COOPERATIVE EXTENSION UNIVERSITY OF CALIFORNIA

California Turfgrass Culture

Volume 45, 1 & 2, 1995

Buffalograss--A Promising Drought-Resistant Turf for California

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In California, water is becoming a limited resource. The question most commonly asked of turfgrass specialists often is: "What can I plant to save water, yet have an acceptable green, dense grass cover?" There is no Panacea: in most cases, there is no way to have an acceptable turf stand without some irrigation.

Water shortages have caused some municipalities to consider or actually place restrictions on the amount of water that may be used on home, park, and cemetery lawns or golf course and sports turf. In some cities, a limit has been imposed on the area per household of lawn, composed of high-water-requiring grasses. Water shortages and changes in philosophy by many turfgrass "consumers" have led to increased use of drought-tolerant grasses on sod farms, golf courses, industrial parks, parkways, and similar locations. Seed suppliers are also offering less luxurious, drought-tolerant grasses for turf purposes. The change to poorer quality "pasture" grasses from high quality, "turf-type" grasses can cause many problems. More research is needed on how to manage the drought-resistant grasses for turf, and this, in turn, requires research to define the unique characteristics of these less familiar grasses.

Generally, annual grasses escape drought as seed, while perennial grasses go dormant during extended dry periods. Some grasses stay green longer into drought periods than others; although this can be a valuable attribute, if such grass dies due to lack of water, one that turns brown earlier and lives through the long dry period is still preferable.

Several environmental factors contribute to the ability of a grass to withstand extended drought. A deep-rooted grass growing in deep soil with good subsoil moisture, can remain green for extended periods. Once the subsoil moisture is depleted, however, heavy rainfall or irrigation is required to recharge the entire soil profile. Thus, in dry areas where rain or irrigation may wet the soil to a depth of only a few inches, deep-rooted plants, such as tall fescue, might not survive extended drought.

The following list, based on observations in California, ranks common turfgrass species according to their relative drought resistance.

Drought Resistance

High	Hybrid bermudagrass,
	Zoysiagrass
	Common bermudagrass
	Seashore paspalum
	St. Augustinegrass
	Kikuyugrass
	Tall Fescue
	Red Fescue
	Kentucky bluegrass
	Perennial ryegrass
	Highland bentgrass
	Creeping bentgrass
Low	Colonial bentgrass

Since development of the above scale, several new grasses have entered the market, most notably buffalograss. Experiments have been underway in California since 1981 to determine the suitability of this species as a drought-resistant, "low-maintenance" turfgrass, and to investigate its genetic, morphological, and physiological characteristics.

What is Buffalograss?

Buffalograss [Buchloe *dactyloides* (Nutt.) Engelm.] is the oldest grass of the American great plains, growing on rangelands of the mid-western and western United States. Fossilized seed structure found in Kansas prairies reveals that buffalograss existed 5 to 7 million years ago. In the last 100 years, it has been used primarily for forage, but because of its drought tolerance, low nutritional requirements, and short growth stature, its potential for use as a low-maintenance turfgrass is drawing increasing attention.

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Buffalograss is largely dioecious (with female and male flowers occurring on separate individual plants) and shows striking structural differences between male and female inflorescences (flower). Although buffalograss is grown for seed commercially, the seed supply is limited by seed shattering and extremely short female flowers that are difficult to harvest. In addition, seed burrs contain an oil that inhibits seed germination, and sex expression within buffalograss is inconsistent, making selection and breeding difficult. Extended winter dormancy and a relatively open turf stand, encourage weed invasion, another inferior trait. Research was required to determine whether these significant drawbacks are sufficiently offset by positive attributes to justify development and use of buffalograss as a low-maintenance turfgrass.

At the University of California, Davis, and the University of California Bay Area Research and Extension Center in Santa Clara, research is aimed at identifying those turfgrass characteristics of buffalograss most amenable to improvement. In addition, selection of vegetatively propagated varieties has progressed with the goal of making this form of the species available to the public. The following series of articles are results of research already concluded. The results of research currently underway will be made available as they are concluded.

Acknowledgements: The authors acknowledge the significant financial support of the following for making these studies possible: The Elvenia J. Slosson Endowment Fund for Ornamental Horticulture; The Northern California Turf and Landscape Council; and the Golf Course Superintendent's Association of Northern California.

Development of New Buffalograss Cultivars

Lin Wu and Ali Harivandi [1]

Buffalograss *[Buchloe dactyloides* (Nutt.) Engelm.] is a native warm-season grass species of the American great plains. Buffalograss's potential usefulness has been emphasized and discussed in the literature and by turfgrass professionals. This species is known as a dioecious plant. Seedheads borne by the pistillate plant are near the ground making seed harvest difficult and limiting seed supply and species availability. Since 1981, a series of research projects were undertaken to examine the genetic makeup of buffalograss and possible development of new cultivars at University of California-Davis and UC Bay Area Research and Extension Center (BAREC) in Santa Clara. The following is a summary of these projects.

For the initial study, seed of 'Colorado Common' buffalograss harvested from an established stand at BAREC was used. Plants established from these seeds were used to determine sex ratio and size classes of buffalograss. Seeds were germinated and grown in the greenhouse and then examined for seed population sex ratio. Later, stolons of some of these plants were transplanted into pots, and the resulting vegetatively produced plants were grown both in the greenhouse and outdoors. The sex ratio for the plants was also examined.

The sex ratio determined from all these plants indicated three distinct sex forms. The ratio of the three forms was about 1: 1 (Table 1). Male and female plants had a similar average number of 30 inflorescences per plant. The monoecious plants had an average of about 15 female and 15 male inflorescences. The sex ratio in terms of number of inflorescences in the population was also about 1: 1. Variations in number of male inflorescences between the monoecious plants was much greater than that of female inflorescences of dioecious inflorescences .

