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Experiments were conducted at the Industry Hills Golf Course, City of Industry, CA, and at the California State Polytechnic University, Pomona to evaluate the growth and development of new cultivars of *Poa annua* from Penn Sate University. There were some variations in germination, percent coverage, turf color, quality, leaf texture, tiller numbers, and number of seedheads among the *Poa annua* cultivars. Some of the cultivars like PSU 98-4-21, PSU 99-1-10, and PSU 97-1-3 have a great potential to be used on golf course putting greens even when grown under warmer growing conditions like Southern California.

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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 350 projects at a cost of $29 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

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Evaluating New *Poa annua* Cultivars under Warmer Growing Conditions

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SUMMARY

Annual bluegrass (*Poa annua* L.) is probably the most common turf species found on golf courses around the world. Golf course superintendents in Southern California often manage *Poa annua* as the major turf species on their greens. Researchers at Pennsylvania State University have collected *Poa annua* germplasm from all over the world and have been breeding them to develop desirable traits for use on putting greens. Experiments were conducted at the Industry Hills Golf Course and at the California State Polytechnic University, Pomona to evaluate the growth and development of these new cultivars from Penn Sate University.

- Some of the *Poa annua* cultivars were slow in germination and establishment, but cultivars like PSU 97-1-9 and PSU 98-2-16 were quick in germinating and establishing in the plots at both locations.
- Most of the *Poa annua* cultivars were adversely affected during the summer heat during the first year of the trial in both locations, but most entries came back in the fall and were well established in the plots by spring of the following year at the Cal Poly Pomona site.
- Overall, though there were some variations in germination, percent coverage, turf color, quality, leaf texture, tiller numbers and number of seedheads among the *Poa annua* cultivars, some of the cultivars like PSU 98-4-21, PSU 99-1-10 and PSU 97-1-3 have a great potential to be used on golf course putting greens even when grown under warmer growing conditions like Southern California.

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Annual bluegrass (*Poa annua* L) can be grown as the turfgrass of choice on golf course putting greens. *Poa annua* greens can be of high quality due to its fine texture and high shoot density that is uniform and tolerant of close mowing (1). Piper and Oakley (12) reported that *Poa annua* could be used to maintain high quality putting greens. They reported that when *Poa annua* is abundant enough to make a solid turf, its putting quality is most excellent but a little slow. If only scattered plants occur in the turf, it is sometimes objectionable, as it may make the putting surface uneven. No matter how closely the grass is cut, it will still blossom and produce seedheads at the very surface of the ground. As the grass nears maturity, it gradually becomes paler, partly due to the abundant flowers, and is then not so attractive. On the whole, the grass is to be considered desirable rather than a weed (12).

Poa annua is probably the most invasive plant on a golf course. The grass is native to

Layout of plots after seeding on March 17, 2007. Some of the *Poa annua* cultivars were slow in germination like PSU 98-5-11 while others like PSU 98-4-10, PSU 97-1-9, and PSU 97-1-10 germinated quickly.

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Some of the *Poa annua* cultivars were adversely affected by the heat of the summer in Southern California.

Europe, but now it is found all over the world (12). *Poa annua* is a highly variable species. It contains forms that behave as annuals and other forms that behave as long-lived perennials. The annual form has a bunch-type, upright growth habit of low shoot density and is found in open fields, orchards, and meadows. Plants of the annual form tend to behave more as annuals in that they are non-creepers and are prolific seed producers (5). The perennial form has either an upright growth habit of diminutive stature or a more prostrate, spreading growth habit capable of rooting and producing new shoots from the upper nodes of the decumbent shoots. In addition, the perennial form produces a high shoot density which contributes to the appearance of a rather tight turf (5).

Researchers at Penn State University have been breeding *Poa annua* to develop a desirable cultivar which could be used as the turfgrass of choice on golf course putting greens. They have collected thousands of *Poa annua* samples from existing golf course greens and evaluated tens of thousands of *Poa annua* plants for a period of five years (5, 8). These early selections exhibited a wide range of genetic variation in nearly every imaginable trait including tiller density, color, seedhead production, disease resistance, and environmental stress tolerance (6, 7, 8).

