a	98 a	80 a	98 a	94 a	95 a	99 a	99 a	95 a
Pyroxasulfone fb pyroxasulfone + atrazine	PRE fb POST	150 fb 60 + 1120	99 a	98 a	85 a	99 a	96 a	95 a	99 a	99 a	95 a
Atrazine	PRE	1120	90 b	59 d	73 a	99 a	94 a	93 a	94 a	95 c	95 a
Atrazine fb pyroxasulfone	PRE fb POST	1120 fb 60	99 a	90 abc	63 a	98 a	86 a	90 a	99 a	99 a	95 a
Atrazine fb atrazine	PRE fb POST	1120 fb 1120	97 a	90 abc	83 a	99 a	96 a	93 a	99 a	99 a	95 a
Atrazine fb pyroxasulfone + atrazine	PRE fb POST	1120 fb 60 + 1120	99 a	87 bc	78 a	98 a	93 a	95 a	99 a	99 a	95 a
Pyroxasulfone + atrazine	PRE	150 + 1120	99 a	90 abc	80 a	98 a	90 a	93 a	99 a	99 a	95 a
Pyroxasulfone + atrazine fb pyroxasulfone	PRE fb POST	150 + 1120 fb 60	99 a	96 ab	88 a	99 a	96 a	95 a	99 a	99 a	95 a
pyroxasulfone + atrazine fb atrazine	PRE fb POST	150 + 1120 fb 1120	99 a	97 a	85 a	99 a	94 a	95 a	99 a	99 a	93 a
Pyroxasulfone + atrazine fb pyroxasulfone + atrazine	PRE fb POST	150 + 1120 fb 60 + 1120	99 a	97 a	68 a	98 a	90 a	95 a	99 a	99 a	95 a
Pyroxasulfone	POST	60	99 a	91 abc	73 a	99 a	93 a	95 a	99 a	99 a	93 a
Atrazine	POST	1120	98 a	86 c	63 a	99 a	100 a	93 a	98 a	99 a	90 a
Pyroxasulfone + atrazine	POST	60 + 1120	99 a	85 c	85 a	99 a	94 a	93 a	98 a	99 a	93 a

[1] Data for 7, 30, and 118 days after POST (DAPOST) application correspond to 27, 50, and 140 days after preemergence (PRE) treatments were applied.

[2] All POST herbicide treatments included glyphosate at 860 g ae/ha.

[3] Means within each column followed by the same letter are not significantly different at $P \leq 0.05$.

Table 2.5. Corn yield with pyroxasulfone and atrazine applied preemergence (PRE) and followed by (fb) pyroxasulfone, atrazine, and glyphosate applied postemergence (POST).

Herbicide treatment[1]	Timing	Rate	Yield
		g ai/ha	kg/ha
Pyroxasulfone	PRE	150	11,020 abc[2]
Pyroxasulfone fb pyroxasulfone	PRE fb POST	150 fb 60	11,270 abc
Pyroxasulfone fb atrazine	PRE fb POST	150 fb 1120	10,550 bc
Pyroxasulfone fb pyroxasulfone + atrazine	PRE fb POST	150 fb 60 + 1120	11,450 abc
Atrazine	PRE	1120	8170 d
Atrazine fb pyroxasulfone	PRE fb POST	1120 fb 60	11,510 ab
Atrazine fb atrazine	PRE fb POST	1120 fb 1120	10,910 abc
Atrazine fb pyroxasulfone + atrazine	PRE fb POST	1120 fb 60 + 1120	11,250 abc
Pyroxasulfone + atrazine	PRE	150 + 1120	10,790 abc
Pyroxasulfone + atrazine fb pyroxasulfone	PRE fb POST	150 + 1120 fb 60	10,420 c
pyroxasulfone + atrazine fb atrazine	PRE fb POST	150 + 1120 fb 1120	10,480 bc
Pyroxasulfone + atrazine fb pyroxasulfone + atrazine	PRE fb POST	150 + 1120 fb 60 + 1120	11,660 a
Pyroxasulfone	POST	60	11,230 abc
Atrazine	POST	1120	11,150 abc
Pyroxasulfone + atrazine	POST	60 + 1120	10,890 abc
Nontreated	--	--	6,700 e

[1] All POST herbicide treatments included glyphosate at 860 g ae/ha.

[2] Means within each column followed by the same letter are not significantly different at $P \leq 0.05$.

applied PRE with no follow up POST treatment. When pyroxasulfone, atrazine, and pyroxasulfone plus atrazine were applied PRE and followed POST with pyroxasulfone plus glyphosate, atrazine plus glyphosate, or pyroxasulfone plus atrazine plus glyphosate, corn yield was equivalent to that of pyroxasulfone applied PRE with no follow up POST treatment and of pyroxasulfone plus glyphosate applied POST with no PRE treatment. Jha et al. (2012) observed no corn injury or yield reduction for pyroxasulfone applied at 300 g/ha, twice that of the highest rate evaluated in the present study.

PYROXASULFONE VS. STANDARD HERBICIDE PROGRAMS STUDY. Prior to POST application of herbicide treatments, the PRE treatments pyroxasulfone at 150 g/ha alone and at 120 g/ha applied with saflufenacil at 50 g/ha, saflufenacil plus dimethenamid-P at 440 g/ha, or atrazine at 1680 g/ha, and of atrazine at 1830 g/ha applied with *S*-metolachlor at 1420 g/ha or atrazine at 1475 g/ha with *S*-metolachlor at 1475 g/ha plus mesotrione at 190 g/ha controlled barnyardgrass, browntop millet, smooth pigweed, Palmer amaranth, sicklepod, and ivyleaf morningglory 94 to 100% 12 days after application (Table 2.6). Barnyardgrass and smooth pigweed were controlled 95 to 100% 20 DAPRE application for all herbicide treatments. Corn injury was not observed for any of the PRE treatments.

When pyroxasulfone was applied alone PRE, weed control 66 DAPRE application was 83% for barnyardgrass, 93% for smooth pigweed, 95% for Palmer amaranth, and 86% for hophornbeam copperleaf (Table 2.7). Weed control compared with pyroxasulfone applied alone PRE, weed control was not increased when pyroxasulfone was applied with saflufenacil, saflufenacil plus dimethanamid-P PRE or when atrazine plus *S*-metolachlor or atrazine plus metolachlor plus mesotrione were applied PRE. Kurtz et al. (2009) reported 90 to 100% control

Table 2.6. Barnyardgrass, browntop millet, smooth pigweed, Palmer amaranth, sicklepod, and ivyleaf morningglory control following pyroxasulfone applied preemergence (PRE) alone or with other herbicides compared with standard PRE herbicide treatments.

			Barnyardgrass		Browntop millet	Smooth pigweed		Palmer amaranth	Sickle-pod	Ivyleaf morning-glory
Herbicide treatment	Timing	Rate	12 DAPRE	20 DAPRE	12 DAPRE	12 DAPRE	20 DAPRE	12 DAPRE	12 DAPRE	12 DAPRE
		g ai/ha	%							
Pyroxasulfone	PRE	150	100 a[1]	96 bc	100 a	99 a	99 a	99 a	99 a	99 a
Pyroxasulfone + saflufenacil	PRE	120 + 50	100 a	98 ab	100 a	100 a	99 a	99 a	96 a	99 a
Pyroxasulfone + saflufenacil + dimethenamid-P	PRE	120 + 50 + 440	100 a	100 a	100 a	100 a	99 a	99 a	99 a	99 a
Pyroxasulfone + atrazine	PRE	120 + 1680	100 a	96 bc	100 a	99 a	99 a	99 a	99 a	97 a
Atrazine + *S*-metolachlor	PRE	1830 + 1420	100 a	95 c	100 a	100 a	99 a	98 a	99 a	94 b
Atrazine + *S*-metolachlor + mesotrione	PRE	1475 + 1475 + 190	100 a	100 a	100 a	100 a	99 a	99 a	99 a	97 a

[1] Means within each column followed by the same letter are not significantly different at $P \leq 0.05$.

Table 2.7. Barnyardgrass, smooth pigweed, Palmer amaranth, and hophornbeam copperleaf control following pyroxasulfone applied preemergence (PRE) and postemergence (POST) compared with standard PRE and POST herbicide treatments.

			Barnyardgrass		Smooth pigweed		Palmer amaranth		Hophornbeam copperleaf	
Herbicide treatment[1]	Timing	Rate	7 DAPOST 28 DAPRE	42 DAPOST 66 DAPRE	7 DAPOST 28 DAPRE	42 DAPOST 66 DAPRE	7 DAPOST 30 DAPRE	42 DAPOST 65 DAPRE	7 DAPOST 30 DAPRE	42 DAPOST 65 DAPRE
		g ai/ha	%							
Pyroxasulfone	PRE	150	95a[2]	83ab	88b	93a	99a	95a	98a	86a
Pyroxasulfone + saflufenacil	PRE	120 + 50	95a	82ab	100a	99a	99a	93a	99a	85a
Pyroxasulfone + saflufenacil + dimethenamid-P	PRE	120 + 50 + 440	97a	86a	99a	100a	99a	95a	99a	89a
Pyroxasulfone + atrazine	PRE	120 + 1680	93ab	83ab	91ab	89a	99a	100a	99a	88a
Atrazine + *S*-metolachlor	PRE	1830 + 1420	96a	88a	95ab	88a	99a	100a	99a	80a
Atrazine + *S*-metolachlor + mesotrione	PRE	1475 + 1475 + 190	97a	88a	100a	100a	99a	94a	99a	91a
Pyroxasulfone + atrazine	POST	120 + 1680	88bc	85a	96a	100a	99a	99a	99a	99a
S-metolachlor + mesotrione + atrazine	POST	1050 + 105 + 1120	88bc	81ab	98a	100a	99a	100a	99a	99a
Atrazine	POST	1680	85c	71b	95ab	98a	99a	100a	99a	93a

[1] All POST herbicide treatments included glyphosate at 860 g ae/ha except S-metolachlor plus mesotrione plus atrazine, which was a premix containing glyphosate.

