12-2015

Improving Establishment of Seeded Buffalograss

Luqi Li

University of Nebraska-Lincoln

Follow this and additional works at: http://digitalcommons.unl.edu/agronhortdiss

Part of the Agronomy and Crop Sciences Commons

http://digitalcommons.unl.edu/agronhortdiss/95

This Article is brought to you for free and open access by the Agronomy and Horticulture Department at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Theses, Dissertations, and Student Research in Agronomy and Horticulture by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.
IMPROVING ESTABLISHMENT OF SEEDED BUFFALOGRASS

by

Luqi Li

A THESIS

Presented to the Faculty of
The Graduate College at the University of Nebraska
In Partial Fulfillment of Requirements
For the Degree of Master of Science

Major: Agronomy
Under the Supervision of Professor
Zac Reicher
and
Keenan Amundsen

Lincoln, Nebraska

December 2015
Buffalograss \(\textit{Buchloë dactyloides} \) (Nutt.) Engelm. is a warm-season grass native to the North American Great Plains. Buffalograss is drought resistant, heat resistant and cold tolerant, and thus is well-adapted to many uses in areas that require low maintenance or erosion control. Since buffalograss is slow-growing, one challenge of establishing seeded buffalograss is to maximize seedling maturation and establishment before winter. We evaluated dormant seeding buffalograss in late fall and winter, when germination is not expected until soils warm in spring. We successfully dormant seeded ‘Sundancer’, ‘Bowie’ or ‘Cody’ buffalograss at 146 kg ha\(^{-1}\) from late November though late March, which allowed establishment before the following winter. Increasing seeding rate beyond 146 kg ha\(^{-1}\) had no effect on August buffalograss cover, regardless of seeding date.

Buffalograss burs are commercially KNO\(_3\)-treated and chilled to overcome dormancy. Our studies suggest commercial treatment of burs may not be necessary when dormant seeding, but should maximize germination when dormant seeding during exceptionally dry winters. Though established buffalograss can be maintained with minimal inputs, weed control is critical during the establishment period. We found the herbicides mesotrione, sulfentrazone, quinclorac, carfentrazone, simazine, amicarbazone, sulfentrazone + quinclorac, carfentrazone + quinclorac, or sulfentrazone + prodiamine applied either at seeding or at emergence were safe on ‘Bowie’ or ‘Sundancer’ buffalograss, effectively minimized weed pressure, and maximized buffalograss establishment.
For my parents, and Junsí
I could not have accomplished this without your support.
I would like to thank everyone that has helped me navigate though the most challenging period of my life and complete this master’s degree, and I would like to specifically thank Dr. Zac Reicher as my advisor as an undergraduate and graduate student. Zac corrected hundreds of tenses, singular or plural mistakes in my writing, and helped me improve my English. More importantly, he inspired and motivated me to pursue this master’s degree, and trained me to become a researcher. I would also like to thank my graduate committee members Dr. Keenan Amundson and Dr. John Lindquist who provided suggestions on my research, presentation and writing skills, and how to become a better scientist.

In my country, there are millions of students who would achieve a higher level of education if they could afford it. I was a lucky kid. My parents, Fan Li and Weiling Liu, provided me financial support that allowed me to spend all of my time on academics, without worrying about living expenses. I met Junsì Yang last year, who comes from my hometown Beijing and is pursuing her master’s degree in food science at the University of Nebraska-Lincoln. Studying abroad was a lonely journey until I met her and we always say to each other, “Together, we’ll go far”.

I also thank my graduate officemates Matt P., Darrell, Glen, Lacy, Collin, and Jesse, and all the staff, faculty and ‘turfies’ who have helped me. I could not have learned so much in culture, language, and technique without the help of all these people.

When I failed my first Intensive English Program test in the fall of 2008, I thought I wouldn’t make it and might have to go back home within months. Fortunately, I passed
everything else thereafter, and have just extended my legal presence in the United States until the end of 2020. None of my achievements would have happened without the endless patience and support from all of you.
TABLE OF CONTENTS

INTRODUCTION........................................................................................................ 1
CHAPTER ONE ........................................................................................................... 11
  CULTIVAR, SEEDING DATE OR SEEDING RATE HAVE LITTLE EFFECT ON SUCCESS OF DORMANT SEEDING OF BUFFALOGRASS
CHAPTER TWO ........................................................................................................ 24
  SEEDING DATE AND BUR TREATMENT AFFECTS SUCCESS OF DORMANT-SEEDED BUFFALOGRASS
CHAPTER THREE..................................................................................................... 42
  HERBICIDES APPLIED AT OR SHORTLY AFTER SEEDING ARE EFFECTIVE FOR WEED CONTROL IN SEEDING BUFFALOGRASS
INTRODUCTION

Overview

Buffalograss \textit{[Buchloë dactyloides (Nutt.) Engelm.]} is a warm-season grass native to the North American Great Plains (Wenger, 1943), adapted from central Montana to western Minnesota in the North, and western Louisiana, Texas, Arizona, and central Mexico in the South. Buffalograss is perennial, stoloniferous, and with light grayish-green color (Beard, 1973). Buffalograss is a C4 plant that is well-adapted in northern latitudes with 300 to 650mm annual precipitation (Turgeon, 1991). Buffalograss is drought and heat tolerant with a high degree of cold tolerance (Beetle, 1950; Briggs, 1914; Wenger, 1943), which allows it to successfully survive the coldest winters of the Northern Great Plains (Wenger, 1943). However, it cannot survive in dense shade in most landscape-planting environments (Beetle, 1950; Huff and Wu, 1987). Buffalograss is used in areas that require low maintenance, or control of erosion from wind or water (Wenger, 1941; Wenger, 1943). However, additional establishment and management requirements, especially weed control, are required to maintain high quality stands in areas with higher than 500 mm rainfall (Shearman et al., 2004).

Historically, non-turf-type buffalograss is slow to establish when established from seed (Wenger, 1943; Pozarnsky, 1983). However, recently developed turf-type cultivars can be established within the first growing season (Shearman et al., 2004). Therefore, establishment and management recommendations from the 1930s and 1940s may not be applicable to newer turf type cultivars developed for turfgrass use (Savage, 1934; Wenger, 1943; Shearman et al., 2004).
**Taxonomy and Morphology**

Buffalograss is a member of the Chlorideae tribe and the only member of the genus *Buchloë* (Hitchcock, 1951). Buffalograss is dioecious with strikingly different staminate and pistillate plants (Chase, 1977). The staminate plants were originally classified as *Sesleria dactyloides* (Nutt.), and pistillate plants were classified as *Antephora axilliflora* (Steud.)(Beetle, 1950; Quinn, 1991; Huff and Wu, 1992). Buffalograss was reclassified as *Buchloë dactyloides* (Nutt.) Englem. due to the similarity of morphological characteristics between the staminate and pistillate plants (Hitchcock, 1951; Quinn, 1991). Based on phylogenetic estimates, Columbus (1999) reclassified buffalograss as *Bouteloua dactyloides* (Nutt.) J.T. Columbus. However, Shearman et al. (2004) indicated that little information about materials and methods were presented in Columbus’ reclassification, and suggested the use of ribosomal and chloroplast DNA sequences could be useful for taxonomically characterizing buffalograss. More research is needed before reclassification is justified. Therefore, we are using *Buchloë dactyloides* (Nutt.) Englem in this thesis.

Buffalograss leaves are grey-green in color and turn to a purplish-red hue in fall with cool nights (Beetle, 1950; Wenger, 1943). One to three spicate are found in elevated panicles in staminate plants. Culms range from 5 to 25 cm above the foliage canopy, with 5 to 10 mm long primary-unilateral branches. The membranous ligule at the collar region, is surrounded by a fringe of hairs 1 to 2 mm long and leaf blades have pubescence on surface and margins. Pistillate plants form a 3 to 8 mm wide, bur-like spike inflorescence on a short culm within the foliage canopy. The pistillate inflorescence contains three to
five spikelets and mature burs usually contain one to four caryopses (Shearmen et al., 2004).

Seed Germination and Establishment

Buffalograss burs contain oils that likely serve as a mechanism to delay germination in unfavorable conditions (Ahring and Todd, 1977). Wenger (1941) improved germination by 35% by soaking two-year old buffalograss seed in tap water for up to four days, which were dried before seeding. Wenger (1943) further observed buffalograss seed soaked in potassium nitrate (KNO₃) solution followed by six weeks of chilling at 5°C reduced seed dormancy and enhanced germination. Fry et al. (1993) found KNO₃-treated and chilled burs had 30% more emergence than untreated burs two weeks after seeding. However, treated burs reached complete ground cover only one week sooner than untreated burs in this study, likely due to aggressive spreading by stolons. Gaitan-Gaitan et al. (1998) and Riordan et al. (1997) reported more rapid establishment using deburred caryopses compared to intact burs. However, the deburring process is expensive and not readily available throughout the industry (Harivandi and Wu, 1995). Therefore, most buffalograss stands are seeded with burs that are KNO₃-treated and chilled (Fry, 1995).

