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EPTC in sugarcane (Saccharum spp. hybrids): incorporation methods, weed control, and crop tolerance

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EPTC IN SUGARCANE (*SACCHARUM* SPP. HYBRIDS): INCORPORATION METHODS, WEED CONTROL, AND CROP TOLERANCE

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ABSTRACT

Research conducted over two years evaluated EPTC at 2.0, 2.9, 3.9, and 4.9 kg ai/ha incorporated on pre-formed sugarcane beds using a Lilliston® rolling cultivator and a hipper/bedder. Averaged across EPTC rates 30 days after application, bermudagrass was controlled 62% when incorporated with a rolling cultivator compared with 43% for the hipper/bedder. For johnsongrass and purple nutsedge, incorporation implements were equally effective and control with EPTC 30 days after application averaged 49 and 30%, respectively. Averaged across incorporation methods, control of all weeds 30 days after EPTC application was maximized at 3.9 kg/ha, but control was no greater than when applied at 2.0 kg/ha (45% bermudagrass, 57% johnsongrass, and 33% purple nutsedge control). EPTC treatments were followed by glyphosate at 2.24 kg ai/ha and weed control was compared with a glyphosate alone program consisting of two applications of glyphosate at 2.24 kg ai/ha. Where EPTC was applied 60 days earlier and followed by one application of glyphosate, weed control was no greater than when glyphosate was applied twice (bermudagrass ground cover no more than 5% and johnsongrass control at least 88%). In contrast, purple nutsedge was controlled 31 to 40% where EPTC was followed by one application of glyphosate compared with 63% for two applications of glyphosate. An economic analysis of EPTC and glyphosate programs was performed using herbicide costs and variable costs associated with operation of incorporation implements and herbicide application. Cost of EPTC at 2.0 kg/ha plus application and incorporation would be $38.36/ha with the rolling cultivator and $49.33/ha for the hipper/bedder. Where EPTC at 2.0 kg/ha is followed by glyphosate as Roundup Original Max®, total cost would be $18.66/ha more than where generic glyphosate is used. For EPTC at 2.0 kg/ha incorporated with a rolling cultivator and followed by generic glyphosate, total cost would be $15.31/ha more compared

with generic glyphosate applied twice. In other research, EPTC applied at 2.9 to 6.8 kg/ha and incorporated at planting did not negatively affect sugarcane shoot population 35 and 186 days after planting compared with standard herbicide treatments. EPTC was ineffective on grass and broadleaf winter weeds.

CHAPTER 1

INTRODUCTION

In 2009, sugarcane (*Saccharum* spp. hybrids) was planted on 169,105 hectares by 495 producers in 22 Louisiana parishes, and 158,114 hectares were harvested for sugar (Anonymous 2009). In Louisiana, sugarcane is ranked first among row crops with an estimated value of $447 million. Sugarcane production in Louisiana is unique in that sugarcane is a perennial crop with 3 to 5 harvests made from a single planting. The crop is vegetatively propagated and billets or whole stalks are planted in August and September. After the last harvest year, sugarcane stubble is destroyed and fields are fallowed to prepare for replanting. During the fallow period growers have the opportunity to use tillage and herbicide to control weeds. The success in controlling weeds during the fallow period directly affects level of weed infestation in the newly planted sugar crop (Anonymous 2009).

Perennial weeds such as bermudagrass (*Cynodon dactylon* L. Pers.), johnsongrass (*Sorghum halepense* L. Pers.), and nutsedge (*Cyperus* spp.) are difficult to control in the sugarcane crop. Inconsistent weed control with herbicides, combined with the inability to cultivate tops of sugarcane beds contribute to increased weed infestation over the crop cycle. Research has shown that once bermudagrass is established, sugarcane stalk populations in plant cane, first ratoon, and second ratoon can be reduced as much as 23, 15, and 10 %, respectively (Richard and Dalley 2007). Sugar yields were reduced as much as 32% in the plant cane crop and as much as 9% in the ratoon crops. Even with the use of PRE herbicides, bermudagrass infestation increased over a 3-year crop cycle (Richard 1993). Effective control of bermudagrass can be obtained with glyphosate, but use is limited to the fallow period where multiple applications are made (Richard

1997a). Even with multiples applications, complete control of bermudagrass with glyphosate may not be achieved.

Johnsongrass, a tall growing C4 plant that reproduces from seeds and rhizomes, can be deleterious to sugarcane production. Richard (1990) and Ali et al. (1986) reported that with season long johnsongrass competition, sugar yield was reduced as much as 50% and 36%, respectively. The most consistent in-crop postemergence control for johnsongrass was achieved with a combination of asulam and trifloxysulfuron; 79% control 5 weeks after treatment and 69% 8 WAT (Dalley and Richard 2008). Several preemergence control options are available for seedling johnsongrass including clomazone + diuron, pendimethalin, metribuzin, terbacil, and trifluralin (Anonymous 2009). Rhizome johnsongrass is difficult to control preemergence and no more than 50% can be expected with soil incorporation of pendimethalin or trifluralin.

Johnsongrass control during the fallow period is addressed through combinations of tillage and glyphosate application. Pendimethalin or trifluralin preemergence has also been effective (Richard 1997b). Some producers are planting glyphosate-resistant soybean during the sugarcane fallow period as a means to control weeds and provide additional income. Griffin et al. (2006) reported excellent control of seedling and rhizome johnsongrass in fallowed fields with single or sequential applications of glyphosate in glyphosate-resistant soybeans. Soybeans had no negative effect on the subsequent sugarcane crop.

Purple nutsedge (*Cyperus rotundus* L.) has been labeled the “world’s worst” weed and is a problem in at least 92 countries and 52 crops worldwide. Purple nutsedge is problematic because of its ability to produce an extensive system of rhizomes and tubers (Holm et al. 1997). Control of this weed in newly planted sugarcane is limited to a PRE application of sulfentrazone or postemergence application of halosulfuron or trifloxysulfuron (Anonymous 2009). Halosulfuron postemergence provided 79% control of purple nutsedge compared to 61% control with sulfentrazone 3 week after treatment (Etheredge et al. 2008). Control of purple nutsedge in newly planted sugarcane is critical because of its ability to reestablish and compete with the crop. Complete control of purple nutsedge is nearly impossible, and control measures should be implemental both during the fallow period and in the crop. In a greenhouse study where a one-node sugarcane seed piece was planted along with 4 nutsedge tubers, 115 tubers were present 64 days later (Etheredge et al. 2006). Sugarcane plant height and root and shoot dry weight were reduced with purple nutsedge competition.

Glyphosate and tillage during the fallow period are not effective for controlling purple nutsedge (Anonymous 2009). Yellow nutsedge (*Cyperus esculentus* L.) was controlled 29% with glyphosate at 0.84 kg ai/ha 14 week after treatment (Nelson and Renner 2002). Glyphosate did not negatively affect yellow nutsedge height, panicle density, shoot dry weight, tuber number, and tuber weight. When glyphosate was applied with chlorimuron or halosulfuron, control of yellow nutsedge was greater than for glyphosate applied alone. Halosulfuron and trifloxysulfuron can be effective on nutsedge in fallowed sugarcane fields and when applied with glyphosate, can provide broad spectrum control (Anonymous 2009).

The ineffectiveness of glyphosate on bermudagrass and nutsedge has prompted interest in looking at other herbicides that could be used in a program with glyphosate in fallowed sugarcane fields. One herbicide of interest is EPTC. EPTC, trade name EPTAM, is a thiocarbamate herbicide discovered in 1957 by Stauffer Chemical Company (Senseman 2007) and widely used at one time in safened corn. The mode of action of EPTC is the inhibition of fatty acid and lipid biosynthesis. Specifically, EPTC affects the composition of lipids in the cuticle of plants (Chamel et al. 1997; Wilmesmeier and Wierman 1995). Leaves of corn seedlings treated with EPTC were more brittle than those from safener-protected plants. EPTC reduced photosynthetic CO_2 fixation and inhibited epicuticular wax deposition (Görög et al. 1982). Sullivan and Prendeville (1974) reported that EPTC inhibited root elongation. Because of volatility (vapor pressure of 4.53 Pa at 25 C), EPTC must to be incorporated into soil immediately. EPTC is absorbed by roots and coleoptiles of grass seedlings and by the hypocotyls of broadleaf plants. Although translocated basipetally and acropetally, translocation likely is unimportant in herbicide action because EPTC is absorbed very near its site of action (Fuerst 1987). Susceptible grass and broadleaf weeds fail to emerge. EPTC usually provides 4 to 6 weeks of weed control. Degradation of EPTC by microorganisms can occur rapidly and degradation is greatest at temperatures between 15 and 25 C (Obrigawitch et al. 1982; Tal et al. 1990).

