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WEED CONTROL AND HERBICIDE TOLERANCE OF ESTABLISHED SEED PRODUCTION AREAS OF NATIVE PLANT SPECIES

by
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INTRODUCTION

The amount of land supporting longleaf pine ecosystems has been decreasing for several hundred years. The restoration of this ecosystem is becoming increasingly popular throughout the southeastern United States. Through improvements in forest management, commercial production of longleaf pine seedlings, and increased knowledge of longleaf pine reforestation practices, restoration efforts have become significantly more successful than before. In 2006, the Conservation Reserve Program (CRP) added a requirement that native ground cover species be re-established along with longleaf pine on croplands. Prior to this, native understory plants were not being grown for commercial purposes in nurseries. Today, these native ground covers are recognized as an integral part of longleaf pine restoration and they are being produced across the southeast. The increase in production has made it easier to incorporate native understory species into the ecosystem and increases the probability of restoration success. While restored ecosystems may not equal the appearance of natural ecosystems, the primary focus of restoration efforts is to use the tools available to mimic the plant composition and natural and anthropogenic disturbances.

In addition, America's Longleaf identified research areas that are needed in order to properly restore longleaf pine. One key research need concerned longleaf pine understory species and community composition, including guidelines and standards for the commercial production of longleaf pine understory plant species, and increased knowledge of the community composition and the species that comprise them (America's Longleaf, 2009). While progress has been made on these research questions, there are some production issues that have yet to be addressed. Many forest nurseries have recently developed production systems to commercially grow these native understory plants in seed production areas and in nursery container systems similar to forest-tree production. A major concern is that herbicide guidelines to effectively control weeds that do not also adversely affect the understory native plant species are lacking.

For commercial production of understory native plants, a constant and reliable source of seed is necessary. The process begins with the production of plants of these understory species from which seed is harvested. Seeds are cleaned to remove undesirable weed seeds that might have been collected during the harvest. Reducing weeds will make the whole process more efficient by preventing weeds from getting tangled on the combine during harvest and it will make the seed cleaning process easier by removing undesirable plant seeds. As control of weeds in native plants is a new market, few herbicides are available to control weeds while not harming the understory crop species. Understory crop species include warm season grasses (e.g. *Aristida beyrichiana*, *Schizachyrium scoparium*, *Sorghastrum nutans*) and legumes (e.g. *Tephrosia virginiana*, *Desmodium floridanum*). Often, herbicides are labeled to control both the weeds and the desired understory species which poses an obvious problem if nursery managers spray herbicide which can adversely affect the crop.

In order to produce native understory seedlings, there must be a reliable seed production area from which to gather seed. Seed production areas are comprised of established native plants in bed rows which must be properly managed to ensure that an adequate amount of seed is produced. Weed control in these areas can use herbicides either over-the-top, directed, or spot-spray application method where only the weeds are treated. This project will identify herbicide treatments that can be used to control competitive weeds growing amongst the established native plants and make the seed harvest and cleaning process more efficient.

MATERIALS AND METHODS

A study investigating the herbicides for the control of weeds in native understory plant seed production areas was conducted at the Lolly Creek Farm (Worth County, GA). Six desirable understory plant species were used in this study: 1) wiregrass (*Aristida beyrichiana*), 2) Indian grass (*Sorghastrum nutans*), 3) little bluestem (*Schizachyrium scoparium*), 4) goat's rue (*Tephrosia virginiana*), 5) Florida ticktrefoil (*Desmodium floridanum*), and 6) narrow-leaf sunflower (*Helianthus angustifolius*). The plant species were grouped by plant type and each group received their own set of herbicide treatments. The grasses (wiregrass, Indian grass, and little bluestem) received applications of seven herbicides: 1) atrazine, 2) lactofen, 3) s-metolachlor, 4) oxyfluorfen (Goal 2XL®), 5) oxyfluorfen (GoalTender®), 6) pendimethalin, and 7) dicamba + 2,4-D (Table 1). The legumes (goat's rue and Florida ticktrefoil) received six different herbicide applications: 1) imazamox, 2) pendimethalin, 3) imazapic, 4) imazethapyr, 5) sulfentrazone, and 6) butyric acid (Table 2). The composite forb (narrow-leaf sunflower) received applications of five herbicides: 1) pendimethalin, 2) s-metolachlor, 3) sulfentrazone, 4) sulfentrazone + s-metolachlor, and 5) sulfentrazone + pendimethalin (Table 3). The herbicide rates were chosen based on the herbicide labels.

Prior to herbicide treatments, plots (6 ft wide x 20 ft long) were randomly laid out in the production beds with colored pin flags that corresponded to the various treatments. There was no space between plots, but there was about a foot between production beds. As some weeds require multiple applications of herbicide during the growing season (such as *Ambrosia artemisifolia* in the legume plots), and weed species may change over the season, a comparison of one and two applications of herbicides was made. All plants received an application at time A and half received applications at time A and B. The first application (A) occurred on March 27 and 31, 2014 and the second application (B) occurred on May 5 and 6, 2014. The herbicides were applied using a hand-held spray wand that was CO_2 powered with four nozzles calibrated to spray 187 l/ha at 172 kPa when moving 10 meters per 10 seconds (20 gallons/acre at 25 psi at 30' per 10 seconds). The spray wand was held approximately 1 ft above the native plants as the herbicides were applied.