Optimal seeding rates may vary among cultivars of buffalograss, and seeding rate recommendations often conflict with each other. For instance, Gaitan-Gaitan et al. (1999) recommended seeding ‘Texoka’ and ‘Comanche’ at 177 kg ha⁻¹, whereas Riordan et al. (1997) recommended seeding ‘Hays’ at 98 kg ha⁻¹. Shearman et al. (2005) tested the
later-developed turf-type cultivar ‘Bowie’, suggesting seeding rates at 200 to 400 kg ha\(^{-1}\) for rapid establishment when seeded in July. Shearman et al. (2005) indicated that buffalograss quality ratings increased linearly with increased seeding rate during the first growing season, but with little or no difference in quality ratings for seeding rates \(\geq 100\) kg ha\(^{-1}\) in the following season.

Established buffalograss requires relatively low rates of nitrogen to achieve high quality stands (Frank et al., 2002). Frank et al. (2002) tested the effects of nitrogen, phosphorus and potassium on establishment of seeded buffalograss in Nebraska, Kansas, and Oklahoma. The experiments indicated that N fertilizer applications up to 147 kg ha\(^{-1}\) year\(^{-1}\) hastened establishment in Kansas. Application of P improved buffalograss establishment in Nebraska due to low pre-plant soil levels of P, and in Oklahoma due to competition for P from African bermudagrass. Applications of K at planting did not affect buffalograss establishment, likely due to adequate pre-planting soil levels at the three sites.

Most research on optimal planting date of buffalograss has been initiated in the late spring because buffalograss seeds will not germinate at temperatures \(<16^\circ C\) (Leuthold, 1982). Wenger (1941) reported successful stand establishment with planting dates from 10 April to 15 June in Hays, KS. Planting from April 10 to 20 provided the best plant establishment in undisturbed soils, while planting prior to 15 May resulted in adequate establishment on fallow and cultivated soils in Hays. Leuthold et al. (1991) found late summer plantings often failed to survive the winter, while early spring plantings were subject to frost damage at Manhattan, KS. Fry et al. (1993) tested the effect of seeding dates on buffalograss coverage in 1991 and 1992 in Manhattan, Kansas.
In this study, water soaked ‘Sharp’s Improved’ buffalograss burs seeded in May, June, or July reached full coverage seven weeks after seeding (WAS) in 1991. In 1992, more than 95% coverage was observed 9 WAS when buffalograss burs were seeded in June or July, whereas seeding in April or May in the same year required 13 weeks to reach complete coverage. Seeding in August exhibited < 25% coverage by the end of first growing season. Frank et al. (1998) tested optimal buffalograss seeding dates and growing degree day requirements for ‘Cody’ and ‘Texoka’ buffalograss establishment when both cultivars were seeded at 100 kg burs ha\(^{-1}\) from April through October at Mead, NE and at Logan, UT. They suggested the optimal seeding time for buffalograss in Nebraska was late April through June and late April through July in Utah. In the same study, seeding in August through October at both sites did not result in successful stands. Gaitan-Gaitan et al. (1998) indicated that successful establishment of seedling buffalograss results from planting from mid-May to late August with either burs or caryopses in Lubbock, TX.

*Herbicide Tolerance*

Although buffalograss requires minimal inputs once established, high weed pressure during the first year can greatly reduce turfgrass quality and affect density for several years (Goss et al., 2006). Huffman and Jacoby (1984) reported that buffalograss seed germination was not affected by chlopyralid applied preemergence at rates up to 9.0 kg ha\(^{-1}\). Preemergence application of imazethapyr at 0.07 kg ha\(^{-1}\) provides acceptable control of annual grass and broadleaf weeds with minor injury to seedling buffalograss (Fry et al., 1997).
Dithiopyr (0.6 kg ha⁻¹), DCPA (11.8 kg ha⁻¹), pendimethalin (2.2 kg ha⁻¹), siduron (13.4 kg ha⁻¹), oryzalin (1.7 kg ha⁻¹), and benefin (1.1 kg ha⁻¹) + oryzalin (1.1 kg ha⁻¹) applications at seeding reduced the number of buffalograss seedlings at four weeks after seeding. Imazethapyr (0.07 kg ha⁻¹), simazine (1.1 kg ha⁻¹), pronamide (1.1 kg ha⁻¹), prodiamine (0.8 kg ha⁻¹), benefin (1.7 kg ha⁻¹), bensulide (8.4 kg ha⁻¹), oxadiazon (2.2 kg ha⁻¹), and benefin + oryzalin applications at seeding caused minor buffalograss injury at 12 weeks after application (Fry et al., 1997). Goss et al. (2006) evaluated the tolerance of newly-seeded ‘Cody’ buffalograss to various pre- and postemergence herbicides in Arkansas and Nebraska, and reported adequate seedling tolerance to a majority of the herbicides labelled for use on other warm-season grasses, including benefin, simazine, oxadiazon, prodiamine and bensulide.

Dotray and McKenney (1996) reported established ‘Comanche’ buffalograss had acceptable tolerance to benefin (3.4 kg ha⁻¹), benefin + oryzalin ((1.7 +1.7 kg ha⁻¹), benefin + trifluralin (2.3+1.1 kg ha⁻¹), DCPA (16.8 kg ha⁻¹), dithiopyr (0.6 kg ha⁻¹), isoxaben (1.1 kg ha⁻¹), oryzalin (2.2 kg ha⁻¹), pendimethalin (3.4 kg ha⁻¹), and prodiamine (1.7 kg ha⁻¹) , while atrazine (2.2 kg ha⁻¹), diuron (2.8 kg ha⁻¹), metolachlor (4.5 kg ha⁻¹), and simazine (2.2 kg ha⁻¹) caused injury up to 15 weeks after application. In the same study, on newly-seeded ‘Comanche’ buffalograss, dicamba applied within 24 hours of seeding reduced cover by up to 100% at 4 WAT and up to 85% at 16 WAT compared to the untreated control. Dyke and Johnson (2009) reported tolerance of five-year old ‘Cody’ buffalograss to several post-emergence herbicides applied at the highest labeled rates, including 2,4-D + mecoprop + dicamba (25.93% + 6.93% + 2.76%), carfentrazone-ethyl + 2,4-D + mecoprop-p + dicamba (0.62% + 28.5% + 5.88% + 1.71%), and 2,4-D
(46.4%) applied at 0.05 kg ha\(^{-1}\), sulfentrazone + 2,4-D + mecoprop-p + dicamba (0.67% + 18.79% + 6.80% + 3.02%) applied at 0.02 kg ha\(^{-1}\), and triclopyr + clopyralid (33.0% + 12.1%) applied at 0.02 kg ha\(^{-1}\). Dyke and Johnson (2009) also indicated that temperatures exceeding 27°C did not cause significant damage to buffalograss in the Utah study as suggested in other reports (Fry et al., 1997; Goss et al., 2006).

Goss et al. (2006) summarized the research up to 2004 on herbicides for use in seedling buffalograss and created useful recommendations for practitioners. However, numerous herbicides have been introduced since then with documented seedling safety in cool-season grasses, and it is important to evaluate the feasibility of these newer herbicides applied over newer cultivars of buffalograss.
Literature Cited


CHAPTER ONE

CULTIVAR, SEEDING DATE OR SEEDING RATE HAVE LITTLE EFFECT ON SUCCESS OF DORMANT SEEDING OF BUFFALOGRASS

Abstract

Little information exists on dormant seeding of buffalograss [Buchloë dactyloides (Nutt.) Engelm.] in the Midwest and central Great Plains of the United States. The objectives of these two studies were to determine how seeding rate affects establishment of ‘Sundancer’ buffalograss when dormant seeded, and to evaluate if cultivar or seeding date affects establishment of ‘Cody’, ‘Bowie’ or ‘Sundancer’ buffalograss when seeded at various dates during the winter and spring. ‘Sundancer’ buffalograss was dormant seeded at 146, 244, or 293 kg ha$^{-1}$ in late November in 2012 and 2013 and spring-seeded in early May in 2013 and 2014. Dormant seeding of buffalograss resulted in >80% cover by the following August in all studies. Increasing seeding rate had no effect on establishment of ‘Sundancer’, regardless of seeding date. Furthermore, there was no difference in turf cover by August following seeding of ‘Sundancer’, ‘Bowie’ or ‘Cody’ at 146 kg ha$^{-1}$ in late Nov., Jan., Mar., or May regardless of seeding date. Our results suggest that ‘Sundancer’, ‘Bowie’ or ‘Cody’ can be successfully dormant seeded at 146 kg ha$^{-1}$ from late November though late March, which allows establishment before the following winter.

