FIELD SANDBUR (*Cenchrus spinifex*) CONTROL AND BERMUDAGRASS (*Cynodon dactylon*) RESPONSE TO HERBICIDE AND NITROGEN FERTILIZER TREATMENTS

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TREATMENTS

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FIELD SANDBUR (*Cenchrus spinifex*) CONTROL AND BERMUDAGRASS (*Cynodon dactylon*) RESPONSE TO HERBICIDE AND NITROGEN FERTILIZER TREATMENTS

ABSTRACT

Field experiments were conducted in 2009 at Chickasha (CHK-1) and Mulhall (MHL-1), OK, and in 2010 at Chickasha (CHK-2) and Hennessey (HEN-1, HEN-2, and HEN-3), OK, to measure the effects of herbicide and N fertilizer treatment combinations on field sandbur control and bermudagrass response. Densities of field sandbur ranged from 0 (weed-free locations) to 23 plants m^{-2}. Field sandbur control 6 WAT in 2009 was not evaluated due to drought conditions at MHL-1. At HEN-2 in 2010, no difference among herbicide treatments occurred when evaluating field sandbur control 6 WAT, with control ranging from 92 to 96%. At HEN-3 in 2010, an interaction of herbicide and N fertilizer main effects occurred at the field sandbur control 6 WAT evaluation. Pendimethalin applied alone controlled field sandbur 57% at 0 kg N ha^{-1}. As the N fertilizer rate increased, field sandbur control increased to 90%. Nicosulfuron plus metsulfuron-methyl applied alone controlled field sandbur from 80% at 0 kg N ha^{-1} to 93% at 340 kg N ha^{-1}. All other herbicide treatments exhibited 83 to 100% field sandbur control regardless of N fertilizer. Field sandbur control 9 WAT in 2009 at MHL-1 and 2010 at HEN-2 and HEN-3 were similar. Pendimethalin applied alone controlled field sandbur 80 % in 2009 and 96% in 2010. Nicosulfuron plus metsulfuron-methyl treatments controlled field sandbur 88 to 90% in 2009, and 97 to 99% in 2010. Imazapic plus glyphosate controlled field sandbur 87% in 2009, and 100% in

2010. No difference in field sandbur control occurred as the N fertilizer rate increased in 2009 and 2010. In 2009, field sandbur control 9 WAT ranged from 87 to 90%, and in 2010, control ranged from96 to 99%. Bermudagrass injury 3 WAT in 2009 and 2010 were similar. In both 2009 and 2010, pendimethalin applied alone had minimal bermudagrass injury. Nicosulfuron plus metsulfuron-methyl treatments exhibited 9 to 18% bermudagrass injury 3 WAT where imazapic plus glyphosate exhibited 32 to 50% bermudagrass injury 3WAT. There was no difference in bermudagrass injury 3 WAT as the N rate increased, with injury ranging from 12 to 19%. At CHK-1 in 2009, pendimethalin alone did not cause any yield reduction, nicosulfuron plus metsulfuron-methyl treatments reduced yield 14 to 17 % and imazapic plus glyphosate reduced yield 33%, when compared to the untreated. When evaluating the N fertilizer main effect, bermudagrass yield increased among the herbicide treatments as the N fertilizer rate increased. At CHK-2 in 2010, all herbicide treatments reduced bermudagrass yield except pendimethalin applied alone. Nicosulfuron plus metsulfuron-methyl treatments reduced yield 30 to 38%, whereas imazapic plus glyphosate reduced bermudagrass yields 55%, compared to the untreated. When evaluating the N fertilizer main effect, bermudagrass yield increased among the herbicide treatments as the N fertilizer rate increased. At HEN-1, there was no difference in bermudagrass yield due to wet conditions prior to harvest; however, when evaluating the N fertilizer main effect, bermudagrass yield increased among the herbicide treatments as the N fertilizer rate increased. Pendimethalin followed by (fb) nicosulfuron plus metsulfuron-methyl and nicosulfuron plus metsulfuron-methyl provided excellent field sandbur control with minimal bermudagrass injury and yield reductions. The addition of N fertilizer increased bermudagrass yield and results may suggest that N fertilizer may increase field sandbur control.

Nomenclature: Imazapic; glyphosate; metsulfuron-methyl; nicosulfuron; pendimethalin; field sandbur, *Cenchrus spinifex* Cav. CCHIN; bermudagrass, *Cynodon dactylon* L. CYNDA.

Keywords: Bermudagrass injury, bermudagrass yield, herbicide and nitrogen fertilizer combinations, application timing, bermudagrass pasture management

INTRODUCTION

There are approximately 1.4 million ha of established bermudagrass (*Cynodon dactylon* L.) pastures in the state of Oklahoma and the state currently ranks 2nd nationally in cow/calf production (National Cattlemen's Beef Association 2009; OK Dept. Ag. 2009). In a survey conducted by the Oklahoma State University department of Agricultural Economics, 46% of Oklahoma beef cattle producers stockpile bermudagrass forage for fall and winter grazing and 61% of all stocker cattle producers utilize warm season forages, such as bermudagrass, for grazing (Johnson et al. 2008).

Bermudagrass is a warm-season, perennial grass that spreads by rhizomes and stolons and is intolerant to shade (Hanna and Sollenberger 2003). Although it prefers well-drained, sandy soils with pH ranges of 5.7 to 7.0, it has been known to adapt to a wide range of soil types and pH ranges and can tolerate soils with low fertility (Hanna et al. 2007; Redfearn et al. 2003; Zhang and Raun 2006). Bermudagrass tolerates drought conditions and is well adapted to grazing due to its sod-forming nature, high response to N fertilizer and high yielding capabilities, making it one of the most widely produced perennial forages in the Southern United States (Hanna et al. 2007; Redfearn et al. 2003; Redmon and Hendrickson 2007).

In April of 2009, the Oklahoma Department of Agriculture estimated that 50% of hay and pasture producers had infestations of field sandbur (*Cenchrus spinifex* Cav.) (Peach 2009). Field sandbur is typically described as an annual; however, it can act as a short-lived perennial (Correll and Johnston 1979; Gould 1975) and is commonly found in pastures through Oklahoma and the southern United States. It is a self-compatible bunchgrass, and is especially adapted to dry, sandy soils with poor fertility (Gould 1975; Holm et al. 1991; Stewart 2009). The bur of field sandbur contains one to three spikelets, with each spikelet containing one fertile floret that produces a seed (Bryson et al. 2009). Before field sandbur was classified as *Cenchrus spinifex*, it was classified as *Cenchrus incertus* M. A. Curtis and *Cenchrus pauciflorus* Benth. (Bryson et al. 2009). Very little has been documented on the biology of field sandbur, which confounds control methods for producers and researchers.

The burs of field sandbur easily detach from the racemes, which can attach to humans and livestock, becoming a nuisance. When infestations occur in forage fed to livestock, forage palatability and acceptability is reduced. The burs can irritate the eyes and lips of livestock, which if consumed, can cause ulcers that may become infected (Stewart et al. 2009). Cattle have been reported to graze pre-reproductive field sandbur; however once the burs begin to harden, the sharp spines become painful to the touch, and the species becomes unpalatable (McKinney et al. 1991). Many weed species found in pastures, such as field sandbur, are rejected by grazing animals due to toxic compounds, bitterness, pubescence and spines (Siegmund 1973). Marten (1978) discovered that sheep avoided eating wild mustard (*Sinapis arvensis* L.) and common cocklebur (*Xanthium strumarium* L.) due to toxic compounds and harmful spines of both plant species.

Field sandbur is a poor competitor; however it colonizes well in sandy, disturbed soils and can maintain abundance with repeated disturbance (Liebman et al. 2001). Wrucke and Arnold (1985) reported more *Cenchrus longispinus* [(Hack.) Fern.] plants m^{-1} in a reduced-tillage system than in a conventional-tillage system; with *C. longspine* biomass increasing from 7 kg ha^{-1} in a conventional-tillage system, to 765 kg ha^{-1} in a reduced-tillage system. Williams and Wicks (1978) observed a shift in annual grass species from *Setaria spp*, to fall panicum [*Panicum dicotomiflorum* (L.) Michx.], large crabgrass [*Digitaria sanguinalis* (L.) Scop.) and field sandbur

(*Cenchurus pauciflorus* Benth.) due to reduced tillage. In a reduced tillage system, the soil disturbance is similar to the soil disturbances that frequently occur in Oklahoma's pasture and ranges, such as gopher mounds, mole tunnels and badger holes.

Weeds are considered economically detrimental to agricultural systems (Carlisle et al. 1980). In pasture and forage systems, weed infestations directly affect forage production by competing for water, sunlight, nutrients and space; consequently reducing the desired forage biomass. Although production and profit losses attributed to weed infestations in pastures can be difficult to assesss, Watson (1976) reported that the production of the desirable species may increase by 400% or more if proper weed control practices are followed. Schrieber and Linscott (1985) reported that for every kg of weeds grown in a pasture, the desirable forage will be reduced by an equivalent or more; therefore, proper weed management has a direct economic effect. When evaluating field sandbur interference in bermudagrass, Walker et al. (1998) reported that as bermudagrass biomass increased, southern sandbur (*Cenchrus echinatus* L.) dry matter was reduced by 28 to 38%.

Observations by Murray (personal communication 2008) reported that areas treated with nitrogen (N) fertilizer had less field sandbur compared with areas treated with lower or no N fertilizer. Nitrogen, which is an essential macronutrient, has been reported to influence several crop-weed interactions, including competition and weed community structure (Tilman 1986). When soil N is low or deficient, Mithidla et al. (2008) reported that weed control failures may occur, resulting in an increase in weed-crop competition and weed patchiness, which may require higher herbicide rates to control weeds in low soil N conditions. Cathcart et al. (2004) reported that green foxtail [*Setaria viridis* (L.) Beauv.] grown in low soil N conditions required 5.15 g ha^{-1} of nicosulfuron to reduce green foxtail biomass by 50%, compared to 0.90 g ha^{-1} of nicosulfuron in a high N soil. As N fertilizer rates increased in a perennial ryegrass (*Lolium perenne* L.) pasture, a reduction of weed tiller density and weed relative frequency occurred (McKenzie

1996). Bermudagrass responds favorably to N fertilizer. As bermudagrass rapidly establishes, the opportunity for a weedy species to become established will decrease (Walker et al. 1998).

Previous field sandbur control in bermudagrass pastures by Brewe et al. (2008, 2009) reported that imazapic plus glyphosate controlled field sandbur ≥98%, but resulted in up to 50% bermudagrass yield reductions compared to untreated bermudagrass. Bridges et al. (2001) reported Tifton 85 bermudagrass treated with imazapic plus 2,4-D had 50% injury regardless of imazapic plus 2,4-D rates and that as the rate of imazapic plus 2,4-D increased, bermudagrass injury also increased. Warren et al. (2002) reported that when Coastal bermudagrass was treated with imazapic plus 2,4-D, it never fully recovered by the end of the growing season. Grichar et al. (2000) reported that glyphosate controlled field sandbur ≥89% 30 DAT when applied after the first cutting of bermudagrass; however, bermudagrass injury ranged from 36% to 80%. Bridges et al. (2001) and Grichar et al. (2008) concluded that severe bermudagrass injury such as stunting and stand thinning will occur and may persist under drought stress, but bermudagrass recovery should be expected under normal growing conditions.

Nicosulfuron is a herbicide labeled for use in corn (*Zea mays* L.) for selective postemergence grass control (Anonymous 2011a). When applied at rates of 17.5 to 70 g ai ha^{-1}, it will control most annual and some perennial grasses, including foxtail spp., shattercane [*Sorghum bicolor* (L.) ssp. *arundinaceum* (Desv.) de Wet & Harlan], woolly cupgrass [*Eriochloa villosa* (Thunb.) Kunth], wild-proso millet (*Panicum miliaceum* L.), johnsongrass [*Sorghum halepense* (L.) Pers.], and quackgrass [*Elymus repens* (L.) Gaould] as well as certain broadleaf weeds (Vencill 2002). Bhowmik et al. (1992) and Dobbles and Kapusta (1993) reported when nicosulfuron was applied alone, giant foxtail (*Setaria faberi* Herrm.) and quackgrass was controlled 95 to 100% without any yield reductions. Treatments of nicosulfuron increased corn silage and grain yields when compared to the untreated check due to the control of quackgrass (Dobbles and Kapusta 1993). Matocha et al. (2010) reported that nicosulfuron plus metsulfuron had ≥80% field sandbur control. Tifton 85 and Jiggs bermudagrass varieties had 2 to 27% injury 14 DAT. By 22 DAT, injury had slightly increased to 3 to 29%. No differences in bermudagrass yield occurred with Tifton 85 at any harvest, whereas Jiggs had a slight decrease in yield at the first and second harvest but had fully recovered by the third harvest (Matocha et al. 2010).

Pendimethalin is a PRE herbicide labeled for use in corn, rice (*Orza sativa* L.), soybean [*Glycine max* (L.) Merr.], cotton (*Gossypium hirsitum* L.), peanut (*Arachis hypogaea* L.), potato (*Solanum tuberosum* L.) and sugarcane (*Saccharum officinarum* L.). When applied at rates of 0.56 to 3.36 kg ai ha^{-1}, pendimethalin has been reported to control primarily grass weeds, including barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.], crabgrass spp.(*Digitaria* spp.), *Panicum* spp., field sandbur, foxtail spp., goosegrass [*Eleusine incdica* (L.) Gaertn.], seedling johnsongrass, broadleaf signalgrass [*Urochloa platyphylla* (Nash) R.D. Webster], and shattercane (Vencill 2002; Anonymous 2011b). Prostko et al. (2001) reported that when pendimethalin PRE (1.1 kg ai ha^{-1}) was applied to peanut, southern crabgrass [*Digitaria ciliaris* (Retz.) Koel] and crowfootgrass [*Dactyloctenium aegyptium* (L.) Willd] control was 94 to 98% without affecting yield. When pendimethalin (1.1 kg ai ha^{-1}) was tank mixed with fluometuron (1.7 kg ai ha^{-1}) in cotton, early-season, midseason and late-season, control ranged from 91 to 95% for goosegrass, fall panicum and large crabgrass (*Digitaria sanguinalis* L.) with out affecting cotton lint quality (Byrd and York 1987).

In March 2008 and March 2009, the Oklahoma Department of Agriculture approved a Section 18 Emergency Herbicide Exemption for Prowl H_2O® (pendimethalin 0.456 g ai ml^{-1}) for PRE field sandbur control in dormant bermudagrass pastures. The exemption allowed Oklahoma producers to use Prowl H_2O® at 2.25 to 3.37 kg ai ha^{-1}. For effective field sandbur control, Prowl H_2O® requires at least 2.54 cm of precipitation prior to field sandbur germination in order to be incorporated into the soil (Anonymous 2008a).

