Suppression of Caucasian Old World Bluestem by Split Application of Herbicides[1]

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Abstract: Caucasian old world bluestem (OWB), seeded for conservation and forage production, has escaped into rangelands in the southern and central Great Plains. Five herbicides were applied at the 4 to 5 leaf stage and again eight weeks later, to control Caucasian OWB in both 2003 and 2005. Glyphosate at 1.14 kg/ha at each application was the only treatment that reduced frequency and tiller density of Caucasian OWB, and also controlled over 80% of growth, at six weeks after the first treatment (WAT) both years. After the first frost, glyphosate and imazapyr at 0.28 kg/ha at each application had much lower frequency and much greater suppression of Caucasian OWB growth than other herbicides. Tiller densities and seedhead densities were also much lower for imazapyr and glyphosate compared to other herbicides and the untreated control. Biomass at the end of the season was almost non-existent for glyphosate and imazapyr in 2003, and 26 to 46% of the untreated control biomass in 2005. Frequency of Caucasian OWB the year following treatment was less than 5% for both imazapyr and glyphosate. Both imazapyr and glyphosate also controlled remnant native vegetation in plots, thus different application methods

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may be useful to avoid native grass injury.

Nomenclature: glyphosate; imazapic; imazapyr; imazethapyr; sulfometuron methyl; Caucasian bluestem, *Bothriochloa bladhii* Retz (S.T. Blake) #[3] BOTBL.

Additional index words: biomass, frequency, native vegetation, old world bluestem, suppression, tiller density.

Abbreviations: OWB, old world bluestem; WAT, weeks after treatment; LSD, least significant differences.

INTRODUCTION

Caucasian old world bluestem (OWB) [*Bothrichloa bladhii* (Retz) S.T. Blake], commonly found in portions of Asia and Australia, has been widely introduced in the southern and central Great Plains of the United States as a warm-season perennial grass for soil conservation and forage production. With proper management, monocultures of Caucasian OWB are capable of producing abundant dry matter for hay or grazing (Brejda et al. 1995; Sanderson et al., 1999). However, Caucasian OWB, an introduced species, may be undesirable in native rangelands because of unknown effects on utilization, growth, and reproduction of native vegetation (Wilson and Shay, 1990; Lodge, 1993; Simberloff 1996; Sakai, et al., 2001; Vitousek 1990).

Caucasian OWB matures earlier in the season than other common native warm-season grass

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[3]Letters following this symbol are derived from version 2.1 of the Bayer Code System, for Bayer Codes for Pests (© BayerAG, Germany). A current code from WSSA was not available for this species.

species in west-central Kansas, and, thus, becomes undesirable for grazing (Harmoney and Hickman 2004). Compared with seedlings of indiangrass [*Sorghastrum nutans* (L.) Nash], sand bluestem (*Andropogon hallii* Hack), blue grama [*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths], and switchgrass (*Panicum virgatum* L.), Caucasian OWB seedlings produced more biomass, leaf area per plant, tillers, and leaves per tiller than the native species when grown in a greenhouse environment (Coyne and Bradford 1985). Caucasian OWB is persistent and may remain or increase in native stands indefinitely. In a 36-year assessment of adaptability in Dallam County, Texas, grazed and ungrazed Caucasian OWB was one of only three species to persist in their original plots, and eventually spread into plots seeded to other grasses (Eck and Sims 1984).

Forage quality of Caucasian OWB also has been found to rapidly decline with advancing maturity (Dabo et el. 1988). Individual steer gains and beef gain per ha were lowest for animals grazing Caucasian OWB compared to animals grazing monocultures of switchgrass, western wheatgrass (*Pascopyrum smithii* Rydb. Love), or a native species mixture in a long-term trial in central Kansas (Launchbaugh 1971).