Introduction

Buffalograss is a warm-season grass native to the Great Plains of North America (Wenger, 1943), and is commonly established from burs, each containing three to five
caryopses (Beard, 1973; Quinn, 1983; Riordan et al, 1993). Most buffalograss is commercially treated with KNO$_3$ followed by chilling to overcome dormancy (Fry, 1995), which increases germination from 10% to 80% (Riordan et al., 1997).

Optimum spring seeding dates for buffalograss have been determined at various locations in the U.S. In Kansas, the optimal date of planting was April to May for ‘Sharp’s Improved’ buffalograss (Fry, 1993). In Colorado, fastest establishment of ‘Sharp’s Improved’ buffalograss occurred with seeding in late May (Falkenberg, 1982). Successful establishment resulted sixteen weeks after seeding when ‘Cody’ buffalograss was seeded from late April through June in Nebraska and late April through July in Utah, but not when seeded in August, September or October at either site (Frank et al., 1998).

Optimal seeding rates may vary among cultivars of buffalograss and seeding rate recommendations often conflict with each other. For instance, Gaitan-Gaitan et al. (1999) recommended seeding ‘Texoka’ and ‘Comanche’ at 177 kg ha$^{-1}$, whereas Riordan et al. (1997) recommended seeding ‘Hays’ at 98 kg ha$^{-1}$. Shearman et al. (2005) tested the later-developed turf-type cultivar ‘Bowie’, suggesting seeding rates at 200 to 400 kg ha$^{-1}$ for rapid establishment when seeded in July.

Seeding rate recommendations can also vary depending on the time of seeding. Dormant seeding is defined as seeding late enough in the fall or winter so germination is not expected until soils warm in spring. Dormant seeding is commonly used throughout the Midwest and northern Great Plains of the United States for establishing cool-season turfgrasses, but dormant seeding of buffalograss has not been evaluated. Green et al. (1974) summarized the suitability of cool- and warm-season species for dormant winter seeding, suggesting higher seeding rates should be used for dormant seeding of cool-
season grasses to achieve better vegetative cover and to reduce seed loss via winter erosion. In their study, seeding roughstalk bluegrass (*Poa trivialis* L.) 605 kg ha\(^{-1}\) increased vegetative cover by 58% compared to seeding at 67 kg ha\(^{-1}\) when rated four months after germination. Moreover, seeding creeping red fescue (*Festuca rubra* L.) at 538 kg ha\(^{-1}\) increased cover by 63% compared to 45 kg ha\(^{-1}\), and seeding perennial ryegrass (*Lolium perenne* L.) at 538 kg ha\(^{-1}\) increased cover by 72% compared to seeding at 45 kg ha\(^{-1}\). In the same study, the warm-season bermudagrass (*Cynodon dactylon* (L.) Pers.) or weeping lovegrass (*Eragrostis curvula* (Schrad.) Nees) did not establish acceptable stands when dormant seeded, regardless of seeding rate. However, most recent work using improved cultivars of common bermudagrass, such as ‘Princess-77’, ‘Riviera’ and ‘Yukon’, showed that dormant seeding can be successful (Richardson et al., 2004; Shaver et al. 2006).

Seeding rate and date recommendations for dormant seeding of buffalograss were not evaluated in any of the previous studies. Our first objective was to determine how seeding rate affects establishment of ‘Sundancer’ buffalograss when dormant or spring seeded. Our second objective was to determine if cultivar or seeding date effects establishment of ‘Cody’, ‘Bowie’ or ‘Sundancer’ buffalograss when seeded at various dates during the winter and spring.

*Materials and Methods*

*Seeding rate and date study.* This study was conducted at the John Seaton Anderson Turfgrass Research Facility near Mead, NE, starting in late fall of 2012 and 2013 and continuing until the following August. This study was a 3 by 2 factorial with ‘Sundancer’
buffalograss seeded at three rates on two dates. Design was a randomized complete block with three replications and plots measuring 1.4 m by 1.8 m. Experimental areas were tilled to 10 cm and raked level before seeding. Commercially KNO$_3$-treated ‘Sundancer’ buffalograss from the same 2012 seed lot (95% viability) was seeded at 146, 244, or 293 kg ha$^{-1}$ in both years. Seeding dates were 20 November (± 2 days) for the dormant seeding and 1 May for the spring seeding. Following seeding, plots were lightly raked with a leaf rake to enhance seed-soil contact. Irrigation was initiated after the spring seeding on 1 May. All plots were irrigated two to four times daily after the May seeding with a total of 0.6 cm of irrigation until seedlings were in the 1-3 leaf stage, then 0.6 cm every other day as needed based on 100% replacement of ET. Starter fertilizer (11N-23P-0K) at 49 kg N ha$^{-1}$ was applied to all plots immediately after the spring seeding and again 30 days later. Mesotrione [2-[4-(methylsulfonyl)-2-nitrobenzoyl]-1,3-cyclohexanedione] was applied at 0.18 kg ha$^{-1}$ in the first week of May and first week of June in both years to control crabgrass and other annual weeds. Carfentrazone [2-chloro-3-[2-chloro-5-[4-(difluoromethyl)-3-methyl-5-oxo-1,2,4-triazol-1-yl]-4-fluorophenyl]propanoic acid] was applied at 0.04 kg ha$^{-1}$ in the first week and third week of June to control emerged broadleaf weeds. Areas were mowed at 6.4 cm weekly starting 18 June ± 2 days. Percentage cover of buffalograss was visually rated every two weeks from 22 May until 1 Aug ± 2 days in both years.

Data were first tested with Restricted Maximum Likelihood (Thompson, 1962; Patterson and Thompson, 1971) which found variance between years was heterogeneous. Therefore, variance for each year was modeled separately with PROC GLIMMIX in SAS (Version 9.3, SAS Institute Inc., Cary, NC), which allowed the ANOVA to be performed
over years (Little et al., 2006). Mean separation was performed using Fisher’s least significant difference at P <0.05.

*Cultivar and seeding date study.* This study was conducted adjacent to the previous study and started in late fall of 2013 and 2014. This study was a 3 by 4 factorial with three cultivars of commercially KNO$_3$-treated buffalograss (‘Sundancer’, ‘Bowie’ and ‘Cody’) seeded on four dates (22 November ± 2 days, 23 January, 23 March ± 1 days and 22 May ± 2 days). Design was a randomized complete block with three replications and plots measuring 1.4 by 1.8 m. ‘Sundancer’, ‘Bowie’, or ‘Cody’ were seeded at 146 kg ha$^{-1}$ with seed lots of 95%, 96% or 97% viability, respectively, and the same lot of each cultivar was also used in the second year of the study after storage at 0°C. Pre- and post-seeding management was consistent with the previous study, except irrigation was initiated on 22 May ± 2 days. Percentage cover of buffalograss was visually rated every two weeks from 5 June to 1 Aug ± 2 days when buffalograss cover in most plots reached >90%. Data analysis and mean separation were performed the same as the first study.

*Results and Discussion*

*Seeding rate and date study.* There was no effect of seeding rate on buffalograss cover at any time during this study, regardless of year or seeding date (Table 1). By the end of the study, all three seeding rates produced over 80% cover averaged over year and seeding dates. Green et al. (1974) recommend increasing the seeding rate when dormant seeding. Their studies showed improved cover within three months after germination when raising the seeding rate from 0.5X to 3X the recommended rate. However, there were few differences in cover at any time during their study between 1X and 3X the recommended
rate. Our results suggest that the currently recommended seeding rate of ‘Sundancer’ of 146 kg ha\(^{-1}\) is adequate and there is no need to increase seeding rates of buffalograss when dormant seeding under the conditions of our study. Conversely, our data bring into question if seeding rates lower than 146 kg ha\(^{-1}\) can be used successfully.