In April 2009, the Oklahoma Department of Agriculture approved a Section 18 Emergency Herbicide Exemption for Pastora® [nicosulfuron (56.2%) plus metsulfuron-methyl (15%)] for POST field sandbur control in bermudagrass pastures. The exemption allowed Oklahoma producers to use Pastora® at 0.07 to 0.105 kg ha^{-1}. In order to get effective control of field sandbur, Pastora® must be applied when field sandbur is ≤3.8 cm in height and applied when bermudagrass is less than 10.16 cm in height following bermudagrass green-up to minimize potential bermudagrass injury (Anonymous 2008b; Anonymous 2011c).

Research has shown that nicosulfuron plus metsulfuron-methyl is a viable option for POST field sandbur control with minimal bermudagrass injury to Tifton 85 and Jiggs bermudagrass hybrid varieties (Matocha 2010); however, nicosulfuron plus metsulfuron-methyl injury on common bermudagrass has not been reported as well as the application of a PRE herbicide and N fertilizer for field sandbur control. Therefore, this research was initiated to evaluate field sandbur control, bermudagrass injury and yield with pendimethalin PRE followed by nicosulfuron plus metsulfuron-methyl POST herbicide combinations with N fertilizer applications.

MATERIALS AND METHODS

Field sandbur control and bermudagrass response experiments were conducted at six locations in western and south central Oklahoma throughout the 2009 and 2010 growing seasons. Locations had populations of field sandbur and bermudagrass or only bermudagrass. One location in 2010 (HEN-1) was initially established as a field sandbur and bermudagrass location, but due to lack of field sandbur, was utilized as a bermudagrass only experiment after the 3 WAT bermudagrass injury evaluation.

Field Sandbur Control

In 2009, a field experiment was initiated in Logan County near Mulhall, OK (MHL-1) on a Slaughterville fine sandy loam and in 2010, two experiments were initiated in Kingfisher County near Hennessey, OK, on a Dougherty–Eufaula loamy fine sand complex (HEN-2 and HEN-3). All locations in 2009 and 2010 evaluated field sandbur control in bermudagrass pastures 6 and 9 WAT. Field sandbur population counts were taken outside of the experimental area and in untreated areas inside the experimental area. The MHL-1 location in 2009 had a field sandbur population of 18 to 46 plants m^{-2}. Of the two locations near Hennessey, OK, HEN-2 had a field sandbur population of 22 to 65 plants $m^{-2}$and HEN-3 had a field sandbur population of 32 to 86 m^{-2}.

The experimental plots were 2.4 m wide by 4.6 m long. The experimental design was a factorial treatment combination of N fertilizer (four) and herbicide (five or six) treatments arranged as a randomized complete block with three or four replications (Table 1). N fertilizer treatments included 0, 113,227 and 340 kg N ha^{-1} applied as ammonium nitrate (34-0-0). Herbicide treatments in 2009 included pendimethalin[1] PRE, pendimethalin PRE followed by (fb) nicosulfuron[2] plus metsulfuron-methyl[3] POST, nicosulfuron plus metsulfuron-methyl POST, imazapic plus glyphosate[4] POST and an untreated check. Herbicide treatments in 2010 included pendimethalin PRE, pendimethalin PRE fb nicosulfuron plus metsulfuron-methyl POST, pendimethalin PRE fb nicosulfuron plus metsulfuron-methyl POST, nicosulfuron plus metsulfuron-methyl POST, imazapic plus glyphosate POST, and an untreated check. All POST spray solutions included a non-ionic surfactant[5] (NIS) at 0.5% v/v.

Herbicide treatments were applied with a tractor mounted sprayer equipped with 11002 VS flat-fan nozzles[6] for PRE applications and ULD 12002 flat-fan nozzles[7] for POST applications, calibrated to deliver 142 L ha^{-1} at 207 kPa pressure. PRE treatments were applied in March 2009 and in April 2010, N fertilizer applications were applied May and June 2009 and June 2010, and POST applications were applied May and June 2009 and June 2010; when field sandbur plants were approximately 3.5 cm in height. A summary of location characteristics can be found in Table 2.

Field sandbur control was estimated visually on a scale of 0 to 100 (0 indicated no control and 100 indicated total control), relative to the untreated check. Field sandbur control data was subjected to arcsine transformation, but interpretations were similar to nontransformed data; therefore, nontransformed data were used for analysis. Data was subjected to ANOVA and means were separated using Fischer's protected LSD test at $P \leq 0.05$.

Bermudagrass Injury Response

In 2009, a field experiment was initiated in Logan County near Mulhall, OK (MHL-1) on a Slaughterville fine sandy loam. In 2010, three experiments were initiated in Kingfisher County near Hennessey, OK, on an Eufaula fine sand (HEN-1) and a Dougherty–Eufaula loamy fine sand complex (HEN-2 and HEN-3). All locations in 2009 and 2010 evaluated bermudagrass injury as percent stand chlorosis, stunting and thinning 3 WAT.

The experimental design was a randomized complete block with three or four replications; plots were 2.4 m wide by 4.6 m long at all locations. Factorial treatment combination of N fertilizer and herbicide treatments were the same in 2009 and 2010 as the field sandbur control experiments. Herbicides were applied with a tractor mounted sprayer equipped with 11002 VS flat-fan nozzles for PRE applications and ULD 12002 flat-fan nozzles for POST applications, calibrated to deliver 142 L ha^{-1} at 207 kPa pressure. PRE treatments were applied in March 2009 and in April 2010, N fertilizer applications were applied in May and June 2009 and June 2010, with POST treatments applied in June 2009 and 2010 (Table 2).

Bermudagrass injury was evaluated 3 WAT visually scale of 0 to 100 (0 indicated no bermudagrass injury and 100 indicated total plant death), relative to the untreated check. Data was subjected to arcsine transformation, but interpretations were similar to nontransformed data; therefore, nontransformed data were used for analysis. Data was subjected to ANOVA and means were separated using Fischer’s protected LSD test at $P \leq 0.05$.

Bermudagrass Yield Response

Field experiments were initiated at the Oklahoma State University South Central Research Station in Chickasha, OK on a Pocasset silty clay loam in 2009 (CHK-1) and 2010

(CHK-2) and in Kingfisher County near Hennessey, OK on an Eufaula fine sand in 2010 (HEN-1) to investigate common bermudagrass response to herbicide and fertilizer applications, and were maintained as weed free locations.

The experimental design was a randomized complete block with four replications; plots were 2.4 m wide by 4.6 m long at all locations. Factorial treatment combination of N fertilizer and herbicide treatments were the same in 2009 and 2010 as the field sandbur control and bermudagrass injury experiments. Herbicides were applied with a tractor mounted sprayer equipped with 11002 VS flat-fan nozzles for PRE applications and ULD 12002 flat-fan nozzles for POST applications, calibrated to deliver 142 L ha^{-1} at 207 kPa pressure. PRE treatments were applied in March 2009 and April 2010, N fertilizer applications were applied in May and June 2009 and June 2010, with POST treatments applied in June 2009 and 2010 (Table 2).

Bermudagrass plots were harvested using a Carter forage harvester[8]. The harvested area was approximately 5 m^2. The harvested forage was weighed and subsamples were collected and air dried to determine bermudagrass weight on a dry matter basis. Bermudagrass yield data were subjected to square-root transformation. Interpretations of results were not similar to nontransformed data; therefore transformed data were used in the analysis. Means were back transformed and are presented in data tables. Transformed data were subjected to ANOVA with means separated using Fischer's protected LSD test at $P \leq 0.05$

RESULTS AND DISCUSSION

An attempt was made to pool data over locations; however, due to differences in treatment responses, field sandbur populations, and weather differences, data could not be pooled over locations. Data could not be pooled over years due to differences in treatments.

Field Sandbur Control

In 2009, drought conditions at MHL-1 during the growing season caused all vegetation to go dormant; therefore, field sandbur control 6 WAT was not evaluated. At the 9 WAT field sandbur control evaluation, there was no interaction of the herbicide and N fertilizer main effects. There was no difference in field sandbur efficacy among the herbicide treatments, with field sandbur control ranging from 80 to 90% (Table 3). When evaluating the main effect of N fertilizer, there was no difference in field sandbur control as N fertilizer rates increased with control ranging from 84 to 90% (Table 4).

In 2010 at the HEN-2 location, there was no interaction of herbicide and N fertilizer main effects at any field sandbur control rating. At 6 WAT, there was no difference in field sandbur control among herbicide treatments, with control ranging from 92 to 96% (Table 5). By 9 WAT, field sandbur control increased across all herbicide treatments, with control ranging from 96 to 100%. When evaluating the main effect of N fertilizer treatments, there was no difference in field sandbur control at 6 and 9 WAT as the N rate increased with control ranging from 92 to 95% at 6 WAT to 97 to 99% by 9 WAT (Table 6).

Field sandbur control 6 WAT at HEN-3 exhibited a herbicide by N fertilizer main effect interaction. Pendimethalin and nicosulfuron plus metsulfuron-methyl herbicide treatments exhibited an increase in field sandbur control as the N fertilizer rate increased (Table 7). When pendimethalin was applied alone, field sandbur control was 57% with 0 kg N ha^{-1}, but as the N fertilizer rate increased from 0 kg N ha^{-1}, field sandbur control increased to 90%. When nicosulfuron plus metsulfuron-methyl was applied alone, field sandbur control increased as the N fertilizer rate increased, with control increasing from 80% to 93%. All other herbicide treatments exhibited 83 to 100% field sandbur control regardless of N fertilizer rates. By 9 WAT, the herbicide by N fertilizer main effect interaction was no longer present. Pendimethalin applied alone had 96% field sandbur control, which was similar to the nicosulfuron plus metsulfuron-methyl treatments, but different from the imazapic plus glyphosate treatment (Table 8). Treatments that included nicosulfuron plus metsulfuron-methyl and imazapic plus glyphosate had 97 to 100% field sandbur control. When evaluating the main effect of N fertilizer rates, there was no difference in field sandbur control as the N fertilizer rate increased, with control ranging from 96 to 99% (Table 9).

Bermudagrass Injury Response

In 2009 at MHL, there was no interaction of herbicide and N fertilizer main effects when evaluating bermudagrass injury 3 WAT. Pendimethalin alone injured bermudagrass the least, with 2% injury; whereas the nicosulfuron plus metsulfuron-methyl treatments injured bermudagrass 9 to 10% (Table 10). Imazapic plus glyphosate had 48% bermudagrass injury, the highest of all the herbicide treatments. When evaluating the main N fertilizer effect on bermudagrass injury, there was no difference in bermudagrass injury with bermudagrass injury ranging from 14 to 19 % (Table 11).

In 2010, there was no interaction of herbicide and N fertilizer main effects when evaluating bermudagrass injury 3 WAT at any of the locations. HEN-1, HEN-2 and HEN-3 had similar bermudagrass injury results when evaluating the herbicide and N fertilizer main effects. At all three locations, pendimethalin alone caused little to no bermudagrass injury (Table 12). Treatments including nicosulfuron plus metsulfuron-methyl caused a slight increase in bermudagrass injury, with injury ranging from 9 to 18%. Imazapic plus glyphosate was the most injurious, with bermudagrass injury ranging from 32% to 50%. When evaluating the N fertilizer main effect, there was no difference in bermudagrass injury at any location, with bermudagrass injury ranging from 12 to 18 % (Table 13).

Bermudagrass Yield Response

When evaluating bermudagrass response as yield to herbicide and N fertilizer treatments in 2009 at CHK-1, there was no interaction of herbicide and N fertilizer main effects. Pendimethalin alone did not cause any yield reductions at any of the N fertilizer rates (Table 14). Nicosulfuron plus metsulfuron-methyl treatments reduced yield 14 to 17 % and imazapic plus glyphosate reduced bermudagrass yield 33%. When evaluating the N fertilizer main effect, bermudagrass yield increased among the herbicide treatments as the N fertilizer rate increased. Nicosulfuron plus metsulfuron-methyl and imazapic plus glyphosate yield reductions decreased as the N fertilizer rate increased from 33 and 44% at 0 kg N ha^{-1} to 14 and 27% at 340 kg N ha^{-1}, respectively.

In 2010 at CHK-2, there was no interaction of herbicide and N fertilizer main effects when evaluating bermudagrass yield. All herbicide treatments reduced bermudagrass yield except pendimethalin applied alone (Table 15). Nicosulfuron plus metsulfuron-methyl treatments reduced bermudagrass yield 30 to 38%, whereas imazapic plus glyphosate reduced bermudagrass yields 55% when compared to the untreated. When evaluating the N fertilizer main effect, bermudagrass yield increased among the herbicide treatments as the N fertilizer rate increased.

At HEN-1, there was no interaction of herbicide and N fertilizer main effects when evaluating bermudagrass yield. There was no difference in bermudagrass yield when herbicide treatments were compared to the untreated, due to wet conditions prior to harvest (Table 16). When evaluating the N fertilizer main effect, bermudagrass yield increased among the herbicide treatments as the N fertilizer rate increased.

After evaluating field sandbur control and bermudagrass response to PRE and POST herbicide treatments and N fertilizer applications in 2009 and 2010, pendimethalin fb nicosulfuron plus metsulfuron-methyl as well as nicosulfuron plus metsulfuron-methyl provided excellent field sandbur control with minimal bermudagrass injury and yield reductions. Although imazapic plus glyphosate provided excellent field sandbur control, it resulted in bermudagrass yield reductions up to 55%. Pendimethalin alone was able to adequately control field sandbur with little to no bermudagrass injury and yield reductions; however, due to precipitation requirements following application, pendimethalin alone may not have the ability to adequately control field sandbur every growing season. The addition of N fertilizer not only increased bermudagrass yield, but also decreased the degree of bermudagrass yield reductions as a result of the herbicide treatments. Although there was only one herbicide and N fertilizer interaction at 6 WAT, results may imply that when pendimethalin or nicosulfuron plus metsulfuron-methyl are applied alone, N fertilizer is needed to aid in the control of field sandbur.

These results are similar to previously reported research (Cathcart et al. 2004; Grichar et al. 2008; Matocha et al. 2010; Warren et al. 2002) where control of field sandbur was achieved with nicosulfuron plus metsulfuron-methyl 73 to 82% and imazapic plus 2,4-D 83 to 99%.

However significantly less injury occurred with nicosulfuron plus metsulfuron-methyl, with 3 to 27% bermudagrass injury 3 WAT and 0 to 21% yield reductions on Jiggs and Tifton 85 bermudagrass varieties; whereas imazapic plus 2,4-D injured Tifton 85 bermudagrass 53 to 87% and reduced Coastal bermudagrass yields nearly 50%. Although there are no data available on the combined effect of N fertilizer and field sandbur control, low soil N has been attributed to weed patchiness, which results in higher species abundance in preferable habitats. Field sandbur is not known to be a competitive species; hence the addition of N fertilizer may result in bermudagrass out-competing field sandbur.

We observed sporadic field sandbur germination throughout the growing season, which complicated our control efforts in both 2009 and 2010. Our POST herbicide treatment applications were able to control a single germination flush of field sandbur; however sequential POST applications may be needed for season long field sandbur control. Further investigation is needed to develop potential N fertilizer rate recommendations to aid field sandbur control in combination with herbicide applications. Due to the cost of pendimethalin (Prowl $H_2O^{®}$) and nicosulfuron plus metsulfuron-methyl as packaged products (Pastora®), as well as the variable cost of N fertilizer, further investigation is needed to evaluate the economic impact of pendimethalin fb nicosulfuron plus metsulfuron-methyl and nicosulfuron plus metsulfuron-methyl herbicide treatments and N fertilizer applications for field sandbur control. By knowing the biology of field sandbur, researchers may be able to pinpoint the timing of field sandbur germination, which would provide producers with the tools needed to combat field sandbur infestations. Therefore, further research is needed to evaluate the biology of field sandbur.