Attempts have been made to control established OWB to allow establishment of row crops or other forages. However, most investigation has involved yellow OWB [*Bothriochloa ischaemum* (L.) Keng] rather than Caucasian OWB. Glyphosate at 1.68 kg ai/ha controlled 72% of yellow OWB when wheat (*Triticum aestivum* L.)was seeded no-till into the grass stand, compared to over 90% control of yellow OWB using disk tillage or moldboard plow tillage (Medlin et al. 1998). Medlin et. al. (1998) also found that OWB control was better with glyphosate applied in July rather than May. The herbicides imazapic, imazapyr, sulfometuron, and glyphosate each reduced total season biomass of yellow OWB by more than 50% with a single late spring application at the 4 to 5 leaf stage (Harmoney et. al., 2004). However, late season tiller formation from crown basal buds in glyphosate treated plots resulted in yellow OWB tiller densities that were as great as untreated yellow OWB densities (Harmoney et. al., 2004).

Escape of Caucasian OWB into native rangelands and seeded pastures of native species may create serious management problems in some regions of the Great Plains. Information is lacking on the control of Caucasian OWB that has invaded native species of rangelands, Conservation Reserve Program acres or renovated pastures. The objective of this experiment was to evaluate the efficacy of five herbicides applied in split applications on established stands of Caucasian OWB that had invaded native vegetation.

MATERIALS AND METHODS

Research was conducted at the Kansas State University Agricultural Research Center at Hays, KS (38º 51' 29.8759 N, 99º 20' 06.9770 W, elevation 611 m above sea level). The area consisted of limy upland range sites with Armo loam (Fine-loamy, mixed, mesic Entic Haplustolls) and Harney silt loam (Fine, smectitic, mesic Typic Argiustoll) soils with 1 to 4 percent slope. The study sites were previously dominated by native vegetation consisting of sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.], blue grama [*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths], buffalograss [*Buchloe dactyloides* (Nutt.) Engelm.], and western wheatgrass (*Pascopyrum smithii* Rydb. Love) before being infested by Caucasian OWB.

Five herbicides were tested in field trials in 2003 and 2005 for the ability to suppress growth of Caucasian OWB. Herbicide treatments were applied in a randomized complete block experiment with four replications to OWB in split applications, with the first application taking place when OWB had 4 to 5 fully expanded leaves and was vegetative in growth (V4 to V5 stage), and again at 8 weeks after first treatment. Herbicides and rates applied at each application were imazapyr at 0.28 kg/ha; sulfometuron methyl at 0.157 kg/ha; imazapic at 0.105 kg/ha; imazethapyr at 0.055 kg/ha; and glyphosate at 1.14 kg/ha. Except for glyphosate, herbicides were applied in a mixture of water, 2% (v/v) 28% urea-ammonium nitrate, and 2% (v/v) methylated seed oil[4]. Glyphosate was applied in a mixture of water and 2% (w/v) ammonium sulfate. Herbicides were applied using CO_2 backpack sprayer, equipped with wide angle flat fan spray tipes,[5] delivering 134 L/ha water carrier at 220 kPa and 235 kPa in 2003 and 2005 respectively.

Frequency of OWB was determined using a slightly altered method from Vogel and Masters (2001). A 1-m by 1-m frame, split into 100 squares, each 10 cm by 10 cm, was randomly placed in opposite halves of each plot to achieve two frame readings per plot. Small squares that had living OWB crown bases present were counted as squares containing OWB. The total number of squares with OWB was divided by 100 to arrive at a frequency value for each frame. Two frequency frames were counted for each plot prior to the first herbicide application and again at 6 WAT prior to the second herbicide application.

Basal tiller counts, aerial reproductive tiller counts, and visual control estimates of OWB from treated plots relative to control plots were taken 6 WAT. Two frames 0.33-m by 0.33-m in size were placed randomly within each half plot. Total live basal tillers were counted in each

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[4]MSO Concentrate. Loveland Industries. P.O. Box 1286, Greeley, CO 80632.

