Title: Evaluation of the Efficacy of Various Herbicides for the Control of Broadleaf (*Plantago major*) and Buckhorn (*Plantago lanceolata*) Plantain in Alfalfa

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Abstract: Broadleaf and buckhorn plantain (*Plantago major* and *P. lanceolata*, respectively) are perennial weeds that are notoriously difficult to control in alfalfa cropping systems. The use of commercially available herbicides labeled for the control of plantain weeds has proven ineffective in the field. Sharpen® (saflufenacil) herbicide has been recently registered for the control of broadleaf weeds in dormant alfalfa, though it has not been evaluated on plantain control in the past. Field and greenhouse experiments were conducted to determine the ability of Sharpen® to effectively control plantain with little damage to alfalfa yield. In the greenhouse, applications of Sharpen® alone caused a greater amount of injury to both broadleaf and buckhorn plantain compared to the non-treated control. Additionally, applications of Sharpen® in combination with other herbicides (Pursuit® or Raptor®) caused the greatest amount of injury to both broadleaf and buckhorn plantain compared to all other commercially available herbicide treatments. However, as the study progressed, the digital image data indicated that slower acting herbicides like Roundup® or Rhomene® decreased the amount of green tissue comparable to that of Sharpen® alone or in combination with Pursuit® or Raptor® on both broadleaf and buckhorn plantain. Additionally, this injury was not enough to prevent recovery and regrowth of the weeds over time. In the field, alfalfa did not exhibit damage symptoms or have reduced yield when treated with Sharpen® compared to the non-treated control. This research indicates that applications of Sharpen® provided injury throughout the duration of the study to both broadleaf and buckhorn plantain with few negative effects to alfalfa in the field.

Introduction: As of 2017, alfalfa hay remains the most valuable cash crop in the state of New Mexico with an estimated annual gross of just over $168 million (Lauriault et al., 2017). Additionally, the overall value of alfalfa hay is further enhanced by its essential contributions, as feed and forage, to livestock production (i.e., milk, meat, textiles), which continues to lead New Mexico overall in agricultural commodities. According to the New Mexico Agricultural Statistics for 2017, the dairy industry contributed approximately $1.19 billion in total milk sales, with the remaining livestock industries netting $895 million in total sales for the state of New Mexico (USDA NASS, 2017). As crop production acreage and the availability of resources for management continue to decline, it is important to maximize yield and nutritive value of all alfalfa production as much as possible to meet the agricultural needs of growers, producers, farmers, ranchers, dairy managers, and industry personnel throughout the state of New Mexico and surrounding states.

Managing weeds is a critical and ever-present component of successful alfalfa production. While weeds that emerge during the initial seeding stages of alfalfa typically have the greatest impact by competing for light, water, space, and nutrients, late-season weeds that populate established alfalfa fields can have a significant impact on yield through continued competition for resources throughout the remaining and following growing seasons (Beck et al., 2017). Additionally, the presence of annual and perennial weeds at any time can lower forage nutritive value, reduce stand longevity, cause premature stand loss or reduction, increase the incidence of disease and insect damage, and create detrimental harvesting issues (Ashigh et al., 2010; Green et al., 2003, Gilbert et al., 1988).

Perennial weed populations are especially difficult to control in perennial crops like alfalfa, because management practices have to address seed production and vegetative reproductive structures which allow the plant to survive from season to season. Simple perennial weeds like plantain (*Plantago* spp.) have a hearty root system that allows the plant to die back and survive during non-ideal environmental conditions, proctoring tissue regrowth and re-establishment once conditions become ideal again. Broadleaf plantain (*P. major*) and buckhorn plantain (*P. lanceolata*) are particularly difficult-to-control weeds whose infestations are widespread in alfalfa fields throughout the state of New Mexico and other areas of the western U.S. (Sulser and Whitesides, 2012; Elmore et al., 2007). Weed management of these simple perennial weeds must focus primarily on injury to the root system; however, it is difficult for herbicide active ingredients to move effectively enough within the entire plant to injure a hearty root system located deep within the soil (Elmore et al., 2007). Similarly, the use of herbicides to control broadleaf weeds like plantain in a broadleaf crop like alfalfa further complicates any effective management. As a result, there are only a few registered herbicide active ingredients, such as glyphosate and MCPA that have been reported to cause injury to plantain in alfalfa fields in New Mexico (Beck et al., 2017). Additionally, the continued use of these select few herbicide active ingredients to manage a specific population of weeds like plantain in alfalfa over time, can lead to the development of herbicide resistance in the target weeds (Orloff et al., 2009). As a result, research to evaluate the effectiveness of newly registered herbicides, as well as older traditional herbicides, with different active ingredients is greatly warranted for control of plantain in alfalfa.