At weeks 2, 4, 6, 8, and 10 post treatment, the native plants were evaluated for injury using a scale from 1-9 (1=no injury and 9=mortality). Plots were also visually evaluated to determine how much of the treated area was occupied by weeds (anything other than the target plant). Ten weeks after the second herbicide application (July 10 and 11) a 1 ft x 5 ft frame was placed in the center of every plot and weeds that fell within the counting frame were collected and returned to Auburn University. The weeds within each plot were then identified and enumerated, dried at 70° C for 48hours and weighed to determine weed biomass (g) by treatment. The data (injury, weed coverage, and weed biomass) was analyzed using SAS 9.3. A Duncan's and Dunnett's test was used to determine how the treatments compared to each other (Duncan's) as well as how they compared to the control group (Dunnett's).

RESULTS

The effectiveness of an herbicide to control weeds within the seed production area was dependent on the tolerance of the native plant crop species as well as the susceptibility of weeds within that crop. If an herbicide failed to meet either of those qualifications, then the treatment is not useful. A summary of each native plant treated and the efficacy of each herbicide is discussed below.

Little Bluestem: A total of fourteen different herbicide treatments were applied to little bluestem. After ten weeks, four treatments were detrimental to the growth of little bluestem plants. These were the single and sequential applications of oxyfluorfen (Goal 2XL® and GoalTender®). The other herbicide treatments caused only minor damage to the little bluestem with herbicide injury ratings of 2 or less (Table 4). Eight herbicide treatments resulted in weed coverage of less than 10%: single and sequential applications of lactofen, dicamba + 2,4-D, atrazine and sequential applications of s-metolachlor, and pendimethalin. At the end of the study period, the dry biomass of weeds was greatest in the single and sequential application of oxyfluorfen (GoalTender®) (> 10.0 grams). Single and sequential applications of atrazine and dicamba + 2,4-D (Table 4) offered effective control of weeds with no damage to little bluestem.

Indian Grass: Fourteen different herbicide treatments were applied to plots growing Indian grass. Ten weeks following treatment application, the sequential application of oxyfluorfen (GoalTender®) (5.8) was the only treatment detrimental to the health of the target plant (Table 2.5). The remaining herbicide applications had injury ratings of 3.0 or less. Over the course of the study, all of the herbicide treatments resulted in a substantial amount of weeds within the plots when compared to the other native plant species tested in the study. A sequential application of dicamba + 2,4-D resulted in an average of 17.9% weed coverage of the plots. All other treatments had 20% or more average weed coverage. Single and sequential applications of atrazine and dicamba + 2,4-D (Table 5) performed better than all other treatments when weeds were collected for dry weight biomass.

Wiregrass: Like Indian grass, the sequential applications of oxyfluorfen (Goal 2XL® (4.9) and GoalTender® (3.9)) were detrimental to wiregrass (Table 6). The other treatments resulted in injury ratings on wiregrass of 2.0 or less. While several herbicide treatments resulted in no injury. The single and sequential applications of dicamba + 2,4-D resulted in the lowest weed coverage in the wiregrass plots over a ten-week period, which was 6.9 and 9.4% coverage respectively (Table 6). Unfortunately, as part of management of the production system, the wiregrass plots were burned before the weeds could be collected, and thus, weed biomass in these plots was not collected.

Florida Ticktrefoil: None of the twelve different herbicide treatments resulted in significant injury to Florida ticktrefoil. Sequential applications of imazapic and imazethapyr resulted in an injury rating of 2.6 and 2.4, respectively (Table 7). In addition to acceptable injury, imazethapyr applied sequentially reduced weed coverage (14.6%) ten weeks after treatment application (Table 7). Other herbicide treatments that had low weed biomass were the single (6.94 g) and sequential application (3.26 g) of imazapic (Table 7).

Goat's Rue: None of the twelve herbicide treatments sprayed over-the-top of goat's rue resulted in serious injury to the plant. The most injury occurred in the plots that received sequential applications of sulfentrazone (2.4) and butyric acid (2.1) (Table 8). Weed control with the single and sequential applications of butyric acid resulted in weed coverage of more than 20% (Table 2.8). However, the sequential applications of imazamox, and imazapic provided acceptable control of weeds based on the dry weight biomass (2.0 g and 1.9 g) (Table 8).

Narrow-leaf Sunflower: Ten different herbicide treatments were applied to narrow-leaf sunflower. Sequential applications of s-metolachlor + sulfentrazone (average injury rating of 6.3) and pendimethalin + sulfentrazone (average injury rating of 4.3) were detrimental to the health of narrowleaf sunflower. Other herbicide treatments tested on narrow-leaf sunflower had an injury rating of 3.0 or less (Table 9). Sequential applications of sulfentrazone and pendimethalin resulted in 10% or less average weed coverage (Table 9). The sequential application of sulfentrazone had the lowest dry weight biomass (3.74 g) of the plots that received an herbicide treatment (Table 9). The remaining treatments had >10 grams of weed biomass at the end of the study. Weed control varied among the treatments and weed coverage and biomass was lowest in the control plots.

DISCUSSION

This study was able to identify herbicides that will significantly aid in the production, growth and cultivation of established native plants that are used for seed production. Controlling weedy competition for desirable native plant species grown for seed production will increase seed and seedling production. There was a wide range of both weed control and herbicide tolerance of the native plant species amongst the herbicides tested. The herbicides that were the most successful include dicamba + 2,4-D, atrazine, imazamox, butyric acid, sulfentrazone, imazapic and imazethapyr. Some herbicide treatments were acceptable at the single application but became injurious to native plants when applied twice. In contrast, some sequential applications positively enhanced the performance of the herbicide. This was especially true with sulfentrazone and imazapic when applied to goat's rue, as well as sulfentrazone and pendimethalin when applied to narrow-leaf sunflower (Table 9).