In some of the monoecious plants, flowers containing both pistillate and staminate organs (hermaphrodite) also were found. Hermaphrodite flowers of two monoecious plants were reciprocally pollinated or self-pollinated. Self-pollination may have resulted from different flowers on the same plant. The plants were then isolated in three different green

Table 1. Sex Ratio of Buffalograss Estimated Under Different Growth Conditions.

Growing conditions	Sex ratio: Female	Monoecious	Male
Established by seed	10.5 ± 0.7	8.5 ± 0.7	10.5 ± 2.7
5-year, non-mowed stand: inflorescences/l2 in.	8.7 ± 1.0	0	7.0 ± 6.9
5-year turf: inflorescenced/12 in.	5.8 ± 1.0	0	1.5 ± 0.0
Average no. inflorescences:			
on male plant			22.0 ± 11.0
on female plant	21.0 ± 12.0		
on monoecious plant	17.0 ± 6.0		15.0 ± 16.0

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houses. Three weeks after pollination, 100 flowers from cross-pollinated or self-pollinated flowers of hermaphrodite inflorescences were examined for seed-set. Fifty-one and 45 seeds were found from the cross-pollinated flowers with an average seedset of 48%. Initially, no seed was found in the self-pollinated flowers. In subsequent self-pollination tests, however, up to 30% seedset was found. Seeds developed from hermaphrodite flowers stayed on the inflorescences after ripening, possessing a non-shattering character.

The sex ratio was also examined for field-planted, non-mowed, and regularly mowed buffalograss plots: These plots were established from seeds and maintained at BAREC. The seed source for 5-year-old, non-mowed and weekly mowed turf cannot be identified. The 3-year-old turf was 'Colorado Common' buffalograss.

The sex ratio in the non-mowed stand was found to be 1: 1. In both the 3- and 5-year-old turf, however, the ratio was found to be 5:l. This suggested that mowing provides a differential stress on female and male plants. Mowing encourages increased vegetative reproduction by male plants in contrast to female plants.

Female and male flower culm height distribution showed a considerable variation in both female and male flower culm height. The male flower culms were two or more times taller than the female flower culms. The flower culms of the greenhouse plants were much taller than the flower culms of the field plants. A positive correlation between the flower culm length produced in the greenhouse and in the field was observed. These results suggested that selection for flower culm height is possible and may be conducted either in-field or in-greenhouse conditions.

It was apparent that-three sex forms exist in buffalograss with the monoecious and hermaphrodite being self-compatible. Although only one seed source was examined in this study, monoecious plants of buffalograss have also been reported by other researchers. From this study, we determined that at least two approaches might be applicable for buffalograss seed production improvement: select increased female inflorescence height to facilitate seed harvest, or select for the hermaphrodite character in established hermaphrodite cultivars.

For buffalograss cultivar development and seed production, selection for populations with predominantly female monoecious plants is emphasized in which most plants have more female than male flowers. This not only enhances seed production but also improves turf quality, since male flowers are borne on stalks relatively high above the ground, while female flowers remain below the turf canopy. Complicating matters for buffalograss breeding, however, sex expression of individual plants in this species often varies between years and locations. Hoping to discover a predictable pattern of sex expression in this species, we examined the nature of sex expression in seven buffalograss populations: a commercial cultivar 'Colorado Common', and buffalograss seeds collected from natural habitats in Colorado, Texas, Kansas, New Mexico, and Oklahoma.

When the 'Colorado Common' and the Texas Native populations were compared, the frequency of monoecious plants was much higher (about 38%) in the commercial cultivar than in the Texas Native population (about 17%). Among the natural buffalograss populations, the frequency of monoecious plants was found to be negatively correlated to the density of the buffalograss stand. For example, in populations collected from Oklahoma and Wildrado, Texas, where plant density is high and buffalograss coverage may extend over hundreds of acres,' the frequencies of monoecious plants were less than 10%. In contrast, in populations from low density areas in Chillicothe, Texas, and New Mexico, the frequencies of monoecious plants were as high as 38 % . This relationship between population density and frequency of monoecious plants may be a result of ecological adaptation. Under high density conditions, inbreeding depression of monoecious plants could reduce their vigor and competitiveness in comparison to outcrossed progeny produced by the dioecious plants. Under low density conditions, plants may be isolated as individual clones. The dioecious pollination mechanism may be less efficient, whereas monoecious plants are able to produce seeds through self-pollination. This finding suggests that buffalograss populations with a high frequency of seed-bearing plants may be predictable and can be obtained from natural stands.

Sex expression of buffalograss was studied under different environmental conditions. Plants of four sex forms, including male, female, predominantly male with 1 to 5% female flowers, and predominantly female with 85 to 95% female flowers, were grown either in a warm temperature (95°F day, 80°F night) greenhouse or in a cool temperature (77°F day, 59°F night) greenhouse. Within each greenhouse, there were two levels of light and two levels of nitrogen fertilization treatment. We found that the sex expression of male and female plants remained constant over all environmental treatments. A significant effect on sex expression was produced by the nitrogen treatment for the predominantly female monoecious sex form. The trends of sex expression for monoecious sex forms showed that warm temperature. high light, and low nitrogen were favorable for female sex expression. Cool temperature, low light, and high nitrogen were favorable for male sex expression. Sex expression was different between genotypes with monoecious sex forms, suggesting that the stability of sex expression in buffalograss is a genetic character and is genotype dependent.

The extremely short female flower stem of buffalograss is a critical limitation in seed production.. We found that the height of flower stems varies considerably in both male and female flowers in the 'Colorado Common' buffalograss population and showed positive correlation between flower stem height produced in the greenhouse and in the field. This suggested that selection for this trait is possible under both greenhouse and field conditions. Some monoecious plants containing both male and female organs were found. Hermaphroditic flowers are borne on inflorescences high above the ground, as are male flowers, and can set seed by selfing or reciprocal pollination among flowers on the same plant. Seeds produced by hermaphroditic flowers without burr and seed dormancy stayed on the inflorescence after ripening. In contrast, seeds produced by female flowers are enclosed in burr structures and cannot germinate without pretreatment.