Sharpen® (BASF Corporation) has recently acquired a supplemental label for broadleaf weed control in dormant-season alfalfa in the state of New Mexico (BASF Corporation, 2017). The active ingredient in Sharpen® is saflufenacil, which causes plant cell membrane damage and eventually plant death by inhibiting the production of protoporphyrinogen-oxidase (herbicide group 14). Specifically, Sharpen® can offer contact burn-down control of perennial broadleaf weeds including, but not limited to, field bindweed (*Convolvulus arvensis*) and dandelion (*Taraxacum officinale*) during limited (dormant) season growth of alfalfa. Sharpen® has yet to be studied as a potential herbicide option for broadleaf and buckhorn plantain control in alfalfa fields. The objectives of this study are to: 1) compare the weed control performance of saflufenacil against commercially available herbicide standards under greenhouse conditions, and 2) evaluate the effects on alfalfa regarding damage symptoms and yield reduction resulting from the application of saflufenacil against commercially available herbicide products. Should results indicate that Sharpen® provides acceptable control on broadleaf and buckhorn plantain and equivalent crop safety compared to the commercial standards, we will take action to include plantain as a target weed in the most up-to-date product label.

Materials and Methods: In 2017, a field research trial was established to evaluate the development of herbicide injury symptoms, as well as any negative impacts on yield, in a mature alfalfa stand. Due to the lack of a uniform infestation of the target weeds needed for a comparative research study in the field, research was also initiated in the greenhouse in 2017 to evaluate the efficacy of saflufenacil (Sharpen®) on broadleaf and buckhorn plantain control compared to other industry standard herbicide active ingredients.

<u>Field Study:</u> A field trial was initiated at New Mexico State University's Agricultural Science Center (ASC) in Los Lunas, NM in Dec. 2017, to evaluate any negative impacts of herbicide treatments to alfalfa

growth and yield. The soil at the ASC site is a Vinton Series (Sandy, mixed, Thermic Typic Torrifluvents with 1.5% organic matter) (National Cooperative Soil Survey, 2018). The field at the ASC had previously been prepared for alfalfa using typical procedures including tillage, seeding, irrigation, etc. The alfalfa field was an established (6+ years), healthy stand of Reward II (Fall dormancy rating = 4, semi-dormant) (Lauriault et al., 2008, 2009, 2011). The herbicide treatments for the study are labeled for use in dormant-season alfalfa growth. However, due to warmer temperatures throughout the southern regions of New Mexico, alfalfa tends to display slowed-growth effects rather than true dormancy, thus herbicide applications must be made early enough for the alfalfa to recover during slowed fall-growth and spring re-growth (Lauriault et al., 2009, 2011). As a result, herbicide treatment applications were initiated on December 1, 2017, after the final cutting and during a period of slowed growth starting in late November. This is also the best timing for herbicide control of perennial weeds like plantain since the redistribution of carbohydrates to the root system, in preparation for winter, allows for greater translocation of systemic herbicides, and more effective control (Johnson and VanGessel, 2014).

The experimental design was a randomized complete block design with plot sizes of 10 ft x 10 ft and four replications of ten total treatments. Treatments consisted of the following herbicides: saflufenacil (Sharpen®) at 1 or 2 fl oz/A; 2,4-DB Amine (Butyrac 200®) at 3 qts/A; MCP-4 Amine (Rhomene®) at 1 pt/A; imazethapyr (Pursuit®) at 6 fl oz/A; imazamox (Raptor®) at 6 fl oz/A; hexazinone (Velpar®) at 4.3 lbs/A; and terbacil (Sinbar®) at 1.5 lbs/A. A treatment of glyphosate (Roundup PowerMax®) at 44 oz/A was included to assess potential control of plantain in Roundup Ready® alfalfa systems. A non-treated control (NTC) was included for comparison for a total of 10 treatments. Treatments were applied using a CO_2-powered backpack sprayer equipped with a 4-nozzle boom with 11002 VS TeeJet Flat-fan nozzles calibrated to deliver 20 GPA at 207 kPa. The alfalfa field was not irrigated for approximately 24 hours after the initial application to allow herbicide treatments to dry. Throughout the duration of the study in 2018, fields will be irrigated as needed to maintain alfalfa growth and health.

