1989 ANNUAL RESEARCH REPORT

DEVELOPMENT OF DRYLAND WESTERN TURFGRASS CULTIVARS

Submitted by

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EXECUTIVE SUMMARY

Our work at Fort Collins, CO, on western-adapted grasses continues in the breeding and turf adaptation phases. The three grasses alkaligrass, blue grama and fairway wheatgrass are all in the middle of the second cycle of selection for numerous traits. Seed production, plant type, and small plot evaluation for turf appearance and tolerance to weather, disease, and two mowing heights (3/4" and 1 1/2" by reel mowers, three times a week) are the most important. Seed production of elite types for regional testing is a vital step which is being pursued more vigorously as we get nearer to knowing the identity of the desired parents. For each of the three grasses we have reported progress in the breeding nurseries and in turf evaluation plots, and in some cases we can predict their role in fairway and rough plantings and other turf uses; none of these grasses is suitable for use on greens.

Alkaligrass proved to be a cross-pollinated grass with segregation possibilities to select new genotypes. Plants with a bluish-green (glaucous) leaf color may have more upright stems but they make poor turf. Many plants are semi-prostrate but have good green color and produce attractive turf in spring and fall, better than the cultivar Fults, which was attacked by a brown patch disease in midsummer and by rust in fall. All alkaligrass looks worse in summer by heat stress, even when given 1 - 1.5" irrigation per week, but we have selected materials which are least affected. This species is salt tolerant and survives where bluegrass dies. It tolerates 3/4" mowing well, but is not fertilizer responsive. The better sources are under test in larger plots in Michigan, Nebraska, and Oklahoma, as well as here.

Blue grama tolerates the drought of the Great Plains and has produced an attractive turf under both mowing heights, with only 1/2" supplemental moisture in a dry summer. It greens up in late April and stays green until October frost, with no noticeable response to nitrogen. Since the chief constraint to its wider use as dryland turf is seed supply and cost, we have selected families and plants in the second cycle with more seed-bearing capacity, and some with more or finer leaves. Seed of these will need testing to ensure favorable effects on turf quality, as we put together the parents for a synthetic cultivar.

Fairway wheatgrass (FWG) was tested severely by the 1989 summer where we had two four-week periods without rain, and a week with daily temperatures above 95° (Denver had 5 days consecutively above 100°, a record). As a cool-season grass, FWG went brown and dormant, but watering 1/2 - 1" every two weeks from mid-July brought greening and partial recovery, some of the stand density being lost. It tolerated mowing at 1 1/2" better than 3/4" so FWG's-role may be in roughs rather than modern fairways. However, we are selecting for variation in amount of rhizomes or buried shoots which could cause stand repair and thickening, and also for finer leaves, so the results of the second breeding cycle may show increased versatility.

Cooperative testing here included buffalograss from Nebraska's program, which did only moderately well, probably because of soil salinity up to 8 mmhos/cm. Bermudagrass from Oklahoma, planted in late August, failed to survive -28°F February cold snap.

A. Alkaligrass (Puccinellia distans, etc.)

1. Breeding nurseries

The large second generation nursery planted in 1988 with progenies of 44 individual parent plants was surveyed several times between fall '88 and summer '89 for size, color, leaf width, culm angle (prostrate, erect or a mixture of both) and panicle type and color. All indications are that 41 or 42 families (out of 44) showed segregation in one or more traits, proving that alkaligrass is cross-pollinated rather than apomictic. The remaining families, including collection 74 from Bridgeport CA salt pad, showed 90% identical plants and 10% plants so different as to be either outcrosses or contaminants in the 1987 harvest or cleaning process. Erect plants came only from erect parents suggesting that those native species have a true breeding tendency for erect culms. Unfortunately they are poor in turf texture and color, and may not be usable in the short term.