[2] Means within each column followed by the same letter are not significantly different at $P \leq 0.05$.

of broadleaf signalgrass in a conventional tillage system 46 days after preplant applications of pyroxasulfone at 125 to 332 g/ha, *S*-metolachlor at 1423 g/ha, acetochlor at 2233 g/ha, and dimethenamid-P at 957 g/ha. At 81 days after the preplant application, pyroxasulfone at 166 g/ha controlled broadleaf signalgrass 84% while *S*-metolachlor, acetochlor, and dimethenamid-P provided 53, 28, and 35% control, respectively.

When PRE herbicide was not applied, POST application of pyroxasulfone plus atrazine plus glyphosate, *S*-metolachlor plus mesotrione plus atrazine plus glyphosate, and atrazine plus glyphosate applied POST provided equivalent control of smooth pigweed, Palmer amaranth and hophornbeam copperleaf 42 days after application (93 to 100%); control of barnyardgrass, smooth pigweed, Palmer amaranth, and hophornbeam copperleaf for the POST only treatments 42 days after application was no greater than for pyroxasulfone applied PRE with no follow up POST treatment. Corn injury was not observed for any of the POST treatments.

When POST herbicide was not applied, pyroxasulfone alone, pyroxasulfone plus saflufenacil, pyroxasulfone plus saflufenacil plus dimethanamid-P, and pyroxasulfone plus atrazine around 65 DAPRE application controlled sicklepod 81 to 91%, ivyleaf morningglory 95 to 100%, pitted morningglory 80 to 95%, and prickly sida 84 to 99% (Table 2.8). When atrazine plus metolachlor was applied PRE without a follow up POST treatment, control of ivyleaf morningglory and prickly sida around 65 DAPRE was less compared with pyroxasulfone alone PRE (86 vs. 100% and 74 vs. 91%, respectively). When PRE herbicide was not applied pyroxasulfone plus atrazine plus glyphosate provided equivalent control of sicklepod, ivyleaf morningglory, pitted morningglory, and prickly sida 42 DAPOST to that for *S*-metolachlor plus mesotrione plus atrazine plus glyphosate and atrazine plus glyphosate (86 to 100%). As noted

Table 2.8. Sicklepod, ivyleaf morningglory, pitted morningglory, and prickly sida control following pyroxasulfone applied preemergence (PRE) and postemergence (POST) compared with standard PRE and POST herbicide treatments.

			Sicklepod		Ivyleaf morningglory		Pitted morningglory		Prickly sida	
Herbicide treatment[1]	Timing	Rate	7 DAPOST 30 DAPRE	42 DAPOST 65 DAPRE	7 DAPOST 30 DAPRE	42 DAPOST 65 DAPRE	28 DAPOST 49 DAPRE	42 DAPOST 66 DAPRE	28 DAPOST 49 DAPRE	42 DAPOST 66 DAPRE
		g ai/ha	%							
Pyroxasulfone	PRE	150	98 a[2]	88 a	99 a	100 a	89 a	83 a	94 ab	91 a
Pyroxasulfone + saflufenacil	PRE	120 + 50	97 a	91 a	99 a	98 a	94 a	86 a	99 a	94 a
Pyroxasulfone + saflufenacil + dimethenamid-P	PRE	120 + 50 + 440	96 a	81 a	99 a	100 a	98 a	95 a	100 a	99 a
Pyroxasulfone + atrazine	PRE	120 + 1680	97 a	91 a	99 a	95 a	86 a	80 a	93 ab	84 ab
Atrazine + *S*-metolachlor	PRE	1830 + 1420	94 a	81 a	96 b	86 b	88 a	71 a	88 b	74 b
Atrazine + *S*-metolachlor + mesotrione	PRE	1475 + 1475 + 190	99 a	96 a	98 a	93 ab	93 a	86 a	100 a	98 a
Pyroxasulfone + atrazine	POST	120 + 1680	99 a	100 a	99 a	100 a	99 a	90 a	100 a	100 a
S-metolachlor + mesotrione+ atrazine + glyphosate	POST	1050 + 105 + 1120 + 1050	99 a	96 a	99 a	100 a	100 a	86 a	100 a	100 a
Atrazine	POST	1680	99 a	96 a	99 a	100 a	98 a	93 a	98 a	96 a

[1] All POST herbicide treatments included glyphosate at 860 g ae/ha except S-metolachlor plus mesotrione plus atrazine, which was a premix containing glyphosate.

[2] Means within each column followed by the same letter are not significantly different at $P \leq 0.05$.

Table 2.9. Barnyardgrass, smooth pigweed, pitted morningglory, prickly sida, and hemp sesbania control prior to harvest and following pyroxasulfone applied preemergence (PRE) and postemergence (POST) compared with standard PRE and POST herbicide treatments.

Herbicide treatment[1]	Timing	Rate	Barnyardgrass	Smooth pigweed	Pitted morningglory	Prickly sida	Hemp sesbania
			116 DAPOST 137 DAPRE	116 DAPOST 137 DAPRE	116 DAPOST 137 DAPRE	116 DAPOST 137 DAPRE	116 DAPOST 137 DAPRE
		g ai/ha			%		
Pyroxasulfone	PRE	150	79 a[2]	94 a	86 a	80 a	84 a
Pyroxasulfone + saflufenacil	PRE	120 + 50	83 a	95 a	85 a	91 a	91 a
Pyroxasulfone + saflufenacil + dimethenamid-P	PRE	120 + 50 + 440	81 a	91 a	89 a	94 a	89 a
Pyroxasulfone + atrazine	PRE	120 + 1680	81 a	90 a	84 a	84 a	86 a
Atrazine + *S*-metolachlor	PRE	1830 + 1420	84 a	94 a	71 a	81 a	85 a
Atrazine + *S*-metolachlor + mesotrione	PRE	1475 + 1475 + 190	89 a	94 a	78 a	91 a	85 a
Pyroxasulfone + atrazine	POST	120 + 1680	84 a	93 a	86 a	95 a	86 a
S-metolachlor mesotrione + atrazine + glyphosate	POST	1050 + 105 + 1120 + 1050	86 a	94 a	89 a	91 a	83 a
Atrazine	POST	1680	65 b	94 a	84 a	89 a	83 a

[1] All POST herbicide treatments except S-metolachlor plus mesotrione plus atrazine included glyphosate at 860 g ae/ha.

[2] Means within each column followed by the same letter are not significantly different at $P \leq 0.05$.

earlier, control with the POST only treatments was no greater than when pyroxasulfone was applied PRE without a follow-up POST treatment.

Late season weed control (116 DAPOST/137 DAPRE) when pyroxasulfone was applied alone PRE without a follow-up POST treatment was 79% for barnyardgrass, 94% for smooth pigweed, 86% for pitted morningglory, 80% for prickly sida, and 84% for hemp sesbania (Table 2.9). Control of these weeds with pyroxasulfone applied with other herbicides PRE; with atrazine plus *S*-metolachlor and mesotrione PRE; and with *S*-metolachlor plus mesotrione plus atrazine plus glyphosate POST was no greater than when pyroxasulfone was applied PRE alone without a follow up POST treatment or when pyroxasulfone plus atrazine plus glyphosate was applied POST.

The differences observed in weed control were not always reflected in corn yield. When pyroxasulfone was applied PRE with no POST treatment, corn yield (8,240 kg/ha) was equivalent to that for pyroxasulfone plus saflufenacil (9,700 kg/ha), but was less than for pyroxasulfone plus saflufenacil plus dimethanamid-P (10,610 kg/ha) and for pyroxasulfone plus atrazine (10,570 kg/ha) (Table 2.10). Additionally, yield for pyroxasulfone alone PRE was equivalent to the nontreated (7,780 kg/ha). This suggests that any additional weed control provided when pyroxasulfone was applied PRE with saflufenacil, dimethanamid-P, and atrazine was beneficial in improving yield. Corn yield for the standard PRE treatments of atrazine plus *S*-metolachlor and atrazine plus *S*-metolachlor plus mesotrione without a POST treatment (10,700 and 9,670 kg/ha, respectively) were equivalent to that for pyroxasulfone plus saflufenacil, pyroxasulfone plus saflufenacil plus dimethanamid-P, and pyroxasulfone plus atrazine PRE (9,700 to 10,610 kg/ha). In conventional corn, Geier et al. (2002) reported equivalent yield for

Table 2.10. Corn yield following pyroxasulfone applied preemergence (PRE) and postemergence (POST) compared with standard PRE and POST herbicide treatments.

Herbicide treatment[1]	Timing	Rate	Yield
		g ai/ha	kg/ha
Pyroxasulfone	PRE	150	8,240 bc[2]
Pyroxasulfone + saflufenacil	PRE	120 + 50	9,700 ab
Pyroxasulfone + saflufenacil + dimethenamid-P	PRE	120 + 50 + 440	10,610 a
Pyroxasulfone + atrazine	PRE	120 + 1680	10,570 a
Atrazine + *S*-metolachlor	PRE	1830 + 1420	10,700 a
Atrazine + *S*-metolachlor + mesotrione	PRE	1475 + 1475 + 190	9,670 ab
Pyroxasulfone + atrazine	POST	120 + 1680	10,020 a
S-metolachlor + mesotrione + atrazine + glyphosate	POST	1050 + 105 +1120 +1050	10,830 a
Atrazine	POST	1680	10,160 a
Nontreated	--	--	7,780 c

[1] All POST herbicide treatments except S-metolachlor plus mesotrione plus atrazine included glyphosate at 860 g ae/ha.

[2] Means within each column followed by the same letter are not significantly different at $P \leq 0.05$.

PRE applications of pyroxasulfone at 166 g/ha, pyroxasulfone at 130 g/ha plus atrazine, and *S*-metolachlor plus atrazine applied PRE. In the present study when pyroxasulfone plus atrazine plus glyphosate was applied POST, corn yield was 22% greater than when only pyroxasulfone was applied PRE (10,020 vs. 8,240 kg/ha), but yield was equivalent to when pyroxasulfone plus atrazine was applied PRE (10,570 kg/ha). Comparing POST treatments, corn yield was equivalent for pyroxasulfone plus atrazine plus glyphosate and the standards of *S*-metolachlor plus mesotrione plus atrazine plus glyphosate and atrazine plus glyphosate.

