BENTGRASS (AGROSTIS SPP.) CULTIVAR CHARACTERIZATIONS FOR CLOSELY MOWED PUTTING GREENS IN A MEDITERRANEAN CLIMATE

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This paper represents the final conclusions concerning the adaptation and performance of 17 bentgrass (*Agrostis* spp.) cultivars under the conditions of the study in Italy after 6 years of evaluation. This duration allows the turf-soil ecosystem to stabilize in terms of the soil physical characteristics, rooting, thatch, microorganism population, disease causing fungi, insect pests, and nematode populations.

MATERIALS AND METHODS

Establishment. Eleven commercially available cultivars of creeping bentgrass (*Agrostis stolonifera*) and one cultivar of *Agrostis capillaris* L. (Astoria colonial bentgrass) were planted onto a 6,456 sq. ft. (600 m^2) specially constructed experimental putting green located at the Torino Golf Club northeast of Torino, Italy. The plot size was 6.5 x 11.5 ft. (2.0 x 3.5 m), arranged in a randomized block design with 4 replications. In addition, 5 genotypes which at the time were advanced experimental selections of creeping bentgrass from Pennsylvania State University were planted in an adjacent area. These plots were 6.5 x 5.57 ft (2.0 x 1.75 m) in size, with 2 replications in a randomized block design. The root zone profile construction was a high-sand composition meeting Texas-USGA specifications, including a subsurface drainage system.

The experimental area was planted on May 4, 1992. Preplant fertilization consisted of 2.0 lb per 1,000 sq ft. (1.0 kg 100 m^{-2}) each of N, P, and K incorporated into the upper 4 inches (100 mm) of the root zone. All cultivars were planted at a seeding rate of 1 lb per 1,000 sq. ft. (0.5 kg 100 m^{-2}), with the seed lightly raked into the surface. Vertical barrier boards were used to avoid contamination of seed between plots. No lateral seed movement occurred and successful turfgrass establishment was achieved with distinct perimeters between individual cultivar plots.

Cultural Practices. Cultural practices on the experimental putting green involved mowing 5 times per week in multiple directions at a 5 mm cutting height during 1992 thru 1994, and subsequently from 1995 thru 1997 at a cutting height of 5/32 inch (4 mm) by means of a triplex greensmower with a groomer attachment, with clippings removed. The nitrogen fertilization program consisted of 0.7 lb per 1,000 sq. ft. (0.35 kg 100 m^{-2}) per growing month from May through September, totaling 3.5 lb per 1,000 sq. ft. (1.75 kg 100 m^{-2}) annually in 1993 and 1994. The nitrogen fertility program was increased in 1995 through 1997 to 6 lb per 1,000 sq. ft. (3 kg 100 m^{-2}) annually divided into 8 applications from March through October. The base phosphorus (P) and potassium (K) levels were applied as needed to maintain these nutrient levels in the high range based on an annual chemical soil test. The pH of the root zone was 6.8. Supplemental water was applied as needed to prevent visual wilt of the turf via gear driven, pop-up heads arranged in a tight spacing which sustained uniform moisture conditions across the experimental area. Topdressing was practiced at 2-month intervals during the growing season at a rate of 0. 22 cubic yard per 1,000 sq. ft. (0.16 m^3 100 m^{-2}), using the same mix composition as the underlying root zone. No turf cultivation or vertical cutting was practiced on the turfed plots, to avoid interplot genotype contamination.

Disease and insect problems were minimal, except for dollar spot (*Sclerotinia homoeocarpa* F.T. Bennett) which was allowed to develop, with no fungicide applications made during the 1993 growing season. A modest preventive fungicide program has been followed since 1994. No insecticides or herbicides have been applied. All emerging weeds were manually removed during the 1992 growing season. Subsequently after the turfs had fully stabilized, weeds were allowed to develop across the experimental area.

Assessments. Both turfgrass quality and morphological assessments were made. The turfgrass quality assessments involved visual estimates made by 2 F.I.G. Green Section Agronomists at intervals throughout the growing season. The visual estimates were based on a composite of two primary components: uniformity of appearance and shoot density. The rating scale used was 9 = best and 1 = poorest. A rating of 5.5 or higher represented an acceptable quality putting surface.

Morphological assessments were made in September of each growing season. They consisted of actual shoot density counts conducted on a 2.5 square inch (1,600 mm^2) area of turf. Measurements of leaf width were based on a mid-point measurement of the second youngest leaf, with 10 leaves measured per replication. In addition, visual assessments were made of the comparative extent of moss and annual bluegrass invasion. All data were summarized at the end of each growing season and processed for statistical assessment involving the analyses of variance for the 12 older cultivars being separate from that for the 5 new cultivars.