In 2018, alfalfa injury (%) due to herbicide applications was evaluated visually every two weeks for approximately 170 days after initiation of treatment (DAIT). Evaluations were assessed on a percent scale where 1 equals no injury to alfalfa, and 100 equals death of alfalfa plants. Additionally, weed percent coverage was estimated visually every two weeks for approximately 170 DAIT on a percent scale where 1 equals no weed populations within treated plot, and 100 equals complete weed population coverage within the treated plot. No broadleaf or buckhorn plantain weeds were located within the field trial, predominant weed species throughout the duration of the trial included annual sowthistle (*Sonchus oleraceus*) and prickly lettuce (*Lactuca serriola*). Field plots remained relatively weed-free throughout the duration of the trial. Alfalfa was harvested on May 22, 2018 (172 DAIT), and July 5, 2018 (216 DAIT), to assess any treatment effects on yield. Alfalfa was harvested using hand-clipped fresh forage to collect weights from a 10.56 ft^2 area within each plot. Samples from each plot were collected and weighed prior to drying in a forced-air oven at 52°C until a constant weight to convert field weights to dry matter (DM) yield. Herbicide injury, by rating DAIT, and DM yield data were subjected to pairwise comparisons amongst treatments using analysis of variance (PROC Mixed) in SAS (Version 9.4, SAS Institute Inc.) and treatment means were separated using Fisher's protected least significant difference (LSD) test at $\alpha = 0.05$.

<u>Greenhouse Study:</u> A greenhouse study was initiated on September 1, 2017, when broadleaf and buckhorn plantain were seeded in potting soil at New Mexico State University's Leyendecker Plant Sciences Center Greenhouse in Las Cruces, NM. On November 20, 2017, germinated seedlings of both broadleaf and buckhorn plantain were transplanted into individual 2-in cone-tainers filled with potting

soil for further study. Plants were irrigated daily to allow for healthy growth and development throughout the duration of the trial.

The experimental design was a randomized complete block design with each cone-tainer having a single plant as the experimental unit and four replications of twelve total treatments applied to each plantain species. On December 20, 2017, the same nine herbicide treatments and applications rates that were used in the field trial were also applied in the greenhouse. Additionally, two herbicide treatments of Sharpen® (at 2 fl oz/A) in combination with Pursuit® (at 6 fl oz/A) or Raptor® (at 6 fl oz/A) were added to the greenhouse study to explore the potential of tank-mixing herbicides for improved control of plantain weeds. A NTC was included for comparison for a total of 12 treatments. Treatments were applied using the same spray equipment and settings as the field study. Cone-tainers were not watered for 24 hours following the treatment applications, and were irrigated as needed throughout the study to maintain plantain growth and health.

Beginning 8 DAIT, broadleaf and buckhorn plantain injury due to herbicide applications were evaluated visually once a week until 40 DAIT when plantain began to recover from herbicide injury. Evaluations were assessed on a percent scale where 1 equals no injury to plantain, and 100 equals death of plantain plants. Dark green color index (DGCI) was calculated using digital photographs. One photograph per plant was taken weekly until 40 DAIT using a constructed light box with mounted LED lamps to provide uniform lighting conditions and camera lens height for all the photographs taken (Karcher and Richardson, 2003). A Canon PowerShot SX700 HS (Canon Inc., Tokyo, Japan) camera was set to a shutter speed of 1/10, an aperture of f/4.0, an ISO of 200, and a normal focus lens, and used to take digital images. SigmaScan Pro 5 software package (Systat Software Inc., San Jose, CA) was used to calculate DGCI following methods described by Richardson et al. (2001). The entire picture frame was used to calculate DGCI without excluding bare spots (Karcher and Richardson, 2003), which was then used to calculate percent green cover (cover), or the amount of green pixels in each image, within the software to determine the appearance of herbicide injury in comparison to healthy green plant tissue. Starting at 48 DAIT, above and below-ground tissue was harvested for broadleaf and buckhorn plantain by cone-tainer. Below-ground tissue was washed to remove potting soil contaminants. Plant samples were then oven-dried and weighed by container. Visual herbicide injury, percent green cover, and broadleaf plantain root dry weight data were subjected to pairwise comparisons amongst treatments using analysis of variance (PROC Mixed) in SAS and treatment means were separated using Fisher's protected least significant difference (LSD) test at $\alpha = 0.05$.

