

Adaptive Research on Effective Control of Buffelgrass at Saguaro National Park

**Final report to Western National Parks Association
December 20, 2009**

**Dana Backer and Chris Hannum
Saguaro National Park**

Grant # 08-11



Study location - Rincon Mountain District of Saguaro National Park in Tucson, Arizona.

Abstract

Buffelgrass (*Pennisetum ciliare*), a perennial bunchgrass from Africa, is rapidly spreading across southern Arizona and threatens the Sonoran Desert ecosystem, including the signature saguaro forest and associated wildlife habitat within Saguaro National Park. Three separate experiments were conducted in Saguaro National Park to evaluate the effects of different herbicide protocols on mortality of buffelgrass. In the first experiment, a soil residual herbicide, Plateau® (active ingredient imazapic), was applied to bare soil 3, 2, 1 and 0 months prior to the onset of monsoon precipitation in an area previously infested with buffelgrass to test its effectiveness as a pre-emergent. The second study evaluated the efficacy of two different concentrations of an herbicide. Three percent and 5% glyphosate solution was applied alone and in combination with the adjuvant LI-700® to plants at three different phenological stages: seedling, re-sprout and dormant. In the third experiment, the viability of seeds collected from plants sprayed with herbicide in the above study was tested. The results suggested that Plateau® was highly effective at inhibiting emergence of buffelgrass seedlings in the plots treated before monsoon rains began. There was also evidence that Plateau® inhibited germination of native grasses and annual forbs. Glyphosate applied at a 3% herbicide solution without the adjuvant was as effective at causing buffelgrass mortality at all life stages as all other treatment types. Fifty-five percent of the fascicles were viable. Fascicles from plants treated with a 3% solution of glyphosate alone had lower viability than those from plants treated with 3% solution of glyphosate and adjuvant.

Introduction

The spread of buffelgrass in Saguaro National Park has spurred extensive research and mobilization of effort aimed at discovering how best to control this invasive plant. Buffelgrass occurs in large stands in Saguaro National Park, and studies at the park indicate that it has the potential to spread throughout nearly all saguaro habitat (Ward 2003). As buffelgrass rapidly colonizes new areas, the perennial African bunchgrass has become the greatest non-native species threat the park has ever faced: it out-competes native plants for light and water, and forms dense stands in which nothing else can grow. Buffelgrass is also fire-adapted and has the potential to increase fire frequency, size and intensity in an ecosystem that has historically been relatively fire-free (Esque et al. 2004). Such fires can kill high percentages of saguaros and other native Sonoran desert plants, as well as animals such as the desert tortoise that have not evolved with fire.

Along with the Arizona Department of Transportation and the University of Arizona/USGS Desert Laboratory, Saguaro National Park plays a leading role in cooperative research efforts to identify threats posed by buffelgrass and to test the most effective and ecologically appropriate methods of controlling it on a large geographic scale. Although the plant can be hand-pulled throughout the year, pulling is more labor intensive and less biologically effective than herbicidal treatment (Esque et al. 2007). The current study was designed to investigate unaddressed research questions about herbicide efficacy in comprehensive treatment of buffelgrass.

Objectives

The purpose of this WNPA-funded project was to assess the value of various chemical methods of managing buffelgrass. The resulting information will assist the Park and other land management agencies by improving the effectiveness of control through an adaptive management approach, potentially reducing the number of treatments, and increasing the number of acres treated annually. Specifically, the objectives were to:

- 1) test Plateau® herbicide (active ingredient imazapic) as a pre-emergent to determine whether it

effectively suppresses emergence of buffelgrass seedlings, and to evaluate the best application time for germination control;

- 2) determine the effect of two different concentrations of Razor Pro® (active ingredient glyphosate), used alone and in combination with the adjuvant LI-700® (an additive that helps herbicides adhere to and spread evenly over the leaf surface), and applied as a post-emergent at different phenological (plant life cycle) stages, on inflorescence production and mortality; and
- 3) evaluate the viability of buffelgrass seeds collected from plants that flowered following foliar application of Razor Pro®. It has been observed that some buffelgrass plants treated with herbicide prior to flowering still flower and produce seeds. We wanted to determine if these seeds were viable.

A previous study at the park (Backer and Foster 2007) had determined that a lower concentration glyphosate solution (3%) without the adjuvant LI-700 was as effective as a 5% solution with the adjuvant when buffelgrass plants were 100% green. Plants must be >50% green and actively growing in order for glyphosate to effectively kill them. For the current study, we wanted to evaluate the effects various concentration/adjuvant combinations when buffelgrass plants were at different life stages and treated at different times of year.