There were significant seeding date by year interactions in percent cover when rated from 5 June through 16 July (Table 1). May seeding dates in both years resulted in higher percent buffalograss cover than November seeding dates until 3 July of each year (Fig. 1). Seedlings from the November seeding in the second year were likely damaged by unseasonably cold weather occurring in the second week of May in 2014 when daytime lows were < 4°C for four consecutive days. In a companion study, 80% germination in a November seeding had occurred by 24 May (Li, 2015). Our results along with previous research suggest early dormant or early-spring plantings of buffalograss in the northern Great Plains are subject to frost damage (Leuthold et al., 1991). Regardless of the lower coverage of the November versus May seedings early in the study, all seeding dates produced equivalent cover (≥80%) by the final rating date. Our results with buffalograss are similar to those of dormant seeding bermudagrass (Richardson et al., 2004; Shaver et al. 2006). Our studies were maintained with adequate irrigation, fertility and weed control to encourage density, which may not be practical in all cases. The lower turf coverage from November versus May seedings may increase spring weed pressure requiring additional herbicide use by practitioners. A number of herbicide options now exist for weed control in seedling buffalograss, including mesotrione, sulfentrazone\(\text{N-[2,4-dichloro-5-[4-(difluoromethyl)-3-methyl-5-oxo-1,2,4-triazol-1-yl]phenyl]methanesulfonamide}\), quinclorac [3,7-dichloroquinoline-8-carboxylic
acid], carfentrazone, simazine [6-chloro-2-N,4-N-diethyl-1,3,5-triazine-2,4-diamine], amicarbazone [4-amino-N-tert-butyl-5-oxo-3-propan-2-yl-1,2,4-triazole-1-carboxamide], sulfentrazone + quinclorac, carfentrazone + quinclorac, or sulfentrazone + prodiamine [2,4-dinitro-N3, N3-dipropyl-6-(trifluoromethyl)-1,3-benzenediamine](Li et al., 2015).

*Cultivar and seeding date study*. Few differences in buffalograss cover due to cultivar were observed in this study, regardless of year or seeding date (Table. 2). Occasional differences in cover of cultivars between years were observed, but no meaningful trends were seen. Damage from cold weather in May 2014 mentioned in the first study did not occur in this study likely because irrigation was started two weeks later in this study and after the week of cold temperatures. Seeding date by year interactions were significant on four out of five rating dates, except the final rating on 1 Aug (Table. 2). November seeding resulted in the highest percent cover of buffalograss compared to the other three seeding dates in the first year of the study. November seeding reached 16% cover on 5 June 2014, whereas the other seeding dates produced <10% cover (Fig. 2). By 3 July 2014, November seeding reached 72% cover while the other seeding dates resulted in 44 to 52% cover. In 2015, the three dormant seeding dates of November, January, and March produced similar cover throughout the year and substantially higher than the May seeding date (Fig. 2). This was probably due to record precipitation in early June likely causing seed loss in the May seedings because little buffalograss had germinated and was anchored by roots before the rain events. Buffalograss requires about 15 days after planting to develop a root system (Gaitan-Gaitan, 1995) and there were only eight days between seeding and the rain events. However, there was no difference in
cover among the seeding dates when rated on 1 Aug, suggesting that buffalograss will fill in from lateral stolon growth regardless of the level of seedling success in early summer.

Our results suggest that ‘Sundancer’, ‘Bowie’ or ‘Cody’ can be successfully dormant seeded at 146 kg ha⁻¹ from late November though late March. Dormant seeding can allow for faster establishment, which can be critical with high weed pressure typical of spring seedings. However, a primary risk with dormant seeding of buffalograss is a period of warm spring weather that stimulates germination, only to be followed by cold temperatures that could kill seedlings, which is similar to risks of dormant seeding cool-season grasses (Green et al., 1974; Reicher et al., 2000). Though cold-temperature damage could slow establishment like in our study, our data suggest that buffalograss can still recover to 80% cover by the end of the first growing season. Based on results from our study and previous studies, seeding dates of buffalograss can be highly flexible. Our data show dormant seeding from late November through late March, while others report standard spring/summer seeding from late April through July should allow establishment before winter in the North Great Plains.
Literature Cited


Li, L. 2015. Improving establishment of seeded buffalograss. M.S. Thesis, University of Nebraska-Lincoln, Lincoln, NE.


Table 1. Analysis of variance for percent cover of ‘Sundancer’ buffalograss when seeded in November 2012 or 2013, or in May 2013 or 2014 at 146, 244, or 293 kg ha$^{-1}$ rated once every two weeks from 22 May through 1 Aug.

<table>
<thead>
<tr>
<th></th>
<th>df</th>
<th>22 May</th>
<th>5 June</th>
<th>20 June</th>
<th>3 July</th>
<th>16 July</th>
<th>1 August</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year (Y)</strong></td>
<td>1</td>
<td>*</td>
<td>ns</td>
<td>ns</td>
<td>*</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td><strong>Seeding Date (SD)</strong></td>
<td>1</td>
<td>*</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>ns</td>
</tr>
<tr>
<td><strong>Rate (R)</strong></td>
<td>2</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td><strong>SD x R</strong></td>
<td>2</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td><strong>SD x Y</strong></td>
<td>1</td>
<td>ns</td>
<td>**</td>
<td>*</td>
<td>***</td>
<td>***</td>
<td>ns</td>
</tr>
<tr>
<td><strong>R x Y</strong></td>
<td>2</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td><strong>SD x R x Y</strong></td>
<td>2</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

*, **, *** and ns denote significance at p=0.05, 0.01, and 0.001, and not significant, respectively.

Table 2. Analysis of variance for percent cover of ‘Sundancer’, ‘Bowie’ or ‘Cody’ buffalograss when seeded on third week of November, January, March or May and rated every two weeks during the growing season.

<table>
<thead>
<tr>
<th></th>
<th>df</th>
<th>5 June</th>
<th>18 June</th>
<th>3 July</th>
<th>16 July</th>
<th>1 August</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year (Y)</strong></td>
<td>1</td>
<td>***</td>
<td>ns</td>
<td>ns</td>
<td>***</td>
<td>ns</td>
</tr>
<tr>
<td><strong>Cultivar (C)</strong></td>
<td>2</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td><strong>Seeding date (SD)</strong></td>
<td>3</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>ns</td>
</tr>
<tr>
<td><strong>C x SD</strong></td>
<td>6</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td><strong>C x Y</strong></td>
<td>2</td>
<td>ns</td>
<td>*</td>
<td>*</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td><strong>SD x Y</strong></td>
<td>3</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>ns</td>
</tr>
<tr>
<td><strong>C x SD x Y</strong></td>
<td>6</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

*, **, *** and ns denote significance at p=0.05, 0.01, and 0.001, and not significant, respectively.
Figure 1. Percent cover of ‘Sundancer’ buffalograss in 2013 or 2014 rated on 22 May though 1 Aug. ‘Sundancer’ were seeded in November or May at 146, 244, or 293 kg ha$^{-1}$. Means are over three replications and three seeding rates. Mean separation was performed using Fisher’s least significant difference at P < 0.05. Statistical differences (P=0.05) between dates are indicated by asterisks.
Figure 2 Percent cover of buffalograss rate on 5 June, 18 June, 3 July, 15 July or 1 Aug in 2014 or 2015 when seeded on third week of November, January, March or May in 2013 through 2014 or 2014 through 2015. Means with a different letter are significantly different at P = 0.05. Means are over three replications and three cultivars. Mean separation was performed using Fisher’s least significant difference at P < 0.05. Statistical differences (P=0.05) between dates are indicated by LSD bars.
CHAPTER TWO

SEEDING DATE AND BUR TREATMENT AFFECTS SUCCESS OF DORMANT-SEEDED BUFFALOGRASS

Abstract

Dormant seeding is commonly used for establishing cool-season turfgrasses, but little information exists on dormant seeding of buffalograss [Buchloë dactyloides (Nutt.) Engelm.] in the Midwest and northern Great Plains of the United States. The objective of these studies were to determine the effect of commercial KNO₃ seed treatment on ‘Cody’ buffalograss germination when seeded at various dates in winter and spring. ‘Cody’ buffalograss burs that were either commercially treated or untreated were seeded in the third week of November, January, March or May and cover rated through the following August. Dormant seeding in November, January, or March was as effective as seeding at the traditional May timing. Commercial treatment of burs may not be necessary when dormant seeding in November, but maximized buffalograss germination following exceptionally dry winters. In a second study, buffalograss burs from the same source as the initial study were buried in mesh packets in the field in the third week of each month from November through April. All packets were transferred to a greenhouse in May to test germination. Commercially treated burs resulted in consistently higher cumulative germination regardless of seeding date. Furthermore, cumulative germination data agreed with establishment study data that dormant seeding of buffalograss in November can be as effective as traditional May seeding.
**Introduction**

Buffalograss is a warm-season grass native to the Great Plains of North America (Wenger, 1943), ranging from Mexico to Canada (Beetle, 1950; Reeder, 1971). Buffalograss is commonly established from burs containing three to five caryopses (Wenger, 1940; Beard, 1973; Quinn, 1987; Riordan et al., 1993). Buffalograss burs likely serve as a mechanism to delay germination in unfavorable conditions, and reduces germination by as much as 47% compared to deburred caryopses (Ahring and Todd, 1977).