Seed yields of 10-plant plots varied from 63 to 104 g (Table 1) for the elite families, and these differences were significant (SE mean ± 7g) suggesting genetic differences. These quantities are enough to plant turf tests if the 10 plants in a row are bulked, but single plants do not often yield enough to plant even two 5' x 5' plots since that would need 18g of seed (see Appendix 1). Consequently we have to bulk like kinds of plants together e.g. prostrate green plants from one or more families, in order to discover the turf value of certain plant types. The 100-seed-weight averages 24 mg., representing well-filled seed, and the purity % represents the fraction of such desirable seed in the crude harvest after threshing. One western collection, no. 97, has unusually heavy seed (Table

Table 1. Seed weight, purity, and 100-seed-weight of seed harvested from two alkaligrass nurseries in Fort Collins, 1989. For the first 9 sources, only one family sampled.

Source	Yield of 10-plant plot (g)	Purity (%)	100 sw (mg)	Turf suitability
2	90	91	27	best
14	104	83	21	good
15	66	82	25	
17	102	92	23	best
18	63	88	26	good
20	65	90	25	best
19	80	91	26	poor color
16	59	88	24	poor color
13	60	90	26	poor color
6		93	22	
22		93	23	
24		93	21	
26		94	24	
57	130	97	24	texture poor
69	33	86	23	
70	34	93	20	
71		92	22	
74	65	93	23	
81		93	22	
87	71	90	21	
93		90	24	
97	59	(37)	(32)	
114		87	24	
Mean	(73)	90	24	

1) but for the rest it would be safe to calculate seeding rates from Appendix 1 using the 25 mg line.

There is a close correlation between bluish-green leaf color, seen in certain collections and in some segregating families of sources 2 and 14, and undesirable turf appearance, so we may be able to do some selection on spaced plants. We will remove, or keep heads clipped, on all such undesired parents so as to maximize the breeding value of the rest of the nursery for 1990 seed production. The best plants will make a recombination block for a potential cultivar.

The other seed production was from individual blocks of western collections 6, 22, 24, etc. ... 114 listed in the lower half of Table 1, but not yet weighed for seed yields. These are intended for a final look at the turf potential, as a follow up on the turf test of 1988 which included only some of these collections. Although no. 57 from Aberdeen, ID had good seed yield, its turf appearance had a poor texture with an undesirable yellowish green color and sheen. No. 74 has an attractive short culm, easy for machine harvest, but we have not yet seen its turf mode.

One large problem with these western collections is that the plants tend to die after seed-stalks have been harvested. This happened in the first (1986) nursery but we thought it was due to dry fall 1986 and dry spring 1987 with mite attack; Fults was very susceptible. Only surviving sources yielding a second crop of seed in 1987 are represented in the "apomixis" test nursery, and they are healthy and green after bearing the 1989 seed crop, so they represent the elite stocks 2 through 20 listed as top 6 lines of Tables 1 and 2. These will be vigorously pursued for seed production in 1990, and the fewer promising

items among the western collections will be multiplied as fast as possible despite their biennial (?) habit.

2. Turf plots

All plots were mowed in 1989 from mid-April to mid-October at 3/4" and 1 1/2" with reel mowers three times a week, as requested. They were watered three or four times a week with 1/3" of sprinkler irrigation. Each plot was split by Koski, with the North half receiving 1 lb. N per 1000 ft^2 (M) and the south half 3 lb. per M. No significant nitrogen response was detected.

Alkaligrass seems to be more cool-season adapted than Kentucky bluegrass or tall fescue, because it has consistently looked poorer in summer than in spring or fall, and poorer than those grasses which were irrigated 1 - 1.6" per week on the same schedule in an adjacent strip. Fertility did not have any effect on this reaction, as no difference was seen between the nitrogen levels at any time.

Experimental turf plots planted in September 1986, September 1987 (two parts), and April 1988 were rated several times during the 1989 season. Although the densities on some of these experiments were lower than desired by golf turf experts, these plots represent a stage in evaluation of genotypes for traits like color, seasonal adaptation, disease reaction, fertility response, and ability to tolerate different mowing heights. In early stages of a breeding program it is necessary to have some idea of the behavior of materials when seed supply will not allow more than 2 or 3 plots of 4' x 4' or 5' x 5' size, from each item to be tested. It has become clear that such plots are not adequate for experimentation on certain cultural management practices, hence the need to make larger

plots which will be discussed in section 3.