[5]Turbo Tee Jet 110015. Spraying Systems, Co. P.O. Box 7900, Wheaton, IL 60189.

frame, along with total number of aerial reproductive tillers in order to quantify seed production potential. Some basal tillers produced more than one complete inflorescence branching from multiple aerial tillers. Each aerial tiller with a complete inflorescence was counted as a separate aerial reproductive tiller. Whole plot biomass and plant vigor were visually estimated on a scale of 0% control (full vegetative growth) to 100 % control (no live vegetation).

To quantify end-of-season tiller production, two 0.33-m by 0.33-m frame areas were counted for live basal tillers and total number of aerial reproductive tillers after first frost. Vegetation was clipped from each frame to determine total standing biomass within all plots. Frequency and visual control estimates compared to control plots were also taken at this time. First frost dates occurred 20 WAT in 2003 and 17 WAT in 2005. Frequency values were also collected the last week of May in 2004 and 2006 from plots treated in 2003 and 2005, respectively.

Frequency and visual control data were transformed using an $\mathit{arcsin}\sqrt{\mathit{proportion}}$ transformation (Lorenzen and Anderson 1993). Transformation did not alter results from non-transformed data, therefore non-transformed data are presented. Each period of observation was analyzed separately over years. Total basal tiller density, aerial reproductive tiller density, end-of-season biomass, and non-transformed frequency and visible control data were analyzed using PROC GLM of SAS (SAS Insititute 1990). Fisher's protected F-tests were used to determine least significant differences (LSD) at the $P<0.05$ level.

RESULTS AND DISCUSSION

Precipitation was near normal to above normal for all months except May and July in both 2003 and 2005 (Figure 1). In 2003, less than normal precipitation fell in May, the month of the first herbicide application, and no measurable precipitation occurred in July, the month of the second application. In 2005, herbicides were applied the end of June and August, both months of near normal precipitation. An unexpected and brief rain shower occurred approximately 1 hr following the August 2005 application.

Six WAT. No difference was found in Caucasian OWB frequency prior to treatment application (Table 1). At 6 WAT (2 weeks prior to the second application), tiller densities of all herbicide treated plots except glyphosate were as great or greater than the control plots. Glyphosate had the fewest live tillers at 6 WAT of any herbicide during both years (Table 1). All herbicides except for glyphosate followed the same general pattern of having greater tiller density in 2003 than 2005. A year by treatment interaction resulted for tiller density at 6 WAT, but the only reason for the interaction was that glyphosate had under 200 tillers/m^2 at 6 WAT in 2003, but had almost 600 tillers/m^2 in 2005 (data not shown). All herbicides except glyphosate also had similar frequency proportion (presence in one hundred 10-cm X 10-cm frames) as control treatments. Glyphosate was the only treatment with lower OWB frequency than the control, with OWB found in 75% of glyphosate treated frames at 6 WAT. Herbicidal control of OWB growth varied by year (Table 2). Imazapyr and sulfometuron controlled OWB 86 and 75%, respectively, in 2003, but control was 22% or less in 2005. Imazapic and imazethapyr controlled 56% of OWB in 2003, but controlled OWB less than 13% in 2005. Glyphosate controlled 99% of OWB in 2003 and 80% in 2005 at 6 WAT.

After Frost. At the end of the season following a frost, glyphosate was the only herbicide with less OWB frequency (Table 2) and tiller density (Figure 2) than the control plots each year. Imazapyr had less OWB frequency than the control plots both years, but had similar tiller density as control plots in 2005. With split applications during the season, glyphosate controlled over 90% of OWB growth by the end of each season (Table 2). Imazapyr and sulfometuron controlled greater than 85% of OWB growth in 2003, but control by both herbicides was reduced by 35 to 40% in 2005. Imazapic and imazethapyr did not control more than 40% of OWB growth in any year. Plots treated with glyphosate or imazapyr produced almost no seedheads during the season, and sulfometuron treated plots had significantly fewer seedheads than the control in 2005 (Figure 3). Imazapic and imazethapyr treated plots produced as many seedheads as the control group in 2003. In 2005, seedheads were dramatically reduced by imazapic compared to the control, while seedheads were not reduced by imazethapyr.