In summary, for the pyroxasulfone and atrazine PRE and POST study, pyroxasulfone applied both PRE and POST (with glyphosate POST) controlled barnyardgrass, Palmer amaranth, sicklepod, prickly sida, browntop millet, ivyleaf morningglory, and entireleaf morningglory 90 to 100%, but control was no greater than when pyroxasulfone was applied only PRE. Control of smooth pigweed and pitted morningglory, however, was greater for pyroxasulfone applied both PRE and POST (with glyphosate) compared with pyroxasulfone applied only PRE. When pyroxasulfone was applied only POST (with glyphosate) weed control was equivalent to pyroxasulfone applied both PRE and POST (with glyphosate). Greater control of barnyardgrass, Palmer amaranth, smooth pigweed, and browntop millet was observed for pyroxasulfone applied only PRE compared with atrazine PRE and lower yield was observed for the atrazine treatment. Weed control was equivalent for pyroxasulfone and pyroxasulfone plus atrazine applied PRE without a follow up POST treatment and corn yield was equivalent for the treatments. Corn yield for pyroxasulfone, pyroxasulfone plus atrazine, or atrazine applied POST with glyphosate was equivalent to that observed for pyroxasulfone and pyroxasulfone plus atrazine applied only PRE, and for pyroxasulfone applied PRE and POST with glyphosate.

In the pyroxasulfone vs. standard herbicide programs study, pyroxasulfone applied PRE without a follow up POST treatment controlled barnyardgrass, smooth pigweed, Palmer amaranth, hophornbeam copperleaf, sicklepod, ivyleaf morningglory, pitted morningglory, and prickly sida 83 to 100%. Weed control was equivalent to that for pyroxasulfone plus atrazine and atrazine plus *S*-metolachlor applied PRE without a follow up POST treatment. Weed control with pyroxasulfone plus atrazine plus glyphosate and atrazine plus glyphosate without a PRE treatment was no greater than when pyroxasulfone was applied only PRE.

In contrast to the pyroxasulfone and atrazine PRE and POST study, in the programs study corn yield was lower when pyroxasulfone was applied only PRE compared with pyroxasulfone plus atrazine PRE. Also in the programs study, corn yield was lower when pyroxasulfone was applied only PRE compared with atrazine plus *S*-metolachlor PRE and when pyroxasulfone plus atrazine plus glyphosate and atrazine plus glyphosate was applied POST.

Results show that although pyroxasulfone applied PRE without a follow up POST treatment can be effective in controlling weeds it may not assure maximum corn yield. Although a sequential application of pyroxasulfone PRE followed by POST did not negatively affect corn growth or yield, the value of the treatment from a weed control and yield perspective was no greater than for pyroxasulfone applied PRE followed by glyphosate or for pyroxasulfone plus glyphosate or atrazine plus glyphosate applied POST. In corn at present, effective weed control options are available. However, with the uncertainty in the future registration of atrazine, availability of an alternative like pyroxasulfone could become very important. The efficacy and crop safety of pyroxasulfone plus atrazine PRE or pyroxasulfone plus atrazine plus glyphosate POST may help to provide consistency across environmental conditions and variable weed populations, and may prove useful in management of herbicide-resistant weeds.

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CHAPTER 3

SOYBEAN RESPONSE AND WEED CONTROL WITH PREEMERGENCE AND POSTEMERGENCE APPLICATION OF PYROXASULFONE

INTRODUCTION

Soybean (*Glycine max* L. Merr.) is an economically important crop in Louisiana. In 2012, 1.1 million hectares were harvested, making soybean the number one crop in Louisiana in terms of hectares harvested (USDA 2013). Soybean cultivars are differentiated on the basis of maturity groups (MG) and adaptation to certain latitudes (McWilliams et al. 1999). The majority of soybean cultivars grown in Louisiana represent the MG IV (indeterminate growth type) and V and VI (determinate growth type). The growth types differ with respect to the extent of vegetative growth occurring after flower initiation.

With the introduction of glyphosate-resistant crop technology in the mid-1990's, Louisiana producers rapidly shifted to production of Roundup Ready™ cultivars. Because of the broad spectrum of weed control provided, multiple applications of glyphosate were made in soybean and also in other glyphosate-resistant crops grown in rotation with soybean. Shifts in weed population to weeds less sensitive to glyphosate occurred (Culpepper 2006) and over time, glyphosate-resistant weeds were identified (Norsworthy et al. 2008). As a result, emphasis has been placed on use of herbicides with different modes of action to help control herbicide-resistant weeds and to help prevent development of future herbicide-resistant weeds. In soybean, weed control options include use of soil-applied preemergence (PRE) herbicides and postemergence (POST) herbicides applied most often in combination with glyphosate. Growers also have the option to grow Liberty Link™ soybean that are glufosinate-resistant.

In a soybean production system, PRE herbicides can reduce early season weed competition and in some cases, can help to control weeds that are difficult to control with glyphosate. Research has shown that if weeds emerge with the crop or if not adequately controlled, soybean yield reduction can occur (Ellis and Griffin 2002). Soybean yield was reduced at least 17% when sicklepod was allowed to compete 4 weeks or longer (McWhorter and Sciumbato 1988; Shaw et al. 1991). Common cocklebur competition with soybean for 4 weeks or longer reduced yield as much as 57% (Mosier and Oliver 1995). Use of PRE herbicides can also help to extend the application window for POST herbicide, beneficial in situations where weather conditions or time constraints delay application of glyphosate (Ellis and Griffin 2002). Presently, several PRE herbicides are available for use in soybean, and their length of residual activity can be dependent on rate, soil type and pH, and rainfall following application (Barrett and Lavy 1983; Grey et al. 1997). Also in many cases, PRE herbicides are limited in weed control spectrum with some controlling primarily grasses and others primarily broadleaf weeds.

Pyroxasulfone is a selective herbicide under evaluation for PRE and POST control of grass and broadleaf weeds in soybean and corn (*Zea mays* L.) (Lingenfelter and Curran 2012). Pyroxasulfone could serve as an alternative herbicide for use in soybean, providing an alternative mode of action for management of herbicide-resistant weeds. Yoshitaka et al. (2011) reported the mode of action of pyroxasulfone as an inhibitor of very-long-chain fatty acid elongase (VLCFAE). VLCFAE-inhibiting herbicides, classified in the K3 group by the Herbicide Resistance Action Committee (HRAC), inhibit shoot elongation during seed germination and seedling development (Tanetani et al. 2009). Pyroxasulfone has been evaluated on various soil types applied PRE and POST (Harden et al. 2011). Rate ranges are 94 to 157 (course texture), 125 to 188 (medium texture), and 157 to 220 g ai/ha (fine texture) (Harden et al. 2011). In a study conducted using six soils from Australia ranging from loamy sand to clay, average half-life was 26.6, 10.9, and 15.8 days for pyroxasulfone, dimethenamid, and *S-metolachlor*, respectively (Shaner et al. 2012). Average binding constant across the soils ranged from 0.7 for pyroxasulfone to 2.1 for *S*-metolachlor. Pyroxasulfone has low water solubility (3.1 mg/L) (Anonymous 2004). This compares with 33 mg/L for atrazine and 488 mg/L for *S*-metolachlor (Senseman 2007). The low water solubility of pyroxasulfone would help decrease the possibility of groundwater contamination. In February 2013, EPA approved the use of pyroxasulfone in soybean.

The objectives of this research were to evaluate soybean injury with pyroxasulfone applied at varies rates preemergence (PRE) and postemergence (POST) in soybean, to compare weed control with pyroxasulfone PRE, POST, and PRE followed by POST with current weed control programs, and to establish a pyroxasulfone rate and application timing recommendation that maximizes both weed control and soybean yield.

MATERIALS AND METHODS

PYROXASULFONE APPLICATION TIMING STUDY. Experiments were conducted in 2011 and 2012 at the Dean Lee Research and Extension Center in Alexandria, LA, and in 2012 at the Ben Hur Research Farm in Baton Rouge, LA. The soil in Alexandria was a Coushatta silt loam (fine-salty, mixed, superactive, thermic Fluventic Entrudept) with 2.3% organic matter (OM) and pH of 8 and in Baton Rouge was a Mhoon silty clay loam (fine-silty, mixed, nonacid, thermic Typic Flauaquent) with 1.9% OM and pH of 6.3. ‘Pioneer 94M80’ soybean was planted both years in

Alexandria and ‘Pioneer 95Y31’ was planted in Baton Rouge. Soybean was planted at a rate of 300,000 seed per hectare on April 18, 2011, and May 7, 2012, on raised beds spaced 97 cm apart in Alexandria. In Baton Rouge, soybean was planted at a rate of around 280,000 seed per hectare on May 16 in rows spaced 38 cm apart. Plot size in Alexandria was four rows 9.1 m long both years, and in Baton Rouge plot size was five rows 7.6 m long. In Alexandria, all four rows were treated and at Baton Rouge only the three inside rows were treated.

At both locations, the experimental design was a randomized complete block with a 2 X 6 factorial arrangement. Treatments were replicated four times. Factor A consisted on application timing of PRE or POST. Factor B consisted of pyroxasulfone rates of 0, 60, 120, 180, 240, and 300 g/ha. A nontreated control was included for comparison. Pyroxasulfone PRE treatments were applied the day of planting at each location. Pyroxasulfone POST treatments were applied at V3 (2 fully expanded trifoliates) on May 13, 2011 and May 24, 2012 at Alexandria and June 15, 2012 at Baton Rouge. At both locations, glyphosate was applied POST as needed at 860 g ae/ha to assure that any yield difference was a reflection of pyroxasulfone injury rather than weed competition. Treatments in Alexandria were applied with a spray-mounted tractor at 140 L/ha spray volume and 255 kPa pressure in 2011 and 140 L/ha spray volume and 303 kPa pressure in 2012. Treatments in Baton Rouge in 2012 were applied with a CO_2-pressurized backpack sprayer and 140 L/ha spray volume and 193 kPa pressure.

Soybean injury ratings were made 3, 10, 14, and 28 days after application of PRE (DAPRE) and POST (DAPOST) applications of pyroxasulfone and injury was based on height reduction, leaf appearance (crinkling of leaf surface and irregular leaf margins), and drooping of leaf petioles. The injury rating scale was 0 to 100% with 0 = no injury and 100 = crop death.