Golf course superintendents in California often manage *Poa annua* greens since the coastal cooler climate is conducive to the year-round growth of *Poa annua*. It is very aggressive and can take over creeping bentgrass (*Agrostis stolonifera*) greens even on newly built greens within 5 to 7 years (4). *Poa annua* is generally conspicuous in lawns, golf course greens, and fairways during the spring and autumn when the temperatures are milder. It can also be found in shady areas where other turf species do not thrive (12).

Managing *Poa annua* greens can be a major problem in the summer since *Poa annua* is susceptible to summer decline and diseases like rapid blight (*Labyrinthula terrestris)* and anthracnose (*Colletotrichum cereale*). Rapid blight occurs on *Poa annua* most commonly in the US in the west, southwest, and coastal south and southeast regions where irrigation water is compromised with salts (2). Anthracnose is a destructive fungal disease of weakened turf that occurs throughout the United States, Canada, and Western Europe and is particularly severe on annual bluegrass (10).

Poa annua is also susceptible to decline at high temperatures, heavy traffic, and high irrigation water salinity. High seedhead production, especially during the spring, and puffiness during the growing season (October through late December and February through June) are some of the characteristics that make *Poa annua* an undesirable turf species when maintained on golf course putting greens (4). Reduction in root depth from eight inches to as little as one inch is common on greens built to USGA specifications in warmer growing conditions. Reduction in root depth predisposes the turf to a variety of biotic and abiotic problems resulting in large areas of necrotic turf. One of the problems with a reduced root depth is the ability of the USGA sand-based green to supply sufficient moisture in the upper

two inches during the summer months. Stressed *Poa annua* plants are more susceptible (predisposed) to anthracnose, and managing annual bluegrass greens during summer is a challenge for superintendents in warmer growing conditions.

Turfgrass researchers have suggested that Poa annua could become a desirable species if breeding efforts are undertaken to address the various undesirable characteristics (3, 9). Plant breeders and geneticists at Penn Sate University are trying to address some of the issues like improving seed yield and have studied the indeterminacy of seed maturity (5). They have reported that a special type of *Poa annua* known as dihaploids can evolve in nature due to the natural selection process. Dihaploids occasionally produce a flower stalk, but are absolutely seed sterile and thus exist entirely as vegetative perennials (5). Such dihaploids represent some of the densest, finest, and highest turf quality strains which would be idle for golf course putting greens (5).

The objective of this research project was to evaluate the establishment, growth, and development of some new *Poa annua* cultivars that were developed at Penn State University when grown under warm growing conditions of southern California for use on golf course putting greens.

Entry Number	Entry Name
1	PSU 98-4-10
2	PSU 97-1-9
3	PSU 97-1-10
4	PSU 98-4-17
5	PSU 99-1-21
6	PSU 01-1-36
7	PSU 99-2-5
8	PSU 99-1-10
9	PSU 98-4-21
10	PSU 98-5-2
11	PSU 98-2-16
12	PSU 98-5-11
13	PSU 98-4-4
14	PSU 98-5-29
15	PSU 98-8-3
16	PSU 98-4-6
17	PSU 97-1-3
18	PSU 98-6-18
19	PSU 98-1-31
20	PSU 98-6-27

Table 1. The list of the 20 *Poa annua* cultivars that were evaluated in the trials was developed at Penn State University in Dr. David Huff's turfgrass breeding program.

Materials and Methods

Locations

The *Poa annua* breeding program at Pennsylvania State University has been developing *Poa annua* varieties for golf course greens. Twenty *Poa annua* cultivars from Penn State University were seeded on a USGA-recommended nursery green at the Industry Hills golf course in the City of Industry, California. The 20 cultivars of *Poa annua* were seeded at a rate of 1 lb per acre in 5 ft by 3 ft plots with three replicates in a randomized block design (Table 1). The plots were rated for germination percentage and percent plant cover. The experiment was initiated on June 7, 2006. The month of August in 2006 was very hot and the average temperature reached 100º F for almost the entire month. The *Poa annua* did not establish well enough to withstand the high temperature and most of the cultivars started to die.