Results and Discussion:

Field Study: Average visual estimates for weed percent coverage (%) did not yield any noticeable difference amongst treatments as the study area was relatively clean of weed populations on the treatment application date (Data Not Shown). Similarly, there were no detectible differences amongst treatments of injury or slowed growth as a result of herbicide applications throughout the duration of the study, with the exception of Roundup®, which caused noticeable injury symptoms (stunted top-growth) soon after application and into spring green-up (Data Not Shown). This was not unexpected since the alfalfa used in the field study was not a Roundup Ready® variety. Average DM yields for both the 172 DAIT and the 216 DAIT harvest dates did not result in significant differences among the herbicide treatments, including Sharpen® (Figure 1). Therefore, applications of Sharpen® did not negatively affect DM yield for either cutting compared to the NTC or any other treatment. This is noteworthy as all herbicide applications were made while there was still active (although reduced) growth of the alfalfa on the initial application date of December 1, 2017. This growth was observed in the initial damage of the alfalfa plants treated with Roundup®, which only causes injury to green, actively growing plant tissue (Monsanto Company, 2017).

As a result, Sharpen® may be a viable candidate for late-season weed control when applied on slowed green growth of mature alfalfa crop stands during the fall months.

Greenhouse Study: Analysis of variance revealed several treatment x date interactions; therefore, broadleaf and buckhorn plantain weed injury and control data for each date are presented separately.

Broadleaf Plantain: Percent broadleaf weed injury data indicated that applications of Sharpen® alone, or in combination with Pursuit® or Raptor® provided significantly greater injury compared to the NTC and all other herbicide treatments, until 30 DAIT (Table 1). At 30 DAIT, only treatments including Sharpen in combination with Pursuit® or Raptor® continued to provide the greatest control. At 40 DAIT, Butyrac 200®, Rhomene®, Sinbar®, and Roundup® began exhibiting equal control to Sharpen® treatments.

Percent broadleaf green cover indicated that applications of Sharpen® alone or in combination Pursuit® or Raptor® provided significantly greater injury (less green cover) compared to the NTC throughout the duration of the study. However, as the study progressed, slower acting herbicides like Roundup® or Rhomene® actually displayed a decrease in the amount of green cover comparable to that of Sharpen® alone or in combination with Pursuit® or Raptor® by 30 and 40 DAIT, respectively (Table 2).

Dried root weights at 40 DAIT indicated that Sinbar®, Rhomene®, Butyrac 200®, Sharpen® in combination with Raptor®, and Roundup® had the lowest significant weights compared to the NTC, respectively (Figure 2).

Buckhorn Plantain: Results for percent buckhorn weed injury and green cover were similar to those for broadleaf plantain, with few differences (Tables 3 and 4). Generally, recovery from the application of Sharpen® alone was more rapid and the initial impact of applications of other herbicides was more pronounced, compared to the NTC, and more intense in progressive damage by 40 DAIT, except for Pursuit®, Velpar®, and Sinbar® (Tables 1 & 3). Results for percent green cover were more consistent across plantain species (Tables 2 & 4). As the trial progressed, very large NTC buckhorn plantain weeds continued to grow to the point where they were becoming root-bound within each cone-tainer. Therefore, herbicide-related damage to roots was not enough to display significant differences amongst the NTC and the herbicide treatments (data not shown). Similar to those of broadleaf plantain, the amount of root tissue observed during harvest indicated that root injury was not enough to prevent the recovery of the weed after initial herbicide applications were made (data not shown).

Greenhouse Trial Discussion: Visual ratings and percent green cover data for both broadleaf and buckhorn plantain indicated that Sharpen® alone at both the low and high-labeled rates provided weed injury significantly greater than that of the non-treated control, and comparable to those of the industry standard herbicide treatments throughout the study. However, this injury was often not great enough to provide effective control with little regrowth or recovery of the weed over time. The broadleaf plantain root weights of all the herbicide treatments, including those with Sharpen® also did not indicate enough damage to the root system to prevent recovery while Rhomene®, Roundup®, and Sinbar® did. Observations of Sharpen® in combination with other industry standard herbicides like Raptor® or Pursuit® often significantly increased the injury, or significantly decreased the green cover, of both broadleaf and buckhorn plantain compared to the other herbicide treatments throughout the duration of the trial.