Any occurrences of disease or insect damage were noted, including identification of the causal organism. If the turf damage was sufficiently uniform across the plot area, assessments were made as to the percent of turf area damaged. This occurred only in 1993 and involved dollar spot disease (*Sclerotinia homoeocarpa*). These data were of a unique quality, such that they are presented in a separate F.I.G., Green Section Final Research Report No. 201 (2).

RESULTS AND DISCUSSION

Turfgrass Quality. Visual estimates of turfgrass quality, although subjective, remain the best effective means of assessing the composite turfgrass quality at frequent intervals over a growing season. The primary components assessed are the shoot-leaf density, and the uniformity of leaf width, growth habit, and color. The specific color should be described and not judged as part of turfgrass quality in terms of a color preference. Turfgrass quality estimates above 5.5 indicate an acceptable quality putting green. The comparative seasonal means of visual turfgrass quality of 17 bentgrass cultivars maintained under closely mowed putting green conditions in a Mediterranean climate are shown in Table 1 for 1992 through 1997.

Table 1. Comparative seasonal means of visual turfgrass quality of 17 bentgrass cultivars maintained under closely mowed putting green conditions in a Mediterranean climate.

Genotype	Turfgrass Quality Annual Seasonal Means (9-best; 1-poorest)					
	1992	1993	1994	1995	1996	1997
Providence	7.25	6.13	6.25	6.69	7.22	7.10 a
Penneagle	6.87	6.42	6.38	6.54	7.18	6.91 a
Southshore	—	6.38	6.49	6.81	7.18	6.86 a
PennLinks	7.01	6.15	5.88	6.45	6.99	6.57 a
Penncross	7.11	5.76	5.78	6.29	6.99	6.48 a
SR 1020	6.70	5.03	5.19	6.57	6.57	6.37 ab
Cobra	6.81	5.60	5.73	6.22	6.56	6.31 ab
Putter	7.15	6.15	5.89	6.40	6.69	6.29 ab
National	6.31	4.85	4.91	5.61	6.16	5.36 bc
Emerald	6.39	4.20	4.53	5.43	5.72	4.75 c
Seaside	5.18	3.41	3.87	4.58	4.38	3.61 d
Astoria	4.35	3.50	3.48	3.80	2.79	2.80 d
LSD value*	0.61	0.47	0.78	0.53	0.39	1.05
mean	6.46	5.30	5.37	5.95	6.20	5.78
Penn G-1	7.48	7.22	6.89	7.13	8.10	7.95 a
Penn A-1	7.46	7.37	6.65	6.73	8.06	7.87 a
Penn G-67	7.34	6.72	6.80	6.94	7.38	7.54 ab
Penn G-2	6.80	6.54	6.54	7.33	7.86	7.40 ab
Seaside II	6.39	5.75	5.46	6.23	6.90	7.04 b
LSD value**	0.75	0.48	0.88	0.52	0.42	0.68
mean*	7.10	6.72	6.47	6.87	7.66	7.56

* To determine the statistical differences among the above 12 cultivars, subtract one cultivar's mean from another cultivar's mean; a statistically significant difference occurs when this value is larger than the corresponding LSD value (LSD 0.05).

** To determine the statistical differences among the above 5 cultivars, follow the procedure described in (*).

After five full years being maintained under closely maintained putting green conditions the turfgrass quality ranged from 7.95 down to 2.80. Ranking highest of the older cultivars in visual turfgrass quality after 5+ years were Providence, Penneagle, Southshore, PennLinks, and Penncross, with SR 1020, Cobra and Putter not being significantly different. Ranking inferior and unacceptable as a putting green surface after 5+ years were Emerald, Seaside and Astoria. Among the newer Penn series, the G-1, A-1, G-6 and G-2 all had turfgrass quality values ranking higher than Providence at the end of 5+ growing seasons. The individual seasonal means varied from year-to-year, due to the influence of seasonal variations in climate. It should be noted that no control of dollar spot was practiced during the 1993 season and the height of cut was lowered from 3/16 to 5/32 inch (4.8-4.0 mm) at the start of 1995.

Shoot Density. The comparative shoot densities of 17 bentgrass cultivars maintained under closely mowed putting green conditions in a Mediterranean climate are shown in Table 2 for 1993 through 1997. The shoot densities of the 13 most dense cultivars ranged from 1,522 to 3,003 shoots per square decimeter in 1997, a 2 fold differential. There was a decrease in shoot density from 1993 to 1994, except for Astoria and Seaside. This was most probably the result of a very modest fertilization program. The fertilization rate was adjusted upward in 1995, along with a lowering of the cutting height from 3/16 to 5/32 (4.8-4.0 mm). Subsequently from 1995 through 1997 the shoot density for most cultivars increased, with a few exceptions over the 3 years. Ranking highest in shoot density among the older turfgrass cultivars after 5+ years were PennLinks, Providence, and Southshore, with SR 1020, Cobra and Putter not being significantly different. All the newer Penn series cultivars were higher in shoot density after 5+ years.