SOURCES OF MATERIALS

[1]Prowl H_2O®, BASF Corporation, Research Triangle Park, NC 27709.

[2]Accent®, Du Pont de Nemours and Co., Wilmington, DE 19898.

[3]Ally XP®, Du Pont de Nemours and Co., Wilmington, DE 19898.

[4]Journey®, a premix of 8.13% imazapic and 21.94% glyphosate, BASF, Research Triangle Park, NC 27709.

[5]Kinetic® nonionic adjuvant, Helena Chemical Co., Collierville, TN 38017.

[6]11002 VS flat-fan spray tips, Teejet Spraying Systems Co., Wheaton IL 60188.

[7]12002 ULD flat-fan spray tips, Hypro, New Brighton, MN 55112.

[8]Carter Forage Harvester, Carter MFG Co., Inc, Brookston, IN 47923

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Anonymous. 2008b. Pastora Section 18 exemption specimen label. Wilmington, DE: DuPont. 10 p.

Anonymous. 2011a. Accent herbicide specimen label. Wilmington, DE: DuPont. 13 p.

Anonymous. 2011b. Prowl H_2O herbicide specimen label. Research Triangle Park, NC: BASF. 31 p.

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Table 1. Herbicide and N fertilizer factorial treatment structure for 2009 and 2010.

Herbicide	Rate[a]	Time of application	N fertilizer rate (34-0-0)
	kg ha^{-1}		kg N ha^{-1}
Pendimethalin[1, 2]	3.407	PRE	0, 113, 227, 340
Pendimethalin Nicosulfuron + metsulfuron-methyl[1]	3.407 0.051 + 0.017	PRE POST	0, 113, 227, 340
Nicosulfuron + metsulfuron-methyl[1]	0.077 + 0.025	POST	0, 113, 227, 340
Pendimethalin Nicosulfuron + metsulfuron-methyl[2]	3.407 0.030 + 0.008	PRE POST	0, 113, 227, 340
Pendimethalin Nicosulfuron + metsulfuron-methyl[2]	3.407 0.038 + 0.010	PRE POST	0, 113, 227, 340
Nicosulfuron + metsulfuron-methyl[2]	0.038 + 0.010	POST	0, 113, 227, 340
Imazapic + glyphosate[1, 2]	0.0525 + 0.105	POST	0, 113, 227, 340
Untreated[1, 2]			0, 113, 227, 3400

[a] All herbicides except glyphosate (ae kg^{-1}) are expressed as ai kg^{-1}.
[1] Treatment applied in 2009.
[2] Treatment applied in 2010.

Table 2. Summary location characteristics, by year[a, b].

	2009		2010			
	CYNDA YLD	CYNDA INJ/ CCHIN CTRL	CYNA YLD	CYNDA INJ/ CYNDA YLD	CCHIN CTRL	
Variable	CHK-1	MHL-1	CHK-2	HEN-1	HEN-2	HEN-3
PRE application date	March 10	March 16	April 21	April 12	April 12	April 12
POST application date	June 19	May 18	June 3	June 2	June 2	June 2
N application date	June 19	May 18	May 4	May 7	May 7	May 7
Bermudagrass height (cm)	12-20	13-15	15-22	15-23	13-20	13-20
Field sandbur height (cm)	-	3-5	-	3-10	3-15	3-12
Field sandbur density (no. m^{-2})	-	18-46	-	0-15	22-65	32-86
Harvest date	August 6	-	June 28	July 13	-	-

[a] Bayer Codes: CYNDA, bermudagrass; CCHIN, field sandbur.
[b] Abbreviations: YLD, yield; INJ, injury; CTRL, control.

Table 3. Main herbicide treatment effect on field sandbur control (%) 9 WAT at MHL-1 in 2009.

Herbicide	Rate[a]	Time of application	9 WAT[b, c]
	kg ha^{-1}		%
Pendimethalin	3.407	PRE	80 a
Pendimethalin Nicosulfuron + metsulfuron-methyl	3.407 0.051 + 0.017	PRE POST	90 a
Nicosulfuron + metsulfuron-methyl	0.077 + 0.025	POST	88 a
Imazapic + glyphosate	0.052 + 0.105	POST	87 a
Untreated			0 b

[a] All herbicides except glyphosate (ae kg^{-1}) are expressed as ai kg^{-1}.
[b] 9 WAT indicate after the POST (5/18/2009) application.
[c] Means followed by the same letter within a column are not different at $LSD_{0.05}$.

Table 4. Main N fertilizer treatment effect on field sandbur control (%) 9 WAT at MHL-1 in 2009.

Rate	9 WAT[a]
kg ha^{-1}	%
0	90
113	85
227	84
340	87
Significance	NS[*]

[a] 9 WAT indicate after the POST (5/18/2009) application.
[*] Non significant trend (NS) at the 5% (*) level.

Table 5. Main herbicide treatment effect on field sandbur control (%) at HEN-2 in 2010.

Herbicide	Rate[a]	Time of application	6 WAT[b, c]	9 WAT
	kg ha^{-1}		---------------------- %	---------------------
Pendimethalin	3.407	PRE	92 a	96 a
Pendimethalin Nicosulfuron + metsulfuron-methyl	3.407 0.030 + 0.008	PRE POST	93 a	99 a
Pendimethalin Nicosulfuron + metsulfuron-methyl	3.407 0.038 + 0.010	PRE POST	94 a	98 a
Nicosulfuron + metsulfuron-methyl	0.038 + 0.010	POST	94 a	99 a
Imazapic + glyphosate	0.052 + 0.105	POST	96 a	100 a
Untreated			0 b	0 b

[a] All herbicides except glyphosate (ae kg^{-1}) are expressed as ai kg^{-1}.
[b] 6 and 9 WAT indicate after the POST (6/02/2010) application
[c] Means followed by the same letter within a column are not different at $LSD_{0.05}$.

Table 6. Main N fertilizer treatment effect on field sandbur control (%) at HEN-2 in 2010.

Rate	6 WAT[a]	9 WAT
$kg\ ha^{-1}$	-------------------- % --------------------	
0	95	97
113	94	98
227	92	98
340	94	99
Significance	NS[*]	NS

[a] 6 and 9 WAT indicate after the POST (6/02/2010) application
[*] Non significant trend (NS) at the 5% (*) level

Table 7. Herbicide and N fertilizer treatment interaction effect on field sandbur control (%) 6 WAT at HEN-3 in 2010.

Herbicide	Rate[a]	Time of application	N Fertilizer	6 WAT[b, c]
	kg ha^{-1}		kg N ha^{-1}	%
Pendimethalin	3.407	PRE	0	57 f
			113	90 a - e
			227	90 a - e
			340	90 a - e
Pendimethalin	3.407	PRE	0	90 a - e
Nicosulfuron +	0.030 +	POST	113	83 de
metsulfuron-methyl	0.008		227	92 a - d
			340	90 a - e
Pendimethalin	3.407	PRE	0	87 c - e
Nicosulfuron +	0.038 +	POST	113	95 a - c
metsulfuron-methyl	0.010		227	88 c - e
			340	90 a - e
Nicosulfuron +	0.038 +	POST	0	80 e
metsulfuron-methyl	0.010		113	87 c - e
			227	93 a - d
			340	93 a - d
Imazapic +	0.052 +	POST	0	92 a - d
glyphosate	0.105		113	100 a
			227	98 ab
			340	100 a
Untreated			0	0 g
			113	0 g
			227	0 g
			340	0 g

[a] All herbicide except glyphosate (ae kg^{-1}) are expressed as ai kg^{-1}.
[b] 6 WAT application indicate after POST (6/02/2010) application.
[c] Means followed by the same letter within a column are not different at $LSD_{0.05}$.

Table 8. Main herbicide treatment effect on field sandbur control (%) 9 WAT at HEN-3 in 2010.

Herbicide	Rate[a]	Time of application	9 WAT[b, c]
	kg ha^{-1}		%
Pendimethalin	3.407	PRE	96 b
Pendimethalin Nicosulfuron + metsulfuron-methyl	3.407 0.030 + 0.008	PRE POST	98 ab
Pendimethalin Nicosulfuron + metsulfuron-methyl	3.407 0.038 + 0.010	PRE POST	98 ab
Nicosulfuron + metsulfuron-methyl	0.038 + 0.010	POST	97 ab
Imazapic + glyphosate	0.052 + 0.105	POST	100 a
Untreated			0 c

[a] All herbicide except glyphosate (ae kg^{-1}) are expressed as ai kg^{-1}.
[b] 9 WAT application indicate after POST (6/02/2010) application.
[c] Means followed by the same letter within a column are not different at $LSD_{0.05}$.

Table 9. Main N fertilizer treatment effect on field sandbur control (%) 9 WAT at HEN-3 in 2010.

Rate	9 WAT[a]
$kg\ ha^{-1}$	%
0	96
113	99
227	97
340	99
Significance	NS[*]

[a] 9 WAT indicate after the POST (6/02/2010) application
[*] Non significant trend (NS) at the 5% (*) level

Table 10. Main herbicide treatment effect on bermudagrass injury (%) 3 WAT at MHL-1 in 2009.

Herbicide	Rate[a]	Time of application	3 WAT[b, c]
	kg ha^{-1}		%
Pendimethalin	3.407	PRE	2 a
Pendimethalin Nicosulfuron + metsulfuron-methyl	3.407 0.051 + 0.017	PRE POST	9 b
Nicosulfuron + metsulfuron-methyl	0.077 + 0.025	POST	10 b
Imazapic + glyphosate	0.052 + 0.105	POST	48 c
Untreated			0 a

[a] All herbicides except glyphosate (ae kg^{-1}) are expressed as ai kg^{-1}.
[b] 3 WAT indicate after the POST (5/18/2009) application.
[c] Means followed by the same letter within a column are not different at $LSD_{0.05}$.

Table 11. Main N fertilizer treatment effect on bermudagrass injury (%) 3 WAT at MHL-1 in 2010.

Rate	3 WAT[a]
kg ha^{-1}	%
0	19
113	18
227	18
340	14
Significance	NS[*]

[a] 3 WAT indicate after the POST (6/02/2010) application
[*] Non significant trend (NS) at the 5% (*) level

Table 12. Main herbicide treatment effect on bermudagrass injury (%) 3 WAT in 2010.

Herbicide	Rate[c]	Time of application	3 WAT[a, b] HEN-1	HEN-2	HEN-3
	kg ha^{-1}		---------- % ----------		
Pendimethalin	3.407	PRE	1 a	0 a	1 a
Pendimethalin Nicosulfuron + metsulfuron-methyl	3.407 0.030 + 0.008	PRE POST	14 b	12 b	9 b
Pendimethalin Nicosulfuron + metsulfuron-methyl	3.407 0.038 + 0.010	PRE POST	11 b	10 b	14 bc
Nicosulfuron + metsulfuron-methyl	0.038 + 0.010	POST	9 b	16 b	18 c
Imazapic + glyphosate	0.052 + 0.105	POST	32 c	50 c	45 d
Untreated			0 a	0 a	0 a

[a] 3 WAT indicate after the POST (6/02/2010) application.
[b] Means followed by the same letter within a column are not different at $LSD_{0.05}$.
[c] All herbicides except glyphosate (ae kg^{-1}) are expressed as ai kg^{-1}.

Table 13. Main N fertilizer treatment effect on bermudagrass injury (%) 3 WAT in 2010.

	3 WAT[a]		
Rate	HEN-1	HEN-2	HEN-3
kg ha^{-1}	------------------------------------	%	------------------------------------
0	12	18	17
113	14	18	17
227	14	17	17
340	14	18	18
Significance	NS[*]	NS	NS

[a] 3 WAT indicate after the POST (6/02/2010) application.
[*] Non significant trend (NS) at the 5% (*) level.

Table 14. Bermudagrass yield response to herbicide and N fertilizer applications at CHK-1 in 2009.[a]

Herbicide	Rate[b]	Time of application	0		113		227		340		Mean yield reductions
	$kg\ ha^{-1}$		----------------------------- $kg\ ha^{-1}$						-----------------------------		%
Pendimethalin	3.407	PRE	987	e-g	3061	a-d	4716	a	4683	a	0
Pendimethalin Nicosulfuron + metsulfuron-methyl	3.407 0.051 + 0.017	PRE POST	942	e-g	1780	d-f	2922	a-d	4661	a	17
Nicosulfuron + metsulfuron-methyl	0.077 + 0.025	POST	646	f-g	2570	b-d	3475	a-d	3886	a-c	14
Imazapic + glyphosate	0.052 + 0.105	POST	548	g	1915	de	2529	cd	3314	a-d	33
Untreated			978	e-g	2864	a-d	3981	a-c	4544	ab	-

[a] Means followed by the same letter are not different at $LSD_{0.05}$.
[b] All herbicides except glyphosate (ae kg^{-1}) are expressed as ai kg^{-1}.

Table 15. Bermudagrass yield response to herbicide and N fertilizer applications at CHK-2 in 2010.[a]

Herbicide	Rate[b]	Time of application	0		113		227		340		Mean yield reduction
	$kg\ ha^{-1}$		---------- $kg\ ha^{-1}$ ----------								%
Pendimethalin	3.407	PRE	2081	f-h	6820	a-c	8535	ab	9594	a	0
Pendimethalin Nicosulfuron + metsulfuron-methyl	3.407 0.030 + 0.008	PRE POST	1239	g-i	4623	c-e	5276	b-d	4718	c-e	38
Pendimethalin Nicosulfuron + metsulfuron-methyl	3.407 0.038 + 0.010	PRE POST	1001	hi	4520	c-e	5605	b-d	7039	a-c	30
Nicosulfuron + metsulfuron-methyl	0.038 + 0.010	POST	978	hi	5154	b-d	7050	a-c	5125	b-d	28
Imazapic + glyphosate	0.052 + 0.105	POST	580	i	2988	d-g	3280	d-f	1477	c-e	55
Untreated			2261	e-h	7105	a-c	6320	a-c	9921	a	-

[a] Means followed by the same letter are not different at $LSD_{0.05}$.
[b] All herbicides except glyphosate (ae kg^{-1}) are expressed as ai kg^{-1}.