A number of research projects were conducted to improve germination of buffalograss burs. Wenger (1941) improved germination by 35% over untreated burs by soaking buffalograss burs in tap water for up to four days followed by drying. Ensuing studies showed buffalograss burs treated in potassium nitrate (KNO₃) followed by a 6-week chilling at 5°C further reduced bur dormancy and enhanced germination (Wenger, 1943). Deburring buffalograss caryopses also speeds establishment over intact burs (Riordan et al., 1997; Gaitan-Gaitan et al., 1998), but deburring is expensive and not readily available commercially. Therefore, most buffalograss burs are commercially KNO₃-treated and chilled to overcome dormancy (Fry, 1995). The commercial KNO₃ and chilling treatment process adds approximately $1.10 to $1.90 US to the cost per kilogram of turf-type buffalograss burs (David Stock, personal communication, 2015). In addition, the chilling treatment takes four to six weeks competing for cold storage space that could be used to process other seeds.

Optimum spring seeding dates for buffalograss have been evaluated at various locations in the United States. Early spring plantings in the northern Great Plains are
subject to frost damage, while late summer through fall planting often result in unsuccessful stands due to poor establishment before winter (Leuthold et al., 1991; Frank et al., 1988). Current recommendations include seeding from April through June in Nebraska and late April through July in Utah (Falkenberg, 1982; Fry et al., 1993).

Dormant seeding buffalograss has not been evaluated like in cool-season turf (Reicher et al., 2000). Dormant seeding is defined as seeding late enough in the fall or winter that germination will not be expected until soils warm in spring. Since buffalograss burs will not germinate at temperatures below 16°C (Leuthold, 1982), there is little risk of germination during brief warm periods in winter or early spring followed by cold temperatures killing the seedlings. The objective of these studies was to determine the effect of commercial KNO₃ seed treatment on ‘Cody’ buffalograss germination and establishment when seeded at various dates in winter and spring.

**Materials and Methods**

**Establishment study:** This study was conducted at John Seaton Anderson Turfgrass Research Facility near Mead, NE, starting in November of 2012, 2013 and 2014. Soil type was a Tomek silt loam (fine, smectitic, mesic Pachic Argiudolls) with pH 7.0, 5.1% organic matter and 53 ppm phosphorus. Experimental areas were tilled to a depth of 15 cm, compacted slightly with Brillion cultipacker (Marysville, KS) and raked level before seeding. Treatments were in a 2 by 4 factorial arrangement with two seed treatments (commercial seed treatment or no seed treatment) and four seeding dates (third week of Nov, Jan, March and May). ‘Cody’ buffalograss burs were harvested in August prior to seeding in each year from Stock Seed Farms in Murdoch, NE. each year after harvest,
burs from the same lot were either left untreated or commercially treated in a 0.5% by weight KNO₃/water solution for 24 hours, and then refrigerated at 5°C for 35 days. Burs were then dried for 48 hours to 12 ± 1% moisture. Initial seedings were on 21 Nov ± 2 days in each year. Plots were 1.4 m by 1.8 m plots with 0.5 m borders of perennial ryegrass (*Lolium perrenne* L.) seeded prior to the study to limit bur movement. Three replications were used each year in a randomized complete block design. All plots were seeded at 146 kg burs ha⁻¹ (94.65 – 99.86% pure live bur) and then raked in two directions to enhance seed-soil contact. Starter fertilizer (11N-23P-0K) was applied to all plots at 21 kg P ha⁻¹ immediately after the May seeding and again 30 ± 2 days later. Seedlings up to the 1-3 leaf stage were irrigated with a daily total of 0.6 cm of water when no precipitation was received, then 0.6 cm of irrigation was applied to older seedlings every other day based on evapotranspiration rates. Mesotrione [2-[4-(methylsulfonyl)-2-nitrobenzoyl]-1,3-cyclohexanedione] was broadcast at 0.18 kg ha⁻¹ in first week of May and first week of June in all three years to control crabgrass and other annual weeds. Carfentrazone [2-chloro-3-[2-chloro-5-[4-(difluoromethyl)-3-methyl-5-oxo-1,2,4-triazol-1-yl]-4-fluorophenyl]propanoic acid] was broadcast at 0.04 kg ha⁻¹ in first and third week of June to control emerged broadleaf weeds. Areas were mowed at 5 cm weekly starting 14 days after the May seeding. Percent cover of buffalograss was visually rated every two weeks from 20 June to 1 Aug + 2 days of each year.

*Bur germination study:* This study was initiated adjacent to the previous study with identical site preparation and maintenance. Treatments were arranged in 2 by 8 factorial with two bur treatments (commercial KNO₃-treated or no bur treatment) and eight
seeding dates (Nov through May). ‘Cody’ buffalograss burs from the same source as the establishment study were used. Three replications of 100 burs were placed in 7.5 by 7.5 cm packets of aluminum screen with 1.5 by 1.5 mm mesh and buried in soil to cover approximately 1 cm deep on 20th of Nov, and Dec, 2012, 2013, and 2014 and 20th of January ± 3 days, February, March and April in 2013, 2014 and 2015. On 23 May ± 1 day following seeding, packets were removed from the field and moved to greenhouse facilities at University of Nebraska-Lincoln in Lincoln, NE. Burs were removed from the packets, seeded in 10 x 10 x 7.6 cm flats containing growth media (Fafard FAF 3B 2.8 CF SOUTHERN, Burton, OH) and placed under a mist system delivering 0.25 cm water every 2 hours during the entire study. Two additional treatments were included each year as standards of treated or untreated buffalograss burs that were stored in 5°C cooler after harvest and seeded in greenhouse with the rest of the treatments. Temperatures ranged from 24-28 °C during the day and 18-24°C at night, and artificial light period was 5:00 to 21:00 at 145 μmol m⁻²s⁻¹. Germination was counted twice per week and germinated burs were removed after counting. Burs already germinated at transplanting were counted and removed immediately. No new germination was observed beyond second week of July, thus germination counts ended on Aug 1 of all three years.

Data from both establishment and bur germination studies were analyzed the same. Data were first tested with Restricted Maximum Likelihood (Thompson, 1962; Patterson and Thompson, 1971) showing the variance among years was heterogeneous. Therefore, variance for each year was modeled separately with PROC GLIMMIX in SAS (Version 9.3, SAS Institute Inc., Cary, NC), which allowed the analysis of variance to be
performed over years (Little et al., 2006). Mean separation was performed using Fisher’s least significant difference at P <0.05.

Results and Discussions

Establishment Study: The highest order interactions that were statistically significant were seed date by bur treatment by year, which were significant on all four rating dates (Table 1). Few differences in percent cover were observed when rated 20 June, except low cover resulting from March untreated, May treated, or May untreated in 2015 compared to the other seeding dates and seed treatments in 2015 (Fig. 1). Rated 3 July, buffalograss seeded in November or January and the treated March seeding resulted in higher percent cover compared to March untreated, May treated, or May untreated burs in 2013 and 2015. Conversely in 2014, there were almost no differences in percent cover due to seeding date or seed treatment, with the highest cover on 16 July resulting from treated burs seeded in November or May.

On the final cover rating in August of 2013, all seeding dates and seed treatments produced >85% cover except the May-seeded untreated burs. Similar results were seen in 2015 with all treatments reaching > 80% cover by 1 August, except the May-seeded treated or untreated burs. Rated in August of 2014, treated burs seeded in May, November, or January produced the most cover (>65%), whereas the lowest cover resulted from untreated burs seeded in May or January.

Better performance by November and January seedings in 2012-13 and again in 2014-15 compared to 2013-14 could be explained by winter precipitation. Total precipitation between 20 Nov and 31 March in 2012-13 and 2014-15 was ≥ 93 mm, but
only 31 mm in the exceptionally dry winter of 2013-14 (High Plains Regional Climate Center, 2015). Winter precipitation combined with typical fluctuating temperatures in Nebraska could result in ice formation in and around the buffalograss bur, physically cracking the bur and breaking dormancy. These conditions would be typical of buffalograss grown in a native habitat. This would also help to explain the relative poor performance of March-seeded untreated burs that would have been exposed to less precipitation and fewer freeze-thaw cycles than early seedings. The poor germination following a dry winter may be an evolutionary adaptive mechanism for buffalograss, where germination is limited when soil moisture is low in winter and likely the following spring.