Tables 2 and 3 present results of turf tests from bulks and individual progenies demonstrating that although Fults has at times appeared better, on balance the sources 2, 14, 15, 17, 18, and 20 are superior, especially at the higher cut. Sources 19 and 13 are definitely poorer in color and density and are ready for discard. Certain families within 2 and 14 also should be rejected. Since we had no single-plant progenies for 15 and 17 we can only point out that 17 exceeds 15 and 18 in the bulks (Table 2) and that if we had to go with something right now, our best guess would be 2, 17, and 20.

Results from the 1988 spring-planted test in Table 4 suggest that nothing is very exciting among the western collections in that test, because the ones that seemed most promising in April to July (57 and 97) were only mediocre in September. There are still some from 1989 seed production to be tested for the first time.

The main impression from 1989 is the changing ranking of sources for color or other turf appearance from one season to another. For instance, Fults was brownest (slowest to green-up) in April, but greenest in June. Yet it had a bad attack of patch disease (not identified despite culturing by pathologists) in July in the high cut, and the "healthy" patches appeared lush in September, rust-infected in October. Fults probably had the best appearance of any source at the 3/4" cut, when rated in August through October, but we do not believe this precludes the selection of another source for superior spring and midsummer color and quality. Moreover, these reactions are only from one geographic site, and in the 1989 weather pattern. It is necessary to make some choices in Fort Collins because it is not possible to send seed (in quantity) of more than six to

Table 2. Performance from 1987 bulks from mite-resistant plants in the 1987 alkaligrass turf plot - 1989 data.

Source	Color April 19	Quality 3/4" July 11	Quality 1 1/2" July 11	Quality 3/4" Sept 16	Quality 1 1/2" Sept 17	Color 1 1/2" Oct 6	Sum of ratings
2	3.5	3.5	3.2	5.5	6.2	3.5	25.4
14	3.8	2.8	3.0	5.0	5.8	3.2	23.6
15	3.3	3.0	2.7	5.3	5.0	3.0	22.3
17	3.5	3.8	3.0	5.2	6.0	3.8	25.3
18	4.2	2.8	2.5	5.2	5.2	3.0	22.9
20	4.5	2.8	2.8	5.2	5.8	3.8	24.9
19	2.0	2.0	1.8	3.0	3.0	1.0	12.8
13	2.5	2.2	2.0	3.8	4.5	1.5	16.5
Fults	1.0	1.1d	1.6d	6.4	4.5d	1.8	16.4

Quality rating on 0-9 scale (9 best) d = patch disease
Color: April on 1-5 scale, October on 1-4 scale 1 = brown 4 or 5 = green
Sum of ratings could reach 45 maximum; summer slump decreased sums

Table 3. Progeny performance from individual mite-resistant plants of alkaligrass (1987 test) in 1989 under low and high turf cut.

Source/ Progeny		Color Apr 19	Quality 3/4" July 11	Quality 1 1/2" July 11	Quality 3/4" Sept 16	Quality 1 1/2" Sept 17	Color 1 1/2" Oct 6	Sum of ratings
2	2-3-3	3.5	4.0	4.0	6.5	7.5	4.0	29.5
	4-3-3	2.0	4.5	4.0	6.0	6.0	4.0	26.5
	5-3-1	3.0	4.5	5.0	5.5	7.0	3.5	28.5
	5-3-3	2.0	2.5	4.0	3.0	4.0	1.5	17.0
	6-9-3	2.0	4.5	4.5	5.5	6.5	3.0	26.0
14	1-4-2	3.5	3.5	3.5	5.5	6.0	3.5	25.5
	2-7-2	3.5	4.0	3.0	6.5	6.0	2.5	25.5
	5-11-1	4.0	4.5	4.5	6.5	7.0	4.0	30.5
	7-5-3	2.0	4.0	4.0	6.0	6.0	3.0	25.0
	8-8-3	4.0	3.5	3.5	5.5	6.0	4.0	26.5
	9-11-3	4.0	4.0	4.5	6.5	7.0	4.0	30.0
18	4-5-5	3.5	3.0	4.5	4.5	5.5	3.5	24.5
	6-2-2	2.5	3.0	3.5	6.5	6.5	3.0	25.0
19	2-8-3	2.5	2.5	2.5	5.0	4.0	2.0	18.5
	4-12-1	2.5	2.5	1.5	4.0	3.5	1.0	15.0
	4-12-2	2.0	2.0	2.5	3.5	3.5	1.0	14.5
	4-12-3	2.0	2.0	2.5	2.5	3.0	1.0	13.0
13	7-9-4	2.0	2.5	3.0	4.5	4.5	2.5	19.0
	Fults	1.0	2.2d	2.0d	6.8	5.8	1.8	19.6