Most commercial warm-season turfgrasses are vegetatively propagated; but no vegetatively propagated buffalograss was available commercially until very recently. At both the UC Davis Campus and BAREC, vegetatively propagated buffalograsses, resulting from crosses between various buffalograss genotypes, were studied for differences in spreading rate and turf quality under reduced mowing, irrigation, and fertilization.

Considerable differences were observed between collections in rate of turf establishment through vegetative propagation. Certain clones selected from the natural buffalograss populations formed a solid turf within 5 weeks, starting from l-inch plugs planted 12 inches apart. Turf established from selected female clones remained under 4 inches in height without mowing. Flower heads of female clones are inconspicuous, because they are short and under the turf canopy. Reasonable turf color and density were being maintained with 1 lb nitrogen per year and irrigation once a week during summer months. Selected clones were planted in the field at Davis, BAREC, and in Southern California. Two vegetatively propagated cultivars from these trials were recently released by the University of California under name designations of 'Hilite 15' and 'Hilite 25':

'Hilite 15' and 'Hilite 25' buffalograss are vegetatively propagated, drought- and heat-resistant female buffalograss clones selected by mass selection. For breeding purposes, seeds of diploid buffalograss germplasms were collected from three locations in Central Mexico. Plots were established from seeds and space planted in the experimental field at UC, Davis. Plants were mowed weekly at a 2-inch height during the growing season (from May to the end of October). Individual clones were selected for rapid vegetative growth, high turf density, and extended winter turf green color. About 80% of the plants were eliminated in the selection for the above characteristics. The remaining plants were subjected to drought stress during the following summer months by terminating the irrigation for a period of 8 weeks (from June 15 to August 15).

Two male and two female plants from each of the three populations were selected for their superior performance under the drought stress. For the second selection cycle, a mass-cross was constructed by growing the selected six male and six female clones close together in the field, and seeds were harvested from the female plants. Six hundred plants were propagated from the seed progeny, were space planted in the field, and were subjected to turfgrass management. Through the growing season, the plants were mowed weekly at a 2-inch height, irrigated every 10 days, and fertilized with one lb N/1000 sq ft applied in August. These female clones, named 'Hilite 15' and 'Hilite 25', were selected for their superior performance in rate of vegetative growth, high turf density, retention of green color above freezing temperatures, and superior drought tolerance. Asexual reproduction was accomplished from stolons, sprigs, plugs, and spreads of stolonization. Initially, the two plants were vegetatively reproduced in the greenhouse at the University of California, Davis, campus. Such reproduction was also tested in the field at the University of California, Davis, campus and BAREC in Santa Clara.

'Hilite 15' and 'Hilite 25' are distinguished by their fine texture, high turf density, rapid stolon spreading rate, competitive growth, short height, improved winter green color and short winter dormancy, spring turf quality, drought tolerance, low maintenance requirements, and improved turf performance (Tables 2-4). Subsequent to the development of vegetatively propagated 'Hilite 15' and 'Hilite 25', a seeded variety was also developed entitled 'Hilite Seed (UCHL-1)'. To accomplish this, a seed population of buffalograss was constructed at the University of California, Davis, by interclonal crossing among the selected male and female clones from previous trials which exhibited superior performance in their rate of vegetative growth, high turf density, retention

Table 2. Relative Performance of 'Hilite 15' and 'Hilite 25' in Comparison to Other Varieties for the Following Characteristics.

Character	'Hilite 25'	'Hilite 15'	'Prairie'	'Texoka'
Rate of spread	9a[1]	9a	7b	4c
Turf density	9a	8a	7b	3c
Drought tolerance	9a	9a	9a	7b
Injury regrowth potential	8a	8a	7b	4c
Shade tolerance	4a	4a	4a	3b
Color	7a	7a	4b	5c
Cold tolerance	9a	9a	9a	7b
Heat tolerance	9a	9a	9a	7b
Salinity tolerance	4b	6a	4b	3c

1 Mean separated by Duncan's new multiple range test, P = 1%. Scale: 1 to 9; 9 = best.

Table 3. Mean Turfgrass Quality Ratings of 'Hilite 1.5' and 'Hilite 25' in Comparison to Other Varieties Over a Period of a l-Year Growing Season at Santa Clara. California

Cultivars	Mean Value[2]			
	May	June	July	August
'Hilite 25'	7.5a	7.3a	7.0a	7.3a
'Hilite 1.5'	7.5a	7.0a	7.0a	7.2a
'Prairie'	6.0b	6.5b	6.5b	6.5b
'Texoka'	4.5c	4.7c	5.7c	5.7c
	September	October	November	Mean
'Hilite 25'	7.5a	7.1a	7.0a	7.2a
'Hilite 1.5'	7.5a	7.1a	7.0a	7.1a
'Prairie'	6.3b	5.3b	4.0b	5.8b
'Texoka'	5.oc	3.3c	1.0c	4.2c

' Turfgrass quality is based on uniformity, density of stand, texture of turf canopy, smoothness of surface, and growth habit.

2 Mean separated by Duncan's new multiple range test, P = 1%. Scale: 1 to 9; 9 = best.

Table 4. Rate of turf establishment from 2-inch plugs (% coverage) of 'Hilite 15' and 'Hilite 25' buffalograsses in comparison to 'Prairie' and 'Texoka'.

Cultivars	Date of observation				
	6/1/91	6/16/91	6/30/91	7/15/91	7/30/91
'Hilite 25'	10a[2]	30a	70a	95a	100a
'Hilite 15'	9a	32a	70a	96a	100a
'Prairie'	5b	16b	35b	46b	70b
'Texoka'	4b	9c	18c	25c	45c

1 First observation conducted 2 weeks after planting of plugs in the field at Davis, California.

2 ***Mean*** separated by Duncan's new multiple range test, P = 1%

of green color at low temperatures, and superior drought tolerance.