Accumulated OWB biomass at the end of the season was inversely related to control percentages for all herbicides ($r^2 = 0.91$) (Figure 4). Imazapyr, sulfometuron, and glyphosate plots had significantly less biomass than the control both seasons, and biomass in imazapyr and glyphosate plots in 2003 was essentially non-existent (Figure 5). However, in 2005, OWB biomass in imazapyr and glyphosate plots was 46 and 26% of the total biomass in control plots, respectively. Imazethapyr did not reduce OWB biomass compared to the control in either season. An unexpected rain shower approximately 1 hr following the second application of herbicides in 2005 may have reduced efficacy of glyphosate, since it was the only herbicide evaluated that does not have soil activity. It is not known if the rain shower was the cause of reduced control and increased biomass of OWB in glyphosate treated plots. The year following herbicide treatment, in 2004 and 2006, glyphosate and imazapyr plots had much lower Caucasian OWB frequency than the untreated control plots (Table 3). Caucasian OWB frequency was less than 4%, indicating the trend observed in imazapyr and glyphosate plots at the first frost the previous season carried over into the next season.

All herbicides in this trial had previously reduced biomass of yellow OWB, another closely-related introduced warm-season grass, by more than 50% with a single application at the 4 to5 leaf stage (Harmoney et. al., 2004). However, herbicide rates were reduced and applied twice in split applications in the current trial. In the previous study, imazapyr and glyphosate controlled over 80% of yellow OWB seasonal growth, but dormant basal buds were stimulated once dominant top growth ceased in the glyphosate plots. In this previous study, final tiller density of yellow OWB in glyphosate treated plots was similar to density prior to treatment because new tillers developed from the stimulated basal buds. Split applications in the current study were intended to control any new tillers that may have formed once dormant buds were stimulated following the death of top growth from the first application. Total seasonal rates of imazapyr and glyphosate were 66% and 33% lower than the previous trial, and both were able to reduce initial OWB growth and reduced regrowth with the second application. Especially with glyphosate, split application appears to have reduced new tiller formation compared to the single application from the previous study. Medlin et. al. (1998) found that glyphosate controlled yellow OWB better when applied in July than when applied in May. In this study, imazapyr and glyphosate also controlled most native grass remnants that were identified in plots prior to treatment. Altering the timing of the applications to coincide with different growth stages of Caucasian OWB would likely affect translocation of herbicide to dormant buds and would likely change overall efficacy. Furthermore, different application methods, such as ropewick application, may enable more selective control of Caucasian OWB and allow native vegetation to escape injury since Caucasian OWB elongates and reaches reproductive maturity more quickly than most common native grass species of western Kansas (Harmoney and Hickman, 2004). Altered rate, timing, and application method of imazapyr and glyphosate herbicides may improve efficacy of these herbicides on Caucasian OWB vegetation and allow native vegetation to escape for future production.

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Table 1. Frequency prior to herbicide application, and frequency and tiller density of Caucasian OWB at 6 weeks after one treatment with five herbicides in 2003 and 2005 at Hays, KS. Values within a column differing by more than the LSD value are statistically significant at the $P<0.05$ level.

Herbicide[a]	Rate	Frequency 0 WAT	Frequency 6 WAT	Tiller Density 6 WAT
	kg/ha	----%---	----%---	--tillers/m^2--
Imazapyr	0.280	97	97	2434
Sulfometuron	0.157	94	94	2619
Imazapic	0.105	97	98	2836
Imazethapyr	0.055	96	97	2656
Glyphosate	1.140	96	73	381
Control		97	95	2307
$LSD_{0.05}$		NS	5	675

[a] All treatments except the control and glyphosate were mixed in solution with 28% urea-ammonium nitrate at 2% (v/v) and methylated seed oil at 2% (v/v). Glyphosate was mixed with a 2% (w/v) solution of ammonium sulfate.