Because height reduction was a component of the injury rating, plant height was determined for all treatments 14 DAPOST application by measuring from the soil to the terminal. Data collected 14 DAPOST corresponded to 39 DAPRE at Alexandria 2011, 21 DAPRE at Alexandria 2012, and 44 DAPRE at Baton Rouge.

At soybean maturity, the two center rows of each plot at Alexandria both years and the three inside rows at Baton Rouge were mechanically harvested with a combine. Harvest was on August 29, 2011 and September 14, 2012 at Alexandria and October 9, 2012 at Baton Rouge. For each experiment, seed yield was adjusted to 13% moisture.

Data for experiments conducted in Alexandria and Baton Rouge were subjected to an ANOVA by SAS Proc. Mixed (SAS/STAT Version 6, SAS Institute, Cary, NC). Years, locations, year by location, and replications nested within year by location were considered random effects (Blouin et al. 2011). Preemergence and postemergence herbicide treatments were considered random effects. Considering year and location an environmental or random effect permits inferences about treatments to be made over a range of environments (Carmer et al 1989; Stephenson et al. 2012). Least square means were calculated and mean separation ($P \leq 0.05$) was produced using PDMIX800 in SAS, which is a macro for converting mean separation output to letter groupings (Saxton et al. 1998).

PYROXASULFONE WEED CONTROL STUDY. Experiments were conducted in 2012 at both the Dean Lee Research and Extension Center in Alexandria, LA and at the Ben Hur Research Farm in Baton Rouge, LA. Soil type, soybean cultivar, seeding rate and planting date, and plot size were the same as described for the pyroxasulfone application timing study in 2012. At both locations, the experimental design was a randomized complete block with four replications.

Treatments included: 1) pyroxasulfone at 150 g/ha PRE and followed by (fb) *S*-metolachlor at 1210 g ai/ha plus fomesafen at 265 g ai/ha plus glyphosate at 860 g ae/ha POST or fb fomesafen at 275 g/ha plus glyphosate at 1105 g/ha POST; 2) pyroxasulfone PRE at 150 g/ha plus saflufenacil at 25 g ai/ha; pyroxasulfone PRE at 90 g/ha plus flumioxazin at 70 g ai/ha; pyroxasulfone PRE at 145 g/ha plus fluthiacet-methyl at 5 g ai/ha or pyroxasulfone PRE at 150 g/ha plus chlorimuron ethyl at 5 g ai/ha plus flumioxazin at 70 g/ha plus thifensulfuron methyl at 20 g ai/ha and each was fb glyphosate at 860 g/ha POST; 3) pyroxasulfone PRE at 150 g/ha fb pyroxasulfone at 60 g/ha plus glyphosate at 860 g/ha POST; and 4) commercial standards of saflufenacil at 25 g/ha plus dimethenamid-P at 220 g ai/ha plus pendimethalin at 1120 g ai/ha; flumioxazin at 70 g/ha; *S*-metolachlor at 1210 g/ha plus fomesafen at 270 g/ha; or sulfentrazone at 175 g ai/ha plus metribuzin at 265 g ai/ha PRE and each was followed by glyphosate at 860 g/ha POST. A nontreated control was included for comparison.

Preemergence herbicide treatments were applied the day of planting. For the pyroxasulfone PRE fb fomesafen plus glyphosate and pyroxasulfone PRE fb pyroxasulfone plus glyphosate treatments, the first POST application was made when soybean was at V3; May 24 at Alexandria 17 days after PRE application and June 15 at Baton Rouge 30 days after PRE application. For the remaining treatments, POST application (second POST application) was made 42 days after PRE herbicide application on June 18 at Alexandria and June 27 at Baton Rouge. The difference in the timing for the POST application was to allow for additional comparisons among treatments. The spray equipment, spray volume, and spray pressure used at each location in 2012 were the same as described previously.

Weeds at Alexandria included browntop millet (*Urochloa ramosa* L. Nguyen), hemp sesbania (*Sesbania exaltata* Raf. Cory), hophornbeam copperleaf (*Acalypha ostryifolia* Riddell), ivyleaf moringglory (*Ipomoea hederacea* Jacq.), Palmer amaranth (*Amaranthus palmeri* S. Wats), and sicklepod (*Senna obtusifolia* (L.) H.S. Irwin & Barneby). Weeds at Baton Rouge included barnyardgrass (*Echinochloa crus-galli* L. Beauv), and pitted moringglory (*Ipomoea lacunosa* L.). When the V3 (POST 1) and the 42 day after PRE (POST 2) applications were made, weeds were no more than 7.6 and 12.7 cm, respectively.

At Alexandria, soybean injury and weed control ratings were made prior to POST application at 10 and 20 DAPRE application. Soybean injury and weed control were also evaluated 22 days after the V3 application (22 DAPOST1 and 39 DAPRE) and 11 and 29 days after the second POST application which corresponded to 36 and 54 DAPOST1. In Baton Rouge, soybean injury and weed control ratings were made 30 DAPRE and prior to POST application, and soybean injury and weed control were also evaluated 12 DAPOST1 (42 DAPRE) and 9 and 21 DAPOST2, which corresponded to 21 and 33 DAPOST1 and 51 and 63 DAPRE applications. Crop injury and weed control ratings at both locations were made using the same rating scale described for the pyroxasulfone application timing study. At maturity, soybean yield was determined as described previously for the application timing study. Because weed species differed at the two locations, data for each experiment were analyzed separately and were subjected to an ANOVA using SAS (SAS/STAT Version 6, SAS Institute, Cary, NC). Least square means were calculated and mean separation ($P \leq 0.05$) was produced using PDMIX800 in SAS, which is a macro for converting mean separation output to letter groupings (Saxton et al. 1998).

RESULTS AND DISCUSSION

PYROXASULFONE APPLICATION TIMING STUDY. Soybean injury with pyroxasulfone applied PRE consisted of a slight reduction in plant growth along with crinkling of leaf surface, irregular leaflet margins, and an indentation in tip of the center leaflet (drawstring effect). For POST application of pyroxasulfone, soybean injury consisted of drooping of the top leaf petioles resulting in a greater canopy width appearance; crinkling of leaf surface, irregular leaflet margins, and leaflet tip indentation were also observed, particularly at higher rates.

When pyroxasulfone was applied PRE, soybean injury 3 and 10 DAPRE was no more than 6% (Table 3.1). At 14 DAPRE, soybean was injured 10 and 12% for pyroxasulfone at rates of 240 and 300 g/ha. For rating 3 and 10 DAPRE, rainfall for activation had not been received at Baton Rouge. Injury 14 DAPRE appears related to greater rainfall received 3 to 10 days after PRE application at Alexandria compared with Baton Rouge. For pyroxasulfone applied POST, soybean injury 3 DAPOST was 18% for 60 g/ha and 21 to 23% for rates of 120 to 300 g/ha (Table 3.1). At 10 DAPOST, soybean was injured 15% with pyroxasulfone at 60 g/ha and 18 to 21% for pyroxasulfone at 120 g/ha or more. By 14 DAPOST, injury from pyroxasulfone was no more than 9%. At 28 days after herbicide application, injury was not observed for pyroxasulfone applied PRE or POST at any of the rates. Waggoner et al. (2012) evaluated the effects of POST application of pyroxasulfone at 59 and 118 g/ha and acetochlor at 1300 g/ha on soybean injury and yield. An overlap application of each herbicide was also evaluated by applying a double rate of each treatment. Results show that soybean injury, height, and yield reduction can occur with overlapped applications of acetochlor (2600 g/ha) and pyroxasulfone (236 g/ha) when applied at V6 or R1; injury was not observed with either herbicide (pyroxasulfone at 118 g/ha

Table 3.1. Soybean injury 3, 10, 14, and 28 days following pyroxasulfone applied preemergence (PRE) and postemergence (POST).

Pyroxasulfone rate	Application timing[2]	Soybean injury[1] 3 DAT	10 DAT	14 DAT	28 DAT
g ai/ha					
0	PRE	1 lm[3]	1 lm	1 lm	0 m
60	PRE	3 j-m	2 klm	2 klm	0 m
120	PRE	5 ijk	3 j-m	4 jkl	0 m
180	PRE	6 hij	4 jkl	8 ghi	0 m
240	PRE	6 hij	4 jkl	10 fg	0 m
300	PRE	6 hij	5 ijk	12 ef	0 m
0	POST	1 lm	5 ijk	0 m	0 m
60	POST	18 cd	15 de	5 ijk	0 m
120	POST	21 abc	18 cd	6 hij	0 m
180	POST	22 ab	19 bc	8 ghi	0 m
240	POST	23 a	19 bc	8 ghi	1 m
300	POST	23 a	21 abc	9 fgh	0 m

[1] Data averaged for Alexandria in 2011 and 2012 and for Baton Rouge in 2012.

[2] PRE treatments applied April 18, 2011 and May 7, 2012 at Alexandria and May 16, 2012 at Baton Rouge. POST treatments applied at V3 (two fully expanded trifoliates) on May 13, 2011 and May 24, 2012 at Alexandria and June 15, 2012 at Baton Rouge. Plots were maintained weed free with timely application of glyphosate.

[3] Means within and among columns followed by the same letter are not significantly different at $P \leq 0.05$.

and acetochlor at 1300 g/ha) when applied prior to V6.

Soybean height determined 14 DAPOST application of pyroxasulfone, which corresponded to 21 to 44 DAPRE depending on location and year, was not negatively affected by pyroxasulfone (Table 3.2). Plant height averaged across three experiments and pyroxasulfone rates and application timings was 44 cm. Soybean yield was also not affected by pyroxasulfone applied PRE or POST and yield averaged 3,570 kg/ha. Others have reported excellent soybean tolerance to pyroxasulfone applied PRE and POST (Grey et al. 2012; Kurtz et al. 2011; Lingenfelter and Curran 2012).