Table 16. Bermudagrass yield response to herbicide and N fertilizer applications at HEN-1 in 2010.[a]

Herbicide	Rate[b]	Time of application	0		113		227		340		Mean yield reductions
	kg ha^{-1}		kg ha^{-1}								%
Pendimethalin	3.407	PRE	6341	e	9352	a-d	9870	a-d	10590	a-c	0
Pendimethalin Nicosulfuron + metsulfuron-methyl	3.407 0.030 + 0.008	PRE POST	4050	de	9400	a-d	10226	a-c	12014	a	0
Pendimethalin Nicosulfuron + metsulfuron-methyl	3.407 0.038 + 0.010	PRE POST	7827	c-e	9145	a-d	10253	a-c	9442	a-d	0
Nicosulfuron + metsulfuron-methyl	0.038 + 0.010	POST	6128	e	10245	a-c	9701	a-d	10934	ab	0
Imazapic + glyphosate	0.052 + 0.105	POST	5689	e	9169	a-c	8051	b-e	10754	a-c	0
Untreated			5809	e	10122	a-c	9391	a-d	11121	a	-

[a] Means followed by the same letter are not different at $LSD_{0.05}$.
[b] All herbicides except glyphosate (ae kg^{-1}) are expressed as ai kg^{-1}.

APPPENDICES

Appendix Table 17. Daily average air temperature and precipitation near Mulhall, Oklahoma for March 2009.

Date	Air temperature	Precipitation
	C˚	cm
3/01/2009	-2	0.00
3/02/2009	4	0.00
3/03/2009	9	0.00
3/04/2009	15	0.00
3/05/2009	23	0.00
3/06/2009	20	0.00
3/07/2009	21	0.00
3/08/2009	13	0.00
3/09/2009	20	0.84
3/10/2009	9	0.03
3/11/2009	1	0.00
3/12/2009	1	0.38
3/13/2009	5	0.03
3/14/2009	8	0.00
3/15/2009	11	0.00
3/16/2009	15	0.00
3/17/2009	20	0.00
3/18/2009	20	0.00
3/19/2009	14	0.00
3/20/2009	15	0.00
3/21/2009	17	0.00
3/22/2009	19	0.00
3/23/2009	20	3.33
3/24/2009	12	0.89
3/25/2009	9	0.00
3/26/2009	9	0.00
3/27/2009	3	2.67
3/28/2009	0	0.58
3/29/2009	9	0.08
3/30/2009	15	1.40
3/31/2009	8	0.00

Appendix Table 18. Daily average air temperature and precipitation near Mulhall, Oklahoma for April 2009.

Date	Air temperature	Precipitation
	C˚	cm
4/01/2009	14	0.00
4/02/2009	8	0.00
4/03/2009	11	0.00
4/04/2009	18	0.00
4/05/2009	6	0.00
4/06/2009	4	0.00
4/07/2009	8	0.00
4/08/2009	16	0.00
4/09/2009	20	0.00
4/10/2009	10	0.00
4/11/2009	13	0.08
4/12/2009	10	2.62
4/13/2009	8	0.03
4/14/2009	14	0.00
4/15/2009	17	0.00
4/16/2009	18	0.03
4/17/2009	14	0.05
4/18/2009	14	0.05
4/19/2009	12	0.64
4/20/2009	16	0.00
4/21/2009	18	0.00
4/22/2009	24	0.00
4/23/2009	26	0.00
4/24/2009	24	0.00
4/25/2009	24	0.00
4/26/2009	22	1.93
4/27/2009	17	0.28
4/28/2009	12	0.03
4/29/2009	17	2.92
4/30/2009	21	0.03

Appendix Table 19. Daily average air temperature and precipitation near Mulhall, Oklahoma for May 2009.

Date	Air temperature	Precipitation
	C˚	cm
5/01/2009	16	0.04
5/02/2009	12	0.74
5/03/2009	13	0.08
5/04/2009	13	0.26
5/05/2009	14	0.30
5/06/2009	18	0.01
5/07/2009	22	0.01
5/08/2009	24	0.00
5/09/2009	17	0.01
5/10/2009	15	0.02
5/11/2009	15	0.01
5/12/2009	17	0.02
5/13/2009	26	0.14
5/14/2009	19	0.00
5/15/2009	23	1.05
5/16/2009	16	0.04
5/17/2009	15	0.00
5/18/2009	17	0.00
5/19/2009	19	0.00
5/20/2009	20	0.00
5/21/2009	21	0.00
5/22/2009	22	0.00
5/23/2009	22	0.00
5/24/2009	22	0.02
5/25/2009	22	0.00
5/26/2009	21	0.14
5/27/2009	16	0.00
5/28/2009	19	0.00
5/29/2009	22	0.00
5/30/2009	24	0.00
5/31/2009	26	0.00

Appendix Table 20. Daily average air temperature and precipitation near Mulhall, Oklahoma for June 2009.

Date	Air temperature	Precipitation
	C˚	cm
6/01/2009	26	0.00
6/02/2009	23	0.07
6/03/2009	19	0.05
6/04/2009	19	0.00
6/05/2009	23	0.00
6/06/2009	27	0.04
6/07/2009	28	0.00
6/08/2009	26	0.02
6/09/2009	28	0.00
6/10/2009	23	0.24
6/11/2009	22	0.01
6/12/2009	24	0.00
6/13/2009	26	0.00
6/14/2009	25	0.00
6/15/2009	28	0.03
6/16/2009	30	0.00
6/17/2009	29	0.00
6/18/2009	29	0.00
6/19/2009	29	0.00
6/20/2009	28	0.01
6/21/2009	31	0.00
6/22/2009	32	0.00
6/23/2009	31	0.00
6/24/2009	31	0.00
6/25/2009	31	0.00
6/26/2009	31	0.00
6/27/2009	32	0.00
6/28/2009	27	0.27
6/29/2009	27	0.00
6/30/2009	28	0.00

Appendix Table 21. Daily average air temperature and precipitation near Mulhall, Oklahoma for July 2009.

Date	Air temperature	Precipitation
	C˚	cm
7/01/2009	27	0.00
7/02/2009	29	0.00
7/03/2009	31	0.00
7/04/2009	26	0.28
7/05/2009	23	0.00
7/06/2009	23	0.00
7/07/2009	26	0.00
7/08/2009	26	2.29
7/09/2009	31	0.03
7/10/2009	33	0.00
7/11/2009	34	0.00
7/12/2009	34	0.00
7/13/2009	34	0.00
7/14/2009	34	0.00
7/15/2009	33	0.00
7/16/2009	27	0.64
7/17/2009	25	0.00
7/18/2009	24	0.74
7/19/2009	26	0.00
7/20/2009	28	0.00
7/21/2009	24	0.25
7/22/2009	24	0.00
7/23/2009	26	0.00
7/24/2009	28	0.00
7/25/2009	29	0.00
7/26/2009	26	0.10
7/27/2009	23	0.53
7/28/2009	24	3.99
7/29/2009	24	1.45
7/30/2009	23	2.54
7/31/2009	24	0.00

Appendix Table 22. Daily average air temperature and precipitation near Mulhall, Oklahoma for August 2009.

Date	Air temperature	Precipitation
	C˚	cm
8/01/2009	25	0.00
8/02/2009	25	0.00
8/03/2009	30	0.08
8/04/2009	31	0.00
8/05/2009	28	0.20
8/06/2009	26	0.84
8/07/2009	29	0.00
8/08/2009	30	0.00
8/09/2009	29	0.00
8/10/2009	28	3.00
8/11/2009	24	4.85
8/12/2009	26	0.03
8/13/2009	25	0.00
8/14/2009	26	0.00
8/15/2009	28	0.00
8/16/2009	30	0.00
8/17/2009	28	3.23
8/18/2009	22	4.17
8/19/2009	24	1.50
8/20/2009	24	2.16
8/21/2009	24	0.00
8/22/2009	23	0.00
8/23/2009	24	0.00
8/24/2009	26	0.00
8/25/2009	27	0.00
8/26/2009	26	1.68
8/27/2009	23	0.69
8/28/2009	22	0.00
8/29/2009	22	0.00
8/30/2009	19	0.00
8/31/2009	18	0.00

Appendix Table 23. Daily average air temperature and precipitation at Chickasha, Oklahoma for March 2009.

Date	Air temperature	Precipitation
	C˚	cm
3/01/2009	-1	0.00
3/02/2009	4	0.00
3/03/2009	11	0.00
3/04/2009	16	0.00
3/05/2009	22	0.00
3/06/2009	21	0.00
3/07/2009	21	0.00
3/08/2009	14	0.00
3/09/2009	20	0.00
3/10/2009	14	0.00
3/11/2009	4	0.00
3/12/2009	2	0.41
3/13/2009	4	0.03
3/14/2009	7	0.05
3/15/2009	9	0.00
3/16/2009	13	0.00
3/17/2009	18	0.00
3/18/2009	20	0.00
3/19/2009	13	0.03
3/20/2009	16	0.00
3/21/2009	18	0.00
3/22/2009	19	0.00
3/23/2009	21	1.14
3/24/2009	14	0.03
3/25/2009	26	0.00
3/26/2009	11	0.00
3/27/2009	4	0.86
3/28/2009	1	0.08
3/29/2009	10	0.03
3/30/2009	16	1.14
3/31/2009	8	0.00

Appendix Table 24. Daily average air temperature and precipitation at Chickasha, Oklahoma for April 2009.

Date	Air temperature	Precipitation
	C˚	cm
4/01/2009	14	0.00
4/02/2009	8	0.00
4/03/2009	11	0.00
4/04/2009	19	0.00
4/05/2009	7	0.00
4/06/2009	5	0.00
4/07/2009	9	0.00
4/08/2009	17	0.00
4/09/2009	21	0.00
4/10/2009	11	0.00
4/11/2009	12	0.94
4/12/2009	11	3.94
4/13/2009	10	0.03
4/14/2009	13	0.00
4/15/2009	16	0.00
4/16/2009	15	0.13
4/17/2009	16	0.18
4/18/2009	13	0.05
4/19/2009	15	0.00
4/20/2009	17	0.00
4/21/2009	22	0.00
4/22/2009	24	0.00
4/23/2009	23	0.23
4/24/2009	24	0.00
4/25/2009	22	0.00
4/26/2009	18	2.16
4/27/2009	15	0.00
4/28/2009	17	0.00
4/29/2009	16	6.15
4/30/2009	21	0.23

Appendix Table 25. Daily average air temperature and precipitation at Chickasha, Oklahoma for May 2009.

Date	Air temperature	Precipitation
	C°	cm
5/01/2009	19	0.00
5/02/2009	12	4.06
5/03/2009	13	0.00
5/04/2009	13	0.23
5/05/2009	15	3.28
5/06/2009	19	0.43
5/07/2009	22	0.05
5/08/2009	25	0.00
5/09/2009	19	0.00
5/10/2009	15	0.61
5/11/2009	14	3.43
5/12/2009	18	0.28
5/13/2009	25	0.61
5/14/2009	22	0.00
5/15/2009	23	0.66
5/16/2009	17	0.25
5/17/2009	15	0.00
5/18/2009	17	0.00
5/19/2009	18	0.00
5/20/2009	19	0.00
5/21/2009	20	0.00
5/22/2009	22	0.00
5/23/2009	22	0.10
5/24/2009	22	0.00
5/25/2009	22	0.00
5/26/2009	21	2.16
5/27/2009	17	0.00
5/28/2009	19	0.00
5/29/2009	21	0.00
5/30/2009	23	0.00
5/31/2009	24	0.00

Appendix Table 26. Daily average air temperature and precipitation at Chickasha, Oklahoma for June 2009.

Date	Air temperature	Precipitation
	C°	cm
6/01/2009	24	0.00
6/02/2009	22	0.99
6/03/2009	19	1.07
6/04/2009	19	0.00
6/05/2009	22	0.00
6/06/2009	26	0.00
6/07/2009	28	0.03
6/08/2009	27	0.00
6/09/2009	28	0.00
6/10/2009	22	0.51
6/11/2009	23	0.03
6/12/2009	27	0.00
6/13/2009	27	0.05
6/14/2009	27	0.05
6/15/2009	27	1.27
6/16/2009	29	0.00
6/17/2009	28	0.00
6/18/2009	28	0.00
6/19/2009	28	0.15
6/20/2009	28	0.03
6/21/2009	30	0.00
6/22/2009	30	0.00
6/23/2009	29	0.00
6/24/2009	29	0.00
6/25/2009	29	0.00
6/26/2009	29	0.00
6/27/2009	31	0.00
6/28/2009	27	1.17
6/29/2009	26	0.00
6/30/2009	27	0.00

Appendix Table 27. Daily average air temperature and precipitation at Chickasha, Oklahoma for July 2009.

Date	Air temperature	Precipitation
	C°	cm
7/01/2009	28	0.00
7/02/2009	29	0.00
7/03/2009	31	0.00
7/04/2009	28	2.72
7/05/2009	24	0.08
7/06/2009	23	0.00
7/07/2009	24	0.00
7/08/2009	28	0.00
7/09/2009	30	0.00
7/10/2009	32	0.00
7/11/2009	31	0.00
7/12/2009	32	0.00
7/13/2009	32	0.00
7/14/2009	32	0.00
7/15/2009	32	0.00
7/16/2009	29	0.48
7/17/2009	26	0.03
7/18/2009	25	0.00
7/19/2009	27	0.00
7/20/2009	28	0.00
7/21/2009	26	0.94
7/22/2009	24	0.00
7/23/2009	25	0.00
7/24/2009	28	0.00
7/25/2009	30	0.00
7/26/2009	26	0.18
7/27/2009	23	1.22
7/28/2009	26	0.00
7/29/2009	26	0.79
7/30/2009	24	2.11
7/31/2009	24	0.00

Appendix Table 28. Daily average air temperature and precipitation at Chickasha, Oklahoma for August 2009.

Date	Air temperature	Precipitation
	C˚	cm
8/01/2009	26	0.00
8/02/2009	27	0.00
8/03/2009	29	1.55
8/04/2009	30	0.00
8/05/2009	29	0.00
8/06/2009	26	1.14
8/07/2009	30	0.00
8/08/2009	30	0.00
8/09/2009	29	0.00
8/10/2009	29	0.00
8/11/2009	26	0.10
8/12/2009	26	0.00
8/13/2009	26	0.00
8/14/2009	27	0.00
8/15/2009	30	0.00
8/16/2009	32	0.00
8/17/2009	31	0.00
8/18/2009	24	0.53
8/19/2009	27	1.19
8/20/2009	26	0.08
8/21/2009	25	0.00
8/22/2009	24	0.00
8/23/2009	27	0.00
8/24/2009	29	0.00
8/25/2009	29	0.00
8/26/2009	27	6.15
8/27/2009	23	0.53
8/28/2009	22	0.00
8/29/2009	22	0.00
8/30/2009	20	0.00
8/31/2009	19	0.00

Appendix Table 29. Daily average air temperature and precipitation near Hennessey, Oklahoma for April 2010.

Date	Air temperature	Precipitation
	C˚	cm
4/01/2010	22	0.00
4/02/2010	15	0.99
4/03/2010	13	0.00
4/04/2010	21	0.03
4/05/2010	22	0.00
4/06/2010	22	0.00
4/07/2010	8	0.00
4/08/2010	9	0.00
4/09/2010	15	0.00
4/10/2010	18	0.00
4/11/2010	18	0.00
4/12/2010	19	0.00
4/13/2010	19	0.00
4/14/2010	20	0.00
4/15/2010	19	0.00
4/16/2010	13	1.73
4/17/2010	12	1.07
4/18/2010	11	1.57
4/19/2010	12	0.00
4/20/2010	13	0.00
4/21/2010	18	0.00
4/22/2010	20	0.00
4/23/2010	19	1.12
4/24/2010	16	0.25
4/25/2010	16	0.00
4/26/2010	11	0.05
4/27/2010	11	0.00
4/28/2010	18	0.00
4/29/2010	23	0.00
4/30/2010	18	1.37

Appendix Table 30. Daily average air temperature and precipitation near Hennessey, Oklahoma for May 2010.