Table 2. Percent control of Caucasian OWB at 6 weeks after first treatment, and frequency and control of Caucasian OWB after the first frost following split application of five herbicides in 2003 and 2005 at Hays, KS. Values within columns or rows differing by more than the LSD value are statistically significant at the P<0.05 level.

Herbicide[a]	Rate	Control 6 WAT		Frequency After Frost		Control After Frost	
		2003	2005	2003	2005	2003	2005
	kg/ha	----------%--------		---------%--------		---------%--------	
Imazapyr	0.280	86	22	12	15	100	64
Sulfometuron	0.157	76	16	94	78	87	46
Imazapic	0.105	56	13	96	88	24	41
Imazethapyr	0.055	56	11	96	97	24	16
Glyphosate	1.140	99	80	19	5	100	91
Control		0	0	99	95	0	0
$LSD_{0.05}$		11		10		18	

[a] All treatments except the control and glyphosate were mixed in solution with 28% urea-ammonium nitrate at 2% (v/v) and methylated seed oil at 2% (v/v). Glyphosate was mixed with a 2% (w/v) solution of ammonium sulfate.

Table 3. Frequency of Caucasian OWB combined over years in late May of 2004 and 2006, the year following treatment with split application of five herbicides in 2003 and 2005 at Hays, KS. Values in the column differing by more than the LSD value are statistically significant at the $P<0.05$ level.

Herbicide[a]	Rate	Frequency Year After Treatment
	kg/ha	------%-----
Imazapyr	0.280	4
Sulfometuron	0.157	94
Imazapic	0.105	98
Imazethapyr	0.055	97
Glyphosate	1.140	1
Control		98
$LSD_{0.05}$		3

[a] All treatments except the control and glyphosate were mixed in solution with 28% urea-ammonium nitrate at 2% (v/v) and methylated seed oil at 2% (v/v). Glyphosate was mixed with a 2% (w/v) solution of ammonium sulfate.

Fig. 1. Precipitation for Hays, KS during the 2003 and 2005 growing seasons. Long-term (30-year) mean is included for reference.