Herbicides have been an important cultural practice in forestry for decades. Herbicides can be used for site preparation that aid in the establishment and release of southern pines. Removing less desired and competitive understory species is important to maintain the survival of the desired native understory plant species when restoring longleaf ecosystems. These desirable plant species include those tested including wiregrass, bluestem grasses as well as various composites, forbs and legumes. It should be noted that herbicides are not meant to replace fire within longleaf ecosystems but be used in addition to fire for the removal of competitive non-native species.

Some of the herbicides and plant species used in this study performed as in previous studies. Kaiser and Kirkman in (2010) evaluated the effects of nine herbicides at two rates each on ten native understory species grown in a greenhouse environment. They found atrazine (AAtrex®) to be detrimental to grass species, whereas, in this study atrazine did not adversely affect the native grass species and it effectively controlled undesirable species. The difference in results could be attributed to the age and sensitivity of the plants. The young seedlings appear to be more susceptible to herbicide damage than mature established plants. Both studies tested butyric acid and imazapic on native legume species and achieved similar results in respect to injury level.

Another study by Freeman and Jose (2009) evaluated the effects of four herbicide treatments on native grasses and understory species within a study site that was being converted from slash pine to longleaf pine. The four treatments were imazapyr, hexazinone, sulfometuron, and sulfometuron + hexazinone tank mixture. Four years post- application, wiregrass cover had increased in all treatments except for the control group. The treatment that resulted in the largest increase of wiregrass was the sulfometuron + hexazinone tank mixture. Although our study Lolly Creek did not analyze the size or biomass of the wiregrass, most of the herbicides used were tolerated by the established wiregrass plants (with the exception of oxyfluorfen) and weed control was observed when dicamba + 2,4-D and atrazine were used compared to control plots.

Multiple herbicides that have been reported in past research to be beneficial for the cultivation of native plants found in longleaf pine ecosystems. As the native plant market expands to meet the demand for longleaf pine ecosystem restoration and plants become more widely grown throughout the southeast, new obstacles and situations may arise which will require the use of herbicides. These obstacles could include growing other native plant species commercially, weeds becoming tolerant of herbicides, or the removal or addition of usable herbicides.

Dicamba + 2,4-D and atrazine were the best herbicides for weed control in little bluestem and Indian grass. Injury was minimal or nonexistent with both single and sequential applications of the herbicides and provided successful weed control. Since the single application of both atrazine and dicamba + 2,4-D provided similar weed control to the sequential application, the single application of either herbicide would be most efficient in weed control with respect to cost. A few of the more problematic weeds in little bluestem and Indian grass were *Digitaria sanguinalis* (crabgrass) and *Solidago canadensis* (goldenrod), both of which were controlled with these herbicide treatments (Figures 1 and 2). As part of the management of the production system, the land manager of Lolly Creek uses prescribed winter burns on the little bluestem and Indian grass fields which remove most of the undesirable plant species and the dead plant tissue from the previous growing season. Atrazine and dicamba + 2,4-D treatments also worked well in wiregrass, resulting in low injury and successful weed control (Table 6). However, since the wiregrass field was burned before weed biomass could be collected, a complete analysis could not be provided. The prescribed burn controlled the undesirable plant species and allowed the wiregrass to grow uninhibited. Additionally, growing season burns have been shown repeatedly to improve wiregrass seed production which is the ultimate goal of the landowner (Mulligan and Kirkman, 2002). Growing season burns may be the best treatment for wiregrass, not only for seed production but also for weed control. However, in some cases herbicides may also be required to control weeds left behind by fire.

Weed control and seed production in the Florida ticktrefoil and goat's rue was successfully obtained with imazapic (Table 7). The single and sequential applications of imazapic resulted in comparable weed control and injury ratings when used over Florida ticktrefoil. Thus, a single application would be more desirable economically. In contrast, goat's rue required a sequential application of imazapic to yield successful control of undesirable plant species. Neither the single nor sequential applications of imazapic caused significant damage to either species. Although the sequential applications of imazapic was the best treatment at removing undesirable plant species within goat's rue, sequential applications of imazamox and butyric acid also significantly reduced the amount of weeds.

Of all the herbicide treatments applied to narrow-leaf sunflower, the control group had the least amount of weed biomass. This occurred because the narrow-leaf sunflower was injured by the herbicide applications reducing crop size and coverage, allowing the weeds to grow with less competition. The herbicide treatment that resulted in the least amount of weed biomass was the sequential application of sulfentrazone although it did cause minor damage to the non-target plants (3.1) (Table 9). Since a higher level of weed control can be achieved by not applying any herbicides, no treatment is recommended for narrow-leaf sunflower.