Quality rating on 0-9 scale (9 best) d = patch disease
Color rated 1-5 April, 1-4 October, with 1 brown and 4-5 green
Sum of ratings could reach 45 maximum; hot weather caused midsummer slump

Table 4. Turf color and quality on Western alkaligrass collections, seeded April 1988, rated in 1989.

Source	Color 1 1/2" Apr. 29	Quality 3/4" July 11	Quality 1 1/2" July 11	Quality 3/4" Sept. 16	Quality 1 1/2" Sept. 16	Color 1 1/2" Oct. 6	Notes
6	1.0	2.0d	2.3d	6.3	6.3	1.3	
22	1.0	1.3d	1.3d	6.3	4.3	1.7	
24	1.7	2.0d	2.0d	7.3	5.3	2.0	
26	1.0	2.0d	2.3d	6.3	6.0	1.7	
57	3.3	3.3	3.7	5.3	6.0	3.7	yellow-green
71	1.0	2.0d	2.3d	7.7	5.3	1.7	
81	1.0	1.5d	2.0d	7.0	5.0	2.5	
87	1.0	2.3	3.3	7.3	6.0	2.0	
93	1.0	1.7d	2.7d	6.3	6.0	2.7	
97	2.5	2.0	3.0	5.0	4.5	2.5	
Fults	1.0	2.0d	2.0d	7.0	6.0	2.0	worst for patch dis.

Quality rating on 0-9 scale (9 best) d = patch disease
Color: 1-4 scale 1 = brown 4 = green Brown in April is due to slow start from dormancy; in October more because of disease (Puccinia rust identified). Fults in mid-June slightly greener than rest, and usually greener at 3/4" in late summer.

eight elite types for regional testing.

3. Larger turf test

Plots 10' x 10' in size were seeded in 3 replications on an adjacent panel on 14 Oct. 1989 to serve as cultural practice tests, as agreed at the September meeting of specialists. The entries were Fults and the Experimentals 2, 17, and 20 using ample seed of each (1986 seed, of which we had about 1 lb. each). Germination this month tested at 81-89% and the pure seed was all about 25 mg per 100, so my recommended seeding rate was 0.93 lb/M (see Appendix 1: 0.79 lb/0.85 germ = 0.93). To reach 15 seed per in^2 would take 1.5 x 0.93 or 1.4 lb/M.

4. Regional tests

We have sent samples of 2, 14, 15, 18, 20 and Fults to three stations in fall 1988. Nebraska and Oklahoma had to do some replanting in spring 1989, for which we supplied extra seed. Michigan has not commented on any survival or stand problems. Oklahoma found (as might be expected) that alkaligrass does not tolerate summer heat well. We look forward to receiving more data.

B. Blue Grama (Bouteloua gracilis)

1. Breeding nurseries

The 1988-planted nursery with 15 plants from 20 elite families headed well this summer and was rated for seedhead number and leafiness. All families segregated for different expressions of these traits, whose range and mean are shown in Table 5, and superior plants of grades 9, 8 and 7 heads were harvested individually in September.

Table 5. Analysis of seedhead ratings on Sept. 1, '89 in blue grama turf cycle-2 evaluation nursery rated 1 (sparse) to 9 (profuse).