Rated in 2015, almost all seeding dates, regardless of bur treatment, produced higher percent cover compared to the May seedings. Record precipitation fell starting eight days after the May seedings, likely causing seed loss in the May seedings because buffalograss was not completely germinated and anchored by roots before the rain events. Buffalograss requires about 15 days after planting to develop a root system (Gaitan-Gaitan, 1995).

Our results suggest dormant seeding in November, January, or March can be as effective as traditional May seeding. Commercial KNO$_3$ and chilling treatment of burs may not be necessary when dormant seeding, but commercial seed treatment maximizes germination when dormant seeding during exceptionally dry winters. Anecdotal reports from seed producers suggest that effects of buffalograss bur treatment wear off with prolonged storage at ambient temperatures and burs require retreatment to maximize germination (Dave Stock, personal communication). Therefore, dormant seeding of
buffalograss stored for a prolonged period at ambient temperatures may allow adequate germination in the spring without the need for additional bur treatments. However, there was no decrease in germination rates of our standard treatments that were stored at 5°C for up to three years since the bur germination study (Fig. 2) and thus effects of bur treatment does not appear to wear off when stored in refrigerated conditions.

*Bur germination study:* The highest order significant interaction in final cumulative germination was the three way interaction of year by bur treatment by seeding date (Table 2). Untreated buffalograss burs seeded in November 2012 or 2014 produced similar cumulative germination as treated burs (Fig. 3). However, treated burs produced higher cumulative germination than untreated burs on the rest of the seeding dates in 2012-13 and 2014-15. Seeding in November likely allows buffalograss burs to undergo the maximum period of cold temperatures, temperature fluctuations, and freeze-thaw cycles, reducing bur dormancy, potentially by physically cracking the coating.

Similar to the results from the establishment study, treated burs produced higher germination than untreated burs on all of the seeding dates in 2013-14, suggesting the value of commercial seed treatments to overcome bur dormancy in exceptionally dry winters. Anecdotal information from buffalograss seed producers suggests buffalograss germination rates are variable due to the weather during the summer growing season of seed production. Though this could also help to explain the relatively low germination of buffalograss burs during 2013-14, the standard treatments that were not exposed to winter weather, showed no difference in germination rates regardless of the year of seed harvest (Fig. 4).
Untreated burs in 2013-14 produced <18% germination regardless of seeding date, which was lowest among the three years of the study (Fig. 3). Similarly, untreated burs in the 2013-14 establishment study produced less than 50% cover by the final rating date in August, the lowest in the three years of the study (Fig. 1). Combined, these results indicate that even though lateral stolon expansion occurs later in the growing season and helps buffalograss fill-in, successful buffalograss establishment is still highly dependent on bur germination rate.

Results of our studies justify the importance of commercial KNO₃ and chilling treatment, where treated burs resulted in consistently higher cumulative germination and cover regardless of seeding date. Cumulative germination data agree with establishment study data that November seeding of buffalograss can be as effective as May seeding. The dormancy mechanism of buffalograss is still largely unknown, but our results suggest cold, moist winter weather may help naturally break bur dormancy when dormant seeded. Previous research in cool-season grasses showed that cold, moist treatments mobilize carbohydrate (La Croix & Jaswal, 1967) and lipid reserves (Ross, 1984) in the seed embryo, but warm-season grasses were not tested. Adkins et al. (2002) summarized seed dormancy mechanisms in warm-season grass species, and suggested warm-season grass seeds have at least two locations for dormancy mechanisms. This includes mechanisms based within the embryo covering structures, including mechanical, permeability and chemical barriers to germination; and mechanisms based within the embryo, including gene expression, levels of certain plant growth regulator, activity of respiratory pathways or mobilization of food reserves (Adkins et al., 2002). Our results cannot identify if reduced bur dormancy as a result of dormant seeding was due to
physical cracking of the bur or due to chemical or biological reactions within the embryo.

Future studies may focus on if cold, moist treatment can affect such dormancy mechanisms in buffalograss or other warm season grasses.
Literature Cited


Table 1. Analysis of variance for percent cover of ‘Cody’ buffalograss from 18 June through 1 Aug in 2013, 2014, or 2015. Buffalograss burs from the immediately previous harvest were seeded in the field on third week of each month from November through April, 2012-13, 2013-14, or 2014-15.

<table>
<thead>
<tr>
<th></th>
<th>df</th>
<th>18-Jun</th>
<th>3-Jul</th>
<th>16-Jul</th>
<th>1-Aug</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year (Y)</td>
<td>2</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Bur treatment (BT)</td>
<td>1</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Seeding date (SD)</td>
<td>3</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>**</td>
</tr>
<tr>
<td>BT x SD</td>
<td>3</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>BT x Y</td>
<td>2</td>
<td>ns</td>
<td>Ns</td>
<td>ns</td>
<td>**</td>
</tr>
<tr>
<td>SD x Y</td>
<td>6</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>BT x SD x Y</td>
<td>6</td>
<td>**</td>
<td>**</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

*, **, *** and ns denote significance at p=0.05, 0.01, and 0.001, and not significant, respectively.
Table 2. Analysis of variance for cumulative germination of ‘Cody’ buffalograss when seeded from November through April, 2012-13, 2013-14, or 2014-15. Buffalograss burs from the immediately previous harvest were buried in aluminum screen packets in the field from November through following April. Packets were transferred into a greenhouse to test germination.

<table>
<thead>
<tr>
<th>Effect</th>
<th>df</th>
<th>Cumulative germination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year (Y)</td>
<td>2</td>
<td>*</td>
</tr>
<tr>
<td>Seeding date (SD)</td>
<td>5</td>
<td>***</td>
</tr>
<tr>
<td>Bur treatment (T)</td>
<td>1</td>
<td>***</td>
</tr>
<tr>
<td>SD x T</td>
<td>5</td>
<td>***</td>
</tr>
<tr>
<td>SD x Y</td>
<td>10</td>
<td>***</td>
</tr>
<tr>
<td>T x Y</td>
<td>2</td>
<td>***</td>
</tr>
<tr>
<td>SD x T x Y</td>
<td>10</td>
<td>***</td>
</tr>
</tbody>
</table>

*, **, *** and ns denote significance at p=0.05, 0.01, and 0.001, and not significant, respectively.
Figure 1. Percent cover of ‘Cody’ buffalograss after seeding untreated (UT) or commercially treated (TR) burs in the third week of November, January, March or May. Means are over three replications in each of the three years and bars represent LSD (0.05).
Figure 2. Cumulative bur germination on 1 Aug in 2013, 2014, or 2015. ‘Cody’ buffalograss burs harvested in 2012 were either untreated or commercially KNO₃-treated and stored at 5°C before seeding flat in the greenhouse on 22 May ± 1 day in 2013, 2014, or 2015. Germination means with a different letter are significantly different at P = 0.05. Means are over three replications in each year.
Figure 3. Cumulative bur germination on 1 Aug in 2013, 2014, or 2015. ‘Cody’ buffalograss burs harvested the season immediately prior to seeding were either untreated or commercially KNO₃-treated. One hundred burs per treatment were buried monthly in soil to cover from November through April, and then transferred to a greenhouse in May to test germination. Germination means within each year with a different letter are significantly different at P = 0.05. Means are over three replications in each of the three years.
Figure 4. Cumulative bur germination on 1 Aug in 2015. ‘Cody’ buffalograss burs harvested the season immediately prior to seeding were either untreated or commercially KNO$_3$-treated. One hundred burs per treatment were directly seeded into greenhouse flat on 24 May in 2015 to test germination. Germination means with a different letter are significantly different at P = 0.05. Means are over three replications in each of the harvest years.
CHAPTER THREE

HERBICIDES APPLIED AT OR SHORTLY AFTER SEEDING ARE EFFECTIVE FOR WEED CONTROL IN SEEDING BUFFALOGRASS


Abstract

Herbicides applied shortly after seeding of buffalograss [Buchloë dactyloides (Nutt.) Engelm.] can help reduce weed pressure and maximize establishment of buffalograss. This study evaluated 12 relatively recently developed herbicides for turf safety and weed control when applied at seeding or zero or two weeks after emergence (WAE) of ‘Bowie’ or ‘Sundancer’ buffalograss. Primary weed species on the site were common purslane (Portulaca oleracea L.), redroot pigweed (Amaranthus retroflexus L.), and/or yellow foxtail (Setaria lutescens L.). Regardless of cultivar, untreated checks had <15% buffalograss cover and >53% weed cover by 6 WAE, while most of the herbicide treatments resulted in >80% buffalograss cover and <20% weed cover. Mesotrione, sulfentrazone, quinclorac, carfentrazone, simazine, amicarbazone, sulfentrazone + quinclorac, carfentrazone + quinclorac, or sulfentrazone + prodiamine applied either at seeding or 0 WAE are safe on ‘Bowie’ or ‘Sundancer’ buffalograss, effectively minimize weed pressure, and maximize buffalograss establishment. Herbicides applied at 2 WAE were less effective than earlier applications at minimizing weed pressure and resulted in lower buffalograss establishment.
Introduction

Buffalograss \textit{[Buchloë dactyloides} (Nutt.) Engelm.] is a warm-season grass native to the North American Great Plains (Wenger, 1943). Buffalograss requires low inputs after establishment with its relatively low growth habit, drought tolerance, and natural competitiveness (Browning et al, 1994; McCarly and Colvin, 1992; Qian et al, 1997; Wenger, 1941; Wenger, 1943).