Soil incorporation and effective placement of herbicides such as EPTC and trifluralin are critical for weed control. Weed control was greatest in field beans (*Phaseolus vulgaris* L.) where EPTC was incorporated 5 to 10 cm deep using tandem disk compared with a chisel plow or spike-tooth harrow (Fenster et al. 1971). Robison and Fenster (1968) reported comparable weed control with EPTC incorporated with a tandem disk and rotary cultivator. Roeth (1973) reported 65% johnsongrass control (seedling and rhizomatous) 4 week after treatment when EPTC at 3.4 kg/ha was incorporated 5 cm deep and 84 and 94% control when incorporated 10 cm deep. Nutsedge shoot emergence from tubers placed in soil where EPTC at 4.5 kg/ha was incorporated with rototiller 13 cm deep was 19% 4 week after treatment compared with 84% shoot emergence in the nontreated (Holt et al. 1962). Mechanical incorporation aided in breakage of tuber chains resulting in greater herbicide activity. Rincon and Warren (1978) conducted experiments in the greenhouse and purple nutsedge tubers were planted 5 cm deep in soil when EPTC was incorporated 6 cm deep. EPTC at 0.5, 1, 2, and 5 kg/ha increased number of sprouts per nutsedge tuber, but sprouts were abnormal and did not reach the soil surface. Number of purple nutsedge rhizomes was reduced when exposed to EPTC. Hauser (1963) recommended that the first application of EPTC for purple nutsedge control be made after thorough disking several weeks before normal date of emergence. Cutting of tuber chains caused tubers to break dormancy, promoting more uniform emergence of purple nutsedge and enhancing EPTC activity.

The effectiveness of EPTC in fallowed sugarcane fields has not been investigated. Research will be conducted to determine the effectiveness of EPTC on three of the most problematic weeds in Louisiana, johnsongrass, bermudagrass, and purple nutsedge. Both EPTC rate and method of incorporation will be evaluated. Research will also evaluate crop safety with EPTC applied at planting.

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CHAPTER 2

PERENNIAL WEED CONTROL WITH EPTC IN FALLOWED SUGARCANE FIELDS

INTRODUCTION

Sugarcane (*Saccharum* spp. hybrids) is a subtropical, perennial crop grown only in Florida, Louisiana, and Texas within the continental U.S. Generally 4 to 6 harvests are made before fields are fallowed and prepared for replanting. In a typical fallow program, sugarcane stubble is destroyed in the spring or early summer and fields are replanted in August and September. During the fallow period, tillage and herbicide programs are used to control weeds that establish during the crop cycle. Weed control during the fallow period is critical and directly affects level of weed infestation in the newly planted crop and in the subsequent ratoon crops (Anonymous 2010). The perennial weeds bermudagrass (*Cynodon dactylon* L. Pers.), johnsongrass (*Sorghum halepense* L. Pers.), and purple nutsedge (*Cyperus rotundus* L.) are especially troublesome. Inconsistent control of perennial weeds with herbicides during the sugarcane crop cycle and the inability to till tops of beds contribute to increased weed infestations.

Richard (1995) reported that bermudagrass biomass in July increased 340% from the plant cane crop to the first ratoon crop and 490% between the first and second ratoon crops. Once bermudagrass is established, sugarcane stalk populations in plant cane, first ratoon, and second ratoon can be reduced as much as 23, 15, and 10%, respectively (Richard and Dalley 2007). In-crop bermudagrass weed control programs include use of metribuzin or clomazone plus diuron preemergence, but control is no greater than 70 to 80% (Anonymous 2010). Because preemergence herbicides persist for only around six weeks and applications are often made after bermudagrass green up, control is short lived and inconsistent. There are no postemergence weed control options for bermudagrass control in the sugarcane crop. During the summer fallow period, glyphosate in conjunction with tillage is used to reduce bermudagrass infestations. Etheredge et al. (2009) reported 86% bermudagrass control 40 days after glyphosate was applied at 1.12 kg ai/ha and control increased to 98% when the same rate was applied sequentially. When glyphosate was applied as a substitute for a tillage operation, bermudagrass control was increased compared with a tillage alone program. Costs associated with fallow weed control programs are dependent on herbicide cost and tillage cost. Elimination of a single tillage operation reduced cost $18.49/ha and addition of glyphosate (2.8 kg/ha plus application cost) increased cost $43.47/ha (Etheredge et al. 2009). Total cost for the conventional tillage alone program was $110.94/ha and where herbicide was used in reduced tillage or no-tillage programs, total cost was $19.47 to $77.38/ha more.

Richard (1990) reported that season long johnsongrass competition reduced sugar yield as much as 50%. Although several preemergence control options are available for seedling johnsongrass (Anonymous 2010), rhizome johnsongrass is difficult to control. No more than 50% rhizome johnsongrass control can be expected with soil incorporation of pendimethalin or trifluralin. Johnsongrass control during the fallow period is addressed through combinations of tillage and glyphosate application (Etheredge et al. 2009). Pendimethalin and trifluralin applied preemergence in fallowed fields also have been effective (Richard 1997).

Purple nutsedge (*Cyperus rotundus* L.) has been labeled the "world's worst" weed and is problematic because of its ability to produce an extensive system of rhizomes and tubers (Holm et al. 1997). Etheredge et al. (2010b) reported that one tuber planted per 26.5 L pot with a surface area of 0.093 m^2 produced 37.3 tubers in 64 days. The increase in purple nutsedge infestation over the last few years in sugarcane in Louisiana is likely due to the poor control obtained with glyphosate during the summer fallow period (Anonymous 2010). Also contributing to the purple nutsedge problem could be the expanded use of pendimethalin that reduces grass competition, but is ineffective on purple nutsedge (Dotray et al. 2001; Grichar and Nester 1997). Halosulfuron, trifloxysulfuron, and sulfentrazone have activity on nutsedge and can be used both in the sugarcane crop and during the fallow period (Anonymous 2010). Etheredge et al. (2010a) reported greater nutsedge control with halosulfuron and sulfentrazone when applied postemergence compared with preemergence. Halosulfuron at 54 and 72 g ai/ha and trifloxysulfuron at 10.5 and 15.7 g ai/ha controlled 10 to 15 cm purple and yellow nutsedge (*Cyperus esculentus* L.) an average of 77 and 68%, respectively. Control of purple nutsedge in newly planted sugarcane is critical because of its ability to reestablish and compete with the crop. In a greenhouse study the critical purple nutsedge density, the density at which a reduction in sugarcane shoot weight or root weight occurred compared with the weed-free control, was 4 and 1 tuber/pot (0.093 m^2 surface area), respectively (Etheredge et al. 2010b).

Because glyphosate applied during the fallow period has not adequately controlled bermudagrass and purple nutsedge, interest has increased in the evaluation of herbicide alternatives. One herbicide that could be used in a program with glyphosate is EPTC. EPTC is a thiocarbamate herbicide discovered in 1957 by Stauffer Chemical Company (Senseman 2007). The mode of action of EPTC is the inhibition of fatty acid and lipid biosynthesis. In the 1960’s and 1970’s EPTC was widely used as a preemergence treatment in corn (*Zea mays L.*). Because of its high vapor pressure (4.53 Pa at 25 C), EPTC must to be incorporated into soil immediately (Senseman 2007). EPTC applied at 3.4 kg ai/ha and incorporated 5 cm deep controlled johnsongrass 4 weeks after treatment 65%, but when incorporated 10 cm deep, control was 94% (Roeth 1973). When EPTC was applied as a 20% granular formulation at 4.5 kg/ha and incorporated 13 cm deep with rotary tiller, purple nutsedge shoot emergence at four weeks of exposure was 19% compared with 84% shoot emergence for the nontreated (Holt et al. 1962). Nutsedge control was greater with the granular compared with the emulsifiable formulation. Hauser (1963) suggested that purple nutsedge control could be increased when fields were disked several weeks before EPTC was applied. Segmenting rhizomes with disking caused tubers to break dormancy, promoting more uniform germination and improved EPTC activity.

Prior to labeling of pendimethalin in sugarcane in Louisiana, trifluralin herbicide, which requires incorporation, was used extensively. A common incorporation implement was a rolling cultivator equipped with six independent gangs which incorporated trifluralin on the row top and sides. The implement was set to operate at a 5 to 8 cm depth so as to not injure sugarcane buds. With the availability of pendimethalin, which did not require incorporation, sugarcane growers shifted away from trifluralin and rolling cultivators. Many growers still have rolling cultivators that could be used for incorporation of EPTC. A hipper/bedder is often used in fallowed sugarcane fields to eliminate weeds after beds have been established. This implement has a sweep centered on the top of the bed which opens the bed followed by 3-disk gangs that re-hip the beds in a single operation. Our research addressed the control of bermudagrass, johnsongrass, and purple nutsedge in fallowed sugarcane fields with EPTC applied at several rates and incorporated with either a rolling cultivator or a hipper/bedder. EPTC treatments were followed by a postemergence application of glyphosate and weed control was compared with that of a multi-application glyphosate alone treatment. Economics of EPTC followed by glyphosate and glyphosate alone programs were compared.