Date	Air temperature	Precipitation
	C˚	cm
5/01/2010	16	0.41
5/02/2010	17	0.00
5/03/2010	16	0.00
5/04/2010	19	0.00
5/05/2010	19	0.00
5/06/2010	23	0.00
5/07/2010	17	0.00
5/08/2010	12	0.00
5/09/2010	14	0.18
5/10/2010	18	0.05
5/11/2010	18	0.00
5/12/2010	23	0.00
5/13/2010	20	2.31
5/14/2010	20	0.03
5/15/2010	21	0.03
5/16/2010	23	0.15
5/17/2010	21	0.00
5/18/2010	20	0.00
5/19/2010	17	8.76
5/20/2010	17	0.00
5/21/2010	20	0.00
5/22/2010	25	0.00
5/23/2010	26	0.00
5/24/2010	25	0.00
5/25/2010	23	1.24
5/26/2010	23	0.00
5/27/2010	24	0.00
5/28/2010	24	0.00
5/29/2010	25	0.00
5/30/2010	25	0.15
5/31/2010	24	0.00

Appendix Table 31. Daily average air temperature and precipitation near Hennessey, Oklahoma for June 2010.

Date	Air temperature	Precipitation
	C˚	cm
6/01/2010	28	0.00
6/02/2010	28	0.00
6/03/2010	26	0.00
6/04/2010	27	0.00
6/05/2010	28	0.00
6/06/2010	26	0.00
6/07/2010	24	1.73
6/08/2010	29	0.00
6/09/2010	26	0.05
6/10/2010	26	0.00
6/11/2010	28	0.00
6/12/2010	28	0.00
6/13/2010	28	0.18
6/14/2010	21	0.84
6/15/2010	24	0.13
6/16/2010	26	1.96
6/17/2010	28	0.00
6/18/2010	29	0.00
6/19/2010	29	0.00
6/20/2010	29	0.00
6/21/2010	29	0.00
6/22/2010	29	0.00
6/23/2010	29	2.26
6/24/2010	27	0.00
6/25/2010	28	0.00
6/26/2010	29	0.00
6/27/2010	27	2.21
6/28/2010	26	0.00
6/29/2010	26	0.00
6/30/2010	25	0.00

Appendix Table 32. Daily average air temperature and precipitation near Hennessey, Oklahoma for July 2010.

Date	Air temperature	Precipitation
	C˚	cm
7/01/2010	26	0.00
7/02/2010	26	0.00
7/03/2010	24	2.34
7/04/2010	25	0.46
7/05/2010	24	3.48
7/06/2010	24	0.05
7/07/2010	24	0.08
7/08/2010	25	0.08
7/09/2010	25	0.03
7/10/2010	26	0.00
7/11/2010	27	1.27
7/12/2010	26	0.00
7/13/2010	29	0.00
7/14/2010	29	0.00
7/15/2010	29	0.00
7/16/2010	29	0.00
7/17/2010	31	0.00
7/18/2010	31	0.00
7/19/2010	31	0.00
7/20/2010	30	0.00
7/21/2010	29	0.00
7/22/2010	29	0.00
7/23/2010	30	0.00
7/24/2010	28	3.33
7/25/2010	25	0.20
7/26/2010	27	0.00
7/27/2010	27	0.00
7/28/2010	26	0.00
7/29/2010	28	0.00
7/30/2010	29	0.00
7/31/2010	30	0.00

Appendix Table 33. Daily average air temperature and precipitation near Hennessey, Oklahoma for August 2010.

Date	Air temperature	Precipitation
	C°	cm
8/01/2010	31	0.00
8/02/2010	32	0.00
8/03/2010	32	0.00
8/04/2010	31	0.00
8/05/2010	28	0.00
8/06/2010	28	0.00
8/07/2010	30	0.00
8/08/2010	32	0.00
8/09/2010	32	0.00
8/10/2010	31	0.00
8/11/2010	32	0.00
8/12/2010	32	0.00
8/13/2010	34	0.00
8/14/2010	32	0.00
8/15/2010	25	1.27
8/16/2010	26	0.15
8/17/2010	24	1.37
8/18/2010	25	0.00
8/19/2010	28	0.00
8/20/2010	32	0.00
8/21/2010	29	0.00
8/22/2010	28	0.00
8/23/2010	31	0.00
8/24/2010	23	0.56
8/25/2010	21	0.00
8/26/2010	21	0.00
8/27/2010	23	0.00
8/28/2010	26	0.00
8/29/2010	28	0.00
8/30/2010	28	0.00
8/31/2010	29	0.99

Appendix Table 34. Daily average air temperature and precipitation at Chickasha, Oklahoma for April 2010.

Date	Air temperature	Precipitation
	C°	cm
4/01/2010	21	0.00
4/02/2010	17	1.07
4/03/2010	13	0.00
4/04/2010	22	0.00
4/05/2010	22	0.00
4/06/2010	22	0.61
4/07/2010	10	0.00
4/08/2010	9	0.00
4/09/2010	14	0.00
4/10/2010	16	0.00
4/11/2010	19	0.00
4/12/2010	19	0.00
4/13/2010	18	0.00
4/14/2010	19	0.00
4/15/2010	18	0.00
4/16/2010	16	0.41
4/17/2010	18	3.05
4/18/2010	11	1.78
4/19/2010	12	0.00
4/20/2010	13	0.00
4/21/2010	18	0.00
4/22/2010	19	0.00
4/23/2010	19	1.04
4/24/2010	17	0.00
4/25/2010	16	0.00
4/26/2010	11	0.00
4/27/2010	12	0.00
4/28/2010	17	0.00
4/29/2010	23	0.00
4/30/2010	21	0.05

Appendix Table 35. Daily average air temperature and precipitation at Chickasha, Oklahoma for May 2010.

Date	Air temperature	Precipitation
	C˚	cm
5/01/2010	15	0.03
5/02/2010	18	0.00
5/03/2010	14	0.00
5/04/2010	20	0.00
5/05/2010	21	0.00
5/06/2010	22	0.00
5/07/2010	18	0.00
5/08/2010	15	0.00
5/09/2010	14	0.05
5/10/2010	22	0.08
5/11/2010	21	0.00
5/12/2010	24	0.00
5/13/2010	14	1.57
5/14/2010	14	3.05
5/15/2010	17	0.05
5/16/2010	19	0.05
5/17/2010	18	0.03
5/18/2010	19	0.00
5/19/2010	22	0.05
5/20/2010	20	0.03
5/21/2010	22	0.00
5/22/2010	25	0.00
5/23/2010	26	0.00
5/24/2010	26	0.00
5/25/2010	23	0.00
5/26/2010	24	0.00
5/27/2010	25	0.00
5/28/2010	25	0.08
5/29/2010	26	0.00
5/30/2010	27	0.00
5/31/2010	26	0.00

Appendix Table 36. Daily average air temperature and precipitation at Chickasha, Oklahoma for June 2010.

Date	Air temperature	Precipitation
	C˚	cm
6/01/2010	84	0.00
6/02/2010	84	0.00
6/03/2010	79	0.00
6/04/2010	81	0.00
6/05/2010	84	0.00
6/06/2010	83	0.00
6/07/2010	81	0.00
6/08/2010	84	0.00
6/09/2010	80	0.00
6/10/2010	79	0.00
6/11/2010	82	0.00
6/12/2010	84	0.00
6/13/2010	85	0.00
6/14/2010	74	4.70
6/15/2010	75	0.28
6/16/2010	81	0.00
6/17/2010	83	0.00
6/18/2010	84	0.00
6/19/2010	84	0.00
6/20/2010	84	0.00
6/21/2010	84	0.00
6/22/2010	85	0.00
6/23/2010	85	0.00
6/24/2010	84	0.00
6/25/2010	82	0.00
6/26/2010	84	0.00
6/27/2010	83	0.03
6/28/2010	77	2.84
6/29/2010	78	0.00
6/30/2010	78	0.03

Appendix Table 37. Daily average air temperature and precipitation at Chickasha, Oklahoma for July 2010.

Date	Air temperature	Precipitation
	C°	cm
7/01/2010	26	0.00
7/02/2010	25	0.53
7/03/2010	24	1.91
7/04/2010	24	2.36
7/05/2010	26	0.03
7/06/2010	27	0.00
7/07/2010	24	1.70
7/08/2010	24	1.55
7/09/2010	24	2.46
7/10/2010	26	0.00
7/11/2010	27	2.24
7/12/2010	26	1.17
7/13/2010	29	0.00
7/14/2010	28	0.00
7/15/2010	29	0.00
7/16/2010	29	0.00
7/17/2010	30	0.00
7/18/2010	29	0.00
7/19/2010	29	0.00
7/20/2010	29	0.00
7/21/2010	28	0.00
7/22/2010	29	0.00
7/23/2010	29	0.00
7/24/2010	29	0.00
7/25/2010	28	0.00
7/26/2010	28	0.00
7/27/2010	26	0.00
7/28/2010	26	0.18
7/29/2010	28	0.00
7/30/2010	29	0.00
7/31/2010	30	0.00

Appendix Table 38. Daily average air temperature and precipitation at Chickasha, Oklahoma for August 2010.

Date	Air temperature	Precipitation
	C˚	cm
8/01/2010	88	0.00
8/02/2010	89	0.00
8/03/2010	88	0.00
8/04/2010	90	0.00
8/05/2010	84	0.00
8/06/2010	83	0.00
8/07/2010	85	0.00
8/08/2010	87	0.00
8/09/2010	86	0.00
8/10/2010	87	0.00
8/11/2010	86	0.00
8/12/2010	88	0.00
8/13/2010	90	0.00
8/14/2010	90	0.00
8/15/2010	85	0.00
8/16/2010	83	0.00
8/17/2010	81	0.05
8/18/2010	81	0.00
8/19/2010	84	0.00
8/20/2010	89	0.00
8/21/2010	86	0.20
8/22/2010	86	0.00
8/23/2010	86	0.00
8/24/2010	76	0.00
8/25/2010	74	0.00
8/26/2010	71	0.00
8/27/2010	74	0.00
8/28/2010	76	0.00
8/29/2010	80	0.00
8/30/2010	83	0.00
8/31/2010	81	0.97

Appendix Table 39. Visual bermudagrass injury ratings 3 WAT at MHL (6/10/2009).

Herbicide	Rate[a]	Time of application	Replication I	II	III	IV
	kg ha^{-1a}		---------- % ----------			
Pendimethalin	3.407	PRE	0	0	10	10
Ammonium nitrate	0					
Pendimethalin	3.407	PRE	10	10	10	10
Nicosulfuron +	0.051 +	POST				
metsulfuron-methyl	0.017					
Ammonium nitrate	0					
Nicosulfuron +	0.077 +	POST	20	10	10	10
metsulfuron-methyl	0.025					
Ammonium nitrate	0					
Imazapic +	0.0525 +	POST	50	50	50	50
glyphosate	0.105					
Ammonium nitrate	0					
Untreated			0	0	0	0
Ammonium nitrate	0					

Appendix Table 39. (cont.) Visual bermudagrass injury ratings 3 WAT at MHL (6/10/2009).

Herbicide	Rate	Time of application	Replication I	Replication II	Replication III	Replication IV
	kg ha^{-1}		%			
Pendimethalin	3.407	PRE	10	0	0	0
Ammonium nitrate	113					
Pendimethalin	3.407	PRE	10	10	10	10
Nicosulfuron +	0.051 +	POST				
metsulfuron-methyl	0.017					
Ammonium nitrate	113					
Nicosulfuron +	0.077 +	POST	10	10	10	10
metsulfuron-methyl	0.025					
Ammonium nitrate	113					
Imazapic +	0.0525 +	POST	50	50	50	50
glyphosate	0.105					
Ammonium nitrate	113					
Untreated			0	0	0	0
Ammonium nitrate	113					

Appendix Table 39. (cont.) Visual bermudagrass injury ratings 3 WAT at MHL (6/10/2009).

			Replication			
Herbicide	Rate	Time of application	I	II	III	IV
	kg ha^{-1}		------------------	------------------ %	------------------	------------------
Pendimethalin	3.407	PRE	0	0	0	0
Ammonium nitrate	227					
Pendimethalin	3.407	PRE	10	10	10	10
Nicosulfuron +	0.051 +	POST				
metsulfuron-methyl	0.017					
Ammonium nitrate	227					
Nicosulfuron +	0.077 +	POST	10	10	10	10
metsulfuron-methyl	0.025					
Ammonium nitrate	227					
Imazapic +	0.0525 +	POST	50	50	50	50
glyphosate	0.105					
Ammonium nitrate	227					
Untreated			0	0	0	0
Ammonium nitrate	227					

Appendix Table 39. (cont.) Visual bermudagrass injury ratings 3 WAT at MHL (6/10/2009).

Herbicide	Rate	Time of application	Replication I	II	III	IV
	kg ha^{-1}		---------- % ----------			
Pendimethalin	3.407	PRE	0	0	0	0
Ammonium nitrate	340					
Pendimethalin	3.407	PRE	10	10	0	10
Nicosulfuron +	0.051 +	POST				
metsulfuron-methyl	0.017					
Ammonium nitrate	340					
Nicosulfuron +	0.077 +	POST	20	10	0	0
metsulfuron-methyl	0.025					
Ammonium nitrate	340					
Imazapic +	0.0525 +	POST	50	50	10	50
glyphosate	0.105					
Ammonium nitrate	340					
Untreated			0	0	0	0
Ammonium nitrate	340					

[a] All herbicides except glyphosate (ae kg^{-1}) are expressed as ai kg^{-1}.

Appendix Table 40. Visual control ratings for field sandbur 9 WAT at MHL (7/30/2009).

Herbicide	Rate[a]	Time of application	Replication I	II	III	IV
	kg ha^{-1a}		---------- % ----------			
Pendimethalin	3.407	PRE	80	80	100	100
Ammonium nitrate	0					
Pendimethalin	3.407	PRE	75	95	95	90
Nicosulfuron +	0.051 +	POST				
metsulfuron-methyl	0.017					
Ammonium nitrate	0					
Nicosulfuron +	0.077 +	POST	75	100	90	80
metsulfuron-methyl	0.025					
Ammonium nitrate	0					
Imazapic +	0.0525 +	POST	95	100	80	100
glyphosate	0.105					
Ammonium nitrate	0					
Untreated			0	0	0	0
Ammonium nitrate	0					

Appendix Table 40. (cont.) Visual control ratings for field sandbur 9 WAT at MHL (7/30/2009).