MANAGEMENT IMPLICATIONS

This study was able to identify herbicides that will significantly aid in the production, growth and cultivation of established native plants that are used for seed production. By controlling weedy competition with for a number of highly desired native plant species, their production will increase. Of the herbicide treatments that were evaluated there was a wide range of both weed control and tolerance of the herbicide on the native plant species. The herbicides that were the most successful include dicamba + 2,4-D, atrazine, imazamox, butyric acid, sulfentrazone, imazapic and imazethapyr. Some herbicide treatments were acceptable at the single application but became injurious to native plants when applied twice these include both tank mixes applied to narrow-leaf sunflower. In contrast, some sequential applications positively enhanced the performance of the herbicide this was especially true with sulfentrazone and imazapic when applied to goat's rue as well as sulfentrazone and pendimethalin when applied to narrow-leaf sunflower.

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Table 1. 2014 Lolly Creek herbicide trial applied to little bluestem (*Schizachyrium scoparium*), Indian grass (*Sorghastrum nutans*), and wiregrass (*Aristida beyrichiana*).

Herbicides	**Active Ingredient**	**Rates (L/ha)**
AAtrex®	Atrazine	2.34
Cobra®	Lactofen	1.17
Dual Magnum®	S-metolachlor	1.53
Goal 2XL®	Oxyfluorfen	1.75
GoalTender®	Oxyfluorfen	2.63
Prowl H_2O®	Pendimethalin	1.75
Weedmaster®	Dicamba + 2,4-D	2.34
Control	N/A	N/A

Table 2. 2014 Lolly Creek herbicide trial applied to Florida ticktrefoil (*Desmodium floridanum*) and goat's rue (*Tephrosia virginiana*).

Herbicides	**Active Ingredient**	**Rates (L/ha)**
Clearcast®	Imazamox	0.44
Prowl H_2O®	Pendimethalin	1.75
Plateau®	Imazapic	0.58
Pursuit®	Imazethapyr	0.44
Spartan Charge®	Sulfentrazone	0.27
2,4 DB®	Butyric Acid	2.34
Control	N/A	N/A

Table 3. 2014 Lolly Creek herbicide trial applied to narrow-leaf sunflower (*Helianthus angustifolius*).

Herbicides	**Active Ingredient**	**Rates (L/ha)**
Prowl H_2O®	Pendimethalin	1.75
Dual Magnum®	S-metolachlor	1.53
Spartan Charge®	Sulfentrazone	0.27
Dual Magnum®+ Spartan®	S-metolachlor + Sulfentrazone	1.53 + 0.27
Prowl H_2O® + Spartan®	Pendimethalin + Sulfentrazone	1.75 + 0.27
Control	N/A	N/A

Table 4. 2014 Lolly Creek herbicide trial results of little bluestem (*Schizachyrium scoparium*).

Herbicide	Application	Average Injury[a]	Weed Coverage[b]	Weed Biomass[c]
GoalTender®	Single	5.0 b**	12.1 bc	19.939 a
GoalTender®	Sequential	7.9 a	20.4 a	11.055 ab
Goal 2XL®	Single	3.1 c	11.4 bcd	7.709 bc
Goal 2XL®	Sequential	5.1 b	11.7 bc	7.745 bc
Dual Magnum®	Single	1.1 e	18.9 a	4.498 bc
Dual Magnum®	Sequential	1.3 de	9.2 cd	1.638 bc
Prowl H_2O®	Single	1.1 e	16.8 ab	2.920 bc
Prowl H_2O®	Sequential	2.0 d	7.5 cd	3.245 bc
Cobra®	Single	1.2 de	9.5 cd	1.398 bc
Cobra®	Sequential	1.7 de	7.5 cd	2.265 bc
Weedmaster®	Single	1.0 e	8.2 cd	0.170 c
Weedmaster®	Sequential	1.5 de	5.0 d	0.255 c
AAtrex®	Single	1.0 e	7.7 cd	0.218 c
AAtrex®	Sequential	1.2 e	6.3 cd	0.000 c
Control	N/A	1.0 e	20.0 a	5.035 bc

[a] = Injury rating scale of 1-9 (1=no injury and 9=mortality) which was a measure of phytotoxicity due to herbicide exposure (Kaiser and Kirkman 2010).
[b] = Weed coverage is a percentage representing how much of the research plot was comprised of weeds.
[c] = Weed biomass is the dry weight of the weed sample in grams.
**Means with different letters are significantly different ($p < 0.05$).

Table 5. 2014 Lolly Creek herbicide trial results of Indian Grass (*Sorghastrum nutans*).

Herbicide	Application	Average Injury[a]	Weed Coverage[b]	Weed Biomass[c]
GoalTender®	Single	2.9 b**	35.7 ab	21.01 abc
GoalTender®	Sequential	5.8 a	41.3 a	21.15 abc
Goal 2XL®	Single	1.6 de	32.9 abc	16.58 abc
Goal 2XL®	Sequential	2.9 b	29.6 abc	28.06 ab
Dual Magnum®	Single	1.1 de	36.3 ab	17.22 abc
Dual Magnum®	Sequential	2.0 cd	21.3 bc	25.50 abc
Prowl H_2O®	Single	1.0 e	27.7 abc	6.31 bc
Prowl H_2O®	Sequential	1.5 de	27.9 abc	8.57 bc
Cobra®	Single	1.3 de	30.9 abc	35.75 a
Cobra®	Sequential	1.4 de	27.5 abc	23.93 abc
Weedmaster®	Single	1.1 de	22.7 bc	0.13 c
Weedmaster®	Sequential	2.7 bc	17.9 c	0.72 c
AAtrex®	Single	1.0 e	23.6 bc	0.00 c
AAtrex®	Sequential	1.5 de	25.0 bc	0.42 c
Control	N/A	1.0 e	26.3 abc	18.96 abc

[a] = Injury rating scale of 1-9 (1=no injury and 9=mortality) which was a measure of phytotoxicity due to herbicide exposure (Kaiser and Kirkman 2010).