PYROXASULFONE WEED CONTROL STUDY. Soybean injury and weed control at Alexandria were evaluated 10 and 20 DAPRE and prior to application of POST treatments. Soybean was not injured (0 – 3%) 10 DAPRE when pyroxasulfone was applied alone or with saflufenacil or fluthiacet-methyl or when metolachlor plus fomesafen was applied PRE (Table 3.3). When pyroxasulfone was applied with flumioxazin or with chlorimuron ethyl plus flumioxazin plus thifensulfuron methyl, soybean was injured 30 and 33%, respectively. Flumioxazin applied alone injured soybean 10 DAPRE 21% and injury was 13% for saflufenacil plus dimethanamid-P plus pendimethalin and 11% for sulfentrazone plus metribuzin. At 20 DAPRE, injury was 18% for pyroxasulfone plus flumioxazin and 22% for pyroxasulfone plus chlorimuron ethyl plus flumioxazin plus thifensulfuron methyl, but was no more than 8% for the other treatments. Differences in weed control were not observed among the PRE herbicide treatments at 10 or 20 DAPRE. Hophornbeam copperleaf, hemp sesbania, browntop millet, and sicklepod were controlled 20 DAPRE 91 to 99% (Table 3.3). For ivyleaf morningglory, control 20 DAPRE ranged from 76 to 98%, but differences were not detected among the herbicide treatments. Lingenfelter and Curran (2012) reported 86 to 91% control of giant foxtail (*Setaria faberi* Herrm.), common lambsquarters (*Chenopodium album* L.), velvetleaf (*Abutilon theophrasti* Medik.), common ragweed (*Ambrosia artemisiifolia* L.), and smooth pigweed (*Amaranthus hybridus* L.) with pyroxasulfone PRE. In general, grass control with pyroxasulfone was similar to that for *S*-metolachlor, but annual broadleaf weed activity was greater for pyroxasulfone.

Table 3.2. Soybean height and yield following pyroxasulfone applied preemergence (PRE) and postemergence (POST).

Pyroxasulfone rate	Application timing[2]	Plant height[1] 14 DAPOST	Yield[1]
g ai/ha		cm	kg/ha
0	PRE	45 a[3]	3650 a
60	PRE	43 a	3660 a
120	PRE	45 a	3590 a
180	PRE	43 a	3560 a
240	PRE	44 a	3540 a
300	PRE	45 a	3500 a
0	POST	45 a	3500 a
60	POST	44 a	3500 a
120	POST	43 a	3600 a
180	POST	43 a	3620 a
240	POST	45 a	3530 a
300	POST	43 a	3570 a

[1] Data averaged for Alexandria in 2011 and 2012 and for Baton Rouge in 2012. Data collected 14 days after POST (14 DAPOST) application corresponds to 21 to 44 DAPRE depending on location and year.

[2] PRE treatments applied April 18, 2011 and May 7, 2012 at Alexandria and May 16, 2012 at Baton Rouge. POST treatments applied at V3 (two fully expanded trifoliates) on May 13, 2011 and May 24, 2012 at Alexandria and June 15, 2012 at Baton Rouge. Plots were maintained weed free with timely application of glyphosate.

[3] Means within each column followed by the same letter are not significantly different at $P \leq .05$.

Soybean injury at Alexandria 39 DAPRE (22 DAPOST1) represented injury from both PRE and POST herbicide treatments for pyroxasulfone PRE fb fomesafen plus glyphosate and pyroxasulfone PRE fb pyroxasulfone plus glyphosate applied at V3 (POST1). Soybean injury 39 DAPRE application was 8% for saflufenacil plus dimethenamid-P plus pendimethalin and 20% for pyroxasulfone plus chlorimuron ethyl plus flumioxazin plus thifensulfuron methyl. Soybean injury 11 DAPOST2 (36 DAPOST1) at Alexandria was 23% for saflufenacil plus dimethanamid-P plus pendimethalin fb glyphosate but was no more than 5% for the other treatments (Table

Table 3.3. Soybean injury and weed control with pyroxasulfone applied preemergence (PRE) alone and with other herbicides compared with standard PRE herbicide treatments at Alexandria, LA.

			Soybean injury[2]		Hop-hornbeam copperleaf		Ivyleaf morningglory		Hemp sesbania		Brown-top millet	Sickle-pod
Herbicide treatment[1]	Timing	Rate	10 DAPRE	20 DAPRE	10 DAPRE	20 DAPRE	10 DAPRE	20 DAPRE	10 DAPRE	20 DAPRE	10 DAPRE	20 DAPRE
		g ai/ha	%									
Pyroxasulfone	PRE	150	0 d[3]	0 b	98 a	99 a	87 a	87 a	98 a	97 a	99 a	97 a
Pyroxasulfone	PRE	150	0 d	0 b	93 a	99 a	74 a	77 a	92 a	98 a	99 a	91 a
Pyroxasulfone + saflufenacil	PRE	150 + 25	3 d	1 b	98 a	99 a	99 a	98 a	97 a	97 a	99 a	99 a
Pyroxasulfone + flumioxazin	PRE	90 + 70	30 a	18 a	99 a	98 a	97 a	93 a	99 a	99 a	97 a	98 a
Pyroxasulfone + fluthiacet-methyl	PRE	145 + 5	0 d	0 b	94 a	99 a	73 a	84 a	92 a	95 a	98 a	95 a
Pyroxasulfone + chlorimuron ethyl + flumioxazin + thifensulfuron methyl	PRE	150 + 5 + 70 + 20	33 a	22 a	97 a	98 a	97 a	98 a	97 a	98 a	98 a	98 a
Pyroxasulfone	PRE	150	0 d	1 b	96 a	99 a	95 a	94 a	95 a	98 a	99 a	98 a
Saflufenacil + dimethenamid-P + pendimethalin	PRE	25 + 220 + 1120	13 c	8 b	98 a	99 a	92 a	91 a	97 a	95 a	99 a	97 a
Flumioxazin	PRE	70	21 b	8 b	97 a	92 b	92 a	90 a	97 a	93 a	98 a	93 a
S-metolachlor + fomesafen	PRE	1210 + 270	0 d	2 b	98 a	98 a	90 a	76 a	97 a	99 a	99 a	96 a
Sulfentrazone + metribuzin	PRE	175 + 265	11 cd	5 b	99 a	99 a	99 a	97 a	98 a	99 a	99 a	94 a

[1] PRE herbicides were applied May 7, 2012.

[2] Data represent soybean injury and weed control 10 and 20 days after PRE application (DAPRE).

[3] Means within each column followed by the same letter are not significantly different at $P \leq 0.05$.

3.4). Injury was not observed for any of the treatments 29 DAPOST2 (54 DAPOST1). Hophornbeam copperleaf control 39 DAPRE (22 DAPOST1) for the herbicide treatments was 78 to 99%; at 11 and 29 DAPOST2 control was 94 to 99% (Table 3.4). Sicklepod control for the herbicide treatments was 72 to 99% 39 DAPRE (22 DAPOST1) and control was 97 to 99% 11 and 29 DAPOST2. For both hophornbeam copperleaf and sicklepod, differences in control were not noted among herbicide treatments at any of the rating dates.

Ivyleaf morningglory, browntop millet, and Palmer amaranth control 39 DAPRE (22 DAPOST1) at Alexandria was 77 to 99%, 89 to 99%, and 77 to 99%, respectively, and in most cases, differences in weed control were not noted among the herbicide treatments (Table 3.5). At 11 DAPOST2 (36 DAPOST1) ivyleaf morningglory was controlled 70 to 99%, browntop millet 95 to 99%, and Palmer amaranth 89 to 99%. For ivyleaf moringglory and browntop millet, control for the herbicide treatments 29 DAPOST2 (54 DAPOST1) was 95 to 99%. For hemp sesbania, control was 75 to 99% 39 DAPRE (22 DAPOST1), 86 to 99% 11 DAPOST2 (36 DAPOST1), and 90 to 99% 29 DAPOST2 (54 DAPOST1) (Table 3.6). Differences in weed control among the herbicide treatments at each rating were not observed.

At Baton Rouge, soybean was not injured with any of the PRE herbicide treatments 30 days after application (Table 3.7). Barnyardgrass control 30 DAPRE was no more than 85% for any of the herbicide treatments. Lowest barnyardgrass control was obtained with saflufenacil plus dimethanamid-P plus pendimethalin and with flumioxazin alone, 58 and 59%, respectively. For the other PRE treatments barnyardgrass control was equivalent and ranged from 73 to 85%. Pitted morningglory control ranged from 60 to 84% and differences among the PRE herbicide treatments were not observed.

Table 3.4. Soybean injury and weed control with pyroxasulfone applied preemergence (PRE) alone and with other herbicides followed by (fb) postemergence (POST) herbicide treatments compared with standard PRE fb POST weed control programs at Alexandria, LA.

Herbicide treatment[1]	Timing	Rate	Soybean injury[2]			Hophornbeam copperleaf			Sicklepod		
			39 DAPRE 22 DAPOST1 0 DAPOST2	53 DAPRE 36 DAPOST1 11 DAPOST2	71 DAPRE 54 DAPOST1 29 DAPOST2	39 DAPRE 22 DAPOST1 0 DAPOST2	53 DAPRE 36 DAPOST1 11 DAPOST2	71 DAPRE 54 DAPOST1 29 DAPOST2	39 DAPRE 22 DAPOST1 0 DAPOST2	53 DAPRE 36 DAPOST1 11 DAPOST2	71 DAPRE 54 DAPOST1 29 DAPOST2
		g ai/ha	%								
Pyroxasulfone fb *S*-metolachlor + fomesafen + glyphosate	PRE fb POST1	150 fb 1210 + 265 + 860	0 b[3]	0 b	0 a	98 a	94 a	99 a	99 a	99 a	99 a
Pyroxasulfone fb fomesafen + glyphosate	PRE fb POST2	150 fb 275 + 1105	0 b	0 b	0 a	86 a	99 a	99 a	72 a	99 a	99 a
Pyroxasulfone + saflufenacil fb glyphosate	PRE fb POST2	150 + 25 fb 860	0 b	0 b	0 a	92 a	99 a	99 a	95 a	99 a	99 a
Pyroxasulfone + flumioxazin fb glyphosate	PRE fb POST2	90 + 70 fb 860	4 b	5 b	0a	95 a	99 a	99 a	95 a	97 a	99 a
Pyroxasulfone + fluthiacet-methyl fb glyphosate	PRE fb POST2	145 + 5 fb 860	0 b	0 b	0 a	91 a	99 a	99 a	91 a	97 a	99 a
Pyroxasulfone + chlorimuron ethyl + flumioxazin + thifensulfuron methyl fb glyphosate	PRE fb POST2	150 + 5 + 70 + 17 fb 860	20 a	4 b	0 a	93 a	99 a	99 a	95 a	99 a	99 a
Pyroxasulfone fb pyroxasulfone + glyphosate	PRE fb POST1	150 fb 60 + 860	0 b	0 b	0 a	99 a	99 a	99 a	99 a	99 a	99 a
Saflufenacil + dimethenamid-P + pendimethalin fb glyphosate	PRE fb POST2	25 + 220 + 1120 fb 860	8 b	23 a	0 a	78 a	99 a	99 a	78 a	99 a	99 a
Flumioxazin fb glyphosate	PRE fb POST2	70 fb 860	0 b	0 b	0 a	86 a	99 a	99 a	85 a	99 a	99 a
S-metolachlor + fomesafen fb glyphosate	PRE fb POST2	1210 + 270 fb 860	0 b	0 b	0 a	90 a	99 a	99 a	90 a	99 a	99 a
Sulfentrazone + metribuzin fb glyphosate	PRE fb POST2	175 +265 fb 860	0 b	0 b	0 a	86 a	99 a	99 a	90 a	99 a	99 a