The experiment was reestablished in the spring of 2007 (March 2007) at the California State Polytechnic University Pomona (Cal Poly Pomona) Campus on a USGA-recommended green at the Center for Turf Irrigation and Landscape Technology (C-TILT). The same set of 20 cultivars from Penn State University were seeded at 1 lb per acre rate in 6 ft by 3 ft plots with there replicates in a randomized block design on March 17, 2007. The plots were rated for germination percentage and percent plant cover. The summer of 2008 was quite hot and had a detrimental effect of most of the *Poa annua* varieties, but they all recovered in the fall of 2008. In the

Entry	Entry Name	June 22, 2006 14 DAS Germination	July 6, 2006 30 DAS Germination	July 22, 2006 45 DAS Establishment	August 3, 2006 60 DAS Establishment
		(%)			
1	PSU 98-4-10	26.7 ab	41.7 ab	45.0 ab	13.3 b
2	PSU 97-1-9	26.7 ab	53.3 a	51.7 ab	35.0 a
3	PSU 97-1-10	11.7 ab	41.7 ab	51.7 ab	38.3 a
4	PSU 98-4-17	28.3 ab	51.7 ab	68.3 a	31.7 a
5	PSU 99-1-21	16.7 ab	20.0 ab	16.7 b	8.3 b
6	PSU 01-1-36	16.7 ab	30.0 ab	40.0 ab	38.3 a
7	PSU 99-2-5	36.7 a	55.0 a	58.3 ab	23.3 a
8	PSU 99-1-10	15.7 ab	51.7 ab	60.0 ab	10.0 b
9	PSU 98-4-21	10.0 ab	35.0 ab	40.0 ab	16.7 b
10	PSU 98-5-2	10.0 ab	36.7 ab	48.3 ab	1.7 b
11	PSU 98-2-16	21.7 ab	55.0 a	53.3 ab	5.0 b
12	PSU 98-5-11	3.0 b	10.0 b	13.3 b	0.0 b
13	PSU 98-4-4	31.7 a	48.3 ab	45.0 ab	33.3 a
14	PSU 98-5-29	15.0 ab	33.3 ab	41.7 ab	30.0 a
15	PSU 98-8-3	26.7 ab	45.0 ab	51.7 ab	10.0 b
16	PSU 98-4-6	15.0 ab	30.0 ab	50.0 ab	5.0 b
17	PSU 97-1-3	31.7 a	41.7 ab	31.7 ab	0.0 b
18	PSU 98-6-18	12.3 ab	25.0 ab	43.3 ab	5.0 b
19	PSU 98-1-31	25.0 ab	46.7 ab	56.7 ab	33.3 a
20	PSU 98-6-27	26.7 ab	45.0 ab	48.3 ab	1.7 b
	LSD (P=0.05)	22.5	34.7	40.6	14.1

Means were separated using Duncan's New Multiple range Test (P = 0.05). Means followed by the same letter are not statistically different.

Table 2. Percentage germination and establishment of the *Poa annua* cultivars at the Industry Hills Golf Course site at four dates and days after seeding (DAS).

spring of 2009 almost all the plots came back and were well established by March 2009. Tiller numbers were counted at 10 months after seeding and seedhead ratings were taken one year after seeding.

The plots were maintained at 0.180 inch. The plots were mown 3 times a week using a walk behind greens mower. The frequency of mowing was decreased in the summer to reduce stress on the plants. It was mowed 1 to 2 times per week during the peak summer (July and August). Since the initiation of the trial 5 pounds of N/1000 sq. ft were applied per year. A higher N rate of 1 lb of N/100 sq. ft per month was used during the grow-in period for three months. Once the plots were established, about 1 lb of N/1000 sq. ft was put down from June through mid-September. Heavy fertilization was done in the winter of 2007 to recuperate from summer loss of turf. No growth regulators were applied. Postemergence broadleaf herbicides like Speedzone (carfentrazone-ethyl, 2, 4-D, mecoprop, and dicamba; PBI Gordon, Kansas City, MO) was applied to control prostrate spurge. Fusilade II (fluazifop-p-butyl, Syngenta Professional products, Greensboro, NC) was used to control common bermudagrass that had encroached the green. No fungicides were applied throughout the experiment.

The data were analyzed using the general linear model (GLM) program of SAS. ANOVA analysis was conducted and means were separated using either LSD (P=0.05) or Duncan's New Multiple Range Test (P=0.05).