Entry number	Number of plants in nursery	Range of seedhead ratings	Mean of seedhead ratings	Leafiness
1	15	2-8	5.5	
2	13	4-9	6.5	2 nice pl.
3	15	3-6	4.4	
4	14	2-6	4.5	
6	14	5-8	6.1	1 nice pl.
7	14	4-8	6.3	
8	13	2-7	5.2	1 nice pl.
9	14	5-8	6.1	
10	15	2-8	4.5	
11	14	5-9	6.9	
12	15	3-8	4.7	
17	15	1-9	5.5	
18	15	2-8	6.3	1 nice pl.
19	15	5-8	6.2	
20	11	3-7	5.2	
21	13	2-7	4.6	2 nice pl.
22	15	3-7	5.8	
23	15	1-9	4.7	1 nice pl.
24	12	1-9	5.6	
25	14	4-7	5.2	1 nice pl.

Note: Entries 13-16 were attractive plants but gave no usable seed because of sterility and/or hail damage.

To maximise seed for management trials, we harvested all the grade-6-heads as a bulk (73 plants). All the plants in the recombination 1 nursery were also harvested to add to this bulk if needed. All this seed is to be processed this winter to obtain data on actual seed yield per plant, and spikelet fertility, as a step in selecting a more productive blue grama type. None of the seed can be planted until May because of climatic considerations, so the seed processing was postponed in favor of other tasks of this project. Some narrower-leaved plants have been seen when this and in the foundation seed field for 9055932, and we intend to select in that direction for a finer turf, in choosing elite plants out of this nursery to make the synthetic.

2. Turf plots

Plots seeded in August 1987 and August 1988 were managed by mowing from early May to October at 3/4" and 1 1/2" three times per week. Irrigation was on a schedule of 1/2" per week, about twice the natural summer precipitation. Blue grama turf thus managed has an attractive light green color at both heights (Table 6) and with some attention to leaf width and to securing adequate seed multiplication rates, we believe that blue grama can be a useful turf. No fertilizer response was seen, to the 3 lb. rate as for alkaligrass. Varieties scheduled for release as range types can serve as a first wave for adaptation tests, while we finish the current cycle of the breeding program. Trials to be planted in spring will include these cultivars as checks for the breeding bulks, and will also test the use of naked caryopses (grains) as seed instead of spikelets. These should work in an irrigated seedbed, and technology exists for seed dealers to shuck the caryopses out of the spikelets.

Table 6. Turf appearance of blue grama in 1989.

Source	Turf quality 18 June 3/4"	1 1/2"	Note
Lovington	3.7	5.3	lacks density
Hachita	4.0	5.0	lacks density
Tall	7.0	7.7	
Forage Gen-1	6.7	7.7	

Planted August 1, 1988 with 5 PLS per in^2 (1.2 lb/M)

3. Larger turf test

Tony Koski has a plan to start a large scale plot with one or two cultivars in good market supply and perhaps one entry of caryopses, which can be planted in May 1990 for management variables and first year performance. There is also the area planted by Dorothy (Falkenberg) Borland at PERC in 1980, but it may not be suitable because its density was recorded as not adequate; the highest rate used was 0.5 lb per 1000 sq. ft. (see Appendix 2) and we reckon to put 1500 PLS per square foot takes 2.2-2.9 lb PLS per 1000. Blue grama prices in the seed trade have been up to $15 per lb. (PLS). This could be reduced if seed production can be made more efficient by selecting for seedhead number and spikelet fertility.

C. Fairway wheatgrass (Agropyron cristatum)

1. Breeding nurseries

The main progress was the planting from seedlings raised in the greenhouse, of a new breeding nursery with 12 individuals of each of 77 progenies, arranged in 3 replications of spaced plants. This enables a thorough search for rhizomatous spreading tendency as well as the seed production which will be needed for 1990 turf evaluation plots. Some other traits like disease resistance, plant height, leaf width and color, and seed productivity can be evaluated during the growth of this nursery. Plants have produced from 0 to 25 heads in late summer 1989 - this is normal for a cool-season grass to not head properly the first year, with insufficient vernalization. We expect full flowering in June and seed production in August, 1990. Surveys of rhizomatous tendency, for which

most of the 76 parents were selected, show an encouraging degree of under-soil shoot spread in many progenies, from 75 to 100% in some families.