Like 'Hilite 15' and 'Hilite 25, the 'Hilite Seed' buffalograss is also diploid, with a chromosome number of 20. It is a fine-textured buffalograss with approximately 50% male and 50% female plants in the seed population. In comparison to 'Texoka' (a hexaploid-seeded cultivar, with a chromosome number of 60), the 'Hilite Seed' buffalograss variety exhibits shorter internode length, smaller internode diameter, faster stolon growth rate, no pubescence on the leaves, and considerably less winter dormancy. It retains its green color to about freezing temperatures, and remains 6 to 8 inches high without mowing.

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Buffalograss Response to Cold, Shade, and Salinity

Lin Wu and Ali Harivandi [1]

To determine the suitability of buffalograss *[Buchloe dactyloides* (Nutt.) Engelm.] for the California landscaped sites, with such highly varied soil and climate conditions, a series of studies were undertaken. A summary of these studies follows.

Cold Tolerance

Buffalograss is warm-season, perennial, and native to the North American Great Plains. The geographical distribution of buffalograss includes western Minnesota, Central Iowa, Louisiana, Arizona, Texas, and northern and central Mexico. Although buffalograss is a warm-season grass, it can survive cold winter temperatures through dormancy. For a warm-season turfgrass, extended winter color, early dormancy break, and survival under subfreezing temperatures are important traits. Buffalograss populations collected from both Mexico and the United States were examined for these characteristics. Seeds of the two American buffalograss populations include the commercial cultivar 'Texoka' and a native buffalograss collected from a natural stand near Adrian, Texas. Seeds were germinated and grown in the greenhouse. The resulting plants were then transplanted into field plots on the UC Davis campus in June. Plots were trimmed, fertilized, and irrigated uniformly as needed.

The two American buffalograsses began losing green color and initiating dormancy by mid-November, and had lost all green color by December. The two Mexican buffalograsses retained their green color through December and early January. They became dormant after exposure to frost in mid-January. The two Mexican buffalograss populations resumed growth in March. Both American grasses exhibited better spring color than either of the Mexican grasses. Nearly 100% of the two Mexican buffalograss clones retained their green color in the middle of November, while of the native Texas and

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'Texoka' grasses, less than 20% of the clones were green. By the end of April, all four grasses had fully resumed growth.

To test for cold and freezing resistance, l-inch-diameter buffalograss plugs of both American and Mexican populations were collected from the field in November. Plugs were kept in a low-temperature incubator (35-41°F) for 4 days for dormancy enhancement. After low-temperature storage, buffalograss tillers were separated from the plugs and were stored either under 24 inches of ice at 32°F for 2 or 4 weeks, or in a deep freezer (10°F) for 2 weeks. After the cold or freezing treatment, tillers were transplanted into greenhouse potting soil and kept in the greenhouse under 70°F night and 87°F days. Plants were irrigated with a nutrient solution three times a week.

After 8 weeks of cold treatment, all plugs resumed growth. The Mexican collections showed only a slight reduction in growth recovery after 14 weeks of cold treatment. The Texas Native and 'Texoka' buffalograsses showed no reduced growth recovery even after 14 weeks of cold treatment.

The Texas Native and 'Texoka' buffalograsses fully resumed growth after 2 weeks of freezing treatment and had 80% growth recovery after 4 weeks of treatment. Plants of the two Mexican buffalograsses did not resume growth after 2 weeks of freezing treatment.

These results indicate a substantial variation in both winter color retention and cold tolerance among buffalograss populations. It appears, however, that with the exception of the mountains and far northern parts of California, buffalograss should be able to survive the winter temperatures. The winter dormancy is inevitable, however, although it may vary in duration from site to site.

Shade Tolerance

Most turfgrass shade-related problems are a result of blocking out direct sunlight by tree canopies, large buildings, and other kinds of structures. There is no simple solution or single recommendation available. One reason is that the problem itself is very complex. The conditions found in a shaded site can vary significantly not only between climatic regions, but within a relatively small geographic area. For example, the shade cast from a building can be very different from the shade cast by trees. In addition, different tree species may affect the performance of a particular turfgrass growing beneath them.

To study the performance in shade, the plots of buffalograss turf were established during the summer of 1987 from the commercial seed variety 'Texoka' and a vegetatively propagated experimental variety, 'Hilite 24', at UC Davis. The plots were mowed at a 1.5inch height, irrigated once a week through the summer months, and fertilized with 1 lb N/1000 sq ft as ammonium sulfate in May, July, and September of 1988. In the second week of May 1989, l-inch-diameter turf plugs were collected from the 'Texoka' and 'Hilite 24' turf and transplanted for the shade studies. For shade treatment, 10-ft by 20-ft field plots were shaded with black nylon screens which provided either 50% or 30% full sunlight. Control plots were not shaded. The turf was mowed once every 2 weeks at a 2-inch height. Ammonium sulfate was applied at a rate of 1 lb N/1000 sq ft on May 15, 1989. The following turf characters were measured: growth rate of the buffalograss by measuring stolon elongation; dry weight by collecting 1 sq ft of turf above the soil surface on September 30, 1989; and percentage of ground covered by buffalograss in each turf plot visually estimated on September 28, 1989.

'Hilite 24' had a greater turf establishment rate than 'Texoka' . 'Hilite 24' produced a full turf cover by August 15, 3 months after transplanting. 'Texoka' had a slower growth rate and produced only 70% turf cover by the end of September. The greater turf spreading rate of 'Hilite 24' is attributable to its greater stolon elongation rate. It had a stolon elongation rate of 0.44 inch per day under full sun, and 0.24 and 0.13 inch per day under 50 % and 30 % sunlight, respectively. 'Texoka' had only half of the stolon elongation rate of 'Hilite 24'. Under 50% sunlight, it produced less than 50% ground cover by September 1989. By the second week of September, 'Hilite 24' had produced 100% and 95 % ground cover under 50% and 30% sunlight, respectively. In contrast, 'Texoka' only developed 50% ground cover under 50 % light and 40% cover under 30 % sunlight.