Conclusions: This research has demonstrated that Sharpen® may provide comparable injury to broadleaf and buckhorn plantain as the commercially available industry standard herbicides with minimal effects on the alfalfa yield. Applications of Sharpen® often displayed greater injury to both broadleaf and buckhorn plantain compared to the NTC with minimal negative impacts on the alfalfa. However, this injury was not enough to prevent weed recovery over time. Even though the amount of visually observed injury often increased when Sharpen® was applied in combination with Raptor® or Pursuit®, the injury was still not effective enough to prevent the eventual recovery of the target weeds. Further research is needed to determine if additional combinations of Sharpen® with other commercially available herbicides, as well as sequential applications to cause additional and prolonged injury, can provide adequate control of plantain in dormant alfalfa. Similarly, additional research is needed to determine if the herbicide tank-mixes and sequential application cause a negative effect on alfalfa growth and yield over time. These additional tank combinations and sequential applications will be the focus of Year 2 of this study. This research continues.

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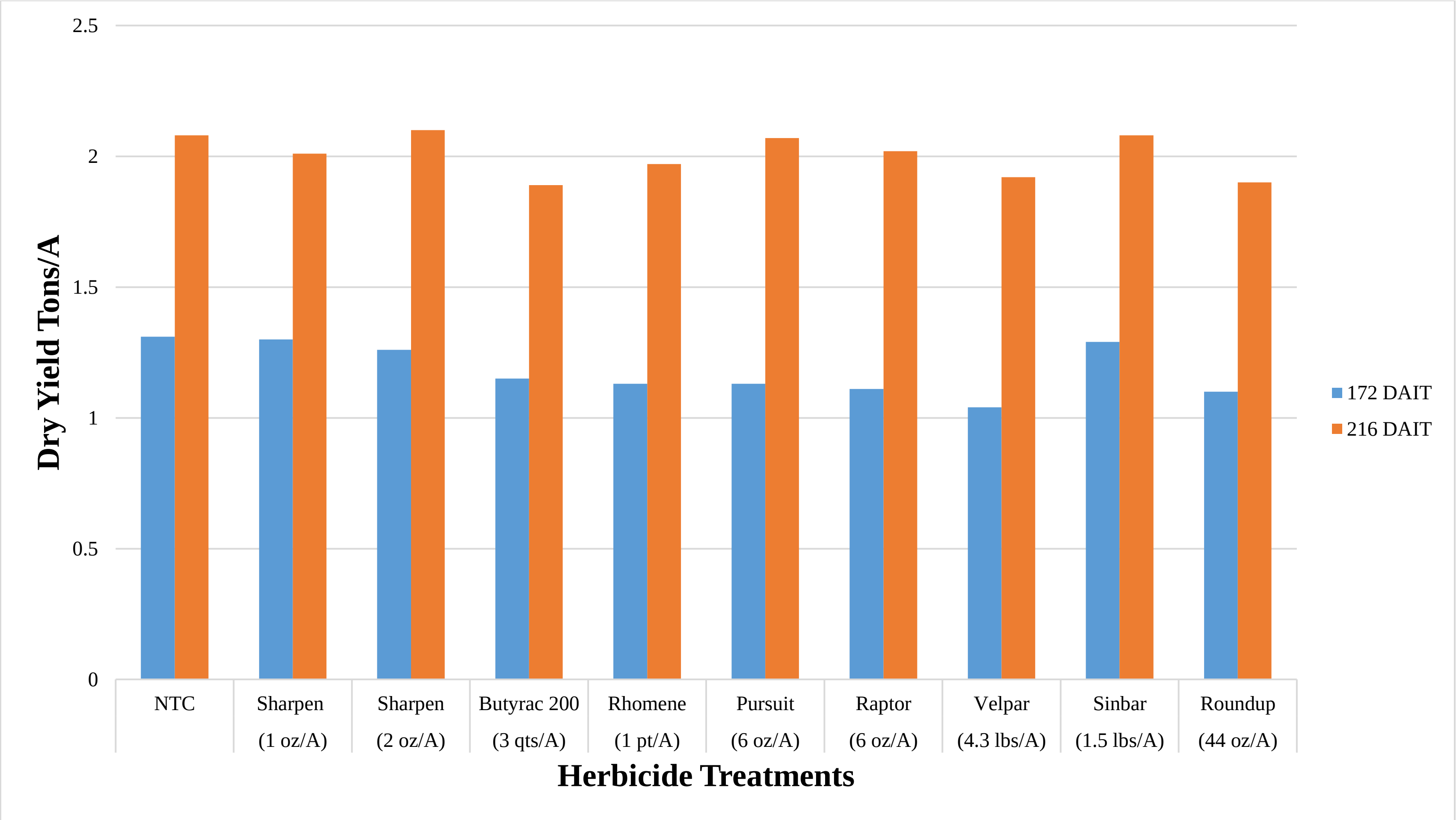