Methods

Pre-emergent Study

Four locations were selected for the study and denoted C, J, LH and LF. Locations C and J are similar in terms of elevation (3120ft), slope (8%), aspect (SE-SW) and soil (Lampshire Romero Rock Outcrop Complex). Plots LF and LH were similar in the same respects: elevation (3080ft), slope (10-12%), and soil (Pantano-Granolite Complex). The vegetation is typical mixed native desert scrub including velvet mesquite (*Prosopis velutina*) and palo verde trees (*Parkinsonia sp*), cacti (*Opuntia sp*, *Carnegiea gigantea*, *Mammillaria sp*), acacia (*Acacia sp*), brittlebush (*Encelia farinosa*) and perennial grasses. All of the plots had been dominated by buffelgrass (cover >50%) which staff and volunteers removed by hand over the course of the year prior to the study.

To test the efficacy of a soil-residual herbicide on buffelgrass and native species, we established five 5m x 5m plots at the four different locations, for a total of 20 plots. Within each 5m x 5m plot, a 1m x 1m subplot was established in which vegetation measurements were taken. Each plot within a given location was randomly assigned a different treatment date: three months (April), two months (May) or one month (June) prior to the average start of the monsoon for Tucson (July 3), or after the onset of the monsoon (July); a control plot receiving no treatment also was established in each of the four locations. In April 2008, we conducted an initial pre-treatment inventory of all vegetation within the 20 subplots, in which all plants were identified and counted. Plants were classified as buffelgrass, other grass, annual forb, perennial forb or shrub. The first treatment was applied one week following the plant inventory. The three month plots were sprayed in April with approximately one gallon of a 0.13% herbicide solution (0.17oz Plateau®, 128oz water, 0.3oz Choice water conditioner, and 1oz indicator dye) using a backpack sprayer. A similar treatment was applied to one set of replicates in each of the subsequent months: May, June and July. Prior to each treatment, an inventory was done on all previously untreated plots to document any new plants and to detect observer error. April, May and June were considered pre-monsoon monitoring periods; July was considered a post-monsoon monitoring period. We conducted post-treatment plant inventories in August 2008 and one final inventory in February 2009.

Phenology Study

Backer and Foster (2007) demonstrated that both 3% and 5% concentrations of glyphosate will effectively kill buffelgrass when it is actively growing (>70% green biomass), regardless of the addition of the adjuvant LI-700®. For this study, we evaluated the effects of different concentrations of the herbicide glyphosate, alone and in combination with the adjuvant LI-700®, at other buffelgrass phenological stages. All herbicide formulations contained a water conditioner and dye, and were delivered with a backpack sprayer. We identified three buffelgrass phenological stages: 1) seedling (Figure 1), 2) basal growth or re-sprouting of already established plants (Figure 2) and 3) plants going dormant, with approximately 50% green biomass (Figure 3). The study area was conducted at an elevation of 3120 ft and dominated by buffelgrass.

A large contiguous patch of mature buffelgrass that had not previously been treated was selected for this study. In July 2008, 100 individual seedlings were tagged. On 15 July 2008, 50 seedlings received a 3% herbicide solution with adjuvant and 50 seedlings received a 3% herbicide solution alone. At the same time, mature plants started re-sprouting (producing new, green tissue) due to monsoon precipitation, and 100 individuals were tagged. Fifty re-sprouting plants received a 3% herbicide solution with adjuvant and 50 received the 3% herbicide solution alone. Plants were monitored eight days after treatment and then weekly until they began to senesce. The final monitoring visit was 21 July 2009. In October, plants began to senesce, and 200 early dormancy plants were tagged. On 2 October 2008, the dormant group received 3% herbicide solution with and without adjuvant, and 5% herbicide solution with and without adjuvant, with 50 plants in each herbicide solution/adjuvant combination. Plants were tagged with a flag denoting the treatment type and an identification number; treated plants were separated from each other by untreated plants. Seedlings and re-sprouts were monitored within eight days of herbicide application, then weekly throughout the remainder of the growing season, with final monitoring on 7 October 2008. The dormant plants were monitored within five days of treatment, then weekly until the first week of November, with final monitoring on 21 July 2009. Necrosis, re-sprouting, evidence of green tissue, inflorescence emergence and mortality were recorded.

Seed Viability Study

To assess the viability of buffelgrass seeds that were produced following herbicide treatment, seeds were collected from plants in the phenology study from the re-sprout group. The seeds were collected on 13 August 2008 and kept in cold storage until March 2009. Buffelgrass seeds occur on the plant in a cluster of spikelets called a fascicle, and each fascicle typically contains 1 – 3 seeds. The fascicle has been the unit used in other studies (Ward et al. 2006) and was subsequently used for this study. Fifty fascicles from plants sprayed with 3% glyphosate and adjuvant and 50 from plants sprayed with 3% glyphosate alone were tested. Clear plastic containers were lined with moist brown paper towels and 10 fascicles from each treatment type were planted in groups. The container lids were kept closed and the containers were placed indoors in direct sunlight for incubation. Two daily observations were made and data was recorded on radicle (first part of a seedling) emergence, temperature, sun exposure, amount of water added and presence of mold. The air temperature ranged from 68 – 77° F. Tap water (pH 7.68) was used.