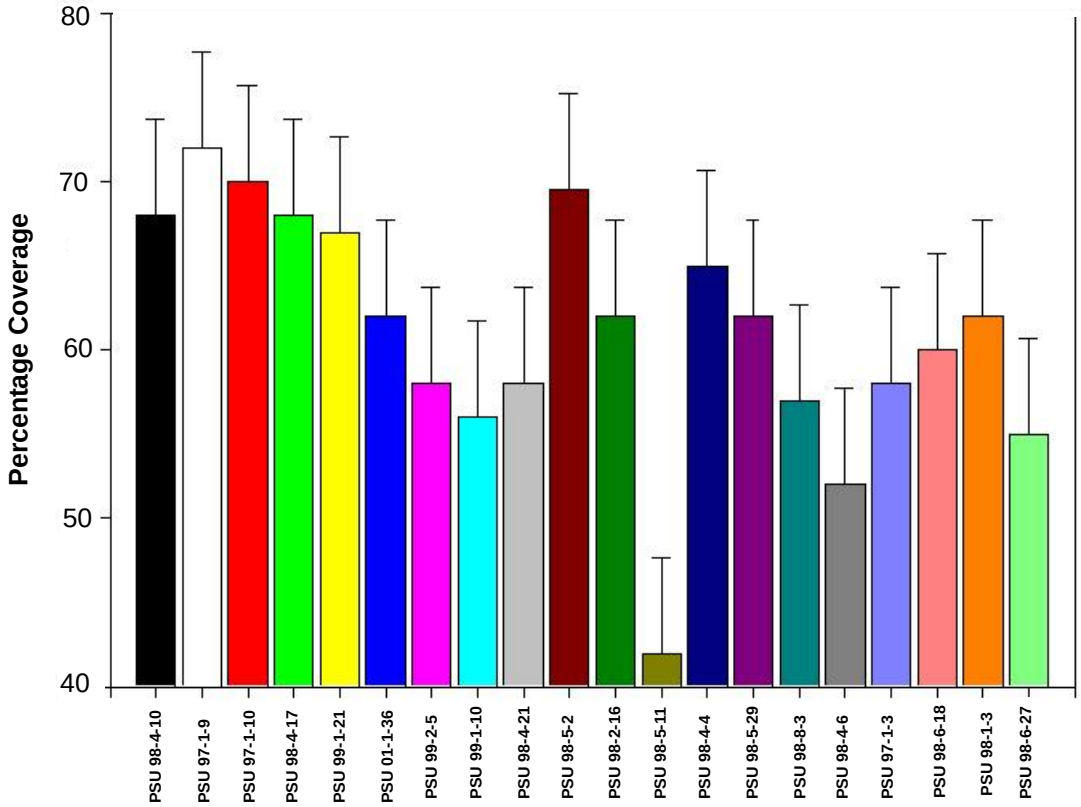

Figure 1. The percentage coverage of plots taken 2 months after seeding at the Cal Poly Pomona site. Some of the *Poa annua* cultivars like PSU 97-1-9, PSU 98-5-2, PSU 97-1-10, PSU 98-4-17, PSU 99-1-21, and PSU 98-4-10 had established quite well, while PSU 98-5-11 was quite slow in establishing. The plots were seeded on March 17, 2007 and the percentage coverage rating was taken on May 18, 2007.