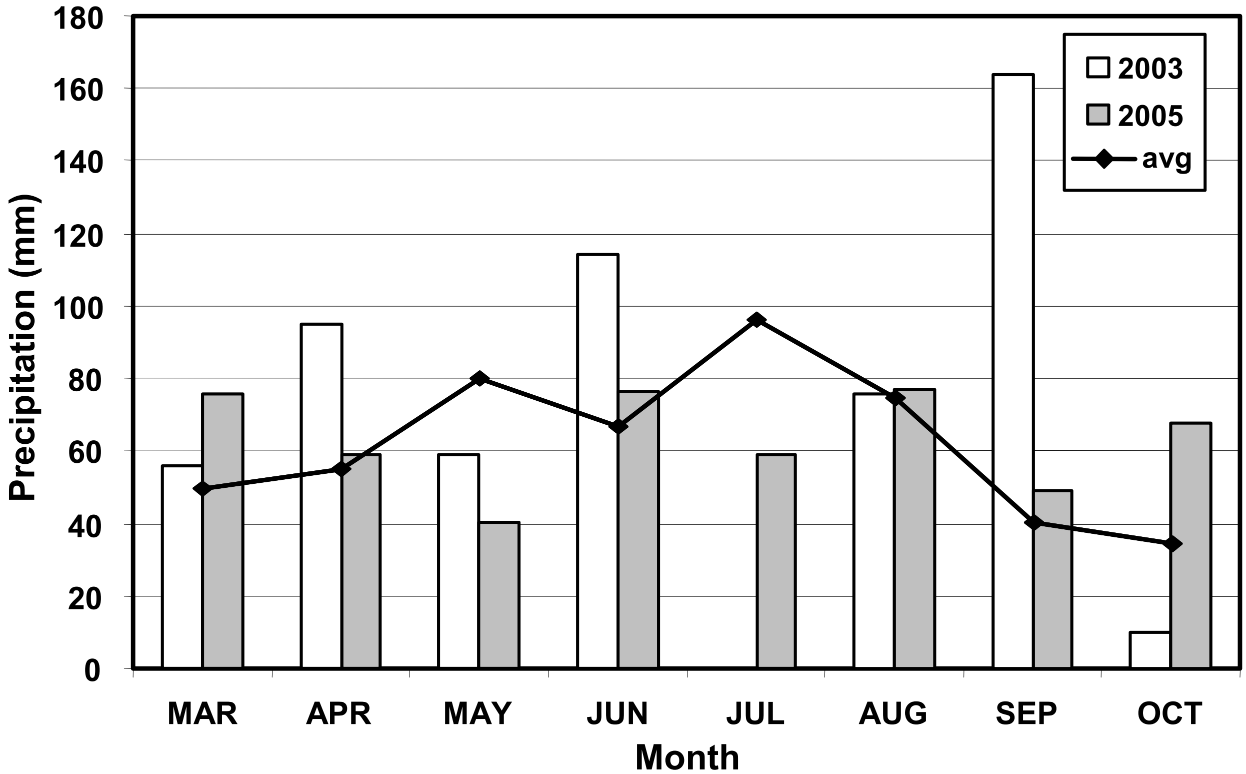

Fig. 2. Fall tiller density mean (± 1 standard error) of Caucasian OWB after the first frost following split application of five herbicides in 2003 and 2005 at Hays, KS.