The newer bentgrass cultivars sustained very high shoot densities under a close mowing height, which can be a positive from a quality playing surface standpoint. However, they may require new approaches in terms of cultural practices such as weekly turf cultivation by means of closely spaced, ¼ inch (6.4 mm) diameter, solid tines, plus periodic vertical cutting to properly manage the canopy biomass.

Table 2. Comparative annual shoot density counts of 17 bentgrass cultivars maintained under closely mowed putting green conditions in a Mediterranean climate.

Cultivar	Shoot Density Count (shoots per square decimeter)				
	1993	1994	1995	1996	1997
PennLinks	1,504	1,301	1,553	1,793	2,186 a
Providence	1,425	1,093	1,395	1,799	2,080 a
Southshore	1,509	1,126	1,692	2,040	2,037 a
SR 1020	1,419	1,204	1,523	1,799	1,876 ab
Cobra	1,195	1,007	1,363	1,521	1,873 ab
Putter	1,272	1,093	1,356	1,681	1,814 ab
Penncross	1,022	987	1,358	1,642	1,631 b
Penneagle	1,240	1,088	1,383	1,651	1,522 b
National	1,013	759	1,156	1,320	—
Astoria	835	943	1,048	1,307	—
Seaside	755	765	1,020	1,268	—
Emerald	1,010	796	1,172	1,212	—
LSD value*	224	174	214	354	376
mean	1,183	1,014	1,335	1,587	1,877
Penn G-6	2,378	1,306	2,700	2,662	3,003 a
Penn A-1	2,240	1,540	2,325	2,656	2,868 a
Penn G-2	2,546	1,793	2,366	2,225	2,725 a
Penn G-1	2,612	1,902	2,228	2,912	2,675 a
Seaside II	2,053	1,309	1,475	2,762	2,550 a
LSD value**	650	259	538	534	1,333
mean	2,366	1,570	2,219	2,643	2,764

* To determine the statistical differences among the above 12 cultivars, subtract one cultivar's mean from another cultivar's mean; a statistically significant difference occurs when this value is larger than the corresponding LSD value (LSD 0.05).

** To determine the statistical differences among the above 5 cultivars, follow the procedure described in (*).

Leaf Blade Width. The comparative leaf blade width measurements of 17 bentgrass cultivars maintained under closely mowed putting green conditions in a Mediterranean climate are shown in Table 3 for 1993 through 1996. In 1996 the leaf blade widths among the 17 cultivars ranged from 0.62 to 0.92 mm. The most narrow leaf blade widths were found among the Penn series cultivars, ranging from 0.62 to 0.69 mm. These 5 cultivars also possessed the highest shoot densities. This contrasts with the older bentgrass cultivars where only SR 1020 and Southshore were under 0.75 mm, with the remainder being wider than 0.81 mm.

Table 3. Comparative annual leaf blade width measurements of 17 bentgrass cultivars maintained under closely mowed putting green conditions in a Mediterranean climate.

Cultivar	Turfgrass Leaf Blade Width (mm)			
	1993	1994	1995	1996
SR 1020	0.84	0.80	0.77	0.73 a
Southshore	0.84	0.84	0.77	0.74 a
Providence	0.96	0.85	0.87	0.81 ab
Putter	0.94	0.86	0.78	0.82 abc
Penncross	0.89	0.85	0.83	0.85 bc
PennLinks	0.93	0.80	0.81	0.85 bc
Penneagle	0.95	0.96	0.86	0.87 bc
Seaside	0.96	0.90	0.97	0.87 bc
Cobra	0.93	0.88	0.88	0.89 bc
Astoria	0.96	0.85	0.86	0.90 bc
National	0.94	0.90	0.85	0.91 c
Emerald	0.95	0.96	0.88	0.92 c
LSD value*	0.10	0.05	0.09	0.09
mean	0.92	0.87	0.84	0.85
Seaside II	0.76	0.79	0.79	0.62 a
Penn G-6	0.73	0.70	0.62	0.63 a
Penn G-2	0.73	0.63	0.70	0.66 a
Penn A-1	0.75	0.70	0.68	0.67 a
Penn G-1	0.69	0.72	0.69	0.69 a
LSD value**	0.18	0.16	0.13	0.08
mean	0.73	0.71	0.70	0.65

* To determine the statistical differences among the above 12 cultivars, subtract one cultivar's mean from another cultivar's mean; a statistically significant difference occurs when this value is larger than the corresponding LSD value (LSD 0.05).