Previous reports suggest differential herbicide tolerance among buffalograss cultivars as well as differences in the ability of individual cultivars to recover from initial damage. Five out of 13 postemergence herbicides caused significant injury to ‘Sharp’s Improved’ buffalograss one or two weeks after treatment when applied at 1-3 leaf or 2-4 tiller stage, and four of these herbicides are phenoxy or benzoic acid herbicides (Fry and Upham, 1994). However, damaged buffalograss recovered from the early injury by six weeks after treatment (WAT). On newly-seeded ‘Comanche’ buffalograss, the benzoic acid herbicide dicamba applied within 24 hours of seeding reduced cover up to 100% at 4 WAT and up to 85% at 16 WAT compared to the untreated control (Dotray and McKeney, 1996). Goss et al. (2006) evaluated the tolerance of newly-seeded ‘Cody’ buffalograss to various pre- and postemergence herbicides in Arkansas and Nebraska, and reported adequate seedling tolerance to a majority of the herbicides labelled for use on other warm-season grasses, including benefin, simazine, oxadiazon, pendimethalin, prodiamine, and bensulide. Pendimethalin and prodiamine did not cause injury to ‘Cody’ buffalograss (Goss et al., 2006). However, seedling injury occurred in Sharps Improved buffalograss with the same herbicides, and was not able to recover in similar studies at the same location in NE (Fry et al., 1997).
Goss et al. (2006) summarized the research up to 2004 on herbicides for use in seedling buffalograss and created useful recommendations for practitioners. However, numerous herbicides have been introduced since then with documented seedling safety in cool-season grasses, and it is important to evaluate the feasibility of these newer herbicides applied over newer cultivars of buffalograss. Our objective was to evaluate 12 herbicides for turf safety and weed control when applied at or shortly after seeding of ‘Bowie’ or ‘Sundancer’ buffalograss.

**Materials and Methods**

Research was conducted at the John Seaton Anderson Turfgrass Research Facility near Mead, NE, in 2012 and 2013. Soil type was a Tomek silt loam (Fine, smectitic, mesic Pachic Argiudolls) with pH 6.5, 4.1% organic matter and 103 ppm phosphorus. Experimental areas were tilled to 10 cm, compacted slightly with the Brillion culti-packer (Marysville, KS) and raked level before seeding. ‘Bowie’ or ‘Sundancer’ buffalograss was seeded in separate but immediately adjacent areas at 146 kg pure live burs ha\(^{-1}\) on 23 May 2012 and 24 May 2013. Following seeding, plots were lightly raked with a leaf rake to maximize seed-soil contact and starter fertilizer (11-52-0) was applied at 48.8 kg P\(_2\)O\(_5\) ha\(^{-1}\). All plots were irrigated two to four times daily based on ET with a total of 0.6 cm of water per day until seedlings were in 1-3 leaf stage, then 0.6 cm applied every other day as needed based on ET. Areas were mowed at 5 cm weekly with a 53 cm walk behind rotary mower (John Deere jx85). Urea (46-0-0) was applied at 24.4 kg N ha\(^{-1}\) on 23 May, 20 June, and 18 July 2012; and 24 May, 22 June, and 19 July 2013. Primary weed species on the site were common purslane (Portulaca oleracea L.) and redroot pigweed
(Amaranthus retroflexus L.) in 2012, and redroot pigweed and yellow foxtail (Setaria lutescens L.) in 2013.

Treatments were arranged in a randomized complete block with three replications of 1.5 m by 1.5 m plots. A 3 X 12 factorial design was used with three application timings and 12 herbicides plus an untreated check. Herbicides were applied using a CO2-powered backpack sprayer at 30 psi in 800 L ha\textsuperscript{-1} through a spray boom with three 8002VS flat fan nozzles (TeeJet Spraying Systems, Wheaton, IL) (Table 2-1). Application timings were at seeding (AS), at emergence (0 WAE), and two weeks after emergence (2 WAE). Emergence was defined as 50% emergence in the control plots. Buffalograss was in the one-to-two leaf stage by 0 WAE and two-to-three leaf stage by the 2 WAE application. Application dates were on 23 May 2012 and 24 May 2013 (AS), 13 June in 2012 and 2013 (0 WAE), and 26 June in 2012 and 2013 (2 WAE). Percent cover of buffalograss or weeds was rated visually every two weeks through 6 WAE. Data were analyzed as a general linear model, which assumes homogeneous variance. Variance between years was heterogeneous, thus variances were fit separately for each year using PROC GLIMMIX in SAS (Version 9.3, SAS Institute Inc., Cary, NC). Analysis of variance was performed over years to determine the main and interaction effects. Mean separation was performed using Fisher’s least significant difference at P < 0.05. The untreated check was not included in the factorial analysis, but those means are presented for reference.

Results and Discussion
Though weed and buffalograss cover were recorded throughout the study, we will focus on the final cover data at 6 WAE for brevity. All data presented are pooled over years. Occasionally, interactions between year occurred (Table 2-2), and these were likely due to the warmer spring of 2012 versus 2013 (Fig. 2-1) speeding maturation of buffalograss and decreasing weed pressure.

When rated at 2 WAE, few herbicides applied at seeding or at emergence inhibited buffalograss establishment, and the majority of treatments resulted in > 20% cover (data not shown). The exceptions were imazapic, prodiamine or sulfentrazone + prodiamine applied AS, which resulted in < 10% cover of both ‘Bowie’ and ‘Sundancer’, and imazapic, simazine, amicarbazone or mesotrione applied 0 WAE, which resulted in < 15% cover (data not shown). The damage caused by prodiamine was similar to that reported by Fry et al., (1997) on ‘Sharp’s Improved’ buffalograss with a higher rate at the same location in NE. There were no differences in weed cover at 2 WAE (3 – 30%, data not shown) among the treatments, and thus differences in buffalograss cover due to herbicides were primarily due to herbicide injury. Though no differences in weed cover were detected due to herbicides, it is important to note that weed cover in the untreated check was double that in the worst-performing herbicide treatment. Herbicide use at or shortly after seeding of buffalograss can reduce weed competition early in the establishment phase increasing the chances for seeding success.

Seven herbicides applied AS and five herbicides applied 0 WAE resulted in the highest cover of ‘Bowie’ at 6 WAE (Fig. 2-2). However, none of the herbicides applied 2 WAE were in the top-performing statistical group suggesting again the importance of weed control at or shortly after seeding. Mesotrione, sulfentrazone + quinclorac,
sulfentrazone, simazine, amicarbazone, quinclorac or carfentrazone applied AS resulted >72% cover of ‘Bowie’ (Fig. 2-2), and 2-25% weed cover (Fig. 2-3). Low cover (<10% at 2WAE) caused by AS application of prodiamine or imazapic remained low at 6 WAE (<45%), but the low cover at 2WAE caused by sulfentrazone + prodiamine also applied AS reached 63% by 6 WAE. When applied 0 WAE, sulfentrazone + quinclorac, sulfentrazone, quinclorac, carfentrazone + quinclorac, or sulfentrazone + prodiamine also produced >72% buffalograss cover (Fig. 2-2), and <20% weed cover rated at 6 WAE (Fig. 2-3). Our results agree with previous research where treatments that produce the highest turf cover at 6 WAE also reduced weed cover the most (Gannon et al., 2004).

There were few differences in ‘Bowie’ cover among the herbicides applied at 2 WAE, but averaged over herbicides, this application timing produced the lowest buffalograss cover, probably due to weed competition.

In ‘Sundancer’ rated at 6 WAE, the top performing treatments included five herbicides applied AS, three herbicides applied 0 WAE and one herbicide applied 2 WAE (Fig. 2-4) suggesting again the importance of weed control shortly after seeding.