Buffalograss turf grown under shade was thinner and more open than that grown under full sun. Therefore, the turf dry weight was severely reduced.

The results of these shade studies indicate that buffalograss basically is intolerant of shade. However, turf quality differences in shade exist between buffalograss varieties. 'Hilite 24' is a recently selected and vegetatively propagated buffalograss line. Its superior turf performance under shade is attributable to its greater stolon growth rate. Regardless, it appears that even newly developed, aggressive buffalograsses are unable to perform well in more than 50% shade.

Salinity Tolerance

Turfgrass management problems associated with salinity continue to increase. This increase is due to several factors: (1) rapid population growth and, thus, increase of turfgrass acreage in arid and semiarid regions where soil and water salinity problems are common; (2) development of turfgrass facilities near bodies of salt water; and (3) use of various salts for deicing highways, sidewalks, and airport runways. Various approaches may be successful in correcting the adverse turfgrass-growing conditions associated with salinity. One successful approach to deal with the salinity problem in turfgrass management is to use salt-tolerant turfgrasses.

To determine the salt tolerance levels in buffalograss genotypes, a series of studies were conducted in which diploid, tetraploid, and hexaploid buffalograss germplasms were used. Seed samples for these plants were collected from locations over a geographical longitudinal gradient from San Luis Potosi, Mexico, to Lincoln, Nebraska, in the United States.

Seed materials of nine buffalograss germplasms, including three diploid, three tetraploid, and three hexaploid buffalograss races were studied. Effects of salt concentration on seed germination and salt uptake were tested in nutrient solutions containing 10, 20, 30, 40, 50, 60, 70, and 80 mM of NaCl (increasing concentrations).

After 3 weeks' growth, plants were harvested and their root length and shoot height were measured. Identical conditions of nutrient solution culture for the preliminary salt resistance studies were used for the seedling establishment and salt uptake studies among the different buffalograss populations. The one-quarter concentration modified nutrient solution was used as a control treatment, and 50 and 100 mM NaCl amendments were used for the salt treatments. After 5 weeks' growth, plants were harvested, and the root and shoot dry weights were measured. Plant tissues were also analyzed for Na and Cl measurements.

Root and shoot growth of all buffalograsses were reduced with the increase in salt concentration. A 50% growth inhibition occurred at 50 mM salt treatment. Under 80 mM salt treatment, buffalograss only produced approximately 20% shoot length and root length of the control treatment. Fifty and 100 mM salt concentrations were chosen for the further salt uptake studies. In addition to growth inhibition, under 50 mM salt treatment, a substantial amount of seedling mortality occurred. Seed germination rate under the salt treatment was significantly different among the populations tested and varied from 20 to 35% seed germination. Under 50 mM salt treatment, both shoots and roots produced about 35% dry weight of those produced in control treatment. Less than 5% plant dry weight was produced in 100 mM salt, compared to the control. No significant difference among the populations was detected, but remarkable differences in salt tolerance among individual plants within buffalograss populations were detected.

The results of sodium and chloride uptake by shoots and roots indicated that among the nine buffalograss populations, sodium and chloride uptakes were about 15 mg g^{-1} dry weight, and were similar for the shoot and root tissues. No significant differences were detected among the nine populations.

There is considerable evidence that turfgrasses are particularly sensitive to soil salinity during seed gemination and early seedling growth. Water uptake in saline conditions is usually reduced due to osmotic stress. As a compensatory adaptive mechanism to osmotic water stress under saline conditions, a turfgrass may enlarge its water-absorbing root surface, thus increasing its root biomass. Salt concentrations used for this study were relatively low, and less than 50 mM salt was able to produce substantial seed germination and seedling growth inhibition. These low salt concentrations may not contribute to osmotic stress, and buffalograss is known as a drought-resistant plant species. Buffalograss may be more sensitive to the toxicity of Na, Cl, or both ions rather than the salinity-induced osmotic stress. Sodium and Cl can reduce plant growth by their influence on photosynthesis. We found that salt-tolerant buffalograss genotypes absorbed less Na and Cl than the salt-sensitive ones. High Na concentrations were found in the roots than the shoot tissue, suggesting a preferential inclusion of Na uptake by the shoots.

Overall, buffalograss can be considered a moderately salt-sensitive species. However, its wealth of genetic variation of salt tolerance represents a potential for development of salt-tolerance cultivars.

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Buffalograss Establishment Studies

Ali Harivandi , Lin Wu, Clyde Elmore, and William L. Hagan [1]

Buffalograss may be established by seeding, sodding, or vegetative plugs. Buffalograss seed is available as cultivars or harvested from natural stands. Establishing buffalograss from seeds of unimproved

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turf-type cultivars may have drawbacks due to the natural genetic variability among seeds. Buffalograss seed burrs are hard and contain a germinaton-inhibiting oil which makes the seed germination and seedling establishment slow and non-uniform. Recently, deburred (hulled) buffalograss seed has been introduced to the market, but seed price is relatively high.

Buffalograss sod of several improved cultivars are available, but at high prices and not readily obtainable. Establishing buffalograss lawns using plugs would appear to provide a practical, economical, and efficient alternative until the seed and sod of improved buffalograss cultivars are available at reasonable prices. In California, however, weed invasion and competition during establishment of buffalograss from seed or plugs is serious and must be dealt with effectively.

Currently, studies are underway at the University of California, Davis, and the Bay Area Research and Extension Center (BAREC) to determine the suitable establishment methods of buffalograss. The following is a summary of the studies which have already been completed.