All statistical analyses were performed using JMP version 8 software (SAS 2008).

Results

Pre-emergent Study

There was very strong evidence to suggest that the Plateau® herbicide affected the number of buffelgrass seedlings in 3, 2, and 1 month plots compared to the 0 month and no treatment plots, when plants were counted in July (Poisson regression, Likelihood ratio $\chi^2_4 = 2552.27$, $P = 0$). Most plots

that were treated in July (post-monsoon) or not treated had more than 10 times the number of buffelgrass plants as the treated plots (Table 1). See photographs in Figures 4 and 5 for evidence of the buffelgrass seedlings. There was no significant difference between 3, 2, and 1 month plots. The results were similar for summer annual forbs (Poisson regression, Likelihood ratio $\chi^2_4 = 444.80$, $P < 0.0001$) and other grasses (Poisson regression, Likelihood ratio $\chi^2_4 = 424.62$, $P < 0.0001$). Prior to the monsoons, none of the plots had any annual forbs or other grasses. With the exception of two plots, only the 0 month and no treatment plots had germination of annual forbs and grasses in July. Although all attempts were made to avoid spraying perennial forbs and shrubs present in the plots, some of the low-lying prostrate plants were sprayed. Due to observer error, we are not able to report the results of the effect of Plateau® when applied as a post-emergent to perennial plants.

Phenology Study

The seedling group exhibited a rapid response to the treatment. Within eight days after the herbicide application, all seedlings in both groups were identified as dead. Within 15 days after treatment, almost all of the seedlings had dried up and blown away. Within eight days of treatment, all of the re-sprout plants in both groups had necrosis. By the final observation period, only one plant had green tissue and there was 99% mortality across both groups. There was no evidence to suggest difference among the two treatments (Fisher's exact test, 2-tailed $P = 1.000$). There was a difference in timing of death between the treatment groups. Plants were treated with herbicide alone survived longer than plants that were treated with herbicide and adjuvant (Kaplan-Meier survival analysis, Log Rank test, $X^2 = 3.84$, $P = 0.05$, Figure 6). The mean survival time for plants treated with herbicide alone was 28 days compared to 17 days for plants treated with herbicide and adjuvant. Within 15 days post-treatment, re-sprout plants treated with herbicide and adjuvant had 84% mortality compared to 36% mortality among plants treated with herbicide alone. Before dying, 88% of the all the resprout plants treated, produced an inflorescence. Slightly more plants that were treated with herbicide alone produced an inflorescence (Fisher's exact test, 2-tailed $P = 0.028$).

All of the dormant plants had evidence of necrosis within 5 days of treatment. Because the plants were already going dormant, the final determination of mortality occurred the following summer. There was no evidence to suggest that the treatments differed (logistic regression, $P = 0.1147$) plants. The dormant plants treated with 3% herbicide solution without the adjuvant had 82% mortality and all of the other treatments had 96% or higher mortality.

Seed Viability

Overall, there was 55% viability of the fascicles: 72% of the fascicles from plants treated with herbicide and adjuvant produced a radicle compared with 38% of fascicles from plants treated with herbicide alone. There is evidence to suggest that fascicles from plants treated with herbicide and adjuvant produced significantly more radicles than fascicles from plants treated only with herbicide (Fisher's exact test, 2-tailed, $P = 0.0012$).

Discussion

The results suggest that the herbicide Plateau® is effective at suppressing emergence of buffelgrass seedlings, regardless of whether it is applied 1, 2 or 3 months prior to the onset of monsoon rain. Unfortunately, this pre-emergent also suppresses emergence of other grasses and annual forbs. Use of a pre-emergent herbicide in previously infested areas may reduce the emergence of buffelgrass seedlings and, thereby, the number of adult plants adding seed to the soil seedbank. It may, however, inhibit the recruitment of native species. We recommend that additional studies evaluate lower concentration rates of Plateau®, and the effects of post-emergent application on buffelgrass and native plants. Future studies should control the number of seeds present in the seed bank and increase the sample size.