Herbicide	Rate	Time of application	Replication I	II	III	IV
	kg ha^{-1}		----------------------------------	%	----------------------------------	
Pendimethalin	3.407	PRE	75	100	90	90
Ammonium nitrate	113					
Pendimethalin	3.407	PRE	90	90	75	80
Nicosulfuron +	0.051 +	POST				
metsulfuron-methyl	0.017					
Ammonium nitrate	113					
Nicosulfuron +	0.077 +	POST	75	50	95	100
metsulfuron-methyl	0.025					
Ammonium nitrate	113					
Imazapic +	0.0525 +	POST	100	100	85	70
glyphosate	0.105					
Ammonium nitrate	113					
Untreated			0	0	0	0
Ammonium nitrate	113					

Appendix Table 10. (cont.) Visual control ratings for field sandbur 9 WAT at MHL (7/30/2009).

Herbicide	Rate	Time of application	Replication I	II	III	IV
	kg ha^{-1}		----------------------------------	%	----------------------------------	
Pendimethalin	3.407	PRE	75	75	75	75
Ammonium nitrate	227					
Pendimethalin	3.407	PRE	95	90	95	95
Nicosulfuron +	0.051 +	POST				
metsulfuron-methyl	0.017					
Ammonium nitrate	227					
Nicosulfuron +	0.077 +	POST	100	75	100	100
metsulfuron-methyl	0.025					
Ammonium nitrate	227					
Imazapic +	0.0525 +	POST	50	80	85	80
glyphosate	0.105					
Ammonium nitrate	227					
Untreated			0	0	0	0
Ammonium nitrate	227					

Appendix Table 40. (cont.) Visual control ratings for field sandbur 9 WAT at MHL (7/30/2009).

Herbicide	Rate	Time of application	Replication I	II	III	IV
	kg ha^{-1}		-----------------------------------	%	-----------------------------------	
Pendimethalin	3.407	PRE	0	95	100	70
Ammonium nitrate	340					
Pendimethalin	3.407	PRE	100	100	90	90
Nicosulfuron +	0.051 +	POST				
metsulfuron-methyl	0.017					
Ammonium nitrate	340					
Nicosulfuron +	0.077 +	POST	100	95	100	80
metsulfuron-methyl	0.025					
Ammonium nitrate	340					
Imazapic +	0.0525 +	POST	100	95	100	75
glyphosate	0.105					
Ammonium nitrate	340					
Untreated			0	0	0	0
Ammonium nitrate	340					

[a] All herbicides except glyphosate (ae kg^{-1}) are expressed as ai kg^{-1}.

Appendix Table 41. Bermudagrass yield response at CHK09-2 (8/06/2009).

Herbicide	Rate[a]	Time of application	Replication I	II	III	IV
	kg ha^{-1a}		------------	kg ha^{-1}	------------	
Pendimethalin	3.407	PRE	1886	933	609	403
Ammonium nitrate	0					
Pendimethalin	3.407	PRE	1381	1078	538	517
Nicosulfuron +	0.051 +	POST				
metsulfuron-methyl	0.017					
Ammonium nitrate	0					
Nicosulfuron +	0.077 +	POST	589	896	859	157
metsulfuron-methyl	0.025					
Ammonium nitrate	0					
Imazapic +	0.0525 +	POST	484	610	426	445
glyphosate	0.105					
Ammonium nitrate	0					
Untreated			455	1529	1248	500
Ammonium nitrate	0					

Appendix Table 41. (cont.) Bermudagrass yield response at CHK09-2 (8/06/2009).

			Replication			
Herbicide	Rate	Time of application	I	II	III	IV
	kg ha^{-1}		----------------------------------	kg ha^{-1}	----------------------------------	
Pendimethalin	3.407	PRE	3717	2697	1802	2881
Ammonium nitrate	113					
Pendimethalin	3.407	PRE	1221	2483	1077	1750
Nicosulfuron +	0.051 +	POST				
metsulfuron-methyl	0.017					
Ammonium nitrate	113					
Nicosulfuron +	0.077 +	POST	1967	2389	3431	1580
metsulfuron-methyl	0.025					
Ammonium nitrate	113					
Imazapic +	0.0525 +	POST	636	2237	2408	1913
glyphosate	0.105					
Ammonium nitrate	113					
Untreated			2560	3364	1870	2537
Ammonium nitrate	113					

Appendix Table 41. (cont.) Bermudagrass yield response at CHK09-2 (8/06/2009).

			Replication			
Herbicide	Rate	Time of application	I	II	III	IV
	kg ha^{-1}		---------------------------------- kg ha^{-1} ----------------------------------			
Pendimethalin	3.407	PRE	5982	5462	4124	1937
Ammonium nitrate	227					
Pendimethalin	3.407	PRE	1766	4692	2407	1994
Nicosulfuron +	0.051 +	POST				
metsulfuron-methyl	0.017					
Ammonium nitrate	227					
Nicosulfuron +	0.077 +	POST	4621	3568	3486	1295
metsulfuron-methyl	0.025					
Ammonium nitrate	227					
Imazapic +	0.0525 +	POST	2090	1679	4138	1520
glyphosate	0.105					
Ammonium nitrate	227					
Untreated			5732	3230	2254	3407
Ammonium nitrate	227					

Appendix Table 41. (cont.) Bermudagrass yield response at CHK09-2 (8/06/2009).

Herbicide	Rate	Time of application	Replication I	II	III	IV
	kg ha^{-1}		kg ha^{-1}			
Pendimethalin	3.407	PRE	3077	3674	5754	4435
Ammonium nitrate	340					
Pendimethalin	3.407	PRE	6481	2903	4854	2904
Nicosulfuron +	0.051 +	POST				
metsulfuron-methyl	0.017					
Ammonium nitrate	340					
Nicosulfuron +	0.077 +	POST	6076	1573	4095	2908
metsulfuron-methyl	0.025					
Ammonium nitrate	340					
Imazapic +	0.0525 +	POST	4432	996	4844	2476
glyphosate	0.105					
Ammonium nitrate	340					
Untreated			5590	1740	6347	3428
Ammonium nitrate	340					

[a] All herbicides except glyphosate (ae kg^{-1}) are expressed as ai kg^{-1}.

Appendix Table 42. Visual bermudagrass injury 3 WAT at HEN-1 (6/24/2010).

			Replication			
Herbicide	Rate[a]	Time of application	I	II	III	IV
	kg ha^{-1a}		%			
Pendimethalin	3.407	PRE	0	0	0	10
Ammonium nitrate	0					
Pendimethalin	3.407	PRE	10	10	0	20
Nicosulfuron + metsulfuron-methyl	0.030 + 0.008	POST				
Ammonium nitrate	0					
Pendimethalin	3.407	PRE	10	10	0	50
Nicosulfuron + metsulfuron-methyl	0.038 + 0.010	POST				
Ammonium nitrate	0					
Nicosulfuron + metsulfuron-methyl	0.038 + 0.010	POST	10	10	0	0
Ammonium nitrate	0					
Imazapic + glyphosate	0.0525 + 0.105	POST	10	50	30	10
Ammonium nitrate	0					
Untreated			0	0	0	0
Ammonium nitrate	0					

Appendix Table 42. (cont.) Visual bermudagrass injury 3 WAT at HEN-1 (6/24/2010).

Herbicide	Rate	Time of application	Replication I	II	III	IV
	kg ha^{-1}		---------- % ----------			
Pendimethalin	3.407	PRE	0	0	0	0
Ammonium nitrate	113					
Pendimethalin	3.407	PRE	10	10	10	50
Nicosulfuron +	0.030 +	POST				
metsulfuron-methyl	0.008					
Ammonium nitrate	113					
Pendimethalin	3.407	PRE	10	10	10	10
Nicosulfuron +	0.038 +	POST				
metsulfuron-methyl	0.010					
Ammonium nitrate	113					
Nicosulfuron +	0.038 +	POST	10	10	10	10
metsulfuron-methyl	0.010					
Ammonium nitrate	113					
Imazapic +	0.0525 +	POST	50	50	10	10
glyphosate	0.105					
Ammonium nitrate	113					
Untreated			0	0	0	0
Ammonium nitrate	113					

Appendix Table 42. (cont.) Visual bermudagrass injury 3 WAT at HEN-1 (6/24/2010).

Herbicide	Rate	Time of application	Replication I	II	III	IV
	kg ha^{-1}		---------------	---------------	% ---------------	---------------
Pendimethalin	3.407	PRE	0	0	0	0
Ammonium nitrate	227					
Pendimethalin	3.407	PRE	10	10	30	10
Nicosulfuron +	0.030 +	POST				
metsulfuron-methyl	0.008					
Ammonium nitrate	227					
Pendimethalin	3.407	PRE	10	10	0	10
Nicosulfuron +	0.038 +	POST				
metsulfuron-methyl	0.010					
Ammonium nitrate	227					
Nicosulfuron +	0.038 +	POST	10	10	10	10
metsulfuron-methyl	0.010					
Ammonium nitrate	227					
Imazapic +	0.0525 +	POST	50	40	10	50
glyphosate	0.105					
Ammonium nitrate	227					
Untreated			0	0	0	0
Ammonium nitrate	227					

Appendix Table 42. (cont.) Visual bermudagrass injury 3 WAT at HEN-1 (6/24/2010).

Herbicide	Rate	Time of application	Replication I	II	III	IV
	kg ha^{-1}		--------------------------------	%	--------------------------------	
Pendimethalin Ammonium nitrate	3.407 340	PRE	0	0	0	0
Pendimethalin Nicosulfuron + metsulfuron-methyl Ammonium nitrate	3.407 0.030 + 0.008 340	PRE POST	0	20	10	20
Pendimethalin Nicosulfuron + metsulfuron-methyl Ammonium nitrate	3.407 0.038 + 0.010 340	PRE POST	10	10	10	10
Nicosulfuron + metsulfuron-methyl Ammonium nitrate	0.038 + 0.010 340	POST	10	10	10	10
Imazapic + glyphosate Ammonium nitrate	0.0525 + 0.105 340	POST	50	50	20	30
Untreated Ammonium nitrate	 340		0	0	0	0

[a] All herbicides except glyphosate (ae kg^{-1}) are expressed as ai kg^{-1}.

Appendix Table 43. Bermudagrass yield response at HEN-1 (7/13/2010).

Herbicide	Rate[a]	Time of application	Replication I	II	III	IV
	kg ha^{-1a}		kg ha^{-1}			
Pendimethalin	3.407	PRE	4549	5038	7747	5538
Ammonium nitrate	0					
Pendimethalin	3.407	PRE	5333	4979	7756	7324
Nicosulfuron +	0.030 +	POST				
metsulfuron-methyl	0.008					
Ammonium nitrate	0					
Pendimethalin	3.407	PRE	4880	7209	8836	7310
Nicosulfuron +	0.038 +	POST				
metsulfuron-methyl	0.010					
Ammonium nitrate	0					
Nicosulfuron +	0.038 +	POST	3777	3544	5465	10173
metsulfuron-methyl	0.010					
Ammonium nitrate	0					
Imazapic +	0.0525 +	POST	3790	4314	6595	5854
glyphosate	0.105					
Ammonium nitrate	0					
Untreated			4415	4369	5453	6653
Ammonium nitrate	0					

Appendix Table 43. (cont.) Bermudagrass yield response at HEN-1 (7/13/2010).

Herbicide	Rate	Time of application	Replication I	II	III	IV
	kg ha^{-1}		---------- kg ha^{-1} ----------			
Pendimethalin	3.407	PRE	7342	8988	9153	7960
Ammonium nitrate	113					
Pendimethalin	3.407	PRE	9619	7929	8755	7329
Nicosulfuron +	0.030 +	POST				
metsulfuron-methyl	0.008					
Ammonium nitrate	113					
Pendimethalin	3.407	PRE	6568	8859	9639	7741
Nicosulfuron +	0.038 +	POST				
metsulfuron-methyl	0.010					
Ammonium nitrate	113					
Nicosulfuron +	0.038 +	POST	9630	6610	12347	8440
metsulfuron-methyl	0.010					
Ammonium nitrate	113					
Imazapic +	0.0525 +	POST	11170	7895	6748	7242
glyphosate	0.105					
Ammonium nitrate	113					
Untreated			10778	6442	10894	8402
Ammonium nitrate	113					

Appendix Table 43. (cont.) Bermudagrass yield response at HEN-1 (7/13/2010).

Herbicide	Rate	Time of application	Replication I	II	III	IV
	kg ha^{-1}		---------------------------------- kg ha^{-1}	----------------------------------		
Pendimethalin Ammonium nitrate	3.407 227	PRE	7850	8661	8824	9953
Pendimethalin Nicosulfuron + metsulfuron-methyl Ammonium nitrate	3.407 0.030 + 0.008 227	PRE POST	8594	8991	9854	9076
Pendimethalin Nicosulfuron + metsulfuron-methyl Ammonium nitrate	3.407 0.038 + 0.010 227	PRE POST	8422	11064	9154	8088
Nicosulfuron + metsulfuron-methyl Ammonium nitrate	0.038 + 0.010 227	POST	6720	7366	12695	8402
Imazapic + glyphosate Ammonium nitrate	0.0525 + 0.105 227	POST	6394	7628	7450	7294
Untreated Ammonium nitrate	 227		8428	7716	7364	10136

Appendix Table 43. (cont.) Bermudagrass yield response at HEN-1 (7/13/2010).

Herbicide	Rate	Time of application	Replication I	II	III	IV
	kg ha^{-1}		---- kg ha^{-1} ----			
Pendimethalin	3.407	PRE	6851	13538	11449	6836
Ammonium nitrate	340					
Pendimethalin	3.407	PRE	13183	9135	10314	10438
Nicosulfuron +	0.030 +	POST				
metsulfuron-methyl	0.008					
Ammonium nitrate	340					
Pendimethalin	3.407	PRE	8761	8153	8111	8683
Nicosulfuron +	0.038 +	POST				
metsulfuron-methyl	0.010					
Ammonium nitrate	340					
Nicosulfuron +	0.038 +	POST	8872	8413	7178	15484
metsulfuron-methyl	0.010					
Ammonium nitrate	340					
Imazapic +	0.0525 +	POST	13752	6630	11254	7572
glyphosate	0.105					
Ammonium nitrate	340					
Untreated			12522	10222	9592	7657
Ammonium nitrate	340					

[a] All herbicides except glyphosate (ae kg^{-1}) are expressed as ai kg^{-1}.

Appendix Table 44. Visual bermudagrass injury 3 WAT at HEN-2 (6/24/2010).

Herbicide	Rate[a]	Time of application	Replication I	II	III	IV
	kg ha^{-1}		%			
Pendimethalin	3.407	PRE	0	0	0	0
Ammonium nitrate	0					
Pendimethalin	3.407	PRE	10	20	10	20
Nicosulfuron +	0.030 +	POST				
metsulfuron-methyl	0.008					
Ammonium nitrate	0					
Pendimethalin	3.407	PRE	10	10	10	10
Nicosulfuron +	0.038 +	POST				
metsulfuron-methyl	0.010					
Ammonium nitrate	0					
Nicosulfuron +	0.038 +	POST	20	10	20	10
metsulfuron-methyl	0.010					
Ammonium nitrate	0					
Imazapic +	0.0525 +	POST	50	50	50	50
glyphosate	0.105					
Ammonium nitrate	0					
Untreated			0	0	0	0
Ammonium nitrate	0					

Appendix Table 44. (cont.) Visual bermudagrass injury 3 WAT at HEN-2 (6/24/2010).