Although a few studies of herbicide effects on buffalograss have been reported recently, most have examined the response of established buffalograss to herbicides. Information on the effects of herbicides on buffalograss during establishment, however, is lacking. Therefore, a study was undertaken to determine the phytotoxic effects of preemergence herbicides on buffalograss during establishment from plugs.

On May 18, 1989, three plugs were taken from a lo-year-old stand of 'Colorado Common' buffalograss and were planted in replicated plots at the BAREC in Santa Clara. Three plugs were planted longitudinally on a straight line in the center of each plot on 2-ft centers. This planting pattern situated each plug 2 ft from the nearest edge of the plot. The plot area was sprayed twice with glyphosate within the 3 weeks previous to planting to control actively growing weeds. Two days prior to plugging, plots were tilled, leveled, and irrigated. Ammonium sulfate was broadcast at the time of tilling at the rate of 21 lb N/1000 sq ft. The area immediately adjacent to each plug was hand-watered at the time of plugging to prevent wilting. The day after planting, on May 19, 11 preemergence herbicides were applied to each plot at the rates indicated in Table 1 by a CO_2 pressure sprayer. Each treatment was replicated three times in a randomized complete block design. A second herbicide application was made on September 21, 1989. Prior to the second herbicide treatment, all annual weeds [primarily purslane (Portulaca olerucea L.) and prostrate pigweed *(Amaranthus libicoides* S. Wats.)] were manually harvested and weighed. Over the course of this study, concluded on May 4, 1990, the following evaluations were periodically performed: visual assessment of phytotoxicity effects on buffalograss; lateral growth and ground coverage by buffalograss; annual weed ground coverage; and weed biomass production (dry weight). At the conclusion of the study, dry weight of buffalograss harvested to a height of 1.5 inches from each plot was also determined. Plots were irrigated throughout the study as needed to prevent stress, were fertilized with ammonium sulfate at 0.5 lb N/1000 sq ft every 2 months during the growing season (i.e., no fertilizer was applied on dormant buffalograss), and were not mowed. Isolated perennial weeds emerging in each plot were spot treated with glyphosate to prevent competition. Plots were established on loam soil and in full sun. Buffalograss was dormant from November 1989 through February 1990.

Table 1 summarizes percent buffalograss and annual weed cover for each treatment. Values are averages of three replicated plots for each treatment. Annual weeds in order from most to least prevalent were: purslane, prostrate pigweed, annual bluegrass *(Poa annua* L.), and prostrate knotweed *(Polygonum aviculare* L.). Weeds were hand-harvested and weighed prior to the second herbicide treatment on September 21, 1989, and again on January 10, 1990 and May 4, 1990. On September 21, 1990, 4 months after the first herbicide application, plots treated with oxadiazon had the highest buffalograss cover (78%) and the least weed cover (5%). Although isoxaben-treated plots also had a weed coverage of 5%) buffalograss cover was only 13%-the lowest coverage among all treatments. Visually, buffalograss treated with isoxaben showed severe phytotoxicity symptoms. Isoxaben was apparently very effective in preventing weed germination (purslane and prostrate pigweed). Untreated check plots contained 82% weed cover and only 17% buffalograss, indicating the strong competitive ability of these two annual weeds relative to buffalograss. Second to oxadiazon in preventing weed emergence with low phytotoxicity (the latter demonstrated by the rapid spread and increased coverage of buffalograss after one application), were isoxaben + trifluralin and pendimethalin. Surprisingly, the phytotoxic effects of isoxaben did not occur when it was applied in combination with trifluralin. It is probable that the proportion of isoxaben (0.5% a.i.) present in combination with trifluralin (2% a.i.) was low enough not to cause noticeable damage.

Although phytotoxicity was not visually apparent in plots treated with bensulide and dithiopyr, buffalograss coverages of 17 % and 15 % , respectively, indicate negative effects on lateral growth. In the case of bensulide, reduced buffalograss coverage may be due to weed competition (i.e., poor weed prevention is indicated by a weed coverage of 58%) and not to a physiological suppressing effect. Similarly, benefin and trifluralin's inefficacy in preventing weed emergence (65% and 53% weed coverage, respectively),

Table 1. Percent Buffalograss and Annual Weed Ground Cover, and Biomass Production as Affected by Preemergence Herbicides.

		Buffalograss Cover			Buffalograss Dry Weight	Annual Weed Cover¹				Annual Weed Dry Weight¹		
Treatment	Rate	9/21/89	11/16/89	4/27/90	5/4/90	9/21/89	11/16/89	1/10/90	4/27/90	9/21/89	1/23/90	5/4/90
	lb/acre	%			*grams*	%				*grams*		
DCPA 75 WP	10	38 a[2]	57 b	80 b	524 cd	25 de	12 ab	20 b	5 b	3185 bc	192 b	103 b
bensulide 4EC	10	17 a	13 ef	15 f	249 de	68 ab	6 bc	10 bc	38 a	3226 abc	83 b	1015 a
pendimethalin 60 WDG	3	42 a	33 c	57 c	756 bc	10 e	1 bc	2 cd	0 b	1172 cd	5 b	0 b
dithiopyr 1 EC	0.5	15 a	17 def	32 de	206 de	38 cd	4 bc	7 cd	6 b	3125 bc	32 b	159 b
oxadiazon 50 WP	2	78 a	90 a	98 a	1398 a	5 e	0 c	0 d	0 b	70 d	3 b	0 b
prodiamine 60 WDG	1	25 a	25 cde	34 d	234 de	20 de	5 bc	5 cd	0 b	3526 abc	25 b	0 b
benefin (1.3%) + trifluralin (0.67%) 2G	2	42 a	37 c	50 c	439 cd	40 cd	6 bc	7 cd	2 b	4394 ab	48 b	43 b
isoxaben (0.5%) + triflurin (2%) 2.56	2.5	43 a	63 b	87 ab	992 b	13 e	7 bc	8 cd	0 b	1398 cd	143 b	0 b
benefm 60 WDG	3	37 a	27 cd	45 cd	354 de	65 ab	4 bc	5 cd	6 b	5105 ab	50 b	164 b
trifluralin 4E	0.5	30 a	37 c	45 cd	387 de	53 bc	7 bc	19 b	7b	4917 ab	262 b	163 b
isoxaben 75DF	2	13 a	10 f	12 f	69 e	5 e	2 bc	0 d	0 b	49 d	5 b	0 b
Untreated control	–	17 a	15 def	17 ef	90 e	82 a	20 a	33 a	30 a	6000 a	620 a	948 a