Figure 1. Alfalfa dry matter (DM) yields for 2 cuttings in 2018 in response to application of selected herbicides in December, 2017 at Los Lunas, NM. Within cutting data are not significantly different according to Fisher's LSD test (α=0.05), LSD = 0.24 (127 DAIT) and 0.38 (216 DAIT); NTC = non-treated control; DAIT = days after initiation of treatment; LSD = least significant difference.

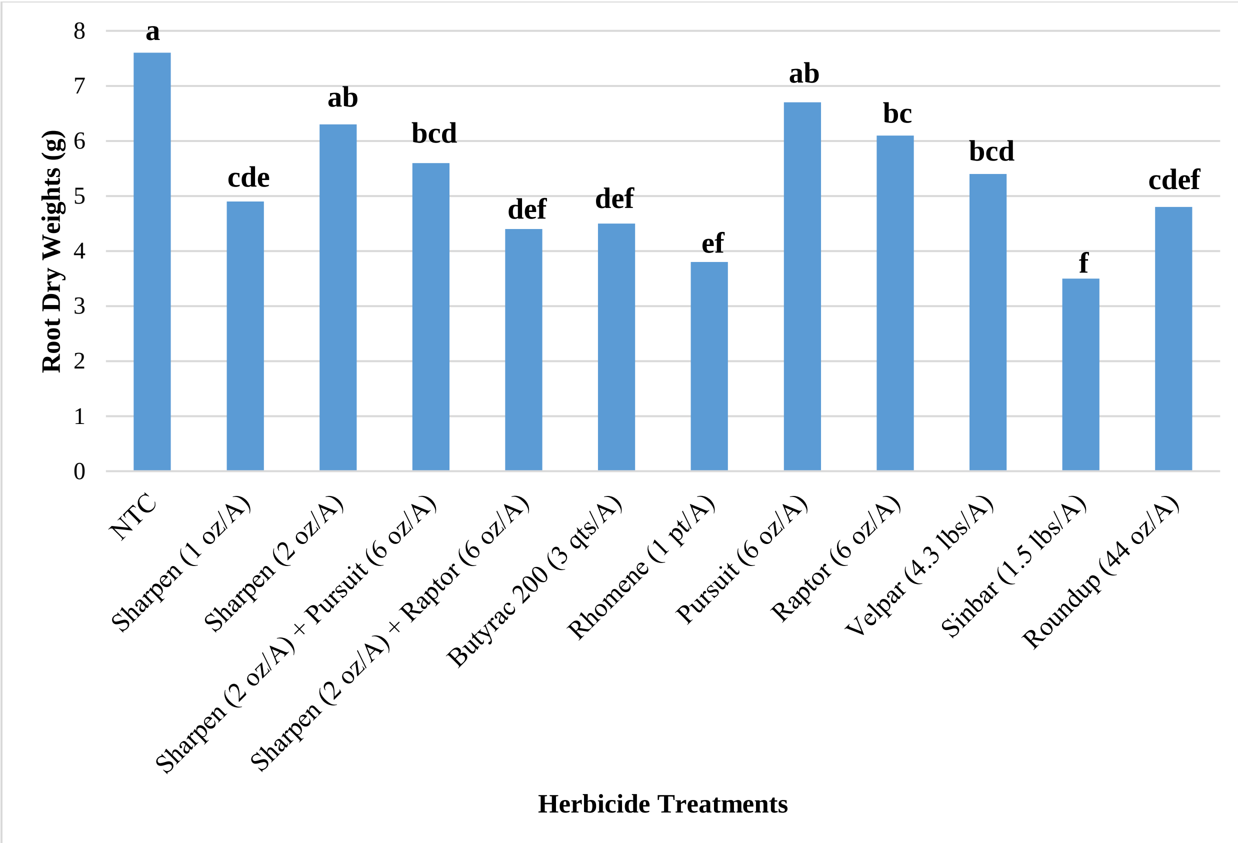

Figure 2. Dry root weights of broadleaf plantain collected 48 DAIT on December 20, 2017, in the greenhouse at Las Cruces, NM. Bars having the same letters are not significantly different at α=0.05, LSD = 1.37; NTC = non-treated control; DAIT = days after initiation of treatment; LSD = least significant difference.

Table 1. Percent broadleaf plantain injury observed visually in greenhouse in response to herbicide treatments applied on December 20, 2017, in Las Cruces, NM.

		Broadleaf Plantain Injury -------------------- % --------------------				
Treatment	Rate	8 DAIT[y]	16 DAIT	21 DAIT	30 DAIT	40 DAIT
NTC[y]	----	1.0 f[z]	1.0 e	1.0 f	1.0 g	1.0 f
Sharpen	1 oz/A	45.0 b	55.0 b	61.3 bc	52.5 bc	55.0 cd
Sharpen	2 oz/A	45.0 b	62.5 ab	70.0 ab	60.0 b	67.5 abc
Sharpen + Pursuit	2 oz/A + 6 oz/A	57.5 a	72.5 a	80.0 a	77.5 a	80.0 a
Sharpen + Raptor	2 oz/A + 6 oz/A	60.0 a	75.0 a	80.0 a	77.5 a	77.5 ab
Butyrac 200	3 qts/A	20.0 cd	25.0 cd	37.5 d	47.5 bcd	62.5 abcd
Rhomene	1 pt/A	25.0 c	32.5 c	42.5 d	50.0 bc	65.0 abcd
Pursuit	6 oz/A	10.0 ef	12.5 de	20.0 e	15.0 fg	22.5 e