[b] = Weed coverage is a percentage representing how much of the research plot was comprised of weeds.

[c] = Weed biomass is the dry weight of the weed sample in grams.

**Means with different letters are significantly different ($p < 0.05$).

Table 6. 2014 Lolly Creek herbicide trial results of wiregrass (*Aristida beyrichiana*).

Herbicide	Application	Average Injury[a]	Weed Coverage[b]	Weed Biomass[c]
GoalTender®	Single	2.1 c**	20.8 a	N/A
GoalTender®	Sequential	4.9 a	13.8 abc	N/A
Goal 2XL®	Single	1.4 d	14.4 abc	N/A
Goal2XL®	Sequential	3.9 b	16.3 abc	N/A
Dual Magnum®	Single	1.0 d	16.0 abc	N/A
Dual Magnum®	Sequential	1.0 d	13.8 abc	N/A
Prowl H_2O®	Single	1.0 d	17.7 ab	N/A
Prowl H_2O®	Sequential	1.0 d	16.9 abc	N/A
Cobra®	Single	1.0 d	17.1 abc	N/A
Cobra®	Sequential	1.3 d	13.8 abc	N/A
Weedmaster®	Single	1.0 d	6.9 c	N/A
Weedmaster®	Sequential	1.0 d	9.4 bc	N/A
AAtrex®	Single	1.0 d	11.3 abc	N/A
AAtrex®	Sequential	1.0 d	13.1 abc	N/A
Control	N/A	1.0 d	15.3 abc	N/A

[a] = Injury rating scale of 1-9 (1=no injury and 9=mortality) which was a measure of phytotoxicity due to herbicide exposure (Kaiser and Kirkman 2010).
[b] = Weed coverage is a percentage representing how much of the research plot was comprised of weeds.
[c] = Weed biomass is the dry weight of the weed sample in grams.
**Means with different letters are significantly different ($p < 0.05$).

Table 7. 2014 Lolly Creek herbicide trial results of Florida Ticktrefoil (*Desmodium floridanum*).

Herbicide	Application	Average Injury[a]	Weed Coverage[b]	Weed Biomass[c]
Prowl H_2O®	Single	1.0 b**	34.5 bc	15.28 b
Prowl H_2O®	Sequential	1.1 b	47.5 a	129.53 a
Spartan Charge®	Single	1.0 b	28.6 bcde	45.08 b
Spartan Charge®	Sequential	1.3 b	56.1 a	61.85 b
Plateau®	Single	1.0 b	17.0 fg	6.94 b
Plateau®	Sequential	2.6 a	25.4 cdefg	3.26 b
2,4 DB®	Single	1.0 b	32.1 bcd	35.83 b
2,4 DB®	Sequential	1.0 b	36.7 b	32.51 b
Pursuit®	Single	1.0 b	20.2 efg	23.04 b
Pursuit®	Sequential	2.4 a	14.6 g	13.69 b
Clearcast®	Single	1.0 b	22.9 defg	31.08 b
Clearcast®	Sequential	1.0 b	26.7 bcdef	28.18 b
Control	N/A	1.0 b	35.5 bc	52.58 b

[a] = Injury rating scale of 1-9 (1=no injury and 9=mortality) which was a measure of phytotoxicity due to herbicide exposure (Kaiser and Kirkman 2010).
[b] = Weed coverage is a percentage representing how much of the research plot was comprised of weeds.
[c] = Weed biomass is the dry weight of the weed sample in grams.
**Means with different letters are significantly different ($p < 0.05$).

Table 8. 2014 Lolly Creek herbicide trial results of goat's Rue (*Tephrosia virginiana*).

Herbicide	Application	Average Injury[a]	Weed Coverage[b]	Weed Biomass[c]
Prowl H_2O®	Single	1.0 b**	17.7 bcd	15.126 ab
Prowl H_2O®	Sequential	1.1 b	17.1 bcd	13.617 ab
Spartan Charge®	Single	1.4 b	15.4 bcd	13.190 ab
Spartan Charge®	Sequential	2.4 a	13.8 cd	7.174 ab
Plateau®	Single	1.2 b	14.4 bcd	12.189 ab
Plateau®	Sequential	1.3 b	15.0 bcd	1.898 b
2,4 DB®	Single	1.0 b	21.0 abc	11.575 ab
2,4 DB®	Sequential	2.1 a	25.6 a	2.555 b
Pursuit®	Single	1.1 b	15.7 bcd	8.576 ab
Pursuit®	Sequential	1.1 b	12.9 d	8.363 ab
Clearcast®	Single	1.1 b	12.1 d	6.800 ab
Clearcast®	Sequential	1.0 b	11.7 d	2.055 b
Control	N/A	1.0 b	21.5 ab	23.060 a

[a] = Injury rating scale of 1-9 (1=no injury and 9=mortality) which was a measure of phytotoxicity due to herbicide exposure (Kaiser and Kirkman 2010).
[b] = Weed coverage is a percentage representing how much of the research plot was comprised of weeds.
[c] = Weed biomass is the dry weight of the weed sample in grams.
**Means with different letters are significantly different ($p < 0.05$).

Table 9. 2014 Lolly Creek herbicide trial results of narrow-leaf sunflower (*Helianthus angustifolius*).