[1] PRE herbicides were applied May 7, 2012. For the pyroxasulfone PRE fb fomesafen + glyphosate and pyroxasulfone PRE fb pyroxasulfone + glyphosate treatments, POST application was made at V3 (two fully expanded trifoliates) on May 24 (17 days after PRE application) and is designated as POST1. For the other treatments, POST herbicide was applied 42 days after PRE application (DAPRE) on June 18 and is designated as POST2.

[2] Data represent soybean injury and weed control 39 DAPRE/22 DAPOST1/0 DAPOST2; 53 DAPRE/36 DAPOST1/11 DAPOST2; and 71 DAPRE/54 DAPOST1/29 DAPOST2. The 39 DAPRE/22 DAPOST1 rating is reflective of only the PRE and POST1 applications, the POST2 application had not been made.

[3] Means within each column followed by the same letter are not significantly different at $P \leq 0.05$.

Table 3.5. Weed control with pyroxasulfone applied preemergence (PRE) alone and with other herbicides followed by (fb) postemergence (POST) herbicide treatments compared with standard PRE fb POST weed control programs at Alexandria, LA.

Herbicide treatment[1]	Timing	Rate	Ivyleaf morningglory[2]			Browntop millet			Palmer amaranth	
			39 DAPRE 22 DAPOST1 0 DAPOST2	53 DAPRE 36 DAPOST1 11 DAPOST2	71 DAPRE 54 DAPOST1 29 DAPOST2	39 DAPRE 22 DAPOST1 0 DAPOST2	53 DAPRE 36 DAPOST1 11 DAPOST2	71 DAPRE 54 DAPOST1 29 DAPOST2	39 DAPRE 22 DAPOST1 0 DAPOST2	53 DAPRE 36 DAPOST1 11 DAPOST2
		g ai/ha				%				
Pyroxasulfone fb *S*-metolachlor + fomesafen + glyphosate	PRE fb POST1	150 fb 1210 + 265 + 860	98 a[3]	91 a	99 a	99 a	98 a	99 a	98 a	99 a
Pyroxasulfone fb fomesafen + glyphosate	PRE fb POST2	150 fb 275 + 1105	87 a	79 a	99 a	92 a	99 a	99 a	90 a	89 a
Pyroxasulfone + saflufenacil fb glyphosate	PRE fb POST2	150 + 25 fb 860	95 a	99 a	99 a	97 a	99 a	99 a	96 a	99 a
Pyroxasulfone + flumioxazin fb glyphosate	PRE fb POST2	90 + 70 fb 860	82 a	84 a	95 a	94 ab	95 a	99 a	86 a	96 a
Pyroxasulfone + fluthiacet-methyl fb glyphosate	PRE fb POST2	145 + 5 fb 860	94 a	70 a	95 a	93 ab	97 a	99 a	94 a	99 a
Pyroxasulfone + chlorimuron ethyl + flumioxazin + thifensulfuron methyl fb glyphosate	PRE fb POST2	150 + 5 + 70 + 20 fb 860	90 a	90 a	99 a	96 ab	99 a	99 a	96 a	96 a
Pyroxasulfone fb pyroxasulfone + glyphosate	PRE fb POST1	150 fb 60 + 860	99 a	99 a	99 a	99 a	99 a	99 a	99 a	99 a
Saflufenacil + dimethenamid-P + pendimethalin fb glyphosate	PRE fb POST2	25 + 220 + 1120 fb 860	77 a	92 a	97 a	97 a	99 a	99 a	77 a	98 a
Flumioxazin fb glyphosate	PRE fb POST2	70 fb 860	86 a	76 a	97 a	89 b	95 a	99 a	85 a	91 a
S-metolachlor + fomesafen fb glyphosate	PRE fb POST2	1210 + 270 fb 860	81 a	81 a	97 a	99 a	99 a	99 a	95 a	99 a
Sulfentrazone + metribuzin fb glyphosate	PRE fb POST2	175 +265 fb 860	85 a	91 a	98 a	96 ab	97 a	99 a	87 a	93 a

[1] PRE herbicides were applied May 7, 2012. For the pyroxasulfone PRE fb fomesafen + glyphosate and pyroxasulfone PRE fb pyroxasulfone + glyphosate treatments, POST application was made at V3 (two fully expanded trifoliates) on May 24 (17 days after PRE application) and is designated as POST1. For the other treatments, POST herbicide was applied 42 days after PRE application (DAPRE) on June 18 and is designated as POST2.

[2] Data represent soybean injury and weed control 39 DAPRE/22 DAPOST1/0 DAPOST2; 53 DAPRE/36 DAPOST1/11 DAPOST2; and 71 DAPRE/54 DAPOST1/29 DAPOST2. The 39 DAPRE/22 DAPOST1 rating is reflective of only the PRE and POST1 applications, the POST2 application had not been made.

[3] Means within each column followed by the same letter are not significantly different at $P \leq 0.05$.

Table 3.6. Weed control with pyroxasulfone applied preemergence (PRE) alone and with other herbicides followed by (fb) postemergence (POST) herbicide treatments compared with standard PRE fb POST weed control programs at Alexandria, LA.

			Hemp sesbania[2]		
Herbicide treatment[1]	Timing	Rate	39 DAPRE 22 DAPOST1 0 DAPOST2	53 DAPRE 36 DAPOST1 11 DAPOST2	71 DAPRE 54 DAPOST1 29 DAPOST2
		g ai/ha		%	
Pyroxasulfone fb *S*-metolachlor + fomesafen + glyphosate	PRE fb POST1	150 fb 1210 + 265 + 860	98 a[3]	94 a	99 a
Pyroxasulfone fb fomesafen + glyphosate	PRE fb POST2	150 fb 275 + 1105	86 a	97 a	99 a
Pyroxasulfone + saflufenacil fb glyphosate	PRE fb POST2	150 + 25 fb 860	93 a	94 a	94 a
Pyroxasulfone + flumioxazin fb glyphosate	PRE fb POST2	90 + 70 fb 860	95 a	99 a	99 a
Pyroxasulfone + fluthiacet-methyl fb glyphosate	PRE fb POST2	145 + 5 fb 860	87 a	86 a	90 a
Pyroxasulfone + chlorimuron ethyl + flumioxazin + thifensulfuron methyl fb glyphosate	PRE fb POST2	150 + 5 + 70 + 20 fb 860	93 a	99 a	98 a
Pyroxasulfone fb pyroxasulfone + glyphosate	PRE fb POST1	150 fb 60 + 860	99 a	97 a	97 a
Saflufenacil + dimethenamid-P + pendimethalin fb glyphosate	PRE fb POST2	25 + 220 + 1120 fb 860	75 a	92 a	94 a
Flumioxazin fb glyphosate	PRE fb POST2	70 fb 860	88 a	99 a	99 a
S-metolachlor + fomesafen fb glyphosate	PRE fb POST2	1210 + 270 fb 860	88 a	99 a	98 a
Sulfentrazone + metribuzin fb glyphosate	PRE fb POST2	175 +265 fb 860	85 a	99 a	98 a

[1] PRE herbicides were applied May 7, 2012. For the pyroxasulfone PRE fb fomesafen + glyphosate and pyroxasulfone PRE fb pyroxasulfone + glyphosate treatments, POST application was made at V3 (two fully expanded trifoliates) on May 24 (17 days after PRE application) and is designated as POST1. For the other treatments, POST herbicide was applied 42 days after PRE application (DAPRE) on June 18 and is designated as POST2.

[2] Data represent weed control 39 DAPRE/22 DAPOST1/0 DAPOST2; 53 DAPRE/36 DAPOST1/11 DAPOST2; and 71 DAPRE/54 DAPOST1/29 DAPOST2. The 39 DAPRE/22 DAPOST1 rating is reflective of only the PRE and POST1 applications, the POST2 application had not been made.

[3] Means within each column followed by the same letter are not significantly different at $P \leq 0.05$.

Table 3.7. Soybean injury and weed control with pyroxasulfone applied preemergence (PRE) alone and with other herbicides compared with standard PRE herbicide treatments at Baton Rouge, LA.

			Soybean injury[2]	Barnyardgrass	Pitted morningglory
Herbicide treatment[1]	Timing	Rate	30 DAPRE	30 DAPRE	30 DAPRE
		g ai/ha	———— % ————		
Pyroxasulfone	PRE	150	0 a[3]	73 ab	68 a
Pyroxasulfone	PRE	150	0 a	73 ab	75 a
Pyroxasulfone + saflufenacil	PRE	150 + 25	0 a	79 a	70 a
Pyroxasulfone + flumioxazin	PRE	90 + 70	0 a	74 ab	78 a
Pyroxasulfone + fluthiacet-methyl	PRE	145 + 5	0 a	74 ab	80 a
Pyroxasulfone + chlorimuron ethyl + flumioxazin + thifensulfuron methyl	PRE	150 + 5 + 70 + 20	0 a	79 a	80 a
Pyroxasulfone	PRE	150	0 a	80 a	76 a
Saflufenacil + dimethenamid-P + pendimethalin	PRE	25 + 220 + 1120	0 a	58 b	60 a
Flumioxazin	PRE	70	0 a	59 b	73 a
S-metolachlor + fomesafen	PRE	1210 + 270	0 a	85 a	83 a
Sulfentrazone + metribuzin	PRE	175 + 265	0 a	79 a	84 a

[1] PRE herbicides were applied May 16, 2012.