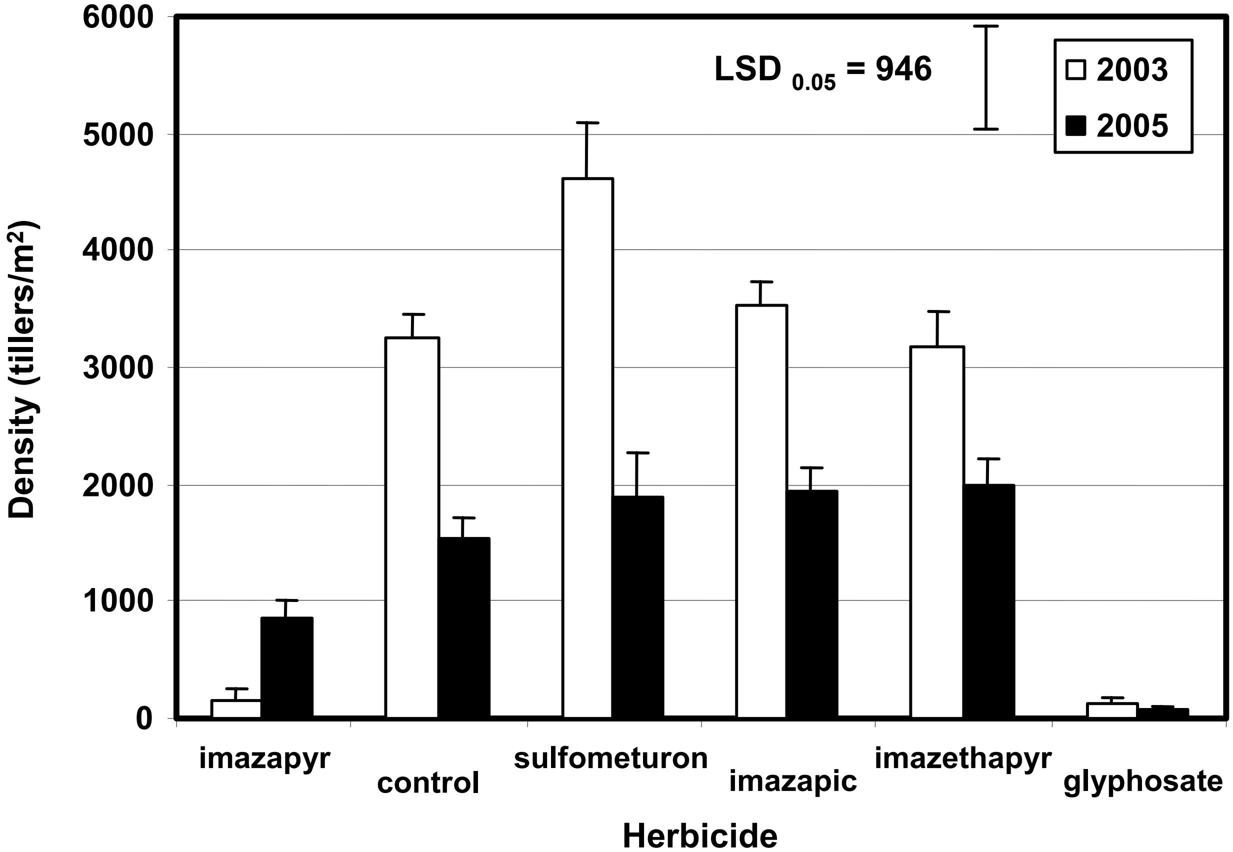

Fig. 3. Fall seedhead density mean (± 1 standard error) of Caucasian OWB after the first frost following split application of five herbicides in 2003 and 2005 at Hays, KS.