** To determine the statistical differences among the above 5 cultivars, follow the procedure described in (*).

Annual Bluegrass Invasion. The comparative annual bluegrass invasions among 17 bentgrass cultivars maintained under closely mowed putting green conditions in a Mediterranean climate are shown in Table 4 for the third through fifth years of the study. The older bentgrass cultivars can be aligned in three groups in terms of the extent of annual bentgrass invasion, with Southshore, PennLinks, Providence, SR 1020 and Penneagle exhibiting the least annual bluegrass invasion, with Penncross, Putter, and Cobra being intermediate after 5+ years. National, Emerald, Seaside and Astoria exhibited the greatest annual bluegrass invasion, being 12.5, 17.5, 35, and 50%, respectively, after 5+ growing seasons. Ranking lowest in annual bluegrass invasion as a group were the Penn series, which also possessed the highest shoot densities. Generally, those cultivars with higher shoot densities exhibited the least proneness to annual bluegrass invasion. Over the third through fifth years the amount of annual bluegrass tended to increase for most of the bentgrass cultivars.

Table 4. Comparative annual bluegrass invasion estimates of 12 bentgrass cultivars maintained under closely mowed putting green conditions in a Mediterranean climate.

Cultivars	Percent of Turf Cover as Annual Bluegrass		
	1995	1996	1997
Southshore	0.8	2.5	2.0 a
PennLinks	2.0	4.3	2.8 a
Providence	1.5	2.8	3.0 a
SR-1020	1.0	2.0	3.5 a
Penneagle	0.5	2.0	3.5 a
Penncross	2.3	5.3	7.0 ab
Putter	3.0	3.8	7.7 ab
Cobra	4.8	5.3	8.0 ab
National	3.3	6.8	12.5 bc
Emerald	4.0	10.0	17.5 c
Seaside	9.3	20.0	35.0 d
Astoria	15.0	41.3	50.0 e
LSD value*	3.76	5.89	8.47
mean	4.0	8.8	12.7
Penn G-1	0.5	1.0	1.2 a
Penn A-1	1.0	1.0	1.3 a
Penn G-6	0.0	1.0	1.3 a
Penn G-2	0.5	1.0	1.8 ab
Seaside II	3.0	3.0	2.1 b
LSD value**	0.70	0.66	0.70
mean	1.0	1.4	1.5

* To determine the statistical differences among the above 12 cultivars, subtract one cultivar's mean from another cultivar's mean; a statistically significant difference occurs when this value is larger than the corresponding LSD value (LSD 0.05).

** To determine the statistical differences among the above 5 cultivars, follow the procedure described in (*).

Moss Invasion. The comparative moss invasion among 17 bentgrass cultivars maintained under closely mowed putting green conditions in a Mediterranean climate are shown in Table 5 for the third through fifth years of the study. Generally bentgrass cultivars with a high shoot density had the lowest moss invasion, while those with the lowest shoot densities had the highest moss invasion. It also can be noted that the extent of moss invasion varied from year-to-year within individual cultivars. There were no distinct trends across the cultivars as a whole. Generally, the greatest moss invasion occurred in June in most years. The cultivars that were particularly prone to moss invasion included National, Penncross, Emerald, Seaside, and Astoria. In contrast, the new cultivars Penn G-6, Penn G-1, and Penn G-2 were characterized by a moss invasion of less than 10% in all 3 years.

Table 5. Comparative moss invasion estimates of 17 bentgrass cultivars in June maintained under closely mowed putting green conditions in a Mediterranean climate.

Cultivars	Percent of Turf Cover as Moss			
	1994	1995	1996	mean
Providence	3.3	8.8	10.0	7.4
SR-1020	6.0	10.0	9.3	8.4
Penneagle	7.0	13.0	7.5	9.3
Putter	7.3	10.5	10.0	9.3
Southshore	5.3	9.8	15.5	10.2
PennLinks	10.0	9.3	16.8	12.2
Cobra	11.7	11.8	17.5	13.7
National	16.7	18.8	12.5	16.0
Penncross	13.3	20.0	15.0	16.1
Emerald	26.7	21.3	16.3	21.4
Seaside	30.0	26.3	18.9	25.1
Astoria	54.0	27.5	35.0	38.8
LSD value*	13.06	8.77	8.54	
mean	15.9	15.6	15.4	
Penn G-6	2.5	5.0	4.0	3.8
Penn G-1	1.0	9.0	4.0	4.7
Penn G-2	2.5	7.5	7.5	5.8
Penn A-1	2.5	13.5	2.5	6.2
Seaside II	6.5	15.0	9.0	10.2
LSD value**	3.35	5.54	3.60	
mean	3.0	10.0	5.4	

* To determine the statistical differences among the above 12 cultivars, subtract one cultivar's mean from another cultivar's mean; a statistically significant difference occurs when this value is larger than the corresponding LSD value (LSD 0.05).

** To determine the statistical differences among the above 5 cultivars, follow the procedure described in (*).

References

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