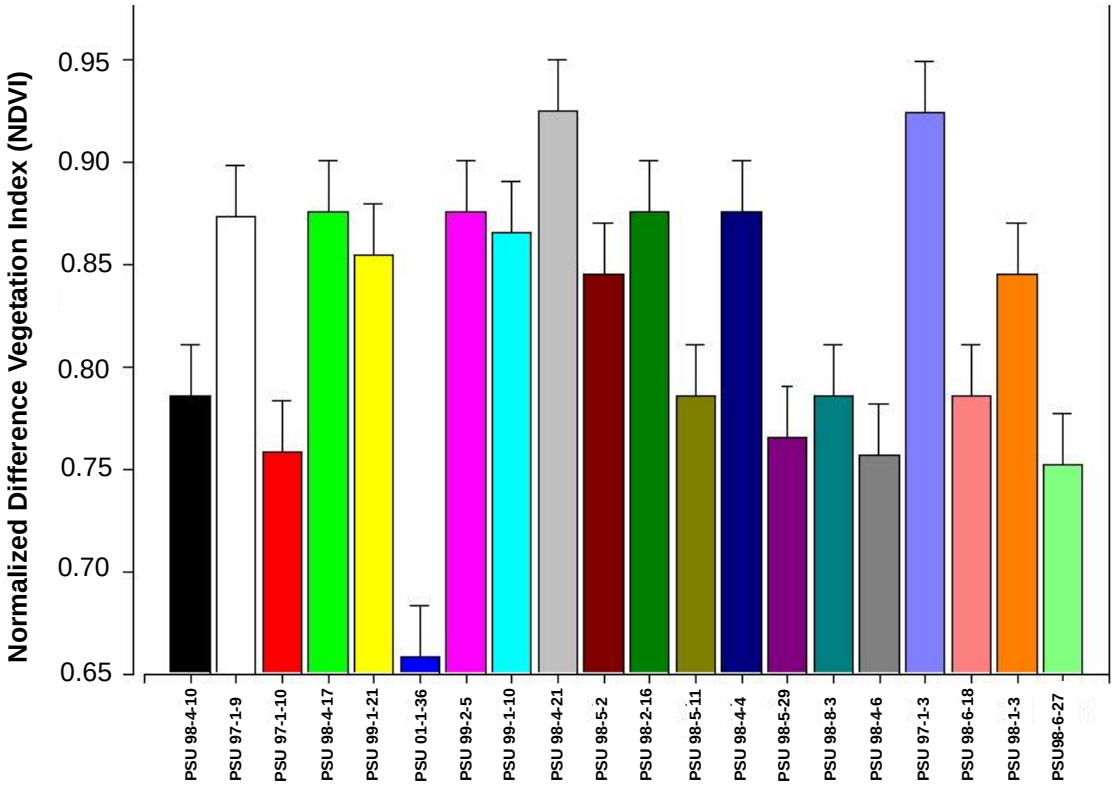

Figure 2. The normalized difference vegetation index (NDVI) values for all the *Poa annua* cultivars. Higher NDVI correlates to darker green color of turf compared to lower NDVI values. NDVI values were measured with a Greenseeker hand-held device.

Entry	Entry Name	April 24, 2007 35 DAS Germination	May 18, 2007 60 DAS Germination	May 22, 2008 425 DAS Leaf texture	June 23, 2008 455 DAS Seedhead
		..... (%).....			
1	PSU 98-4-10	55	68	Medium	Low
2	PSU 97-1-9	55	72	Medium	Low
3	PSU 97-1-10	55	70	Medium	Low
4	PSU 98-4-17	52	68	Medium	Low
5	PSU 99-1-21	38	67	Coarse	Medium
6	PSU 01-1-36	37	62	Medium	Low
7	PSU 99-2-5	37	58	Fine	Low
8	PSU 99-1-10	35	58	Med/Fine	Low
9	PSU 98-4-21	35	58	Medium	Low
10	PSU 98-5-2	35	62	Coarse	Medium
11	PSU 98-2-16	35	63	Coarse	Low
12	PSU 98-5-11	20	42	Medium	Med/Low
13	PSU 98-4-4	38	65	Medium	Med/Low
14	PSU 98-5-29	37	60	Medium	Med/Low
15	PSU 98-8-3	40	57	Medium	Low
16	PSU 98-4-6	38	52	Medium	Low
17	PSU 97-1-3	40	58	Medium	Low
18	PSU 98-6-18	38	60	Medium	Low
19	PSU 98-1-31	35	62	Coarse	Med/Low
20	PSU 98-6-27	38	55	Coarse	Low
	LSD (P = 0.05)	6.5	5.5		

Means were separated using Duncan's New Multiple range Test (P = 0.05). Means followed by the same letter are not statistically different.

Table 3. Percentage germination and establishment of the *Poa annua* cultivars at the Cal Poly Pomona site at two dates and days after seeding (DAS), as well as leaf texture and seedhead production the following season (425 and 455 DAS, respectively

Results and Discussion

Industry Hills Golf Course Site

Some of the cultivars were quick to germinate while some were very slow in germination. Within 14 days after seeding (DAS) the cultivar PSU 99-2-5 and PSU 97-1-9 had a significantly higher germination percentage compared to PSU 98-5-11. Though there were some differences in germination percentages between the cultivars, the data were not significantly different. The PSU 98-4-10, PSU 99-2-5, and PSU 98-2-16 cultivars had the highest germination percentage and were significantly higher than PSU 98-5-11 (Table 2). There was no statistically significant difference between the other cultivars.