Herbicide	Application	Average Injury[a]	Weed Coverage[b]	Weed Biomass[c]
Prowl H_2O®	Single	1.3 fg**	20.5 bc	25.85 ab
Prowl H_2O®	Sequential	1.3 fg	9.2 d	10.32 b
Dual Magnum®	Single	1.4 fg	15.2 cd	38.32 ab
Dual Magnum®	Sequential	2.8 cd	25.8 ab	20.75 ab
Spartan Charge®	Single	1.9 ef	22.5 abc	29.95 ab
Spartan Charge®	Sequential	3.1 c	10.0 d	3.74 b
Dual Magnum®+ Spartan®	Single	3.1 c	13.8 cd	18.65 ab
Dual Magnum®+ Spartan®	Sequential	6.3 a	14.6 cd	38.32 ab
Prowl H_2O® + Spartan	Single	2.1 de	30.7 a	29.87 ab
Prowl H_2O® + Spartan	Sequential	4.3 b	13.3 cd	26.58 ab
Control	N/A	1.0 g	13.8 cd	2.38 b

[a] = Injury rating scale of 1-9 (1=no injury and 9=mortality) which was a measure of phytotoxicity due to herbicide exposure (Kaiser and Kirkman 2010).
[b] = Weed coverage is a percentage representing how much of the research plot was comprised of weeds.
[c] = Weed biomass is the dry weight of the weed sample in grams.
**Means with different letters are significantly different ($p < 0.05$).

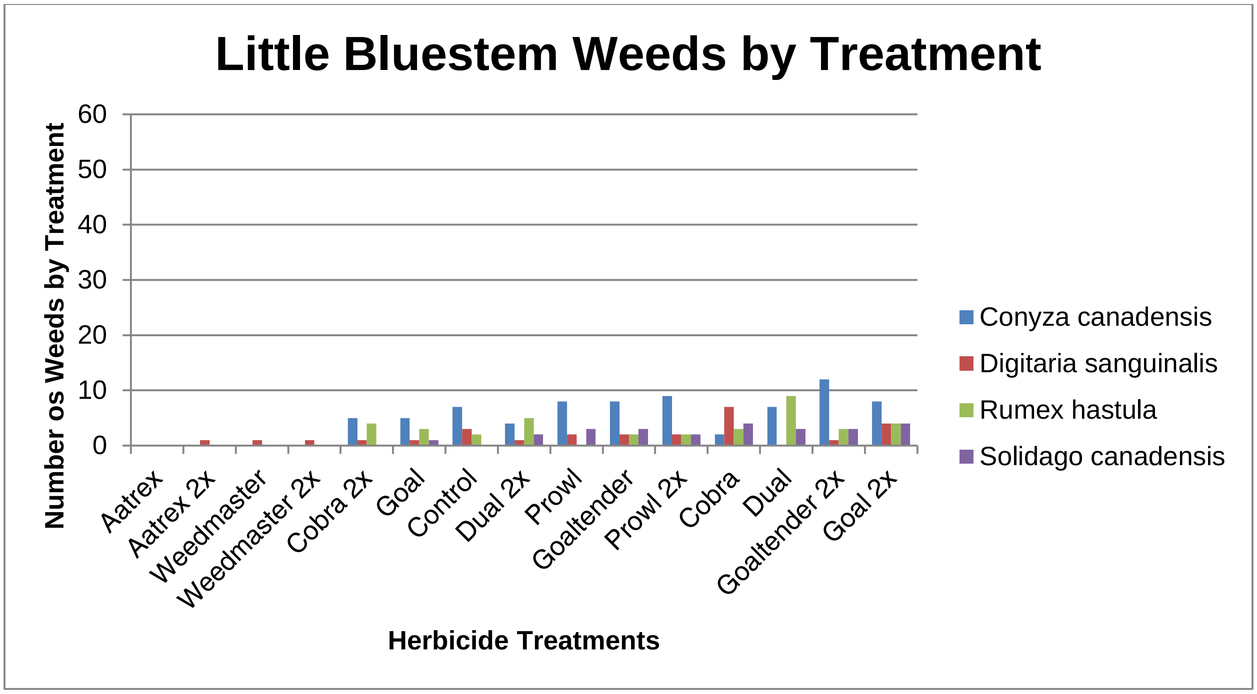

Figure 1. 2014 Lolly Creek herbicide trial weed count of little bluestem (*Schizachyrium scoparium*).