The phenology results suggest that the lower solution (3%) of glyphosate applied both with and without adjuvant will reliably cause mortality of buffelgrass seedlings and mature plants that have re-sprouted. Additionally, re-sprouting plants treated with herbicide and the adjuvant are less likely to produce an inflorescence and die more quickly than those plants treated with glyphosate alone. Overall, results suggest that a lower concentration of glyphosate without the adjuvant is effective at causing mortality at all live stages, although managers may consider using the adjuvant when plants are going dormant. Thus, managers can expand the window of opportunity to control buffelgrass and can reduce the amount of chemicals introduced into the environment, thereby reducing costs. One limitation in this component of the study was the lack of a control group (i.e. groups of plants at each of the different phenological stages that receive no treatment).

More than half of the tested fascicles produced by plants approximately 1-2 weeks after the plants were treated with herbicides were viable. While the adjuvant may have some advantages, it certainly enhanced seed viability. For buffelgrass managers, learning that the plants flower and produce viable seeds *after* they have been treated with herbicide is frustrating and makes control even more challenging. This outcome has important implications for the timing of buffelgrass treatment and underscores the importance of killing buffelgrass plants before they flower and produce seeds.

This project has allowed researchers at Saguaro National Park to address important issues that ultimately may affect the survival of the unique Sonoran Desert ecosystem and its iconic plant, the saguaro cactus. As part of an ongoing endeavor to assess and understand threats to Saguaro National Park and other areas around southern Arizona, buffelgrass research requires continued attention. Early in this century buffelgrass was identified as a serious and long-term threat to the Park's natural resources. Funded studies such as this are essential to expanding buffelgrass control methods and finding new solutions in an effort to protect the ecosystem.

Acknowledgements

Saguaro National Park would like to thank the Western National Parks Association for their generous commitment to supporting research in National Parks and for funding buffelgrass research. We would also like to thank those individuals who assisted with data collection: Bethany Hontz, Kara O'Brien, Stephen Hansen and Mary Williams. We also greatly appreciate the statistical assistance from Erin Zylstra.

Literature Citations

- Backer, D. and D. Foster. 2007. Effectiveness of glyphosate herbicide on buffelgrass (*Pennisetum ciliare* L.) at Saguaro National Park, Tucson, AZ. Technical report to Saguaro National Park.
- Esque, T.C. et al. 2004. Saguaro under siege: Invasive species and fire. *Desert Plants* 20(1):49-55.
- Esque, T.C. et al. 2007. Buffelgrass fuel loads in Saguaro National Park, Arizona, increase fire danger and threaten native species. *Park Science* 24(2):33-37.
- Ward, J.P. 2003. Estimating the potential distribution of buffelgrass in Saguaro National Park, Arizona: Illustration of conservation planning tool in the age of biotic homogenization. M.S. University of Arizona, Tucson, 86 pp.
- Ward, J.P. et al. 2006. Water requirements for emergence of buffelgrass (*Pennisetum ciliare*). *Weed Science* 54:720-725.

Table 1: Buffelgrass plants in July 2008 after the onset of the monsoons.

Treatment Date	Mean July Count	SE (Mean July Count)	Range
April	4.00	1.83	0-8
May	2.75	2.14	0-9
June	0.75	0.25	0-1
July	239.75	78.31	14-374
Not treated	121.25	48.26	36-256

Figure 1: Buffelgrass seedlings in phenology study. Photo taken July 2008.



Figure 2: Re-sprouting buffelgrass plant in phenology study. Photo taken July 2008.



Figure 3: Early dormancy buffelgrass plants. Photo taken October 2008.



Figure 4: Plot sprayed with pre-emergent in May. Photo taken July 2008.

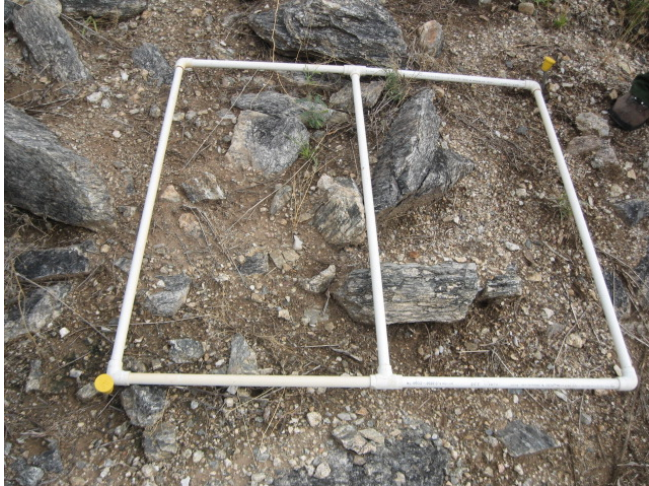


Figure 5: Plot not sprayed with pre-emergent. Photo taken July 2008.



Figure 6: Survival among re-sprouting buffelgrass plants that received glyphosate with and without the adjuvant LI-700. Kaplan-Meier survival analysis, Log Rank test, $X^2 = 3.84$, $P = 0.05$.