[2] Data represent soybean injury and weed control 30 days after PRE application (DAPRE).

[3] Means within each column followed by the same letter are not significantly different at $P \leq 0.05$.

Soybean injury 42 DAPRE and 12 DAPOST1 treatments was 18% for pyroxasulfone PRE fb pyroxasulfone plus glyphosate, reflective of injury from pyroxasulfone applied PRE and POST (Table 3.8). Injury 12 DAPOST1, which was reflective of only PRE treatment and POST1 (POST2 treatments had not been applied), was 28% for pyroxasulfone, 10% for pyroxasulfone plus saflufenacil, and 9% for pyroxasulfone plus flumioxazin and for pyroxasulfone plus chlorimuron ethyl plus flumioxazin plus thifensulfuron methyl. Injury was 0 to 8% for the other treatments. At 9 DAPOST2 (21 DAPOST1) soybean injury was 18% when *S*-metolachlor plus fomesafen plus glyphosate followed pyroxasulfone PRE, but was no more than 6% for the other treatments. By 21 DAPOST2 (33 DAPOST1), soybean injury was no more than 8% for any of the herbicide treatments.

Pitted morningglory control 42 DAPRE and 12 DAPOST1 treatments was 81 to 87% for pyroxasulfone, pyroxasulfone plus chlorimuron ethyl plus flumioxazin plus thifensulfuron methyl, and sulfentrazone plus metribuzin (Table 3.8). Lowest pitted morningglory control was observed for saflufenacil plus dimethanamid-P plus pendimethalin (56%). For pyroxasulfone fb pyroxasulfone plus glyphosate 42 DAPRE (12 DAPOST1), control of pitted morningglory was 94%. Pitted morningglory control 9 DAPOST2 (21 DAPOST1) ranged from 65 to 85% and from 75 to 94% at 21 DAPOST2 (33 DAPOST1). For both ratings, differences in control among the herbicide treatments were not observed.

Barnyardgrass control 42 DAPRE and 12 DAPOST1 treatments was 93% for pyroxasulfone and 88% for *S*-metolachlor plus fomesafen (Table 3.8). Barnyardgrass was controlled no more than 50% with saflufenacil plus dimethanamid-P plus pendimethalin. For pyroxasulfone fb pyroxasulfone plus glyphosate, control of barnyardgrass 42 DAPRE (12

DAPOST1) was 95%. At 9 DAPOST2 (21 DAPOST1), barnyardgrass control was at least 85% for pyroxasulfone fb *S*-metolachlor plus fomesafen plus glyphosate; pyroxasulfone fb fomesafen plus glyphosate; pyroxasulfone plus saflufenacil fb glyphosate; pyroxasulfone plus flumioxazin fb glyphosate; pyroxasulfone fb pyroxasulfone plus glyphosate; and *S*-metolachlor plus fomesafen fb glyphosate. Control was 74% for flumioxazin fb glyphosate. At 21 DAPOST2 (33 DAPOST1), barnyardgrass was controlled 85 to 97% for all treatments except saflufenacil plus dimethanamid-P plus pendimethalin fb glyphosate (79%) and flumioxazin fb glyphosate (76%). Kurtz et al. (2011) reported that pyroxasulfone controlled both grass and broadleaf weeds with excellent soybean tolerance.

Soybean yield for herbicide treatments at Alexandria ranged from 3,160 to 3,770 kg/ha and in most cases, yield was equivalent for the various treatments (Table 3.9). Of interest is that yield was not reduced when pyroxasulfone was applied PRE and POST. The lower yield observed for saflufenacil plus dimethenamid-P plus pendimethalin fb glyphosate may have been related to crop injury observed 11 days after glyphosate was applied and attributed to PRE herbicides (Table 3.4). Soybean yield following all herbicide treatments at Alexandria were greater than the nontreated (2,490 kg/ha). At Baton Rouge, soybean yield for the herbicide treatments ranged from 3,300 to 3,770 kg/ha (Table 3.9). Although numerically the yield for the nontreated (3,030 kg/ha) was less than that for the herbicide treatments, the differences among the treatments were not significant.

In summary, soybean injury evaluated in three experiments was observed when pyroxasulfone was applied PRE and POST and injury was more severe following the POST application. Injury to soybean consisted of crinkling/undulation of leaflet surface, irregular

Table 3.8. Soybean injury and weed control with pyroxasulfone applied preemergence (PRE) alone and with other herbicides followed by (fb) postemergence (POST) herbicide treatments compared with standard PRE fb POST weed control programs at Baton Rouge, LA.

			Soybean injury[2]			Pitted morningglory			Barnyardgrass		
Herbicide treatment[1]	Timing	Rate	42 DAPRE 12 DAPOST1 0 DAPOST2	51 DAPRE 21 DAPOST1 9 DAPOST2	63 DAPRE 33 DAPOST1 21 DAPOST2	42 DAPRE 12 DAPOST1 0 DAPOST2	51 DAPRE 21 DAPOST1 9 DAPOST2	63 DAPRE 33 DAPOST1 21 DAPOST2	42 DAPRE 12 DAPOST1 0 DAPOST2	51 DAPRE 21 DAPOST1 9 DAPOST2	63 DAPRE 33 DAPOST1 21 DAPOST2
		g ai/ha	%								
Pyroxasulfone fb *S*-metolachlor + fomesafen + glyphosate	PRE fb POST1	150 fb 1210 + 265 + 860	28 a[3]	18 a	8 a	87 ab	78 a	87 a	93 ab	94 ab	95 a
Pyroxasulfone fb fomesafen + glyphosate	PRE fb POST2	150 fb 275 + 1105	8 bc	5 b	1 a	75 abc	81 a	94 a	75 a-d	88 abc	95 a
Pyroxasulfone + saflufenacil fb glyphosate	PRE fb POST2	150 + 25 fb 860	10 bc	6 b	4 a	78 abc	74 a	92 a	78 abc	85 a-d	90 ab
Pyroxasulfone + flumioxazin fb glyphosate	PRE fb POST2	90 + 70 fb 860	9 bc	6 b	3 a	76 abc	74 a	94 a	68 bcd	85 a-d	85 abc
Pyroxasulfone + fluthiacet-methyl fb glyphosate	PRE fb POST2	145 + 5 fb 860	5 bc	3 b	3 a	70 abc	71 a	80 ab	70 a-d	83 bcd	88 ab
Pyroxasulfone + chlorimuron ethyl + flumioxazin + thifensulfuron methyl fb glyphosate	PRE fb POST2	150 + 5 + 70 + 20 fb 860	9 bc	4 b	3 a	86 ab	79 a	86 a	73 a-d	83 bcd	85 abc
Pyroxasulfone fb pyroxasulfone + glyphosate	PRE fb POST1	150 fb 60 + 860	18 b	6 b	3 a	94 a	85 a	92 a	95 a	95 a	97 a
Saflufenacil + dimethenamid-P + pendimethalin fb glyphosate	PRE fb POST2	25 + 220 + 1120 fb 860	5 bc	3 b	8 a	56 c	66 a	75 a	50 d	78 cd	79 bc
Flumioxazin fb glyphosate	PRE fb POST2	70 fb 860	1 c	0 b	4 a	79 abc	75 a	89 a	55 cd	74 d	76 c
S-metolachlor + fomesafen fb glyphosate	PRE fb POST2	1210 + 270 fb 860	6 bc	4 b	5 a	64 bc	65 a	88 a	88 ab	89 abc	93 a
Sulfentrazone + metribuzin fb glyphosate	PRE fb POST2	175 +265 fb 860	0 c	0 b	3 a	81 ab	76 a	90 a	69 a-d	81 cd	86 abc

[1] PRE herbicides were applied May 16, 2012. For the pyroxasulfone PRE fb fomesafen + glyphosate and pyroxasulfone PRE fb pyroxasulfone + glyphosate treatments, POST application was made at V3 (two fully expanded trifoliates) on June 15 (30 days after PRE application) and is designated as POST1. For the other treatments, POST herbicide was applied 42 days after PRE application (DAPRE) on June 27 and is designated as POST2.

[2] Data represent soybean injury and weed control 42 DAPRE/12 DAPOST1/0 DAPOST2; 51 DAPRE/21 DAPOST1/9 DAPOST2; and 63 DAPRE/33 DAPOST1/21 DAPOST2. The 42 DAPRE/12 DAPOST1 rating is reflective of only the PRE and POST1 applications, the POST2 application had not been made.

[3] Means within each column followed by the same letter are not significantly different at $P \leq 0.05$.

Table 3.9. Soybean yield with pyroxasulfone applied preemergence (PRE) alone and with other herbicides followed by (fb) postemergence (POST) herbicide treatments compared with standard PRE fb POST weed control programs at Alexandria and Baton Rouge, LA.

Herbicide treatment[1]	Timing	Rate	Soybean Yield[3]	
			Alexandria	Baton Rouge
		g ai/ha	kg/ha	
Pyroxasulfone fb *S*-metolachlor + fomesafen + glyphosate	PRE fb POST1	150 fb 1210 + 265 + 860	3500 ab[2]	3300 a
Pyroxasulfone fb fomesafen + glyphosate	PRE fb POST2	150 fb 275 + 1105	3630 ab	3360 a
Pyroxasulfone + saflufenacil fb glyphosate	PRE fb POST2	150 + 25 fb 860	3160 b	3430 a
Pyroxasulfone + flumioxazin fb glyphosate	PRE fb POST2	90 + 70 fb 860	3700 ab	3500 a
Pyroxasulfone + fluthiacet-methyl fb glyphosate	PRE fb POST2	145 + 5 fb 860	3700 ab	3430 a
Pyroxasulfone + chlorimuron ethyl + flumioxazin + thifensulfuron methyl fb glyphosate	PRE fb POST2	150 + 5 + 70 + 20 fb 860	3500 ab	3360 a
Pyroxasulfone fb pyroxasulfone + glyphosate	PRE fb POST1	150 fb 60 + 860	3300 ab	3360 a
Saflufenacil + dimethenamid-P + pendimethalin fb glyphosate	PRE fb POST2	25 + 220 + 1120 fb 860	3160 b	3360 a
Flumioxazin fb glyphosate	PRE fb POST2	70 fb 860	3770 a	3630 a
S-metolachlor + fomesafen fb glyphosate	PRE fb POST2	1210 + 270 fb 860	3360 ab	3700 a
Sulfentrazone + metribuzin fb glyphosate	PRE fb POST2	175 +265 fb 860	3630 ab	3770 a

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[1] PRE herbicides were applied May 7, 2012 in Alexandria and May 16, 2012 in Baton Rouge. For the pyroxasulfone PRE fb fomesafen + glyphosate and pyroxasulfone PRE fb pyroxasulfone + glyphosate treatments, POST application was made at V3 (two fully expanded trifoliates) on May 24 (17 days after PRE application) at Alexandria and on June 15 (30 days after PRE application) at Baton Rouge and is designated as POST1. For the other treatments, POST herbicide was applied 42 days after PRE application (DAPRE) on June 18 at Alexandria and June 27 at Baton Rouge and is designated as POST2.