MATERIALS AND METHODS

Bermudagrass Study. Experiments were conducted in 2007, 2008 and 2009 at the Sugar Research Station in St. Gabriel, LA, on a Commerce silt loam (fine-silty, mixed, superactive, non-acid, thermic Fluvaquentic Endoaquepts) with 1.0% OM and a pH of 5.9. Fields were selected because bermudagrass was present the previous year when sugarcane was harvested. Prior to initiation of experiments beginning in April, sugarcane stubble and beds were destroyed by disking. Fields were chisel plowed and disked and rows were re-drawn. EPTC[1] was applied preemergence to the soil surface on pre-formed weed-free sugarcane beds and incorporated 7.6 to 10 cm deep immediately (in the same operation) using a Lilliston® rolling-cultivator[2] or within 10 minutes after application using a hipper-bedder. The rolling cultivator was equipped with 6 independent gangs per bed. Gangs with rotating curved tines were set at a slight angle and soil movement was minimal. For the hipper-bedder, a 30 cm sweep centered on the bed and set 15 cm deep opened the bed and 2 sets of 3-disk gangs set at an angle re-hipped the bed in a single operation. Plot size for experiments was either 2 or 3 sugarcane beds (1.82 or 5.4 m wide) x 15.24 m long.

EPTC at 2.0, 2.9, 4.0, and 4.9 kg ai/ha was applied on May 10, 2007; June 11, 2008; and May 29, 2009, using a compressed air sprayer calibrated to deliver 93.5 L/ha at a spray pressure of 140 kPa. Each of the EPTC treatments was followed 45 days later by a postemergence application of glyphosate[3] at 2.24 kg ai/ha on July 24, 2007; July 29, 2008; and July 22, 2009, using a compressed air sprayer calibrated to deliver 93.5 L/ha at a spray pressure of 140 kPa. Glyphosate application was made when bermudagrass was beginning to reestablish and stolons were rooting. For comparison, a glyphosate alone treatment (no preemergence herbicide applied) was included and glyphosate[3] was applied on July 9, 2007; July 14, 2008; and July 7, 2009, and a

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[1] Eptam 7EC, EPTC, S-ethyl dipropylthiocarbamate. Helena Chemical Co., 225 Schilling Blvd., Collierville, TN 38017.

[2] Lilliston® rolling-cultivator. Rolling cultivator for Bigham Brothers, INC., 705 East Slaton Road, Lubbock, Texas 79452.

[3] Roundup Original Max, a glyphosate N-(phosphonomethyl)glycine in the form of its potassium salt. Monsanto Company, 800 North Lindbergh Boulevard, St. Louis, MO 63167.

second application was made 15 to 17 days later at the same time glyphosate was applied following EPTC treatments. A CO_2-pressurized backpack sprayer calibrated to deliver 93.5 L/ha and at a spray pressure of 140 kPa was used to make the initial glyphosate application and the follow up application was made using a compressed air sprayer at 93.5 L/ha and 140 kPa spray pressure.

For all experiments weed control was based on bermudagrass ground cover on a 0.9 m area on the top of the beds in each plot using a scale of 0 to 100% with 0 = no bermudagrass present and 100 = bermudagrass biomass completely covering the soil surface. Ground cover ratings were made 30 days after EPTC application and reflected only the effect of EPTC since glyphosate had not been applied. Ratings made 45 days after EPTC application corresponded to 15 days after the initial application of glyphosate for the glyphosate alone treatment. Ratings made 60 days after EPTC application corresponded to 15 days after glyphosate was applied following EPTC treatments and 15 days after the second glyphosate application for the glyphosate alone treatment. The experimental design was a randomized complete block with an augmented factorial arrangement of treatments (EPTC rate x incorporation method) with a glyphosate alone program included for comparison with 4 replications.

Johnsongrass Study. Experiments were conducted in 2008 at the Sugar Research Station in St. Gabriel, LA, on a Commerce silt loam (fine-silty, mixed, superactive, non-acid, thermic Fluvaquentic Endoaquepts) with 1.0% OM and a pH of 5.9 and in 2009 at Central Research Station, Ben Hur Research Farm, Baton Rouge, LA, on a Mhoon silty clay loam (fine-silty, mixed, nonacid, thermic Typic Fluavaquent) with 1.9% OM and a pH of 6.3. Fields were selected because of heavy rhizome johnsongrass population. Field sites were prepared as described for the bermudagrass study and plot size was either 2 or 3 sugarcane beds (1.82 or 5.4

m wide) x 15.24 m long. EPTC was applied at the same rates using the same incorporation methods described for the bermudagrass study. EPTC was applied June 11, 2008 at the Sugar Research Station and May 29, 2009 at the Ben Hur Farm using a compressed air sprayer calibrated as described previously. At 30 days after application of EPTC treatments on July 14, 2008 and July 29, 2009, glyphosate[3] was applied at 2.24 kg/ha. On the same dates the initial glyphosate application was made in glyphosate alone treatment. Johnsongrass size at application was 50 to 60 cm height. On July 28, 2008 and August 14, 2009 a second glyphosate application was made at 2.24 kg/ha for the glyphosate alone treatment as described previously. Johnsongrass size was 30 to 45 cm height.

Johnsongrass control was determined using a scale of 0 to 100% with 0 = no control and 100 = all plants dead. Johnsongrass control was determined 30 days after EPTC application and glyphosate had not been applied and 45 days after EPTC application, which corresponded to 15 days after the initial application of glyphosate for the glyphosate alone treatment. Ratings made 60 days after EPTC application corresponded to 30 days after glyphosate was applied following EPTC treatments and 15 days after the second glyphosate application for the glyphosate alone treatment. The experimental design was a randomized complete block with an augmented factorial arrangement of treatments (Eptam rate x incorporation method) with a glyphosate alone treatment included for comparison with 4 replications.

Purple Nutsedge Study. Experiments were conducted in 2009 at Convent, LA on a Cancienne silt loam with 0.5% OM and a pH of 6.5 and at the Central Research Station, Ben Hur Farm, Baton Rouge, LA, on a Mhoon silty clay loam (fine-silty, mixed, nonacid, thermic Typic Fluavaquent) with 1.9% OM and a pH of 6.3. Field sites were prepared as described for bermudagrass and johnsongrass studies and plot size was either 2 or 3 sugarcane beds (1.82 or

5.4 m wide) x 15.24 m long. EPTC was applied the same rates using the same incorporation methods described previously. EPTC was applied May 20, 2009 at Convent, LA and June 7, 2009 at the Ben Hur Research Farm using a compressed air sprayer as described previously. At 30 days after application of EPTC treatments on July 30 and June 22 in 2009, glyphosate was applied at 2.24 kg/ha. On the same dates, the initial glyphosate application was made in glyphosate alone treatment. Purple nutsedge was 15 cm height. On June 7, 2009 and May 20, 2009 a second glyphosate application was made at 2.24 kg/ha for the glyphosate alone treatment.

Purple nutsedge control was determined using the same rating scale as for johnsongrass. Nutsedge control was determined 30 days after EPTC application and glyphosate had not been applied and 45 days after EPTC application, which corresponded to 15 days after the initial application of glyphosate for the glyphosate alone treatment. Ratings made 60 days after EPTC application corresponded to 30 days after glyphosate was applied following EPTC treatments and 15 days after the second glyphosate application for the glyphosate alone treatment. The 60 day after EPTC application rating was not made at Convent, LA. The experimental design was a randomized complete block with an augmented factorial arrangement of treatments (Eptam rate x incorporation method) with a glyphosate alone program included for comparison with 4 replications.

Statistical and Economic Analysis. Data for bermudagrass, johnsongrass, and nutsedge control were subjected to mixed procedure in SAS (2003) with treatments considered fixed effects, and years/locations, replications, and all interactions considered random (Carmer et al. 1989). Years were considered random effects that permit inferences about treatments over a range of environments (Carmer et al. 1989; Hager et al. 2003). For all weeds a significant interaction between EPTC rate/glyphosate treatments and incorporation treatments was not observed.

Significant main effects were observed. Least square means were estimated and separated using PDIFF option where a probability level of greater than or equal to 0.05 was considered significant. Letter groupings were converted using the PDMIX800 macro in SAS (Saxton 1998).