2. Turf test

The 56 plots planted in September 1988 showed good color and establishment all through winter, and in spring 1989 we initiated three times a week 3/4" and 1 1/2" turf management. April ratings were made on the high cut and showed promising quality, particularly from source no. 7 and from the cultivar 'Hycrest'. The low cut was not ratable because of being the first cut into those seedling plants. In June appearance was still good, even with no supplementary water, but a combination of stresses in late June and early July (heat and no rain) led to most of the plot becoming very brown, and ratings were all ls and 2s. Because fairway wheatgrass is known to survive and green up after drought and heat-stress browning, we watered it from 11 July on a low frequency, (1/2 - 1" every 2 weeks) as a modification of the stress test. The plot recovered its green color by mid-August but not to the quality seen before mid-June (Table 7) and there was persistent stand thinning. The only future use of this plot is to see how much effect the rhizomatous tendency (scored in the nursery plants) has toward stand-thickening. This should be apparent in Spring of 1990, and then this plot should be replaced by a new plot to be seeded at a higher density (1500 seed per sq. ft. = 5-9 lb. per 1000 sq. ft.) in September 1990, using seed from the nursery families which passed the spring and summer selection and screening.

The problem of quality in fairway wheatgrass is seen to involve a dormancy response to summer stress (heat and drought) which may have been aggravated by the

Table 7. Fairway wheatgrass turf and nursery ratings from Sept. 1988 and June 1989 plots, respectively.

Source	Quality April 29	Quality Index[1] Sept. 3-16	Nursery data heading %	(Oct.) fine leaf %
1	6.3	4.0	52	3
2	6.3	4.2	69	2
3	6.0	3.6	49	8
4	5.6	3.8	27	14
5[2]	6.3	3.6	37	18
6[2]	5.7	3.8	46	11
7[2]	7.3	4.0	58	10
8[2]	6.0	4.0	45	10
9	6.3	4.3	32	2
10	6.5	4.4	14	3
12	6.5	3.0	40	0
13	7.0	2.6	50	3
14	6.3	4.0	26	5
15	7.0	3.0	42	5
16	6.7	4.1	25	11
17[2]	5.0	3.3	68	6
18 Ruff[2]	5.6	4.3	58	0
19 Ephraim	5.3	3.1	75	0
20 Fairway[2]	6.7	3.6	67	0
21 Hycrest	7.0	3.6	52	8
22 I-28	5.3	3.6	-	-

[1] Quality index averaged from low and high cuts on Sept. 3 and 16: scale of 0-9

[2] Denotes diploid sources or cultivars; the others are tetraploid

thrice-weekly mowing schedule, more at the 3/4" height than the 1 1/2". For dryland low maintenance turf the recommendation is to mow at 2 1/2", about once a week. The turf appearance is affected by coarse leaf width, and we have identified quite a few narrow-leaf plants, more in some families than others (Table 7). We shall be watching this trait in the selection process, as it could represent a breakthrough similar to that involved in turf-type tall fescues. The management possibilities with a fine-leaf rhizomatous type of fairway wheatgrass will need to be tested and could be very interesting.

3. Larger turf plot

It was hoped that Tony Koski could establish a 100-200 sq. ft. per plot area in fall 1989 but soil preparation difficulties have postponed this to early spring. Seed of Ruff, Ephraim, and Hycrest is available in the seed trade, but none of these was specifically bred for turf use. We hope to provide some bulk seed from several of our breeding families in August 1990, and may divide some plants in early spring to make a plot to provide such seed (if it can be done without prejudice to the breeding program).

D. Collaborative testing at Fort Collins

We have tested 6 buffalograsses from Terry Riordan, plus one from Dallas sent by Milt Engelke. The latter DALBD-8201 was not well adapted and was sprigged in rather late, on August 29, 1988. The others were put in on August 4 and had varying success. Only one 6' x 6' plot with 8 sprigs spaced in it came to occupy the area by September 1989, and we have learned that buffalograss does not do well on the somewhat saline soil, (6-8 mmhos per cm) with the saline water used for limited irrigation, 1"

every 2 weeks, to test this species. The saline conditions are brought about through the use of slightly saline irrigation water (0.75 - 1.5 mmhos/cm), coupled with infrequent, rather light irrigation regime which does not promote leaching of salts. These plots were mowed at 1 1/2" only once in late August but were sprayed with 2,4-D for broadleaf weed control twice, and some hand-weeding was done. Results have been sent to Lincoln and Dallas. A new test is planned for 1990, to be planted earlier in the summer.