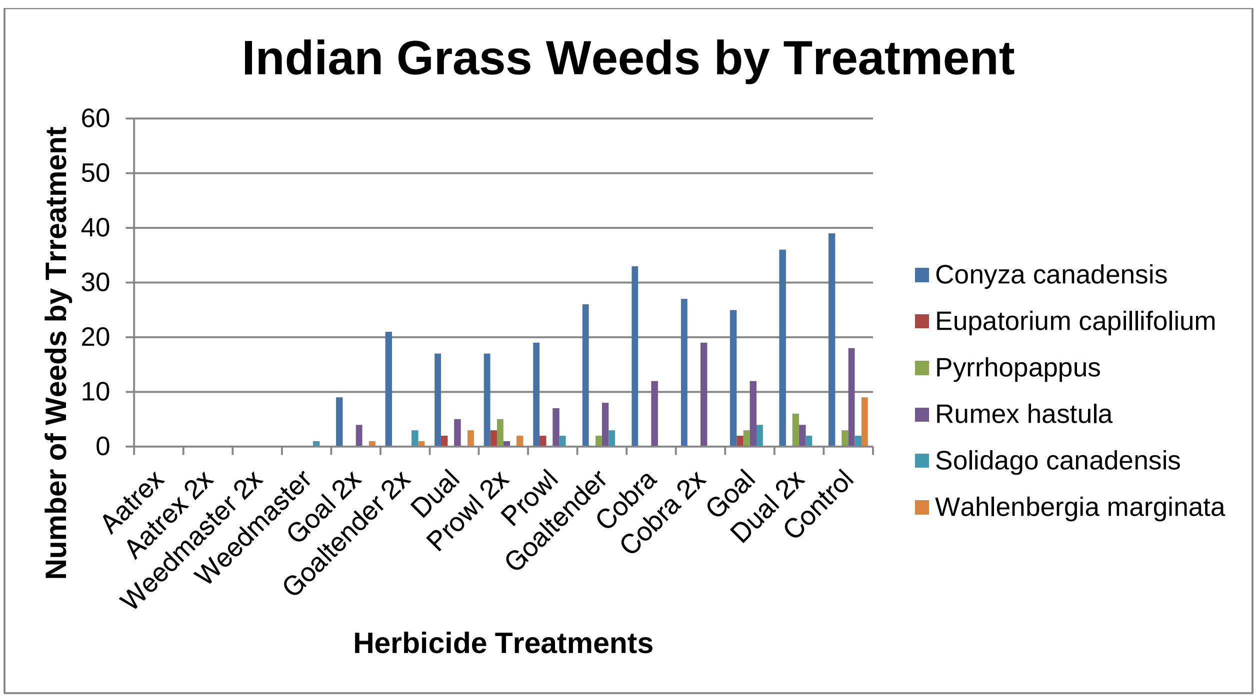

Figure 2. 2014 Lolly Creek herbicide trial weed count of Indian Grass (*Sorghastrum nutans*).

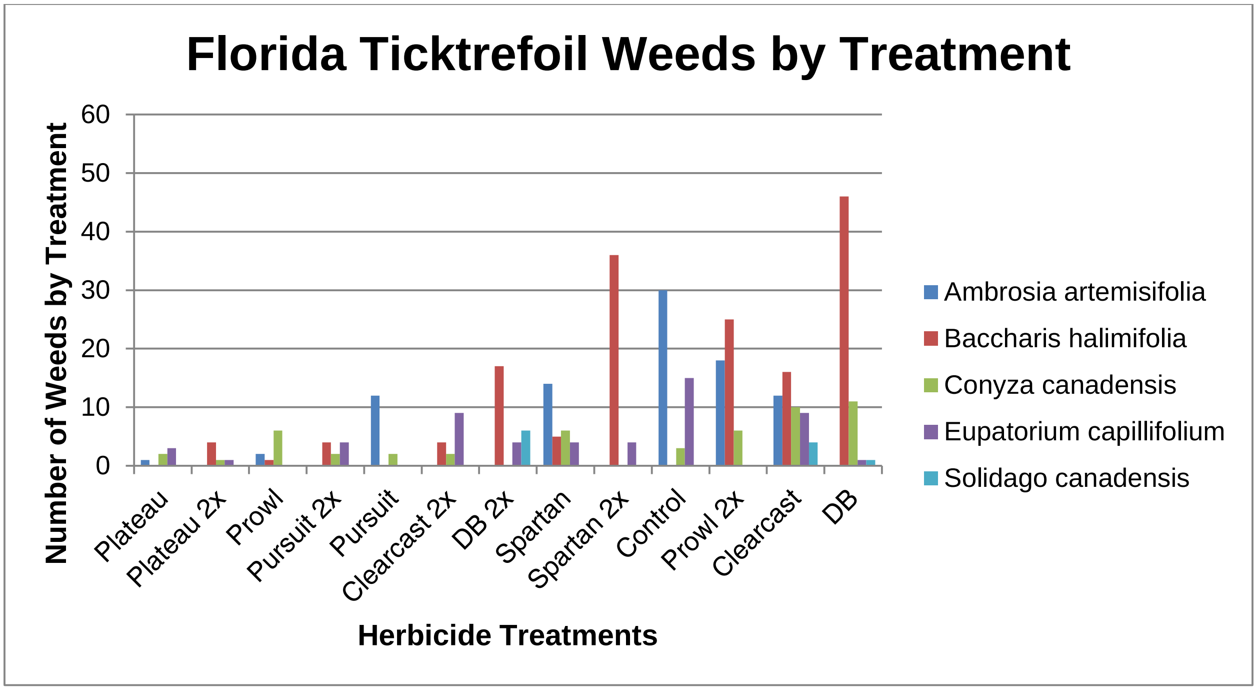

Figure 3. 2014 Lolly Creek herbicide trial weed count of Florida Ticktrefoil (*Desmodium floridanum*).