Sulfentrazone, sulfentrazone + quinclorac, mesotrione, simazine or amicarbazone applied AS resulted in 80-95% cover. Sulfentrazone + prodiamine, sulfentrazone + quinclorac or carfentrazone + quinclorac applied 0 WAE produced >82% cover, and sulfentrazone+prodiamine applied 2WAE produced 78% cover (Fig. 2-4). Cover of ‘Sundancer’ treated with imazapic or prodiamine applied AS remained low at 6 WAE (<35% cover), but ‘Sundancer’ treated with prodiamine+sulfentrazone reached 62% cover.

No herbicide by timing interaction was observed in weed cover of ‘Sundancer’ when rated at 6 WAE. Averaged over herbicide, weed cover was lower when applications
were made AS or 0WAE (Fig. 2-5). When applied AS, weed cover averaged over all 12 herbicides was 18%. Higher average weed cover was observed when applied 0 WAE (23%), and when applied 2 WAE (34%). Regardless of timing, herbicides always resulted in lower weed cover than the untreated check (Fig. 2-5). Averaged over application timing, amicarbazone, mesotrione, sulfentrazone, sulfentrazone + quinclorac, sulfentrazone, sulfentrazone + prodiamine or carfentrazone + quinclorac resulted in lowest weed cover (<25%) in ‘Sundancer’ (Fig. 2-6). Our data agree with Fry et al, (1997) that weed control applied shortly after seeding of buffalograss is required to reduce weed pressure, thus maximizing establishment of buffalograss (Fry et al, 1997).

Primary weed species in our studies were common purslane, redroot pigweed, and/or yellow foxtail, depending on the year. In addition to safety on buffalograss seedlings, it is likely that efficacy of herbicides on the specific weeds on a site will largely determine buffalograss establishment. Therefore, herbicides with multiple active ingredients and/or with effects on a wide range of weeds may be most effective for buffalograss establishment. We did not evaluate the effect of multiple applications of these herbicides on buffalograss safety or weed control. However, given the margin of safety of single applications of these herbicides on newly-seeded buffalograss, and that the labels of many of these herbicides suggest multiple applications for most effective weed control, we speculate that multiple applications would improve weed control without increased risk of reduced buffalograss cover.

Most of the herbicides we evaluated should be applied at seeding or at emergence to maximize weed control and buffalograss establishment. Though we cannot compare cultivars statistically since they were in adjacent studies, both cultivars responded
similarly to individual herbicides and application timings used in this study. Mesotrione, sulfentrazone, quinclorac, carfentrazone, simazine, amicarbazone, sulfentrazone + quinclorac, carfentrazone + quinclorac, or sulfentrazone + prodiamine applied either at seeding or 0 WAE are safe on ‘Bowie’ or ‘Sundancer’ buffalograss, effectively minimize weed pressure, and maximize buffalograss establishment.


Literature Cited


Table 2-1. Herbicides applied at seeding, 0 week after emergence, or 2 weeks after emergence seeding of ‘Bowie’ or ‘Sundancer’ buffalograss.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Brand name(s)</th>
<th>Manufacturer</th>
<th>Rate (kg ai/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amicarbazone</td>
<td>Xonerate</td>
<td>Arysta</td>
<td>0.4</td>
</tr>
<tr>
<td>Carfentrazone</td>
<td>Quicksilver</td>
<td>FMC</td>
<td>0.02</td>
</tr>
<tr>
<td>Imazapic</td>
<td>Plateau</td>
<td>BASF</td>
<td>0.07</td>
</tr>
<tr>
<td>Mesotrione</td>
<td>Tenacity</td>
<td>Syngenta</td>
<td>0.18</td>
</tr>
<tr>
<td>Prodiamine</td>
<td>Barricade 4FL</td>
<td>Syngenta</td>
<td>0.35</td>
</tr>
<tr>
<td>Pronamide</td>
<td>Kerb SC T&amp;O</td>
<td>Dow AgroSciences</td>
<td>0.7</td>
</tr>
<tr>
<td>Quinclorac</td>
<td>Drive XLR8</td>
<td>BASF</td>
<td>0.84</td>
</tr>
<tr>
<td>Simazine</td>
<td>Princep Caliber 90</td>
<td>Syngenta</td>
<td>1.12</td>
</tr>
<tr>
<td>Sulfentrazone</td>
<td>Dismiss</td>
<td>FMC</td>
<td>0.28</td>
</tr>
<tr>
<td>Carfentrazone + quinclorac</td>
<td>SquareOne</td>
<td>FMC</td>
<td>0.03 + 0.57</td>
</tr>
<tr>
<td>Sulfentrazone + prodiamine</td>
<td>Echelon</td>
<td>FMC</td>
<td>0.21 + 0.42</td>
</tr>
<tr>
<td>Sulfentrazone + quinclorac</td>
<td>Solitaire</td>
<td>FMC</td>
<td>0.24 + 0.71</td>
</tr>
</tbody>
</table>

Table 2-2. Analysis of variance for percent ‘Bowie’ or ‘Sundancer’ buffalograss or weed cover after twelve herbicides were applied at seeding, 0 week after seeding, or 2 weeks after seeding of ‘Bowie’ or ‘Sundancer’ buffalograss over two years and rated at 6 weeks after emergence (WAE).

<table>
<thead>
<tr>
<th></th>
<th>‘Bowie’</th>
<th>‘Sundancer’</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Buffalograss</td>
<td>Weed</td>
</tr>
<tr>
<td>df</td>
<td>% cover</td>
<td></td>
</tr>
<tr>
<td>Year (Y)</td>
<td>1</td>
<td>***</td>
</tr>
<tr>
<td>Herbicides (H)</td>
<td>11</td>
<td>***</td>
</tr>
<tr>
<td>Y × H</td>
<td>11</td>
<td>**</td>
</tr>
<tr>
<td>Timing (T)</td>
<td>2</td>
<td>***</td>
</tr>
<tr>
<td>Y × T</td>
<td>2</td>
<td>ns</td>
</tr>
<tr>
<td>H × T</td>
<td>22</td>
<td>**</td>
</tr>
<tr>
<td>Y × H × T</td>
<td>22</td>
<td>ns</td>
</tr>
</tbody>
</table>

*, **, *** and ns denote significance at p=0.05, 0.01, and 0.001, and not significant, respectively.
Fig. 2-1. Average soil temperature (F) at 10 cm during two years of studies at John Seaton Anderson Turfgrass Research Facility near Mead, NE, in 2012 and 2013.
Fig. 2-2. Percent ‘Bowie’ buffalograss cover rated 6 weeks after emergence (6 WAE). Buffalograss was treated with 12 herbicides applied at seeding, at emergence (0 WAE), or 2 weeks after emergence (2 WAE). Buffalograss means with a different letter are significantly different at P = 0.05. Means are over three replications in each of two years. Untreated check means were not included in the factorial analysis and are shown for reference only.
Fig. 2-3. Percent weeds (primarily common purslane, redroot pigweed and/or yellow foxtail) cover in ‘Bowie’ rated 6 weeks after emergence (6 WAE). ‘Bowie’ buffalograss was treated with 12 herbicides applied at seeding, at emergence (0 WAE), or 2 weeks after emergence (2 WAE). Means with a different letter are significantly different at P = 0.05. Means are over three replications in each of two years. Untreated check means were not included in the factorial analysis and are shown for reference only.
Fig. 2-4. Percent ‘Sundancer’ buffalograss cover rated 6 weeks after emergence (6 WAE). Buffalograss was treated with 12 herbicides applied at seeding, at emergence (0 WAE), or 2 weeks after emergence (2 WAE). Means with a different letter are significantly different at P = 0.05. Means are over three replications in each of two years. Untreated check means were not included in the factorial analysis and are shown for reference only.
Fig. 2-5. Percent weeds (primarily common purslane, redroot pigweed and/or yellow foxtail) cover in ‘Sundancer’ rated 6 weeks after emergence (6 WAE). ‘Sundancer’ buffalograss was treated with 12 herbicides applied at seeding (AS), at emergence (0 WAE), or 2 weeks after emergence (2 WAE). Means with a different letter are significantly different at P = 0.05. Means are over 12 herbicides with three replications in each of two years. Untreated check means were not included in the factorial analysis and are shown for reference only.
Fig. 2-6. Percent weeds (primarily common purslane, redroot pigweed and/or yellow foxtail) cover in ‘Sundancer’ rated 6 weeks after emergence (6 WAE). ‘Sundancer’ buffalograss was treated with 12 herbicides applied at or shortly after seeding. Means with a different letter are significantly different at P = 0.05. Means are over three application timings with three replications in each of two years. Untreated check means were not included in the factorial analysis and are shown for reference only.