1 Weeds present: 9/21/89: purslane, prostrate pigweed 11/16/89 - 1/3/90 annual bluegrass; 4/27/89 - 5/4/90: prostrate pigweed, knotweed, purslane, and annual bluegrass.

2 Means within a column, followed by different letters, differ at 5% level of F-test.

also may be the cause of reduced buffalograss coverage (37% and 30%, respectively). For DCPA, prodiamine and benefin + trifluralin, low buffalograss coverage (3 % , 25 % , and 42 % , respectively) in combination with low weed coverage (25 % , 20%, and 40%) respectively) indicate potential physiological suppressing effects. Other than isoxaben, no visual phytotoxicity effects were noticed in any of the treatments .

After the second application of herbicides on September 2 1, 1989 and throughout the remainder of this study, buffalograss coverage increased for all treatments, except bensulide, isoxaben, and untreated plots. By the end of the study, plots treated with oxadiazon were almost entirely (98%) covered with buffalograss and weed free (Table 1). Plots treated with isoxaben + trifluralin and DCPA followed closely with 87% and 30% buffalograss coverage, respectively. They both were almost weed free.

Isoxaben plots had the lowest buffalograss coverage (12%), but were also weed free. While both untreated plots and bensulide-treated plots had very low buffalograss (17% and 16%) respectively), the high weed coverage treatment (30 % and 18 % , respectively) suggests they had physiologically suppressive effects on buffalograss. All other treatments had buffalograss coverage of less than 60% with varying amounts of weeds. It must be noted that since all weeds were harvested twice on September 21, 1989 and January 20, 1990, a sharp drop in weed coverage for all plots was noted on April 27, 1990 (Table 1).

At the conclusion of the study (May 4, 1990), buffalograss and annual weeds (purslane, prostrate spurge, and knotweed) from each plot were harvested, and their dry weights were measured (Table 1). Weeds were harvested from the soil surface, and buffalograss was cut at a height of 1.5 inches. Plots treated with oxadiazon had significantly higher buffalograss dry weights and no weeds. Isoxaben plots had no weeds and had the lowest buffalograss dry weight. Isoxaben + trifluralin plots had the second highest buffalograss production and no weeds. Untreated plots, along with plots treated with bensulide, had the highest weed biomass and, along with isoxaben plots, the lowest buffalograss biomass.

Results of this study indicate that where severe annual weed invasion is common, establishment of buffalograss without the use of preemergence herbicides is not practical. Among the herbicides used in this study, oxadiazon was the least phytotoxic/suppressive to buffalograss growth and establishment, while being effective in suppressing annual weeds.

In a subsequent study, the rate of turf establishment was compared for the UC developed buffalograss variety 'Hilite 25' using both seeding and plugging methods. 'Hilite 25' plugs were planted at l.O-, 1.5-, and 2.0~ft spacing. The same variety was also established from deburred seeds at the rates of 0.5, 1.0, 1.5, and 2.0 lb/1000 sq ft. Oxadiazon, a preemergence herbicide, was applied (4.5 lb granular/ 1000 sq ft) to plug-planted plots, but not to the seeded plots. To control established weeds, glyphosate was applied twice to one-half of the seeded plots during the buffalograss dormancy (in January).

Initial observations of this study revealed the following:

- Plug plantings at l.O-, 1.5-, and 2.0-ft intervals attained full ground cover in 48, 54, and 63 days after planting.
- All summer annual weeds were controlled in the plug-planted plots with the preemergence herbicide oxadiazon, and winter annual weeds did not become established in the dormant buffalograss.
- The first mowing of the plug planting was 76 days after planting.
- The summer annual weed purslane became heavily established in all seeded plots 19 days after planting. Mowing weekly at 3 inches was used to minimize purslane growth.
- Average growth rate ratings (l-9; 9 being best) for buffalograss were 3.0, 2.7, 7.7, and 6.5 for the seeding rates of 0.5, 1.0, 1.5, and 2.0 lb/1000 sq ft, respectively. This suggests that 1.5 and 2.0 lb/1000 sq ft seeding rates are more competitive with weeds than the 0.5 and 1.0 lb/1000 sq ft seeding rates.
- Two winter applications of the glyphosate on one-half of each seeded area killed the winter annual weeds, but also severely injured the apparently dormant (straw-colored) buffalograss.

References

Harivandi, M. A., C. L. Elmore, and L. Wu. 1993. Preemergence herbicide use during buffalograss establishment. Intl. Turf. Soc. Res. J. 7:298-302.

Buffalograss Planting and Management

Ali Harivandi and Lin Wu [1]

Buffalograss *[Buchloe dactyloides* (Nutt.) Engelm.] is a sod-forming, warm-season grass species native to the North American Plains. Its potential for use as a low maintenance and drought-resistant turf-

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grass is gaining attention in California, from both the public and the turfgrass industry. Although buffalograss is naturally one of the most drought-resistant grasses, its use is currently limited by its long winter dormancy, relatively low turf quality, low shade tolerance, and relatively high seed and sod cost. Substantial genetic variation has been found among buffalograss collections, spawning selections and breeding research programs at various universities and private seed companies. Research is also underway to determine the management practices most likely to create and maintain acceptable buffalograss turf stands. The following guidelines for planting and managing buffalograsses in California are based on the current limited information available. These recommendations will be modified as updated information becomes available.