For economic analysis, the cost of EPTC[1] treatments was based herbicide rate and on herbicide price of $11.91/L. Glyphosate cost was based on herbicide rate and herbicide price $9.51/L for Roundup Original Max[3] and $2.90/L for generic glyphosate[4]. Also included in the economic analysis were variable costs associated with herbicide incorporation and application (Salassi and Deliberto 2009). Fuel cost was based on $0.58/L and labor at $9.60/hour. For EPTC incorporation, variable cost for the rolling cultivator was $6.23/ha (fuel), $1.90/ha (repair), and $2.37/ha (labor). For the hipper/bedder variable cost for EPTC incorporation was $7.46/ha (fuel), $1.71/ha (repair), and $2.84/ha (labor). For EPTC or glyphosate application variable cost was $5.98/ha (fuel), $0.64/ha (repair), and $2.84/ha (labor). Total cost for each treatment was determined based on EPTC cost, glyphosate cost (Roundup Original Max or generic glyphosate), and variable costs associated with each treatment.

RESULTS AND DISCUSSION

Bermudagrass Study. A significant interaction between EPTC rate and incorporation method was not observed for bermudagrass ground cover ratings made 30, 45, and 60 days after EPTC application. Averaged across EPTC rates (including the nontreated control), bermudagrass ground cover where EPTC was incorporated with the rolling cultivator was 15% at the 30 day rating and 12% at the 45 day rating, 21 and 29% less, respectively, compared with the hipper/bedder (Table 2.1). The rolling cultivator with six disk gangs per pre-formed bed

[4] Mad Dog Plus, a glyphosate N-(phosphonomethyl)glycine in the form of its isopropylamine salt. Loveland Products, Inc., P.O. Box 1286, Greeley, CO 80632-1286.

appeared more effective in incorporating EPTC in soil and in fragmenting bermudagrass stolons and rhizomes when compared with the hipper/bedder. Compared with the nontreated control at the 30 day rating, bermudagrass control averaged across EPTC rates of 2.0 to 4.9 kg/ha was 62% when incorporated with the rolling cultivator compared with 43% for the hipper/bedder. Where EPTC was not applied, bermudagrass ground cover was 29% at the 30 day rating. Averaged across incorporation methods, bermudagrass ground cover 30 days after EPTC application was 14 to 16% where EPTC was applied at 2.0, 2.9, and 3.9 kg/ha and averaged 47% less than where EPTC was not applied. At 4.9 kg/ha EPTC, bermudagrass ground cover was less than for 2.0 to 2.9 kg/ha and averaged 66% less than the nontreated.

At 45 days after EPTC application, bermudagrass ground cover averaged across incorporation methods was 17 and 18% for EPTC applied at 2.0, 2.9, and 3.9 kg/ha (Table 2.1). At 4.9 kg/ha EPTC, bermudagrass ground cover was 13%. At the 45 day rating, glyphosate had not been applied following EPTC treatments, but had been applied 15 days earlier for the glyphosate alone treatment. Where glyphosate was applied, bermudagrass ground cover at the 45 day rating was 8%, which was less than for all EPTC treatments and a 72% reduction in ground cover compared with 15 days earlier.

At 60 days after EPTC application, glyphosate had been applied 15 days earlier for the EPTC treatments and for the second glyphosate application in the glyphosate alone treatment. Bermudagrass ground cover averaged was 4 to 5% and was equal where glyphosate followed EPTC and where glyphosate was applied alone (Table 2.1). Averaged across EPTC rates, bermudagrass ground cover was less where EPTC was incorporated with the rolling cultivator compared with the hipper/bedder (4 vs. 5%) but the difference was not of practical significance. Results show that EPTC applied preemergence and incorporated and followed by glyphosate

Table 2.1. Bermudagrass ground cover 30, 45 and 60 days after EPTC application as affected by incorporation using a rolling cultivator (RC) and a hipper/bedder (H/B) and application of glyphosate in 2007, 2008, and 2009.[1]

		Days after EPTC application/Incorporation method[2]								
		30			45			60		
Treatment	Rate	RC	H/B	Average	RC	H/B	Average	RC	H/B	Average
	kg ai/ha	Ground cover (%)								
EPTC followed by glyphosate	2.0 2.24	13	18	16 b[3]	13	21	17 ab	4	6	5 a
EPTC followed by glyphosate	2.9 2.24	14	17	16 b	15	20	18 a	3	5	4 a
EPTC followed by glyphosate	3.9 2.24	10	18	14 bc	13	21	17 ab	4	5	4 a
EPTC followed by glyphosate	4.9 2.24	7	13	10 c	10	15	13 b	3	5	4 a
Glyphosate followed by glyphosate	2.24 2.24	29	29	29 a	8	8	8 c	5	5	5 a
Average		15 a	19 b	-	12 a	17 b	-	4 a	5 b	-
P-level		---0.0042---		0.0001	---0.0034---		0.0001	---0.0017---		0.16

[1] EPTC was applied preemergence and incorporated on May 10, 2007; June 11, 2008; and May 29, 2009 at St. Gabriel, LA. Glyphosate was applied 45 days after EPTC application on July 24, 2007; July 29, 2008; and July 22, 2009. For the glyphosate alone treatment, glyphosate was applied on July 9, 2007; July 14, 2008; and July 7, 2009 and repeated 15 to 17 days later.
[2] For the ground cover ratings 30 days after EPTC application, glyphosate had not been applied. The 45 day rating was made 45 days after EPTC application and 15 days after initial glyphosate application for the glyphosate alone treatment. The 60 day rating was made 15 days after glyphosate was applied following EPTC treatments and 15 days after the second glyphosate application for the glyphosate alone treatment.

(Table 2.1 continued)

[3] Within each rating date, herbicide treatment means and incorporation method means followed by the same letter are not significantly different (P>0.05).

was no more effective in controlling bermudagrass than two applications of glyphosate in a glyphosate alone program.

Johnsongrass Study. A significant interaction between EPTC rate and incorporation method was not observed for rhizome johnsongrass control 30, 45, and 60 days after EPTC application. Averaged across EPTC rates, johnsongrass control was equal where EPTC was incorporated with either the rolling cultivator or hipper/bedder; 49% at 30 days, 94% at 45 days, and 89% at 60 days (Table 2.2). Averaged across incorporation methods, johnsongrass control 30 days after EPTC application was 57 to 63% where EPTC was applied at 2.0, 2.9, and 3.9 kg/. At 4.9 kg/ha EPTC, johnsongrass was controlled 67% and control was greater than when EPTC was applied at 2.0 and 2.9 kg/ha.

At 45 days after EPTC application, glyphosate had been applied 15 days earlier for the EPTC treatments and for the first application in the glyphosate alone treatment. Averaged across incorporation methods, johnsongrass control was equal for both the EPTC and glyphosate alone treatments and averaged 94% (Table 2.2). At 60 days after EPTC application, glyphosate had been applied 30 days earlier for the EPTC treatments and 15 days earlier for the second glyphosate application in the glyphosate alone treatment. For EPTC followed by glyphosate and glyphosate alone treatment, johnsongrass control averaged across incorporation methods was equal and averaged 89% (Table 2.2). Hicks and Fletchall (1967) reported that EPTC at 3.4 kg/ha delayed emergence of rhizomatous johnsongrass but did not provide control. Other research has addressed seedling johnsongrass control with EPTC. When EPTC at 3.4 kg/ha was incorporated 10 cm deep using a rotary tiller, johnsongrass was controlled 84 and 94% four weeks after treatment over two years (Roeth 1973). Millhollon (1983) reported excellent seedling johnsongrass control with EPTC at 4.5 kg/ha when applied at layby in sugarcane and

Table 2.2. Johnsongrass control 30 and 45 days after EPTC application as affected by incorporation using a rolling cultivator (RC) and a hipper/bedder (H/B) and application of glyphosate in 2008 and 2009.[1]

		Days after EPTC application/Incorporation method[2]								
		30			45			60		
Treatment	Rate	RC	H/B	Average	RC	H/B	Average	RC	H/B	Average
	kg ai/ha	Control (%)								
EPTC followed by glyphosate	2.0 2.24	57	57	57 b[3]	93	95	94 a	88	88	88 a
EPTC followed by glyphosate	2.9 2.24	57	58	57 b	95	95	95 a	88	90	90 a
EPTC followed by glyphosate	3.9 2.24	62	64	63 ab	96	96	96 a	88	88	88 a
EPTC followed by glyphosate	4.9 2.24	69	66	67 a	97	89	93 a	91	87	90 a
Glyphosate followed by glyphosate	2.24 2.24	0	0	0 c	90	90	90 a	90	90	90 a
Average		49 a	49 a	-	93 a	94 a	-	89 a	89 a	-
P-level		---0.9744---		0.0001	---0.3651---		0.146	---0.7968---		0.80

[1] EPTC was applied preemergence and incorporated on June 11, 2008 at St. Gabriel, LA and May 29, 2009 at Ben Hur Research Farm, Baton Rouge, LA. Glyphosate was applied 30 days after EPTC application for EPTC treatments and glyphosate alone treatment on July 14, 2008 and July 29, 2009. For the glyphosate alone treatment, glyphosate was applied on July 28, 2008 and August 14, 2009 and repeated 15 to 17 days later.