Raptor	6 oz/A	10.0 ef	17.5 cd	17.5 e	15.0 fg	27.5 e
Velpar	4.3 lbs/A	10.0 ef	20.0 cd	37.5 d	30.0 ef	47.5 d
Sinbar	1.5 lbs/A	7.5 ef	22.5 cd	52.5 cd	32.5 de	60.0 bcd
Roundup	44 oz/A	11.3 de	27.5 cd	42.5 d	42.5 cde	51.3 cd
LSD[y] value		9.64	15.37	15.35	15.16	19.28

[y]NTC = non-treated control; DAIT = days after initiation of treatment; LSD = least significant difference.

[z] Within columns, means followed by the same letter are not significantly different (α=0.05).

Table 2. Percent green cover of broadleaf plantain in response to herbicide treatments applied on December 20, 2017, in the greenhouse at Las Cruces, NM.

		Broadleaf Plantain Cover			
		-------------------- % --------------------			
Treatment	Rate	16 DAIT[y]	21 DAIT	30 DAIT	40 DAIT
NTC[y]		85.0 ab[z]	76.7 abc	74.8 ab	72.3 ab
Sharpen	1 oz/A	71.8 cd	65.9 cd	63.5 bcd	60.8 bc
Sharpen	2 oz/A	66.4 d	61.0 d	55.0 cde	53.0 cde
Sharpen + Pursuit	2 oz/A + 6 oz/A	53.4 e	45.3 e	38.8 f	33.8 f
Sharpen + Raptor	2 oz/A + 6 oz/A	52.0 e	47.6 e	44.7 ef	42.5 def
Butyrac 200	3 qts/A	83.9 ab	75.1 bc	67.4 abc	58.5 bcd
Rhomene	1 pt/A	85.6 ab	78.0 ab	63.6 bcd	50.0 cdef
Pursuit	6 oz/A	91.1 a	87.0 a	82.8 a	79.8 a
Raptor	6 oz/A	84.3 ab	78.6 ab	74.9 ab	72.6 ab
Velpar	4.3 lbs/A	84.0 ab	76.7 abc	72.6 ab	70.0 ab
Sinbar	1.5 lbs/A	82.1 b	70.2 bcd	63.6 bcd	59.5 bc
Roundup	44 oz/A	78.9 bc	68.5 bcd	49.2 def	36.4 ef
LSD[y] value		8.79	11.29	15.65	16.68

[y]NTC = non-treated control; DAIT = days after initiation of treatment; LSD = least significant difference.