Herbicide	Rate	Time of application	Replication I	II	III	IV
	kg ha^{-1}		------------------------	%	------------------------	
Pendimethalin	3.407	PRE	0	0	0	0
Ammonium nitrate	113					
Pendimethalin	3.407	PRE	10	10	10	10
Nicosulfuron +	0.030 +	POST				
metsulfuron-methyl	0.008					
Ammonium nitrate	113					
Pendimethalin	3.407	PRE	10	10	10	10
Nicosulfuron +	0.038 +	POST				
metsulfuron-methyl	0.010					
Ammonium nitrate	113					
Nicosulfuron +	0.038 +	POST	10	10	50	10
metsulfuron-methyl	0.010					
Ammonium nitrate	113					
Imazapic +	0.0525 +	POST	50	50	50	50
glyphosate	0.105					
Ammonium nitrate	113					
Untreated			0	0	0	0
Ammonium nitrate	113					

Appendix Table 44. (cont.) Visual bermudagrass injury 3 WAT at HEN-2 (6/24/2010).

Herbicide	Rate	Time of application	Replication I	II	III	IV
	kg ha^{-1}		----------------------------------	%	----------------------------------	
Pendimethalin	3.407	PRE	0	0	0	0
Ammonium nitrate	227					
Pendimethalin	3.407	PRE	10	10	10	20
Nicosulfuron +	0.030 +	POST				
metsulfuron-methyl	0.008					
Ammonium nitrate	227					
Pendimethalin	3.407	PRE	10	10	10	10
Nicosulfuron +	0.038 +	POST				
metsulfuron-methyl	0.010					
Ammonium nitrate	227					
Nicosulfuron +	0.038 +	POST	10	10	10	10
metsulfuron-methyl	0.010					
Ammonium nitrate	227					
Imazapic +	0.0525 +	POST	50	50	50	50
glyphosate	0.105					
Ammonium nitrate	227					
Untreated			0	0	0	0
Ammonium nitrate	227					

Appendix Table 44. (cont.) Visual bermudagrass injury 3 WAT at HEN-2 (6/24/2010).

Herbicide	Rate	Time of application	Replication I	II	III	IV
	kg ha^{-1}		----------------------------------	%	----------------------------------	
Pendimethalin	3.407	PRE	0	0	0	0
Ammonium nitrate	340					
Pendimethalin	3.407	PRE	10	10	10	10
Nicosulfuron +	0.030 +	POST				
metsulfuron-methyl	0.008					
Ammonium nitrate	340					
Pendimethalin	3.407	PRE	10	10	10	10
Nicosulfuron +	0.038 +	POST				
metsulfuron-methyl	0.010					
Ammonium nitrate	340					
Nicosulfuron +	0.038 +	POST	10	20	20	20
metsulfuron-methyl	0.010					
Ammonium nitrate	340					
Imazapic +	0.0525 +	POST	50	50	50	50
glyphosate	0.105					
Ammonium nitrate	340					
Untreated			0	0	0	0
Ammonium nitrate	340					

[a] All herbicides except glyphosate (ae kg^{-1}) are expressed as ai kg^{-1}.

Appendix Table 45. Visual field sandbur control 6 WAT at HEN-2 (7/21/2010).

Herbicide	Rate[a]	Time of application	Replication I	II	III	IV
	kg ha^{-1}		------------------------------- %	-------------------------------		
Pendimethalin	3.407	PRE	90	90	95	99
Ammonium nitrate	0					
Pendimethalin	3.407	PRE	98	95	90	95
Nicosulfuron +	0.030 +	POST				
metsulfuron-methyl	0.008					
Ammonium nitrate	0					
Pendimethalin	3.407	PRE	100	90	95	100
Nicosulfuron +	0.038 +	POST				
metsulfuron-methyl	0.010					
Ammonium nitrate	0					
Nicosulfuron +	0.038 +	POST	10	95	90	99
metsulfuron-methyl	0.010					
Ammonium nitrate	0					
Imazapic +	0.0525 +	POST	95	99	95	95
glyphosate	0.105					
Ammonium nitrate	0					
Untreated			0	0	0	0
Ammonium nitrate	0					

Appendix Table 45. (cont.) Visual field sandbur control 6 WAT at HEN-2 (7/21/2010).

Herbicide	Rate	Time of application	Replication I	II	III	IV
	kg ha^{-1}		%			
Pendimethalin	3.407	PRE	95	90	90	90
Ammonium nitrate	113					
Pendimethalin	3.407	PRE	95	90	90	90
Nicosulfuron +	0.030 +	POST				
metsulfuron-methyl	0.008					
Ammonium nitrate	113					
Pendimethalin	3.407	PRE	99	95	98	90
Nicosulfuron +	0.038 +	POST				
metsulfuron-methyl	0.010					
Ammonium nitrate	113					
Nicosulfuron +	0.038 +	POST	99	95	90	95
metsulfuron-methyl	0.010					
Ammonium nitrate	113					
Imazapic +	0.0525 +	POST	95	99	95	95
glyphosate	0.105					
Ammonium nitrate	113					
Untreated			0	0	0	0
Ammonium nitrate	113					

Appendix Table 45. (cont.) Visual field sandbur control 6 WAT at HEN-2 (7/21/2010).

Herbicide	Rate	Time of application	Replication I	II	III	IV
	kg ha^{-1}		%			
Pendimethalin	3.407	PRE	95	80	100	90
Ammonium nitrate	227					
Pendimethalin	3.407	PRE	95	95	90	85
Nicosulfuron +	0.030 +	POST				
metsulfuron-methyl	0.008					
Ammonium nitrate	227					
Pendimethalin	3.407	PRE	90	95	90	90
Nicosulfuron +	0.038 +	POST				
metsulfuron-methyl	0.010					
Ammonium nitrate	227					
Nicosulfuron +	0.038 +	POST	95	95	90	95
metsulfuron-methyl	0.010					
Ammonium nitrate	227					
Imazapic +	0.0525 +	POST	90	100	90	90
glyphosate	0.105					
Ammonium nitrate	227					
Untreated			0	0	0	0
Ammonium nitrate	227					

Appendix Table 45. (cont.) Visual field sandbur control 6 WAT at HEN-2 (7/21/2010).

Herbicide	Rate	Time of application	Replication I	II	III	IV
	kg ha^{-1}		----------------------------------	%	----------------------------------	
Pendimethalin	3.407	PRE	90	90	95	90
Ammonium nitrate	340					
Pendimethalin	3.407	PRE	100	90	95	90
Nicosulfuron +	0.030 +	POST				
metsulfuron-methyl	0.008					
Ammonium nitrate	340					
Pendimethalin	3.407	PRE	90	95	90	90
Nicosulfuron +	0.038 +	POST				
metsulfuron-methyl	0.010					
Ammonium nitrate	340					
Nicosulfuron +	0.038 +	POST	90	95	95	95
metsulfuron-methyl	0.010					
Ammonium nitrate	340					
Imazapic +	0.0525 +	POST	100	100	99	95
glyphosate	0.105					
Ammonium nitrate	340					
Untreated			0	0	0	0
Ammonium nitrate	340					

[a] All herbicides except glyphosate (ae kg^{-1}) are expressed as ai kg^{-1}.

Appendix Table 46. Visual field sandbur control 9 WAT at HEN-2 (8/01/2010).

Herbicide	Rate[a]	Time of application	Replication I	Replication II	Replication III	Replication IV
	kg ha^{-1}		%			
Pendimethalin	3.407	PRE	90	90	99	100
Ammonium nitrate	0					
Pendimethalin	3.407	PRE	10	100	95	100
Nicosulfuron +	0.030 +	POST				
metsulfuron-methyl	0.008					
Ammonium nitrate	0					
Pendimethalin	3.407	PRE	100	90	99	100
Nicosulfuron +	0.038 +	POST				
metsulfuron-methyl	0.010					
Ammonium nitrate	0					
Nicosulfuron +	0.038 +	POST	100	90	100	100
metsulfuron-methyl	0.010					
Ammonium nitrate	0					
Imazapic +	0.0525 +	POST	100	99	100	100
glyphosate	0.105					
Ammonium nitrate	0					
Untreated			0	0	0	0
Ammonium nitrate	0					

Appendix Table 46. (cont.) Visual field sandbur control 9 WAT at HEN-2 (8/01/2010).

Herbicide	Rate	Time of application	Replication I	II	III	IV
	kg ha^{-1}		----------	----------	% ----------	----------
Pendimethalin	3.407	PRE	100	90	95	100
Ammonium nitrate	113					
Pendimethalin	3.407	PRE	100	95	99	100
Nicosulfuron +	0.030 +	POST				
metsulfuron-methyl	0.008					
Ammonium nitrate	113					
Pendimethalin	3.407	PRE	100	99	100	95
Nicosulfuron +	0.038 +	POST				
metsulfuron-methyl	0.010					
Ammonium nitrate	113					
Nicosulfuron +	0.038 +	POST	100	99	100	95
metsulfuron-methyl	0.010					
Ammonium nitrate	113					
Imazapic +	0.0525 +	POST	100	100	100	95
glyphosate	0.105					
Ammonium nitrate	113					
Untreated			0	0	0	0
Ammonium nitrate	113					

Appendix Table 46. (cont.) Visual field sandbur control 9 WAT at HEN-2 (8/01/2010).

Herbicide	Rate	Time of application	Replication I	II	III	IV
	kg ha^{-1}		%			
Pendimethalin	3.407	PRE	100	80	100	100
Ammonium nitrate	227					
Pendimethalin	3.407	PRE	100	99	99	99
Nicosulfuron +	0.030 +	POST				
metsulfuron-methyl	0.008					
Ammonium nitrate	227					
Pendimethalin	3.407	PRE	100	100	100	95
Nicosulfuron +	0.038 +	POST				
metsulfuron-methyl	0.010					
Ammonium nitrate	227					
Nicosulfuron +	0.038 +	POST	100	100	100	100
metsulfuron-methyl	0.010					
Ammonium nitrate	227					
Imazapic +	0.0525 +	POST	100	100	100	100
glyphosate	0.105					
Ammonium nitrate	227					
Untreated			0	0	0	0
Ammonium nitrate	227					

Appendix Table 46. (cont.) Visual field sandbur control 9 WAT at HEN-2 (8/01/2010).

Herbicide	Rate	Time of application	Replication I	II	III	IV
	kg ha^{-1}		%			
Pendimethalin	3.407	PRE	100	100	100	90
Ammonium nitrate	340					
Pendimethalin	3.407	PRE	100	100	100	99
Nicosulfuron +	0.030 +	POST				
metsulfuron-methyl	0.008					
Ammonium nitrate	340					
Pendimethalin	3.407	PRE	95	100	100	95
Nicosulfuron +	0.038 +	POST				
metsulfuron-methyl	0.010					
Ammonium nitrate	340					
Nicosulfuron +	0.038 +	POST	100	100	100	100
metsulfuron-methyl	0.010					
Ammonium nitrate	340					
Imazapic +	0.0525 +	POST	100	100	100	100
glyphosate	0.105					
Ammonium nitrate	340					
Untreated			0	0	0	0
Ammonium nitrate	340					

[a] All herbicides except glyphosate (ae kg^{-1}) are expressed as ai kg^{-1}.

Appendix Table 47. Visual bermudagrass injury 3 WAT at HEN-3 (6/24/2010).

Herbicide	Rate[a]	Time of application	Replication I	Replication II	Replication III
	kg ha^{-1}		----------------------	%	----------------------
Pendimethalin	3.407	PRE	0	0	0
Ammonium nitrate	0				
Pendimethalin	3.407	PRE	10	10	10
Nicosulfuron + metsulfuron-methyl	0.030 + 0.008	POST			
Ammonium nitrate	0				
Pendimethalin	3.407	PRE	10	10	10
Nicosulfuron + metsulfuron-methyl	0.038 + 0.010	POST			
Ammonium nitrate	0				
Nicosulfuron + metsulfuron-methyl	0.038 + 0.010	POST	20	10	20
Ammonium nitrate	0				
Imazapic + glyphosate	0.0525 + 0.105	POST	50	50	50
Ammonium nitrate	0				
Untreated			0	0	0
Ammonium nitrate	0				

Appendix Table 47. (cont.) Visual bermudagrass injury 3 WAT at HEN-3 (6/24/2010).

Herbicide	Rate	Time of application	Replication I	Replication II	Replication III
	kg ha^{-1}		----------------------	%	----------------------
Pendimethalin	3.407	PRE	0	0	0
Ammonium nitrate	113				
Pendimethalin	3.407	PRE	10	10	10
Nicosulfuron +	0.030 +	POST			
metsulfuron-methyl	0.008				
Ammonium nitrate	113				
Pendimethalin	3.407	PRE	10	10	50
Nicosulfuron +	0.038 +	POST			
metsulfuron-methyl	0.010				
Ammonium nitrate	113				
Nicosulfuron +	0.038 +	POST	10	20	20
metsulfuron-methyl	0.010				
Ammonium nitrate	113				
Imazapic +	0.0525 +	POST	50	50	10
glyphosate	0.105				
Ammonium nitrate	113				
Untreated			0	0	0
Ammonium nitrate	113				

Appendix Table 47. (cont.) Visual bermudagrass injury 3 WAT at HEN-3 (6/24/2010).

Herbicide	Rate	Time of application	Replication		
			I	II	III
	kg ha^{-1}		----------------------	%	----------------------
Pendimethalin	3.407	PRE	0	0	0
Ammonium nitrate	227				
Pendimethalin	3.407	PRE	10	10	30
Nicosulfuron +	0.030 +	POST			
metsulfuron-methyl	0.008				
Ammonium nitrate	227				
Pendimethalin	3.407	PRE	10	10	0
Nicosulfuron +	0.038 +	POST			
metsulfuron-methyl	0.010				
Ammonium nitrate	227				
Nicosulfuron +	0.038 +	POST	20	10	50
metsulfuron-methyl	0.010				
Ammonium nitrate	227				
Imazapic +	0.0525 +	POST	50	50	30
glyphosate	0.105				
Ammonium nitrate	227				
Untreated			0	0	0
Ammonium nitrate	227				

Appendix Table 47. (cont.) Visual bermudagrass injury 3 WAT at HEN-3 (6/24/2010).

			Replication		
Herbicide	Rate	Time of application	I	II	III
	kg ha^{-1}		----------------------	%	----------------------
Pendimethalin	3.407	PRE	10	0	0
Ammonium nitrate	340				
Pendimethalin	3.407	PRE	10	10	10
Nicosulfuron +	0.030 +	POST			
metsulfuron-methyl	0.008				
Ammonium nitrate	340				
Pendimethalin	3.407	PRE	10	10	20
Nicosulfuron +	0.038 +	POST			
metsulfuron-methyl	0.010				
Ammonium nitrate	340				
Nicosulfuron +	0.038 +	POST	10	20	10
metsulfuron-methyl	0.010				
Ammonium nitrate	340				
Imazapic +	0.0525 +	POST	50	50	50
glyphosate	0.105				
Ammonium nitrate	340				
Untreated			0	0	0
Ammonium nitrate	340				

[a] All herbicides except glyphosate (ae kg^{-1}) are expressed as ai kg^{-1}.