[2] For the control ratings 30 days after EPTC application, glyphosate had not been applied. The 45 day rating was made 45 days after EPTC application and 15 days after the initial glyphosate application for all treatments. The 60 day rating was made 30 days after

(Table 2.2 continued)

glyphosate was applied following EPTC treatments and 15 days after the second glyphosate application for the glyphosate alone treatment.

[3] Within each rating date, herbicide treatment means and incorporation method means followed by the same letter are not significantly different (P>0.05).

incorporated with either a rotary-tine or disk cultivator.

Purple Nutsedge Study. For control 30, 45, and 60 days after EPTC application a significant interaction between EPTC rate and incorporation method was not observed. Averaged across EPTC rates, purple nutsedge control was equal where EPTC was incorporated with the rolling cultivator or the hipper/bedder; 30% at 30 days, 45% at 45 days, and 40% at 60 days (Table 2.3). Averaged across incorporation methods, nutsedge control 30 days after EPTC application was 33 to 38% and equal where EPTC was applied at 2.0, 2.9, and 3.9 kg/ha. At 4.9 kg/ha EPTC, purple nutsedge was controlled 47% and control was greater than when EPTC was applied at 2.0 and 2.9 kg/ha.

At 45 days after EPTC application and 15 days after the initial glyphosate application, purple nutsedge control averaged across incorporation methods was 39 to 48% for various EPTC rates and for the glyphosate alone treatment (Table 2.3). EPTC at 2.0 kg/ha followed by glyphosate and the glyphosate alone treatment provided equal purple nutsedge control. At 60 days after EPTC was applied, which corresponded to 30 days after glyphosate was applied following EPTC treatments and 15 days after the second glyphosate application in the glyphosate alone treatment, purple nutsedge control for the glyphosate alone program was 63% and greater than for all rates of EPTC followed by glyphosate (31 to 40%).

For bermudagrass control, incorporation of EPTC with the rolling cultivator was more effective than incorporation with the hipper/bedder. Incorporation of EPTC with either the rolling cultivator or hipper/bedder, however, was equally effective in controlling johnsongrass and purple nutsedge. Robison and Fenster (1968) reported that for the volatile herbicides EPTC and trifluralin, a tandem disk was needed for incorporation to promote soil movement and mixing of herbicide. A spring-tooth harrow tended to furrow the soil and did not provide enough

Table 2.3. Purple nutsedge control 30 and 45 days after EPTC application as affected by incorporation using a rolling cultivator (RC) and a hipper/bedder (H/B) and application of glyphosate in 2009.[1]

		Days after EPTC application/Incorporation method[2]								
		30			45			60 [4]		
Treatment	Rate	RC	H/B	Average	RC	H/B	Average	RC	H/B	Average
	kg ai/ha	Control (%)								
EPTC followed by glyphosate	2.0 2.24	35	34	34 b[3]	42	51	46 ab	38	43	40 b
EPTC followed by glyphosate	2.9 2.24	29	36	33 b	39	39	39 b	35	30	33 b
EPTC followed by glyphosate	3.9 2.24	31	44	38 ab	39	51	45 ab	24	38	31 b
EPTC followed by glyphosate	4.9 2.24	50	43	47 a	41	44	42 ab	26	40	33 b
Glyphosate followed by glyphosate	2.24 2.24	0	0	0 c	48	48	48 a	63	63	63 a
Average		29 a	31 a	-	42 a	47 a	-	37 a	43 a	-
P-level		---0.5252---		0.0001	---0.0903---		0.2676	---0.1624---		0.0001

[1] EPTC was applied preemergence and incorporated on June 7, 2009 at Ben Hur Research Farm, Baton Rouge, LA and May 20, 2009 at Convent, LA. Glyphosate was applied 30 days after EPTC application for EPTC treatments and glyphosate alone treatment on July 29 and June 22 in 2009. For the glyphosate alone treatment at Ben Hur Research Farm, glyphosate was applied on August 14, 2009 and repeated 15 to 17 days later.

[2] For the control ratings 30 days after EPTC application, glyphosate had not been applied. The 45 day rating was made 45 days after EPTC application and 15 days after the initial glyphosate application for all treatments. The 60 day rating was made 30 days after glyphosate was applied following EPTC treatments and 15 days after the second glyphosate application for the glyphosate alone treatment.

(Table 2.3 continued)

[3] Within each rating date, herbicide treatment means and incorporation method means followed by the same letter are not significantly different (P>0.05).
[4]At the 60 DAT rating, data was collected at only the Baton Rouge site.

soil movement for incorporation. When trifluralin was incorporated with a power rotary tiller operated at a 10 cm depth, herbicide was concentrated in the top 2.5 cm of soil (Bode and Gebhardt (1969). A disk operated at the same depth concentrated trifluralin in the top 5 to 7.6 cm of soil. Use of a rolling cultivator as an incorporation implement resulted in 80% of trifluralin in the top 2.5 cm of soil. Although in the present study control of bermudagrass, johnsongrass, and purple nutsedge was maximized with EPTC at 3.9 kg/ha, weed control at this rate was no greater than EPTC applied at 2.0 kg/ha (45% bermudagrass control, 57% johnsongrass control, and 34% purple nutsedge control). Bermudagrass and johnsongrass control where EPTC was followed by one application of glyphosate was no greater than for two applications of glyphosate in a glyphosate alone program (no more than 5% bermudagrass ground cover and johnsongrass control at least 88%). Purple nutsedge control, although greatest for the glyphosate alone program, was only 63%. Other control measures for purple nutsedge should be implemented along with glyphosate during the fallow period to reduce purple nutsedge infestation (Etheredge 2010a).

To further delineate the value of EPTC in fallow weed control programs, an economic analysis of program cost was performed. In this research, EPTC was applied and incorporated with the rolling cultivator in the same operation compared with EPTC application and incorporation with hipper/bedder in separate operations. Variable cost associated with EPTC application and incorporation were $10.50/ha for the rolling cultivator ($6.23/ha fuel, $1.90/ha repair, and $2.37/ha labor) and $21.47/ha [$9.46/ha for application ($5.98/ha fuel, $0.64/ha repair, and $2.84/ha labor) and $12.01 for incorporation ($7.46/ha fuel, $1.71/ha repair, and $2.84/ha labor)] for the hipper/bedder (Table 2.4). In this research bermudagrass control was enhanced when EPTC was incorporated with the rolling cultivator. The added benefit of EPTC application and incorporation in a single operation would make use of rolling cultivator the preferred method of incorporation. The cost of various EPTC programs would be directly dependent on EPTC rate. In this research weed control with EPTC at 2.0 kg/ha was equal to that at 3.9 kg/ha. Using the 2.0 kg/ha rate of EPTC, herbicide cost ($27.86/ha) plus application/incorporation cost would be $38.36/ha for the rolling cultivator and $49.33/ha for the hipper/bedder.

In this research, glyphosate (Roundup Original Max) was used and the cost for the 2.24 kg/ha rate was $32.25/ha. Another option would have been to use a generic glyphosate product[4] and at the rate of 2.24 kg/ha, the cost would be $13.59/ha, $18.66/ha less than for Roundup Original Max. Including the application cost for glyphosate ($9.46 per application per ha) and using the 2.0 kg/ha EPTC rate, total cost would be lowest for EPTC incorporated with the rolling cultivator and use of generic glyphosate ($61.41/ha) compared with total cost of $72.38/ha for incorporation with hipper/bedder and use of generic glyphosate. The cost of herbicide programs would increase proportionally as the EPTC rate increased.