[2] Means within each column followed by the same letter are not significantly different at $P \leq 0.05$.

leaflet margins, indentation of leaflet tips, and a drooping of leaf petioles (POST application only). Injury following pyroxasulfone at 60 g/ha, a rate most likely to be used commercially injured soybean 15% 10 days after application and by 14 days injury had dropped to 5%. At a 2x pyroxasulfone rate of 120 g/ha soybean was injured 18% 10 days after treatment. The injury exhibited by pyroxasulfone can also be seen with other herbicides having the same mode of action to include acetochlor and metolachlor (Senseman 2007). Plant height and yield were not negatively affected by pyroxasulfone applied PRE or POST at rates as high as 300 g/ha.

In the weed control study, pyroxasulfone applied alone PRE at 150 g/ha controlled, browntop millet an average of 99%, barnyardgrass 75%, hophornbeam copperleaf 99%, ivyleaf morningglory 86%, hemp sesbania 98%, sicklepod 95% and pitted morningglory 73% and 20 to 30 day after treatment. Weed control was not improved when pyroxasulfone at 150 g/ha was applied PRE with saflufenacil, flumioxazin, fluthicet-methyl, or chlorimuron ethyl plus flumioxazin plus thifensulfuron methyl. Weed control with pyroxasulfone at 150 g/ha followed by pyroxasulfone at 60 g/ha plus glyphosate POST was no greater than when pyroxasulfone was applied PRE and followed POST by pyroxasulfone or other herbicides in combination with glyphosate. The standard treatments of saflufenacil plus dimethanamid-P plus pendimethalin, flumioxazin, *S*-metolachlor plus fomesafen, or sulfentrazone plus metribuzin applied PRE and followed POST with glyphosate provided weed control and crop yield response comparable to that of the pyroxasulfone treatments. Pyroxasulfone applied PRE or PRE fb POST would offer a safe and viable weed control alternative for use in soybean in the mid-south.

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CHAPTER 4
SUMMARY

Pyroxasulfone, a new herbicide in the isoxazoline chemical family, is an inhibitor of very-long-chain fatty acid elongase (VLCFAE). By inhibiting VLCFAE, pyroxasulfone can affect shoot elongation during seed germination and seedling development when applied preemergence (PRE) and can also affect plant growth when applied postemergence (POST). Other herbicides with this mode of action include acetochlor, *S*-metolachlor, and dimethenamid-P. Research was conducted in Alexandria and Baton Rouge, LA to evaluate corn (*Zea mays* L.) and soybean (*Glycine max* L. Pers.) response and weed control associated with pyroxasulfone applied PRE and POST. Weed control programs including pyroxasulfone were compared with standard herbicide programs in each crop.

In the pyroxasulfone and atrazine PRE and POST study in corn, pyroxasulfone applied both PRE and POST (with glyphosate POST) controlled barnyardgrass, Palmer amaranth, sicklepod, prickly sida, browntop millet, ivyleaf morningglory, and entireleaf morningglory 90 to 100%, but control was no greater than when pyroxaulfone was applied only PRE. Control of smooth pigweed and pitted morningglory, however, was greater for pyroxasulfone applied both PRE and POST (with glyphosate) compared with pyroxasulfone applied only PRE. When pyroxasulfone was applied only POST (with glyphosate) weed control was equivalent to pyroxasulfone applied both PRE and POST (with glyphosate). Greater control of barnyardgrass, Palmer amaranth, smooth pigweed, and browntop millet was observed for pyroxasulfone applied only PRE compared with atrazine PRE and lower corn yield was observed for the atrazine treatment. Weed control was equivalent for pyroxasulfone and pyroxasulfone plus atrazine applied PRE without a follow up POST treatment and corn yield was equivalent for the treatments. Corn yield for pyroxasulfone, pyroxasulfone plus atrazine, or atrazine applied POST with glyphosate was equivalent to that observed for pyroxasulfone and pyroxasulfone plus atrazine applied only PRE, and for pyroxasulfone applied PRE and POST with glyphosate.

In the pyroxasulfone vs. standard herbicide programs study in corn, pyroxasulfone applied PRE without a follow up POST treatment controlled barnyardgrass, smooth pigweed, Palmer amaranth, hophornbeam copperleaf, sicklepod, ivyleaf morningglory, pitted morningglory, and prickly sida 83 to 100%. Weed control was equivalent to that for pyroxasulfone plus atrazine and atrazine plus *S*-metolachlor applied PRE without a follow up POST treatment. Weed control with pyroxasulfone plus atrazine plus glyphosate and atrazine plus glyphosate without a PRE treatment was no greater than when pyroxasulfone was applied only PRE.

In contrast to the pyroxasulfone and atrazine PRE and POST study in corn, in the programs study corn yield was lower when pyroxasulfone was applied only PRE compared with pyroxasulfone plus atrazine PRE. Also in the programs study, corn yield was lower when pyroxasulfone was applied only PRE compared with atrazine plus *S*-metolachlor PRE and when pyroxasulfone plus atrazine plus glyphosate and atrazine plus glyphosate was applied POST.

Results show that although pyroxasulfone applied PRE without a follow up POST treatment can be effective in controlling weeds it may not assure maximum corn yield. Although a sequential application of pyroxasulfone PRE followed by POST did not negatively affect corn growth or yield, the value of the treatment from a weed control and yield perspective was no greater than for pyroxasulfone applied PRE followed by glyphosate or for pyroxasulfone plus glyphosate or atrazine plus glyphosate applied POST.

In the application timing study in soybean, injury was observed when pyroxasulfone was applied PRE and POST and injury was more severe following the POST application. Injury to soybean consisted of crinkling of leaflet surface, irregular leaflet margins, indentation of leaflet tips, and a drooping of leaf petioles (POST application only). Injury following pyroxasulfone at 60 g/ha POST, a rate most likely to be used commercially, was 15% 10 days after application and by 14 days injury had dropped to 5%. At a 2x rate of 120 g/ha pyroxasulfone, soybean was injured 18% 10 days after treatment. The injury exhibited by pyroxasulfone can also be seen with other herbicides having the same mode of action. Plant height and yield were not negatively affected by pyroxasulfone applied PRE or POST at rates as high as 300 g/ha.

In the weed control study in soybean, pyroxasulfone applied alone PRE at 150 g/ha controlled, browntop millet an average of 99%, barnyardgrass 75%, hophornbeam copperleaf 99%, ivyleaf morningglory 86%, hemp sesbania 98%, sicklepod 95% and pitted morningglory 73% at 20 to 30 day after treatment. Weed control was not improved when pyroxasulfone at 150 g/ha was applied PRE with saflufenacil, flumioxazin, fluthicet-methyl, or chlorimuron ethyl plus flumioxazin plus thifensulfuron methyl. Weed control with pyroxasulfone at 150 g/ha followed by pyroxasulfone at 60 g/ha plus glyphosate POST was no greater than when pyroxasulfone was applied PRE and followed POST by pyroxasulfone or other herbicides in combination with glyphosate. The standard treatments of saflufenacil plus dimethanamid-P plus pendimethalin; flumioxazin; *S*-metolachlor plus fomesafen; or sulfentrazone plus metribuzin applied PRE and followed POST with glyphosate provided weed control and crop yield response comparable to that of the pyroxasulfone treatments.

Licensing agreements with Kumiai Chemical Industry will allow the marketing of pyroxasulfone in corn and soybean as Zidua® through BASF for use preplant, PRE, and POST; of pyroxasulfone plus flumioxazin in corn and soybean as Fierce® through Valent USA for use preplant and PRE; and of pyroxasulfone plus fluthiacet-methyl in corn as Anthem™ through FMC for use preplant, PRE, and early POST. At present in both corn and soybean in Louisiana, numerous weed control options are available. The efficacy and crop safety of pyroxasulfone plus atrazine PRE or pyroxasulfone plus atrazine plus glyphosate POST provided consistent weed control across environments with diverse weed populations. With the uncertainty in the future registration of atrazine in corn, availability of pyroxasulfone could be an invaluable management tool in the future. Pyroxasulfone may also prove useful in weed control programs to delay or prevent the development of herbicide-resistant weeds and also in the management of herbicide-resistant weeds already present. The crop safety, consistency in weed control, and the flexibility in application timing with pyroxasulfone suggests that it should have a fit in corn and soybean weed management programs in the mid-south.

VITA

Jon Marshall Hardwick is the son of Mary and Jay Hardwick. Born June 1987, he was raised on a family farm in northern Tensas parish near the town of Newellton, Louisiana. He attended Tensas Academy in St. Joseph, Louisiana, and graduated with honors in May 2006 from St. Frederick Catholic High School in Monroe, Louisiana. Marshall went on to study at Louisiana State University where he graduated with a bachelor's degree in Agricultural Business in May 2011. He was then accepted into the Graduate school where he pursued a Master of Science degree in the School of Plant, Environmental, and Soil Sciences under the direction of Dr. James L. Griffin. He is currently a candidate for graduation with a degree in agronomy and emphasis in weed science. After graduation, Marshall plans to return to the family farm in Newellton, Louisiana.