At 45 days after seeding the PSU 98-4-17 had the highest percent cover and was significantly higher than PSU 99-1-21 and PSU 98-5-11 cultivars. After 2 months after seeding in August the temperatures started to rise and reached a 100º F for almost a month. This high heat adversely affected the *Poa annua* seedlings and lot of the cultivars started to die. The PSU 98-5-11 and PSU 97-1-3 cultivars were most affected and almost 75% of the stand was lost while PSU 97-1-10 and PSU 01-1-36 cultivars was the least affected (Table 2).

Cal Poly Pomona Site

The *Poa annua* plots were seeded at the Cal Poly Pomona site in March of 2007. Overall ,there was a significant difference between the cultivars in germination and the speed of estab-

Entry	Entry Name	Turf Color	Turf Quality
		(1-9)	
1	PSU 98-4-10	7.00	7.67
2	PSU 97-1-9	7.33	7.33
3	PSU 97-1-10	7.00	7.67
4	PSU 98-4-17	7.33	8.00
5	PSU 99-1-21	7.33	7.67
6	PSU 01-1-36	6.67	7.33
7	PSU 99-2-5	7.33	7.67
8	PSU 99-1-10	7.33	8.33
9	PSU 98-4-21	8.00	8.33
10	PSU 98-5-2	7.33	8.33
11	PSU 98-2-16	7.67	7.33
12	PSU 98-5-11	7.00	7.33
13	PSU 98-4-4	7.67	8.00
14	PSU 98-5-29	7.00	7.67
15	PSU 98-8-3	7.00	8.00
16	PSU 98-4-6	7.00	8.00
17	PSU 97-1-3	8.00	8.33
18	PSU 98-6-18	7.33	7.33
19	PSU 98-1-31	7.67	7.67
20	PSU 98-6-27	7.00	7.00
	LSD (P = 0.05)	0.36	0.40

Table 4. Mean turf color and quality ratings of the *Poa annua* cultivars at the Cal Poly Pomona site taken on March 29, 2009. Ratings utilize 1-9 where 1 was light green, non uniform stand of *Poa annua,* and 9 indicated dark green, uniform dense stand.

lishment. The cultivar PSU 97-1-9 had established quite well within 60 days after seeding (DAS). It had filled up over 72% of the plot area within the first two months after seeding (Table 3). PSU 97-1-9 had a higher germination and establishment percentage at both locations. The cultivars PSU 98-4-10, PSU 97-1-10, PSU 98-4-17, and PSU 98-4-4 germinated faster and established faster in the plots compared to other *Poa annua* cultivars. Cultivars PSU 97-1-10, PSU 99-1-21, PSU 98-4-10, PSU 98-4-17, PSU 98-5-2, PSU 98-4-4, and PSU 98-1-31 germinated faster and covered the plot area quicker than compared to the rest of the other varieties within two months after seeding (Figure 1).

Once the plots were established, the quality of the putting surface was quite good. There was quite a difference in leaf texture between the *Poa annua* cultivars. PSU 99-2-5 had the finest leaf texture while PSU 99-1-21, PSU 98-5-2, PSU 98-2-16, PSU 98-1-31, and PSU 98-6-27 had coarse leaf texture (Table 3). Several of the *Poa annua* cultivars could not stand the summer heat and were adversely affected. The plots started to recover in the winter, and by the spring of 2009 almost all the cultivars had recovered and reestablished.

Overall, there was significant difference in color and quality between the different *Poa annua* cultivars. PSU 98-4-21 and PSU 97-1-3 had the best color compared to all the other entries. PSU 99-1-10, PSU 98-4-21, PSU 98-5-2, and PSU 97-1-3 had the best quality followed by PSU 98-4-17, PSU 98-4-4, PSU 98-8-3, and PSU 98-4-6. Once established, all the plots had a color rating of over 7.0 and quality rating of over 7.0 when rated on a scale of 1 through 9, where 1 was light green, non uniform stand of *Poa annua,* and 9 indicated dark green, uniform dense stand (Table 4).

The health, growth, and development of turf was monitored with a Greenseeker (N Tech Instruments, Ukiah, CA). The Greenseeker sends light from a source and records the reflectance from the turf canopy. Monitoring the reflectance in the near infrared (NIR) and red (R) wavelengths allows the determination of turfgrass quality and detection of early water stress (11). The characteristics of healthy, live, green vegetation are that it has a low reflectance of light from the visual spectrum (R) as a result of the leaf pigments and has a high reflectance of NIR from the scattering of light in the leaf mesophyll cells (11).