For the glyphosate alone treatment, glyphosate was applied twice and glyphosate rate was the same as used in EPTC treatments. Total cost of glyphosate alone treatment (herbicide cost plus application cost) was $83.43/ha where Roundup Original Max was used compared with $46.11/ha for generic glyphosate. For the glyphosate alone treatment using Roundup Original Max, total cost was $3.36/ha greater than when EPTC at 2.0 kg/ha was incorporated with the rolling cultivator followed by Roundup Original Max and $7.61/ha less than when EPTC was incorporated with the hipper/bedder followed by Roundup Original Max. In contrast for the glyphosate alone treatment using generic glyphosate, total cost was $15.31/ha less than when EPTC at 2.0 kg/ha was incorporated with the rolling cultivator followed by generic glyphosate and $26.28/ha less than EPTC was incorporated with the hipper/bedder followed by generic

Table 2.4. Cost comparisons of fallow weed control programs for EPTC incorporated with a rolling cultivator or a hipper/bedder and followed by a single application of Roundup Power Max (ROM) or generic glyphosate and a glyphosate alone treatment consisting of two application of Roundup Power Max or generic glyphosate.[1]

		Treatment cost						
		EPTC[2]			Glyphosate			
EPTC Rate	EPTC incorporation method	Herbicide cost	Application cost	Incorporation cost	ROM cost	Generic cost	Application cost	Total Cost[3]
kg ai/ha		---			$/ha	---		
2.0	Rolling cultivator	27.86	----- 10.50 -----		32.25	-	9.46	80.07
	Rolling cultivator	27.86	----- 10.50 -----		-	13.59	9.46	61.41
	Hipper/bedder	27.86	9.46	12.01	32.25	-	9.46	91.04
	Hipper/bedder	27.86	9.46	12.01	-	13.59	9.46	72.38
2.9	Rolling cultivator	41.79	----- 10.50 -----		32.25	-	9.46	94.00
	Rolling cultivator	41.79	----- 10.50 -----		-	13.59	9.46	75.34
	Hipper/bedder	41.79	9.46	12.01	32.25	-	9.46	104.97
	Hipper/bedder	41.79	9.46	12.01	-	13.59	9.46	86.31
3.9	Rolling cultivator	55.72	----- 10.50 -----		32.25	-	9.46	107.93
	Rolling cultivator	55.72	----- 10.50 -----		-	13.59	9.46	89.27
	Hipper/bedder	55.72	9.46	12.01	32.25	-	9.46	118.90
	Hipper/bedder	55.72	9.46	12.01	-	13.59	9.46	100.24
4.9	Rolling cultivator	69.65	----- 10.50 -----		32.25	-	9.46	121.86
	Rolling cultivator	69.65	----- 10.50 -----		-	13.59	9.46	103.20
	Hipper/bedder	69.65	9.46	12.01	32.25	-	9.46	132.83
	Hipper/bedder	69.65	9.46	12.01	-	13.59	9.46	114.17
None	NA	-	-	-	64.50	-	18.93	83.43
None	NA	-	-	-	-	27.18	18.93	46.11

[1] Herbicide costs: EPTC (Eptam) $11.91/L; glyphosate (Roundup Original Max) $9.51/L; generic glyphosate (Mad Dog plus) $2.90/L. Glyphosate was applied at 2.24 kg ai/ha following EPTC treatments and 2.24 kg ai/ha applied twice for glyphosate alone treatment.

(Table 2.4 continued)

Generic glyphosate cost was based on 2.24 kg ai/ha.
[2] For the rolling cultivator, EPTC was applied and incorporated in the same operation. For the hipper/bedder, EPTC application and incorporation were separate operations.
[3] Total cost for each treatment was determined based on EPTC cost, glyphosate cost (Roundup Original Max or generic glyphosate), and variable costs associated with each treatment. Variable cost associated with EPTC application and incorporation was $10.50/ha for the rolling cultivator ($6.23/ha fuel, $1.90/ha repair, and $2.37/ha labor) and was $21.47/ha for the hipper/bedder [$9.46/ha for application ($5.98/ha fuel, $0.64/ha repair, and $2.84/ha labor)] and $12.01 for incorporation ($7.46/ha fuel, $1.71/ha repair, and $2.84/ha labor) (Salassi and Deliberto 2009).

glyphosate.

The minimum labeled rate of EPTC in fallow program is 3.4 kg/ha. This increase in cost of EPTC compared with lower rates would increase cost and further reduce its economic value when compared with a glyphosate alone program. Use of EPTC in fallowed sugarcane fields would be dependent on cost of EPTC, availability of incorporation equipment, glyphosate cost, and grower preference. Previous research has shown that isopropylamine salt formulations of glyphosate are as effective in controlling bermudagrass as the more expensive potassium salt formulations (Etheredge et al. 2009). Growers could consider use of generic glyphosate products where possible to reduce cost.

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CHAPTER 3

SUGARCANE TOLERANCE AND WEED CONTROL WITH EPTC APPLIED AT PLANTING

INTRODUCTION

In Louisiana, sugarcane (*Saccharum* spp. hybrids) is planted in August and September using whole stalk or billet seed pieces. Sugarcane shoots and roots emerging from lateral buds develop rapidly. Above ground growth is killed during winter and re-growth occurs in late February or early March. Weed control at planting is critical to sugarcane stand establishment and stubble longevity. Herbicide application at planting can play an important role in reducing weed competition and maximizing yield potential in both the plant cane crop and in the successive ratoon crops. It is also important that herbicides applied at planting do not negatively affect the sugarcane crop (Richard 1989). Metribuzin applied at planting has excellent crop safety (Anonymous 2010). In contrast, clomazone can cause bleaching and stunting of sugarcane and terbacil can severely affect sugarcane growth on sandy soils. Of the herbicides labeled for use at planting, differences in sugarcane variety response have not been reported (Richard 1989).

In Louisiana sugarcane, major weed problems include bermudagrass (*Cynodon dactylon* L. Pers.), johnsongrass (*Sorghum halepense* L. Pers.), and nutsedge (*Cyperus* spp.). Richard and Dalley (2007) reported that bermudagrass reduced sugarcane stalk populations in the plant cane, first ratoon, and second ratoon crops as much as 23, 15, and 10%, respectively. Richard (1993) reported that sugar yields were reduced 32% in the plant cane crop and 9% in the ratoon crops. Even with the use of labeled preemergence herbicides at planting, bermudagrass infestation increased over the 3-year crop cycle.

Johnsongrass interference in sugarcane compared with a johnsongrass-free control reduced sugarcane yield an averaged of 3 to 23% in the first ratoon and 7 to 42% in the second ratoon crop (Millhollon 1995). Although seedling johnsongrass can be effectively controlled preemergence with clomazone plus diuron, pendimethalin, metribuzin, terbacil, and trifluralin, rhizome johnsongrass is not effectively controlled with preemergence herbicides (Anonymous 2010). Depending on rainfall and planting date, herbicides applied at planting may also provide residual control of winter weeds. To assure season long control of winter weeds, growers often reapply herbicides such as atrazine, diuron, and metribuzin in October or November for control of Italian ryegrass (*Lolium multiflorum* Lam.), black medic (*Medicago lupulina* L.), hairy vetch (*Vicia sativa* L.), white clover (*Trifolium repens* L.), spiny sowthistle (*Sonchus asper* (L.) Hill), and other weeds.

EPTC is a thiocarbamate herbicide discovered in 1957 by Stauffer Chemical Company (Senseman 2007). In the 1960's and 1970's, EPTC was widely used as a preemergence treatment in corn (*Zea mays L.*). EPTC inhibits synthesis of unsaturated fatty acid in isolated spinach (*Spinacia olearacea* L.) chloroplasts (Wilkinson and Smith 1974). EPTC also inhibits formation of epicuticular wax in cabbage (*Brassica oleraceae* L.) and leaf wax formation in pea (*Pisum sativum* L.) leaves (Wilkinson and Smith 1975). Due to volatility, EPTC must be incorporated into soil immediately (Senseman 2007). EPTC is adsorbed by roots and coleoptiles of grass seedlings and by hypocotyls of broadleaf seedlings. Although translocated basipetally and acropetally, translocation likely is unimportant in herbicide action because EPTC is absorbed very near its site of action (Fuerst 1987). Obrigawitch et al. (1982) reported reduced activity of the EPTC in soils with high clay and organic matter due to greater adsorption. EPTC is more readily adsorbed to dry soil, and drying of moist soil can increase loss of EPTC. Millhollon (1983) reported that EPTC at 4 and 6 kg/ha applied at lay-by controlled seedling johnsongrass 95% with no injury to sugarcane. Research, however, has not addressed EPTC when incorporated at planting. At present, trifluralin which also requires incorporation is labeled for use in sugarcane at planting. Research was conducted to evaluate EPTC as an at-planting treatment for weed control and sugarcane response when compared with trifluralin, clomazone plus diuron, and metribuzin.

MATERIALS AND METHODS

In 2008 at the Sugar Research Station in St. Gabriel, LA, two experiments were initiated on September 22 with whole stalk planting of L 99-226 (Experiment 1) and HoCP 96-540 (Experiment 2) . Sugarcane was planted in fields with an expected infestation of bermudagrass and johnsongrass. In 2009, HoCP 96-540 (Experiment 3) was planted using whole stalks on September 18 at the Sugar Research Station. All experiments were conducted on a Commerce silt loam (fine-silty, mixed, superactive, non-acid, thermic Fluvaquentic Endoaquepts) with 0.8 to 1.0% OM and pH of 5.6 to 5.9. At planting, rows were opened and sugarcane was planted, covered with 7.6 to 10.2 cm soil, and packed. Herbicide treatments included EPTC at 2.9, 4.9, and 6.8 kg ai/ha, clomazone at 1.4 kg ai/ha + diuron at 2.8 kg ai/ha, metribuzin at 1.7 kg ai/ha, and trifluralin at 3.4 kg ai/ha. Herbicides were applied using a compressed air sprayer at 93.5 L/ha and 140 kPa spray pressure. EPTC and trifluralin treatments were incorporated 5 to 8 cm deep with a rolling tine cultivator after rows were packed. For each experiment a randomized complete block experimental design with four replications was used. Plots consisted of two rows, 3.7 m wide and 12.2 m in length. Rainfall data for sugarcane planted each year are presented in Table 3.1.