We also planted 4 bermudagrasses from Mike Kenna in late August 1988 but they did not survive the winter - we had temperature down to -28F in early February. If there is interest we could repeat this test along with some locally-adapted bermudagrass; there are a few laws and railroad yards where it can be found.

Appendix 1

Seeding rates to be used in turf tests (revised)

Species and seed wt.	100 sw (mg)	g PLS per sq. ft. @ 10/in²	g PLS per sq. ft. @ 15/in²	g per 5x5' plot	lb. per 1000 sq. ft.
Alkaligrass					
light	15	0.22	0.33	5.5	0.48
medium	25	0.36	0.54	9.0	0.79
heavy	30	0.44	0.66	11.0	0.96
Blue grama					
spikelets:light	70	1.01	1.51	25.2	2.22
heavy	90	1.30	1.95	32.5	2.86
caryopses:light	40	0.58	0.86	14.5	1.28
heavy	60	0.86	1.30	21.6	1.90
Fairway wheatgrass					
2x[a] light	140	2.02	3.03	50.5	4.46
heavy	190	2.74	4.10	68.5	6.04
4x[b] light	220	3.17	4.75	79.2	6.98
heavy	280	4.04	6.06	101.0	8.92

Note all seed amounts PLS for 10 seed/sq. in. (1440/sq ft) except the column for 15/sq in (2160/sq ft)

[a] e.g. Ruff diploid 140 mg

[b] e.g. Hycrest tetraploid 280 mg

Different genotypes have different seed weights; unless 100-seed-weights are known use the "heavy" lines for safety.

Appendix 2

Seeding rates used by Falkenberg (1982)

Species	1b/M	estimated seed numbers per ft. ^{2}	per in^2
Blue grama	0.12	81	0.56
(assume 100 sw = 70 mg)	0.25	162	1.12
	0.50	324	2.25
Fairway wheatgrass	1.0	226	1.57
(assume 100 sw = 200 mg)	2.0	453	3.15
	4.0	906	6.29

This study was supervised by Prof. Jack Butler, as an M.S. thesis. These are not the heaviest 100 sw found in these species, so the highest seed rate might give less than the number quoted per sq. in., and certainly less than 3 for blue grama. With the heaviest blue grama seeding rate she obtained 40 seedlings per 100 sq. cm. (15.5 sq. in.). This agrees rather closely at 2.58 seedlings per sq. in. but the author commented that even the heaviest seeding rate did not produce satisfactory density.

For fairway wheatgrass, her heaviest rate (in the September seeding) produced 90 seedlings per 100 sq. cm. which is 5.8 per sq. in., so evidently her seed were a bit larger than the 200 mg per 100 assumed in my figuring. None of the densities appeared acceptable and even the heaviest seeding rate suffered from stand thinning during the season, as well as color changes produced by heat and drought. The mowing schedule was very relaxed, at 2.5" twice monthly, or monthly from July on. Literature suggests that blue grama rooting habits are hurt by too frequent or too close mowing.

STATEMENT OF EXPENDITURES
U.S. Golf Association
Funding of 2/25/89 - 2/25/90

	Expenses 9/30/89	Encumbered	TOTAL
PERSONNEL			
G. Thor-Salary	$ 7,501	$ 9,978 *	$ 17,479
G. Thor - PERA	1,448	1,975	3,423
Hourly	518		518
MATERIALS AND SUPPLIES	51		51
OTHER DIRECT COSTS	80		80
TOTAL DIRECT COSTS	$ 9,598	$ 11,953	$ 21,551
INDIRECT COST, 16%	1,536	1,913	3,449
TOTAL EXPENDITURES	$ 11,134	$ 13,866	$ 25,000

*Salary encumbered from October 1, 1989 through Feb. 1990