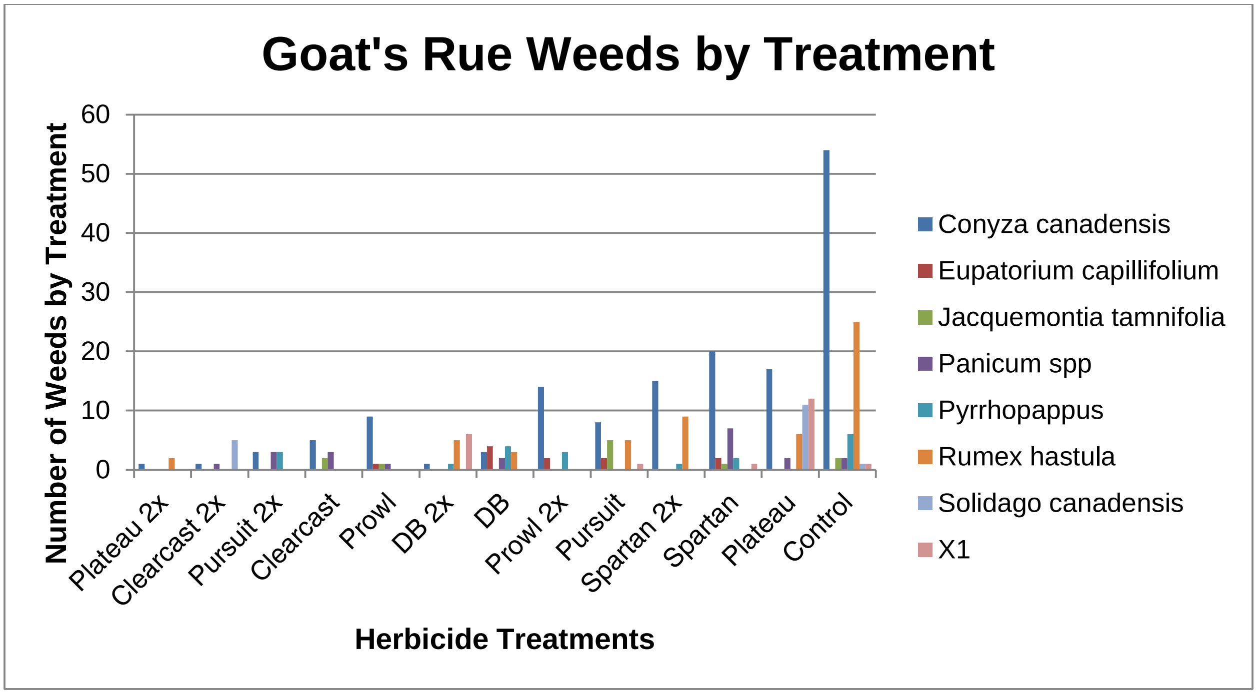

Figure 4. 2014 Lolly Creek herbicide trial results of goat's Rue (*Tephrosia virginiana*).

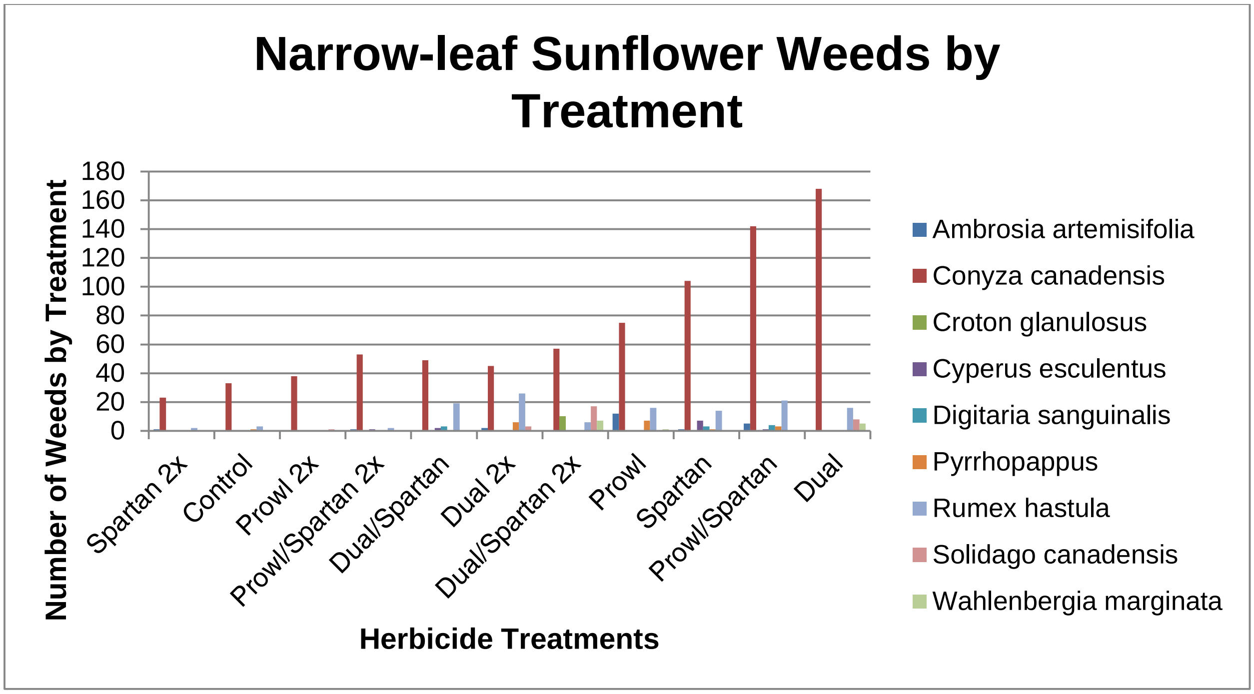

Figure 5. 2014 Lolly Creek herbicide trial results of narrow-leaf sunflower (*Helianthus angustifolius*).