In 2008, it was anticipated that bermudagrass and johnsongrass control rating would be made, but weeds were at levels insufficient to obtain control ratings. Overall, control of annual weeds was excellent for all treatments. In 2009, control of annual weeds as noted for the previous year was very good for all treatments. To quantify sugarcane response to herbicide treatments, shoot

Table 3.1. Rainfall following at-planting herbicide treatments evaluated for sugarcane tolerance and weed control at the Sugar Research Station, St. Gabriel, LA 2008-2010. [1]

Days after planting herbicide application	Experiment 1	Experiment 2	Experiment 3
	-------------------------------------	cm	-------------------------------------
0 - 14	0.03	0.03	7.04
15 - 28	0.81	0.81	21.36
29 - 42	0.10	0.10	3.94
43 - 56	1.91	1.91	6.38
57 - 70	1.60	1.60	2.01
71 - 84	6.55	6.55	17.88
85 - 98	2.54	2.54	16.03
99 - 112	13.67	13.67	7.54
113 - 126	0.86	0.86	4.57
127 - 140	1.35	1.35	5.38
141 - 154	3.91	3.91	10.97
155 - 168	0.03	0.03	8.10
169 - 182	7.26	7.26	1.80
183 - 196	12.40	12.40	1.57
197 - 210	5.28	5.28	1.88
211 - 216	0.05	0.05	0.10
Total	58.34	58.34	116.56

[1] L 99-226 (Experiment 1) and HoCP 96-540 (Experiment 2) were planted and herbicide treatments were applied on September 22, 2008. HoCP 96-540 (Experiment 3) was planted and treated on September 18, 2009. Sugarcane shoot population data were collected at 35, 186, and 216 days after plating (DAP). Winter weed control data were collected 135 DAP (Experiments 1and 2) and 140 DAP (Experiment 3).

population was determined by counting all shoots in the right hand row of each 2-row plot. Shoot population was determined 35, 186, and 216 days after planting (DAP) and herbicide application which corresponded to October 28, 2008, April 1, 2009, and April 29, 2009 (Experiments 1 and 2), and October 23, 2009, March 31, 2010, and April 30, 2010 (Experiment 3), respectively. Data collected in March and April of both years allowed for evaluation of long term effects of at-planting herbicide treatments following the winter dormant period. To further quantity crop response, ten stalks in each plot of HoCP 96-540 planted in 2008 (Experiment 2) were randomly selected and on September 3, 2009, height was determined from soil to upper most leaf collar. For Experiment 1, severe lodging prevented collection of height data and for Experiment 3, height data will be collected in December, 2010. Sugarcane yield was not measured for any of the experiments.

Because differences in winter weed control were observed among herbicide treatments, weed control ratings were made on February 4, 2009 and February 5, 2010 using a scale of 0 to 100% with 0 = no control and 100 = all plants dead. For L 99-226 planted in 2008, control of spiny sowthistle, white clover, and Italian ryegrass were evaluated. Annual bluegrass (*Poa annual* L.) control was evaluated in HoCP 96-540 planted in 2008. Annual bluegrass and spiny sowthistle control was evaluated in HoCP 96-540 planted in 2009.

Sugarcane shoot population data collected 35, 186, and 216 DAP were subjected to mixed procedure in SAS (2003) with years/experiments considered random effects and treatments considered fixed effects. Least square means were estimated and separated using PDIFF option where a probability level of greater than or equal to 0.05 was considered significant. Letter groupings were converted using the PDMIX800 macro in SAS (Saxton 1998). Sugarcane height data collected for only Experiment 2 was analyzed using mixed procedure in SAS with blocks considered as random effect and treatments considered fixed effects. Least square means were estimated and separated using PDIFF option where a probability level of greater than or equal to 0.05 was considered significant. Letter groupings were converted using the PDMIX800 macro in SAS (Saxton 1998). Because winter weed species differed among experiments and response between experiments for like species also differed, weed control data were analyzed by experiment using the procedure described for sugarcane height.

RESULTS AND DISCUSSION

In the first 28 days after herbicide treatments were applied at planting, 0.84 cm of rainfall was received in 2008 for Experiments 1 and 2 compared with 28.4 cm rainfall in 2009 for Experiment 3 (Table 3.1). Prior to around the end of December 112 DAP, total rainfall for 2009 was three times that received in 2008 (82.18 vs. 27.21 cm). Averaged across experiments, sugarcane shoot population 35 and 186 DAP and herbicide application did not differ among EPTC rates and the standard treatments of clomazone plus diuron at 1.4 + 2.8 kg/ha, metribuzin at 1.7 kg/ha, and trifluralin at 3.4 kg/ha (P = 0.2009 for 35 DAP and 0.0878 for 186 DAP) (Table 3.2). At 216 DAP and herbicide application which corresponded to late April, sugarcane shoot population for clomazone plus diuron and metribuzin averaged 140 shoots/12.2 m of row, which was 23% greater than for the EPTC and trifluralin treatments (Table 3.2).

Prior to data collection 216 DAP, around twice as much of rainfall was received for sugarcane planted and treated in 2009 (Experiment 3) compared with 2008 (Experiments 1 and 2) (116.56 vs. 58.34 cm) (Table 3.1). Differences among herbicide treatments for sugarcane shoot population 216 DAP is most likely due to decreased activity of EPTC and trifluralin as a result of excessive rainfall and resulting proliferation of winter weeds (Table 3.3) rather than due to

Table 3.2. Sugarcane shoot counts 35, 186, and 216 days after planting (DAP) and herbicide application and sugarcane height 346 DAP at the Sugar Research Station, St. Gabriel, LA 2008-2010.[1]

Treatment	Rate	Sugarcane shoot population/DAP 35	186	216	Sugarcane height[2]
	kg ai/ha	---------------- No./12.2 m		---------------	---- cm ----
Clomazone + diuron	1.4 2.8	95 a[3]	99 a	134 ab	211 a
Metribuzin	1.7	97 a	106 a	145 a	221 a
EPTC	2.9	77 a	76 a	106 c	213 a
EPTC	4.9	87 a	78 a	107 c	203 a
EPTC	6.8	83 a	77 a	111 bc	216 a
Trifluralin	3.4	75 a	81 a	106 c	213 a
P-level		0.2009	0.0878	0.0062	0.4800

[1] Shoot population data averaged for the varieties L 99-226 and HoCP 96-540 planted September 22, 2008, and for HoCP 96-540 planted September 18, 2009 at the Sugar Research Station, St. Gabriel, LA.

[2] Sugarcane height determined September 3, 2009 (346 DAP) for HoCP 96-540 planted on September 22, 2008.

[3] Means within columns followed by the same letter are not significantly different (P>0.05).

Table 3.3. Winter weed control in early February after sugarcane planting and herbicide application in September of the previous year at the Sugar Research Station, St. Gabriel, LA 2008-2010.[1]

Treatment	Rate	Experiment 1			Experiment 2	Experiment 3	
		Spiny sowthistle	White clover	Italian ryegrass	Annual bluegrass	Annual bluegrass	Spiny sowthistle
	kg ai/ha	%					
Clomazone + diuron	1.4 2.8	99 a[2]	100 a	100 a	100 a	43 b	79 a
Metribuzin	1.7	100 a	100 a	100 a	100 a	59 ab	65 a
EPTC	2.9	0 b	56 b	54 c	40 c	0 c	0 b
EPTC	4.9	0 b	60 b	48 c	41 c	0 c	0 b
EPTC	6.8	0 b	58 b	65 bc	61 b	3 c	13 b
Trifluralin	3.4	0 b	81 ab	90 ab	94 a	75 a	8 b
P-level		0.0001	0.0001	0.0033	0.0001	0.0001	0.0002

[1] L 99-226 (Experiment 1) and HoCP 96-540 (Experiment 2) were planted and herbicide treatments were applied on September 22, 2008. HoCP 96-540 (Experiment 3) was planted and treated on September 18, 2009. Weed control was evaluated on February 4, 2009 for Experiments 1 and 2 (135 days after planting and herbicide application) and February 5, 2010 for Experiment 3 (140 days after planting and herbicide application).