Appendix Table 48. Visual field sandbur control 6 WAT at HEN-3 (7/21/2010).

Herbicide	Rate[a]	Time of application	Replication I	Replication II	Replication III
	kg ha^{-1}		-----------------------	%	-----------------------
Pendimethalin	3.407	PRE	70	50	50
Ammonium nitrate	0				
Pendimethalin	3.407	PRE	90	90	90
Nicosulfuron +	0.030 +	POST			
metsulfuron-methyl	0.008				
Ammonium nitrate	0				
Pendimethalin	3.407	PRE	80	90	90
Nicosulfuron +	0.038 +	POST			
metsulfuron-methyl	0.010				
Ammonium nitrate	0				
Nicosulfuron +	0.038 +	POST	80	80	80
metsulfuron-methyl	0.010				
Ammonium nitrate	0				
Imazapic +	0.0525 +	POST	100	95	80
glyphosate	0.105				
Ammonium nitrate	0				
Untreated			0	0	0
Ammonium nitrate	0				

Appendix Table 48. (cont.) Visual field sandbur control 6 WAT at HEN-3 (7/21/2010).

			Replication		
Herbicide	Rate	Time of application	I	II	III
	kg ha^{-1}		----------------------	%	----------------------
Pendimethalin	3.407	PRE	90	90	90
Ammonium nitrate	113				
Pendimethalin	3.407	PRE	80	90	80
Nicosulfuron +	0.030 +	POST			
metsulfuron-methyl	0.008				
Ammonium nitrate	113				
Pendimethalin	3.407	PRE	95	90	100
Nicosulfuron +	0.038 +	POST			
metsulfuron-methyl	0.010				
Ammonium nitrate	113				
Nicosulfuron +	0.038 +	POST	100	80	80
metsulfuron-methyl	0.010				
Ammonium nitrate	113				
Imazapic +	0.0525 +	POST	100	100	100
glyphosate	0.105				
Ammonium nitrate	113				
Untreated			0	0	0
Ammonium nitrate	113				

Appendix Table 48. (cont.) Visual field sandbur control 6 WAT at HEN-3 (7/21/2010).

Herbicide	Rate	Time of application	Replication I	Replication II	Replication III
	kg ha^{-1}		---------------------- %	----------------------	----------------------
Pendimethalin	3.407	PRE	90	90	90
Ammonium nitrate	227				
Pendimethalin	3.407	PRE	80	95	100
Nicosulfuron +	0.030 +	POST			
metsulfuron-methyl	0.008				
Ammonium nitrate	227				
Pendimethalin	3.407	PRE	80	95	90
Nicosulfuron +	0.038 +	POST			
metsulfuron-methyl	0.010				
Ammonium nitrate	227				
Nicosulfuron +	0.038 +	POST	90	100	90
metsulfuron-methyl	0.010				
Ammonium nitrate	227				
Imazapic +	0.0525 +	POST	100	100	95
glyphosate	0.105				
Ammonium nitrate	227				
Untreated			0	0	0
Ammonium nitrate	227				

Appendix Table 48. (cont.) Visual field sandbur control 6 WAT at HEN-3 (7/21/2010).

			Replication		
Herbicide	Rate	Time of application	I	II	III
	kg ha^{-1}		----------------------	%	----------------------
Pendimethalin Ammonium nitrate	3.407 340	PRE	90	90	90
Pendimethalin Nicosulfuron + metsulfuron-methyl Ammonium nitrate	3.407 0.030 + 0.008 340	PRE POST	90	90	90
Pendimethalin Nicosulfuron + metsulfuron-methyl Ammonium nitrate	3.407 0.038 + 0.010 340	PRE POST	80	95	95
Nicosulfuron + metsulfuron-methyl Ammonium nitrate	0.038 + 0.010 340	POST	90	95	95
Imazapic + glyphosate Ammonium nitrate	0.0525 + 0.105 340	POST	100	100	100
Untreated Ammonium nitrate	 340		0	0	0

[a] All herbicides except glyphosate (ae kg^{-1}) are expressed as ai kg^{-1}.

Appendix Table 49. Visual field sandbur control 9 WAT at HEN-3 (8/01/2010).

			Replication		
Herbicide	Rate[a]	Time of application	I	II	III
	kg ha^{-1}		----------------------	%----------------------	
Pendimethalin	3.407	PRE	99	90	99
Ammonium nitrate	0				
Pendimethalin	3.407	PRE	95	95	99
Nicosulfuron +	0.030 +	POST			
metsulfuron-methyl	0.008				
Ammonium nitrate	0				
Pendimethalin	3.407	PRE	90	99	95
Nicosulfuron +	0.038 +	POST			
metsulfuron-methyl	0.010				
Ammonium nitrate	0				
Nicosulfuron +	0.038 +	POST	100	95	99
metsulfuron-methyl	0.010				
Ammonium nitrate	0				
Imazapic +	0.0525 +	POST	100	100	95
glyphosate	0.105				
Ammonium nitrate	0				
Untreated			0	0	0
Ammonium nitrate	0				

Appendix Table 49. (cont.) Visual field sandbur control 9 WAT at HEN-3 (8/01/2010).

Herbicide	Rate	Time of application	Replication I	II	III
	kg ha^{-1}		----------------------	%	----------------------
Pendimethalin	3.407	PRE	95	95	99
Ammonium nitrate	113				
Pendimethalin	3.407	PRE	100	100	100
Nicosulfuron +	0.030 +	POST			
metsulfuron-methyl	0.008				
Ammonium nitrate	113				
Pendimethalin	3.407	PRE	100	10	100
Nicosulfuron +	0.038 +	POST			
metsulfuron-methyl	0.010				
Ammonium nitrate	113				
Nicosulfuron +	0.038 +	POST	10	100	95
metsulfuron-methyl	0.010				
Ammonium nitrate	113				
Imazapic +	0.0525 +	POST	100	100	100
glyphosate	0.105				
Ammonium nitrate	113				
Untreated			0	0	0
Ammonium nitrate	113				

Appendix Table 49. (cont.) Visual field sandbur control 9 WAT at HEN-3 (8/01/2010).

Herbicide	Rate	Time of application	Replication I	Replication II	Replication III
	kg ha^{-1}		----------------------	%	----------------------
Pendimethalin	3.407	PRE	100	95	95
Ammonium nitrate	227				
Pendimethalin	3.407	PRE	95	100	100
Nicosulfuron +	0.030 +	POST			
metsulfuron-methyl	0.008				
Ammonium nitrate	227				
Pendimethalin	3.407	PRE	90	100	100
Nicosulfuron +	0.038 +	POST			
metsulfuron-methyl	0.010				
Ammonium nitrate	227				
Nicosulfuron +	0.038 +	POST	95	100	85
metsulfuron-methyl	0.010				
Ammonium nitrate	227				
Imazapic +	0.0525 +	POST	100	100	100
glyphosate	0.105				
Ammonium nitrate	227				
Untreated			0	0	0
Ammonium nitrate	227				

Appendix Table 49. (cont.) Visual field sandbur control 9 WAT at HEN-3 (8/01/2010).

Herbicide	Rate	Time of application	Replication I	Replication II	Replication III
	kg ha^{-1}		----------------------	%	----------------------
Pendimethalin	3.407	PRE	900	95	100
Ammonium nitrate	340				
Pendimethalin	3.407	PRE	99	100	100
Nicosulfuron +	0.030 +	POST			
metsulfuron-methyl	0.008				
Ammonium nitrate	340				
Pendimethalin	3.407	PRE	100	99	100
Nicosulfuron +	0.038 +	POST			
metsulfuron-methyl	0.010				
Ammonium nitrate	340				
Nicosulfuron +	0.038 +	POST	100	100	100
metsulfuron-methyl	0.010				
Ammonium nitrate	340				
Imazapic +	0.0525 +	POST	100	100	100
glyphosate	0.105				
Ammonium nitrate	340				
Untreated			0	0	0
Ammonium nitrate	340				

[a] All herbicides except glyphosate (ae kg^{-1}) are expressed as ai kg^{-1}.

Appendix Table 50. Bermudagrass yield response at CHK10-1 (6/28/2010).

Herbicide	Rate[a]	Time of application	Replication I	II	III	IV
	kg ha^{-1a}		---- kg ha^{-1} ----			
Pendimethalin	3.407	PRE	3325	1353	2676	684
Ammonium nitrate	0					
Pendimethalin	3.407	PRE	1386	1012	612	1539
Nicosulfuron + metsulfuron-methyl	0.030 + 0.008	POST				
Ammonium nitrate	0					
Pendimethalin	3.407	PRE	933	1091	557	1046
Nicosulfuron + metsulfuron-methyl	0.038 + 0.010	POST				
Ammonium nitrate	0					
Nicosulfuron + metsulfuron-methyl	0.038 + 0.010	POST	1278	550	1549	385
Ammonium nitrate	0					
Imazapic + glyphosate	0.0525 + 0.105	POST	382	787	1235	68
Ammonium nitrate	0					
Untreated			4236	1037	996	2630
Ammonium nitrate	0					

Appendix Table 50. (cont.) Bermudagrass yield response at CHK10-1 (6/28/2010).

Herbicide	Rate	Time of application	Replication I	II	III	IV
	kg ha^{-1}		--- kg ha^{-1} ---			
Pendimethalin	3.407	PRE	8297	4318	7143	5000
Ammonium nitrate	113					
Pendimethalin	3.407	PRE	3671	2759	7853	3042
Nicosulfuron +	0.030 +	POST				
metsulfuron-methyl	0.008					
Ammonium nitrate	113					
Pendimethalin	3.407	PRE	4189	2228	7361	3170
Nicosulfuron +	0.038 +	POST				
metsulfuron-methyl	0.010					
Ammonium nitrate	113					
Nicosulfuron +	0.038 +	POST	1703	4613	7020	6125
metsulfuron-methyl	0.010					
Ammonium nitrate	113					
Imazapic +	0.0525 +	POST	3325	2656	3849	1245
glyphosate	0.105					
Ammonium nitrate	113					
Untreated			5528	5958	7137	6798
Ammonium nitrate	113					

Appendix Table 50. (cont.) Bermudagrass yield response at CHK10-1 (6/28/2010).

Herbicide	Rate	Time of application	Replication I	II	III	IV
	kg ha^{-1}		---- kg ha^{-1} ----			
Pendimethalin Ammonium nitrate	3.407 227	PRE	3547	10741	8825	8449
Pendimethalin Nicosulfuron + metsulfuron-methyl Ammonium nitrate	3.407 0.030 + 0.008 227	PRE POST	4224	9362	5145	1678
Pendimethalin Nicosulfuron + metsulfuron-methyl Ammonium nitrate	3.407 0.038 + 0.010 227	PRE POST	4639	5638	7677	2709
Nicosulfuron + metsulfuron-methyl Ammonium nitrate	0.038 + 0.010 227	POST	7474	7330	6753	3968
Imazapic + glyphosate Ammonium nitrate	0.0525 + 0.105 227	POST	3712	3835	6562	157
Untreated Ammonium nitrate	 227		6489	5522	6326	4351

Appendix Table 50. (cont.) Bermudagrass yield response at CHK10-1 (6/28/2010).

Herbicide	Rate	Time of application	Replication I	II	III	IV
	kg ha^{-1}		---------- kg ha^{-1} ----------			
Pendimethalin	3.407	PRE	10017	5389	9918	9408
Ammonium nitrate	340					
Pendimethalin	3.407	PRE	2759	2938	5015	6722
Nicosulfuron +	0.030 +	POST				
metsulfuron-methyl	0.008					
Ammonium nitrate	340					
Pendimethalin	3.407	PRE	9200	3563	6070	6967
Nicosulfuron +	0.038 +	POST				
metsulfuron-methyl	0.010					
Ammonium nitrate	340					
Nicosulfuron +	0.038 +	POST	5076	3177	4675	5550
metsulfuron-methyl	0.010					
Ammonium nitrate	340					
Imazapic +	0.0525 +	POST	4721	3363	4112	4589
glyphosate	0.105					
Ammonium nitrate	340					
Untreated			6303	8640	10743	10068
Ammonium nitrate	340					

[a] All herbicides except glyphosate (ae kg^{-1}) are expressed as ai kg^{-1}.

VITA

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Raised on a farm near Marthasville, Missouri; employed as a Undergraduate Research Assistant by the Department of Plant and Soil Sciences, Oklahoma State University, Stillwater, Oklahoma in May 2007; and employed as a Gradate Research Assistant by the Department of Plant and Soil Sciences, Oklahoma State University, Stillwater, Oklahoma in May 2009 to the present.

Name: Amber Nicole Eytcheson Date of Degree: July, 2011

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: FIELD SANDBUR (*Cenchrus spinifex*) CONTROL AND BERMUDAGRASS (*Cynodon dactylon*) RESPONSE TO HERBICIDE AND NITROGEN FERTILIZER TREATMENTS

Pages in Study: 112 Candidate for the Degree of Master of Science

Major Field: Agronomy

Scope and Method of Study: Field experiments were conducted in 2009 and 2010 to evaluate the effects of herbicide and nitrogen fertilizer treatment combinations on field sandbur control and bermudagrass injury and yield responses. Herbicide treatments applied were: pendimethalin PRE, pendimethalin PRE fb nicosulfuron plus metsulfuron-methyl, nicosulfuron plus metsulfuron-methyl, imazapic plus glyphosate and an untreated. All herbicide treatments were applied with 0, 113, 227, and 340 kg ha^{-1} of nitrogen fertilizer as ammonium nitrate (34-0-0). The treatment structure was a factorial arrangement of treatments in a randomized complete block design. Field sandbur control was evaluated at 6 and 9 WAT as percent control relative to the untreated. Bermudagrass injury was evaluated at 3 WAT as percent bermudagrass chlorosis, stand thinning and stunting relative to the untreated.

Findings and Conclusions: Pendimethalin fb nicosulfuron plus metsulfuron-methyl and nicosulfuron plus metsulfuron-methyl provided excellent field sandbur control with minimal bermudagrass injury and yield reductions. Imazapic plus glyphosate provided excellent control; however, it injured bermudagrass up to 50% 3 WAT and had up to 55% bermudagrass yield reductions. Although pendimethalin applied alone provided adequate field sandbur control with minimal injury to bermudagrass, due to precipitation requirements following application, pendimethalin may not have the ability to adequately control field sandbur every growing season. The addition of nitrogen fertilizer increased bermudagrass yield and may aid in decreasing the effects of yield reductions due to herbicide applications.

Although we were able to control one germination flush of field sandbur, sequential postemergence applications of nicosulfuron plus metsulfuron-methyl may be needed for season long field sandbur control. Further investigation is needed to develop nitrogen fertilizer recommendations to aid field sandbur control in combination with herbicide applications. Further investigation is needed to evaluate the biology of field sandbur. Knowing the biology will aid researchers and producers in combating field sandbur infestations.

ADVISER'S APPROVAL: ____________________