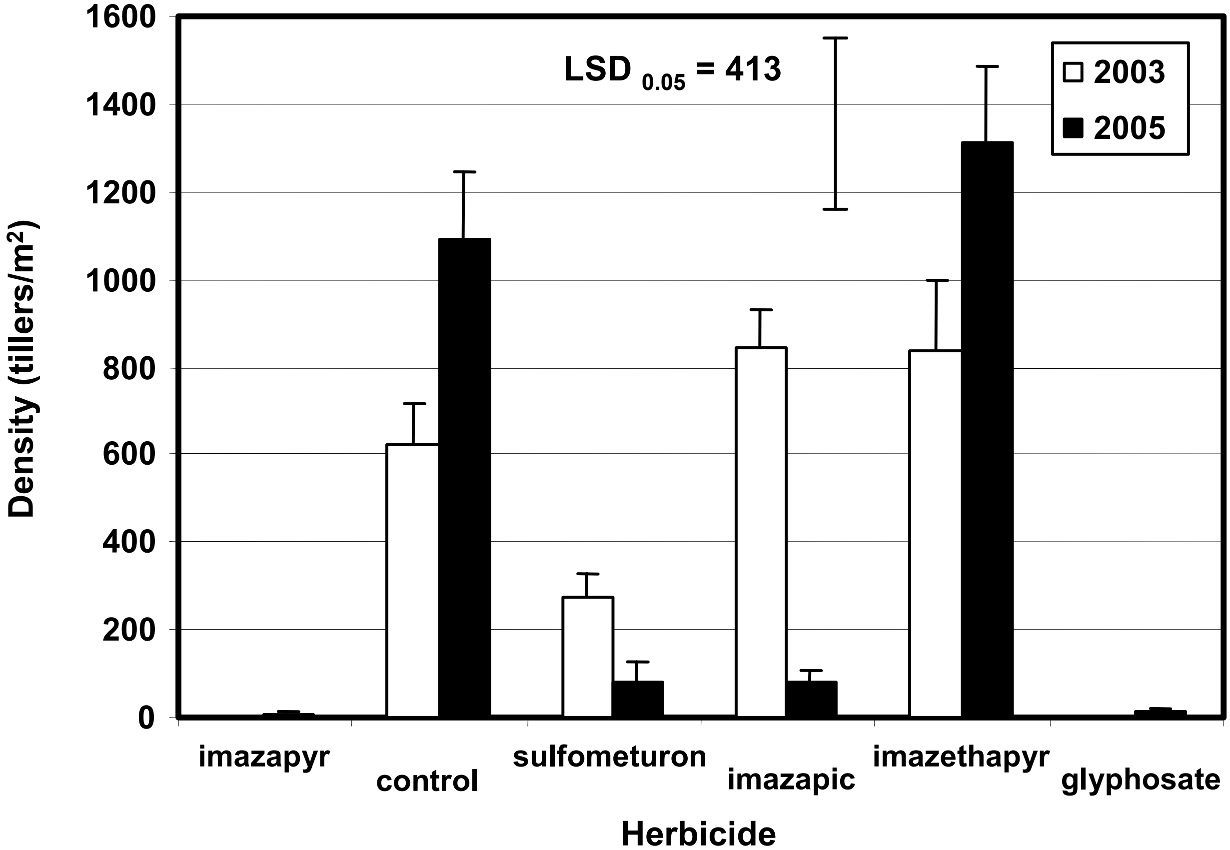

Fig. 4. Relationship between % control and yield after the first frost at the end of the growing season for Caucasian OWB after split application of five herbicides in 2003 and 2005 at Hays, KS.

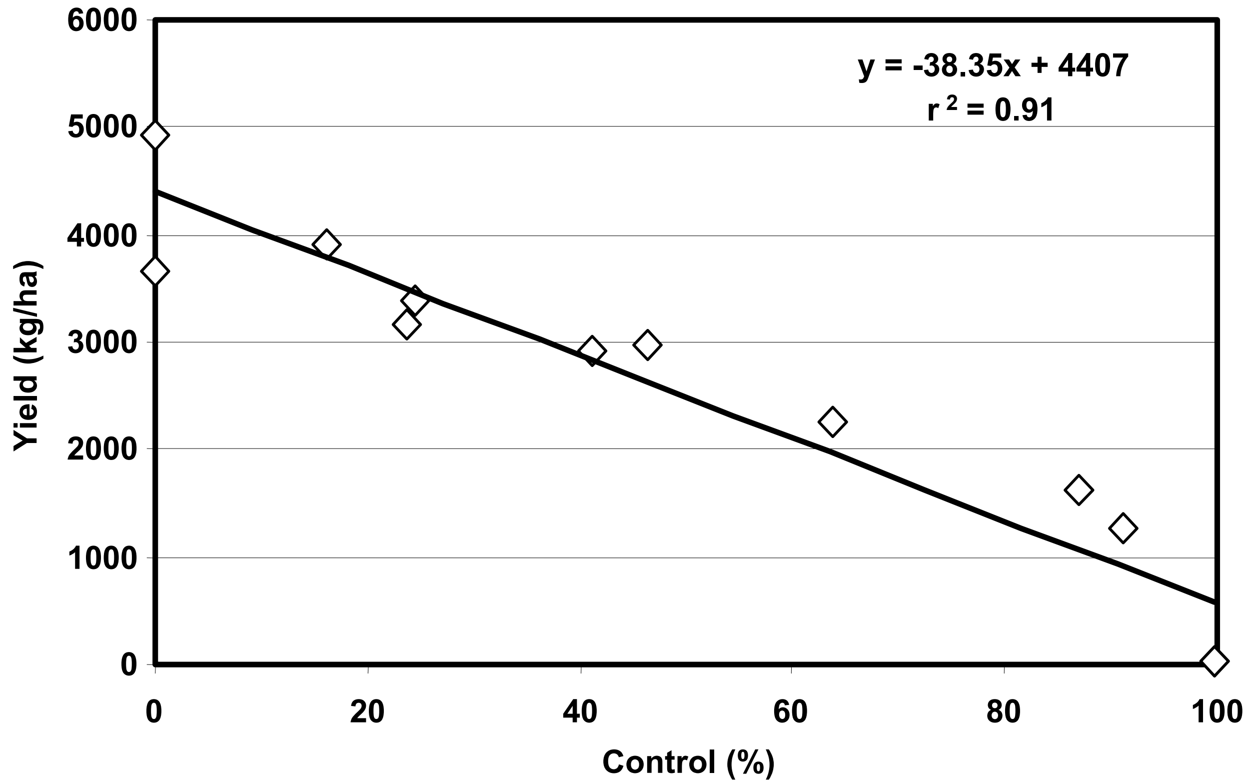

Fig. 5. Fall biomass means (± 1 standard error) of Caucasian OWB after the first frost following split application of five herbicides in 2003 and 2005 at Hays, KS.