Planting

Buffalograss may be established by seed, sod, or plugs. For seeding, deburred seed is best because buffalograss seed burrs are hard and contain an oil which inhibits seed germination and seedling development. Deburred seed is more expensive than regular seed and not readily available; if deburred seed is not available, pretreated seed is recommended. Pretreatment seeds are treated with special chemicals and water to remove the germination inhibiting oils and soften the seed coat.

Buffalograss seeds germinate at soil temperatures above 60°F. Therefore, seeding should be done in late spring-early summer. In most of California, May seeding is ideal. Since weed competition reduces the speed of stand establishment, weed abatement prior to seeding is essential. Although a seeding rate as low as 0.5 lb/1000 sq ft can eventually produce an acceptable buffalograss stand, initial research indicates that buffalograss seeded at 1.5 to 2 lb/1000 sq ft competes with weeds more effectively and produces an acceptable stand in a shorter time than stands seeded at lower rates.

Currently, only limited buffalograss sod is produced and marketed in California; however, stand establishment will be faster with sodding than seeding. Sod should be planted from mid-spring to mid-summer to enable the grass to root well before soil temperatures drop to below 60°F. Soil preparation for both sodding and seeding of buffalograss is similar to what is recommended for other turfgrasses.

If the cost of sodding is prohibitive, then establishing buffalograss from plugs of established stands is a good alternative and will produce a turf stand faster than seeding. Vegetative plugs of about 2 to 3 inches in diameter and depth should be taken from a healthy stand of buffalograss and planted onto the new site, ideally at 1 ft apart. Plugs may be planted as far apart as 24 inches with the fastest rate of coverage resulting from the closer spacing. Under ideal conditions, a buffalograss plugging with a spacing of 1 ft produces a fully covered turf stand within 1.5 to 2 months. Several preemergent herbicides could be used effectively at the time of plugging to reduce weed competition. In California trials, oxadiazon (Ronstar) has been very effective in eliminating weed competition without injuring buffalograss plugs during establishment .

Soil preparation, fertilization, irrigation, and general care of buffalograss during the establishment period are similar to other turfgrasses. Mowing (if desired) can start when an area is fully covered. Stands should be cut high initially and gradually lowered to the desired height.

Fertilization

Buffalograss requires relatively little fertilizer for normal growth. Application of 1 lb N/1000 sq ft in the first week of May stimulates new growth. A second l-lb application in mid-July is important for maintaining healthy growth throughout the growing season, and a third pound of nitrogen applied at the end of August or the first week of September will stimulate a late-season flush of growth, thus prolonging winter turf color and enhancing early spring regrowth.

Mowing

Buffalograss has a low growth stature and requires only infrequent mowing. Under full sun, it should be mowed below 1 inch. In shade, however, buffalograss tends to grow more erect than in sunny areas and a higher mowing height (1.5 inches) is recommended to leave sufficient leaf area for photosynthesis and carbohydrate production. Through the growing season, from May to October, turf may be mowed once a week or once every two weeks. No mowing is needed from late October to April of the following year during the cool winter months, while growth is slow or the turf is dormant.

Irrigation

Buffalograss is drought resistant. It does, however, need irrigation to produce a quality turf stand, and due to lack of summer rains in much of California, must be irrigated from late spring through fall to produce an acceptable stand. Its water requirement, however, is much less than cool-season grasses such as Kentucky bluegrass and tall fescue. Although the actual amount of water needed by buffalograss is determined by the evapotranspiration (ET) demand at each site, in general, acceptable buffalograss stands can be maintained with 50% less water than required by Kentucky bluegrass. Buffalograss should be irrigated infrequently: once every 1 or 2 weeks is adequate for most of California. A non-mowed buffalograss stand requires less water than mowed buffalograss.

Pest Activity

Due to the limited buffalograss plantings in California, no specific insect or disease problems have been observed/reported. It is anticipated, however, that as the use of buffalograss increases in California landscapes, pest activities will develop, requiring research to find remedies.

Weed invasion of buffalograss, particularly during the establishment period, is a potential problem. Several preemergent herbicides can and should be used for weed suppression during stand establishment from sod or plugs, as well as on established buffalograss. Research is underway on the efficacy of herbicides during establishment from seed on established buffalograss.

Thatch Control

Thatch development has not been observed in California buffalograss stands and, considering the buffalograss growth habit, is not anticipated.

WARNING ON THE USE OF CHEMICALS

Pesticides are poisonous. Always read and carefully follow all precautions and safety recommendations given on the container label. Store all chemicals in their original labeled containers in a locked cabinet or shed, away from food or feeds and out of the reach of children, unauthorized persons, pets and livestock.

Recommendations are based on the best information currently available, and treatments based on them should not leave residues exceeding the tolerance established for any particular chemical. Confine chemicals to the area being treated. THE GROWER IS LEGALLY RESPONSIBLE for residues on his crops as well as for problems caused by drift from his property to other properties or crops.

Consult your County Agricultural Commissioner for correct methods of disposing of leftover spray material and empty containers. **Never burn pesticide containers.**

PHYTOTOXICITY: Certain chemicals may cause plant injury if used at the wrong stage of plant development or when temperatures are too high. Injury may also result from excessive amounts of the wrong formulation or from mixing incompatible materials. Inert ingredients, such as wetters, spreaders, emulsifiers, diluents and solvents, can cause plant injury. Since formulations are often changed by manufacturers, it is possible that plant injury may occur, even though no injury was noted in previous seasons.

NOTE: Progress reports give experimental data that should not be considered as recommendations for use. Until the products and the uses given appear on a registered pesticide label or other legal, supplementary direction for use, it is illegal to use the chemicals as described.

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