[2] Means within columns followed by the same letter are not significantly different (P>0.05).

herbicide injury. For Experiment 2 where HoCP 96-540 was planted in 2008, sugarcane height on September 3, 2009 (346 DAP) did not differ (P = 0.48) among herbicide treatments (Table 3.2). Sugarcane yield was not determined for any of the experiments. Turner (1983) reported that in South Africa EPTC applied at planting at twice the recommended rate did not negatively affect sugarcane stalk height, stalk population, or sugar per hectare. In research conducted in Louisiana, EPTC applied at 6 kg/ha and incorporated at the lay-by cultivation did not injure sugarcane or negatively affect yield (Millhollon 1983). Following the lay-by cultivation, root development would be rapid, much the same as at planting. It would be expected that injury to sugarcane with EPTC would occur within 60 days after application when herbicide concentration in soil would be greatest.

Because of differences in rainfall between years and in winter weed species and time of emergence observed among experiments, weed control data for each experiment were analyzed separately. For Experiment 1 (L 99-226 planted in 2008), control of spiny sowthistle, white clover, and Italian ryegrass in early February (135 DAP) was at least 99% with clomazone at 1.4 kg/ha plus diuron at 2.8 kg/ha and metribuzin at 1.7 kg/ha (Table 3.3). Spiny sowthistle was not controlled with EPTC at 2.9 to 6.8 kg/ha or trifluralin at 3.4 kg/ha. White clover in Experiment 1 was controlled 81% with trifluralin, but no more than 60% for EPTC treatments. Italian ryegrass was controlled 90% with trifluralin, equal to that of clomazone plus diuron and metribuzin, but control with EPTC was no more than 65%.

In Experiment 2 (HoCP 96-540 planted in 2008), annual bluegrass was controlled in early February (135 DAP) 100% with clomazone plus diuron and metribuzin and 94% with trifluralin (Table 3.3). In contrast, annual bluegrass control with EPTC treatments was 40 to 61%. In Experiment 3 (HoCP 96-540 planted in 2009) annual bluegrass was controlled in early February

(140 DAP) 43% with clomazone plus diuron, 59% with metribuzin, and 75% with trifluralin (Table 3.3). Annual bluegrass was controlled no more than 3% with EPTC. Spiny sowthistle in Experiment 3 was controlled 79% with clomazone plus diuron and 65% with metribuzin, but control was no more than 13% for EPTC and trifluralin treatments.

Of interest was the variation in control observed between years for spiny sowthistle and annual bluegrass. In Experiment 1 initiated in 2008, spiny sowthistle was controlled at least 99% with clomazone plus diuron and metribuzin, but in Experiment 3 initiated in 2009, control was no more than 79% for the herbicides (Table 3.3). In Experiment 2 initiated in 2008 annual bluegrass was controlled 100% with clomazone plus diuron and metribuzin, but control was no more 59% with these treatments in Experiment 3. Additionally, annual bluegrass was controlled 40 to 94% in Experiment 2 for EPTC and trifluralin treatments, but control was 0 to 75% in Experiment 3. The reduced weed control observed for Experiment 3 is most likely related to the effect of rainfall on herbicide persistence. Prior to winter weed control ratings in early February (around 140 days after planting and herbicide application) rainfall was more than 3 times greater in 2009-2010 compared with 2008-2009. Excessive rainfall can result in washing of beds and herbicide loss. Walker (1987) reported that herbicide persistence is reduced in wetter regions with higher temperatures.

Results show that EPTC at a rate as high as 6.8 kg/ha can be incorporated 5 to 8 cm deep with a rolling tine cultivator at planting without negatively affecting sugarcane shoot development in the plant cane crop. Under conditions where rainfall was limited, EPTC provided no control of spiny sowthistle, and no more than 60% control of white clover, Italian ryegrass, and annual bluegrass. Where the rainfall was excessive, control of spiny sowthistle and annual bluegrass was no more than 13%. At present, EPTC is labeled in sugarcane for application during the fallow period 45 days before planting. Clomazone plus diuron, metribuzin, and trifluralin are currently used to suppress bermudagrass at planting. Although bermudagrass control was not evaluated in this study, other research conducted in fallowed sugarcane fields have shown that EPTC can provide suppression of bermudagrass and nutsedge (Mite et al. 2009). Further research is needed to evaluate EPTC as a control option for bermudagrass and nutsedge control at planting. If EPTC is labeled as an at-planting treatment in sugarcane, growers will need to plan on using other herbicides to control winter weeds.

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CHAPTER 4

SUMMARY

In Louisiana after four to six harvests, sugarcane fields are fallowed in preparation for re-planting. Weed control during the fallow period and at planting is critical to sugarcane stand establishment and stubble longevity. Research was conducted to evaluate control of bermudagrass, johnsongrass, and purple nutsedge in fallowed sugarcane fields with EPTC applied at several rates and incorporated with either a rolling cultivator or a hipper/bedder. EPTC treatments were followed by a postemergence application of glyphosate and weed control was compared with that of a multi-application glyphosate alone treatment. Economics of EPTC followed by glyphosate and glyphosate alone programs were compared.

Significant interaction between EPTC rate and incorporation method was not observed for bermudagrass ground cover, johnsongrass control, and nutsedge control ratings made 30, 45, and 60 days after EPTC application. Averaged across EPTC rates, incorporation with the rolling cultivator at all rating dates was more effective for control of bermudagrass than incorporation with the hipper/bedder. In contrast, EPTC was equally effective at all rating dates in controlling johnsongrass and purple nutsedge regardless incorporation method. Averaged across incorporation methods, control of all weeds 30 days after EPTC application was maximized at 3.9 kg/ha, but weed control was no greater than when applied at 2.0 kg/ha (45% bermudagrass control, 57% johnsongrass control, and 34% purple nutsedge control).

Bermudagrass and johnsongrass control where EPTC was applied 60 days earlier and followed by one application of glyphosate was no greater than for two applications of glyphosate in a glyphosate alone program (no more than 5% bermudagrass ground cover and johnsongrass control at least 88%). Purple nutsedge was controlled 31 to 40% when EPTC was followed by one application of glyphosate compared with 63% for two applications of glyphosate.

An economic analysis of EPTC followed by glyphosate and glyphosate alone programs was performed using herbicide cost and variable costs (fuel, repair, and labor) associated with operation of incorporation implements and herbicide application. Using the 2.0 kg/ha rate of EPTC, herbicide cost of $27.86/ha plus application/incorporation cost would total $38.36/ha for the rolling cultivator and $49.33/ha for the hipper/bedder. The greater cost for the hipper/bedder is because herbicide application and incorporation were separate operations. When glyphosate (Roundup Original Max) at 2.24 kg/ha followed EPTC at 2.0 kg/ha incorporated with the rolling cultivator, total cost would be $80.07/ha. If a generic glyphosate is substituted for Roundup Original Max, total cost would be reduced $18.66/ha.

For the glyphosate alone program, cost of two applications of Roundup Original Max would be $83.43/ha compared with $46.11/ha for generic glyphosate, a saving of $37.32/ha. Where EPTC was applied at 2.0 kg/ha and followed by Roundup Original Max, total cost would be $3.36/ha less when incorporated with the rolling cultivator and $7.61 more when incorporated with the hipper/bedder compared with Roundup Original Max applied twice. Where EPTC was applied at 2.0 kg/ha and followed by generic glyphosate, total cost would be $15.31/ha more when EPTC was incorporated with a rolling cultivator and $26.28/ha more when EPTC was incorporated with a hipper/bedder compared with generic glyphosate applied twice. The cost of the herbicide programs would be directly dependent on EPTC rate and economic value would be diminished as EPTC rate increased above 2.0 kg/ha.

Research also evaluated EPTC at 2.9 to 6.8 kg/ha applied at planting for weed control and crop response when compared with trifluralin at 3.4 kg/ha, clomazone at 1.4 kg/ha plus diuron at 2.8

kg/ha, and metribuzin at 1.7 ka/ha. Averaged across experiments, sugarcane shoot population 35 and 186 days after planting (DAP) and herbicide application did not differ among the herbicide treatments. In the second year of the study, rainfall was around twice that of the previous year. Excessive rainfall the second year contributed to proliferation of winter weeds and at 216 DAP sugarcane shoot population was less where EPTC and trifluralin were applied compared with clomazone plus diuron and metribuzin. Subsequent winter weed control ratings in most cases were less for EPTC compared with the other herbicide treatments.

Results show that EPTC applied in fallowed sugarcane fields can provide suppression of bermudagrass, johnsongrass, and purple nutsedge. EPTC followed by glyphosate provided long term weed control comparable to two application of glyphosate in glyphosate alone program. Cost effectiveness of EPTC programs would be dependent on rate and glyphosate product selected. EPTC at a rate as high as 6.8 kg/ha can be incorporated 5 to 8 cm deep with a rolling tine cultivator at planting without negatively affecting sugarcane shoot development in the plant cane crop. Because EPTC is ineffective on the winter weeds spiny sowthistle, white clover, Italian ryegrass, and annual bluegrass, alternative control options will need to be considered.

VITA

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