[z] Within columns, means followed by the same letter are not significantly different (α=0.05).

Table 3. Percent buckhorn plantain injury observed visually in the greenhouse in response to herbicide treatments applied on December 20, 2017, in Las Cruces, NM.

		Buckhorn Plantain Injury -------------------- % --------------------				
Treatment	Rate	8 DAIT[y]	16 DAIT	21 DAIT	30 DAIT	40 DAIT
NTC[y]		1.0 e[z]	1.0 f	1.0 e	1.0 g	1.0 e
Sharpen	1 oz/A	72.5 a	72.5 a	65.0 b	42.5 def	37.5 d
Sharpen	2 oz/A	70.0 a	77.5 a	62.5 b	47.5 de	45.0 cd
Sharpen + Pursuit	2 oz/A + 6 oz/A	72.5 a	85.0 a	83.8 a	86.3 a	82.5 a
Sharpen + Raptor	2 oz/A + 6 oz/A	67.5 a	77.5 a	81.2 a	80.0 ab	85.0 a
Butyrac 200	3 qts/A	35.0 c	37.5 bc	52.5 bc	55.0 cd	70.0 ab
Rhomene	1 pt/A	55.0 b	47.5 b	55.0 bc	70.0 bc	83.7 a
Pursuit	6 oz/A	25.0 c	27.5 cde	17.5 d	32.5 ef	42.5 d
Raptor	6 oz/A	30.0 c	25.0 cde	25.0 d	42.5 def	60.0 bc
Velpar	4.3 lbs/A	12.5 d	17.5 de	17.5 d	30.0 f	35.0 d
Sinbar	1.5 lbs/A	12.5 d	15.0 ef	17.5 d	32.5 ef	30.0 d
Roundup	44 oz/A	35.0 c	30.0 cd	47.5 c	65.0 bc	78.8 a
LSD[y] value		11.34	14.24	14.02	15.65	16.60

[y]NTC = non-treated control; DAIT = days after initiation of treatment; LSD = least significant difference.

[z] Within columns, means followed by the same letter are not significantly different (α=0.05).

Table 4. Percent green cover of buckhorn plantain in response to herbicide treatments applied on December 20, 2017, in the greenhouse at Las Cruces, NM.

		Buckhorn Plantain Cover -------------------- % --------------------			
Treatment	Rate	16 DAIT[y]	21 DAIT	30 DAIT	40 DAIT
NTC[y]		86.2 ab[z]	87.1 a	82.9 a	79.9 a
Sharpen	1 oz/A	66.7 cd	65.6 bc	62.2 bc	62.5 abcd
Sharpen	2 oz/A	69.0 cd	65.8 bc	63.3 bc	57.5 bcd
Sharpen + Pursuit	2 oz/A + 6 oz/A	44.8 e	37.4 d	33.4 e	32.1 fg
Sharpen + Raptor	2 oz/A + 6 oz/A	62.9 d	54.6 c	48.8 cde	43.6 def
Butyrac 200	3 qts/A	79.2 abc	66.5 bc	61.9 bc	55.4 cde
Rhomene	1 pt/A	71.4 bcd	64.7 bc	42.1 de	18.8 g
Pursuit	6 oz/A	86.7 a	87.0 a	82.6 a	74.8 abc
Raptor	6 oz/A	86.9 a	84.9 a	73.3 ab	64.3 abc
Velpar	4.3 lbs/A	87.0 a	84.7 a	78.9 ab	76.2 ab
Sinbar	1.5 lbs/A	88.0 a	85.0 a	79.3 ab	76.6 ab
Roundup	44 oz/A	79.6 abc	72.4 ab	52.7 cd	36.9 efg
LSD[y] value		15.00	15.63	18.97	19.93

[y]NTC = non-treated control; DAIT = days after initiation of treatment; LSD = least significant difference.
[z] Within columns, means followed by the same letter are not significantly different (α=0.05).