On the other hand, dead, brown vegetation and the soil have the reflectance that increases from the visible spectrum to NIR (11). The normalized difference vegetative index (NDVI) is strongly correlated with plant biomass, leaf area index, canopy photosynthetic capacity, and chlorophyll production (11). Hence healthy dense turf stand has a higher NDVI value and the ratio of R/NIR is lower than the values observed in thin unhealthy stand of turf. PSU 98-4-21 and PSU 97-1-3 had the highest NDVI values followed by PSU 97-1-9, PSU 98-4-17, PSU 99-1-21, PSU 99-2-5, PSU 99-1-10, PSU 98-2-16, PSU 98-4-4 and PSU 98-1-31 (Figure 2). The cultivars PSU 99-1-10, PSU 98-4-21, PSU 98-5-2, PSU 97-1-3, and

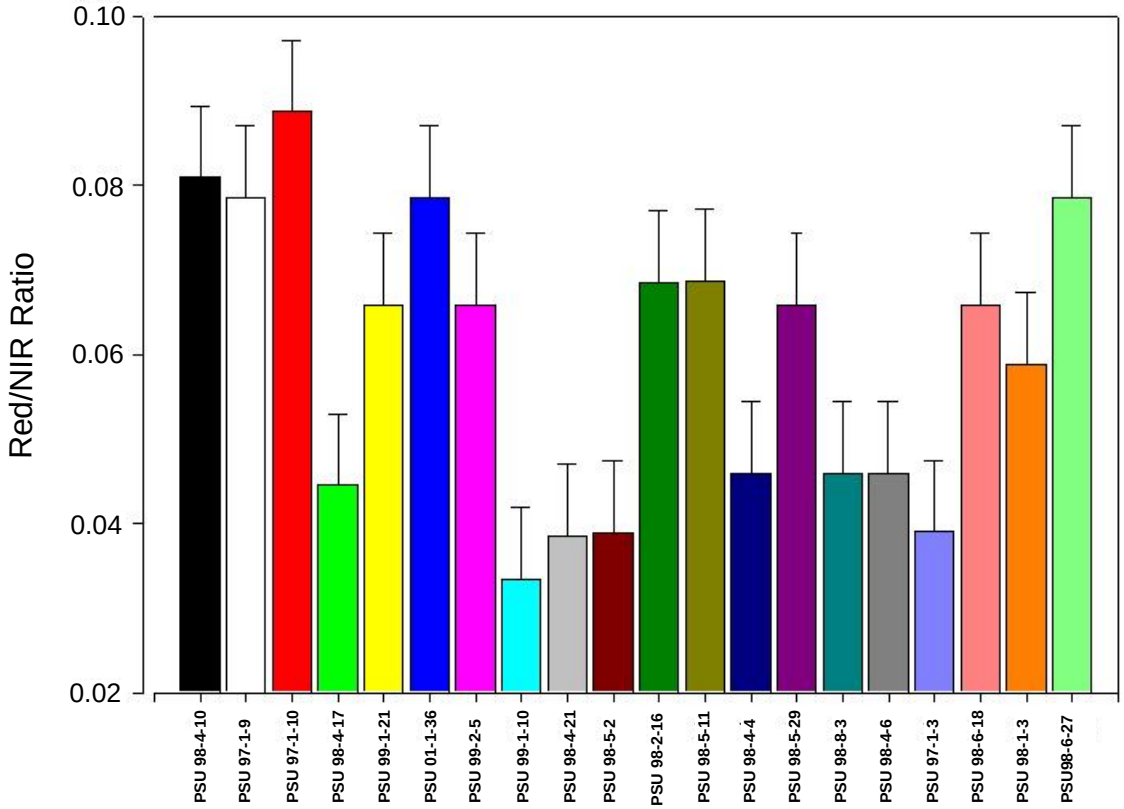

Figure 3. The red/near infra red (R/NIR) ratio of all the *Poa annua* cultivars. Lower R/NIR ratio correlates to healthier turf compared to higher R/NIR values. R/NIR ratios were measured with a Greenseeker hand-held device.

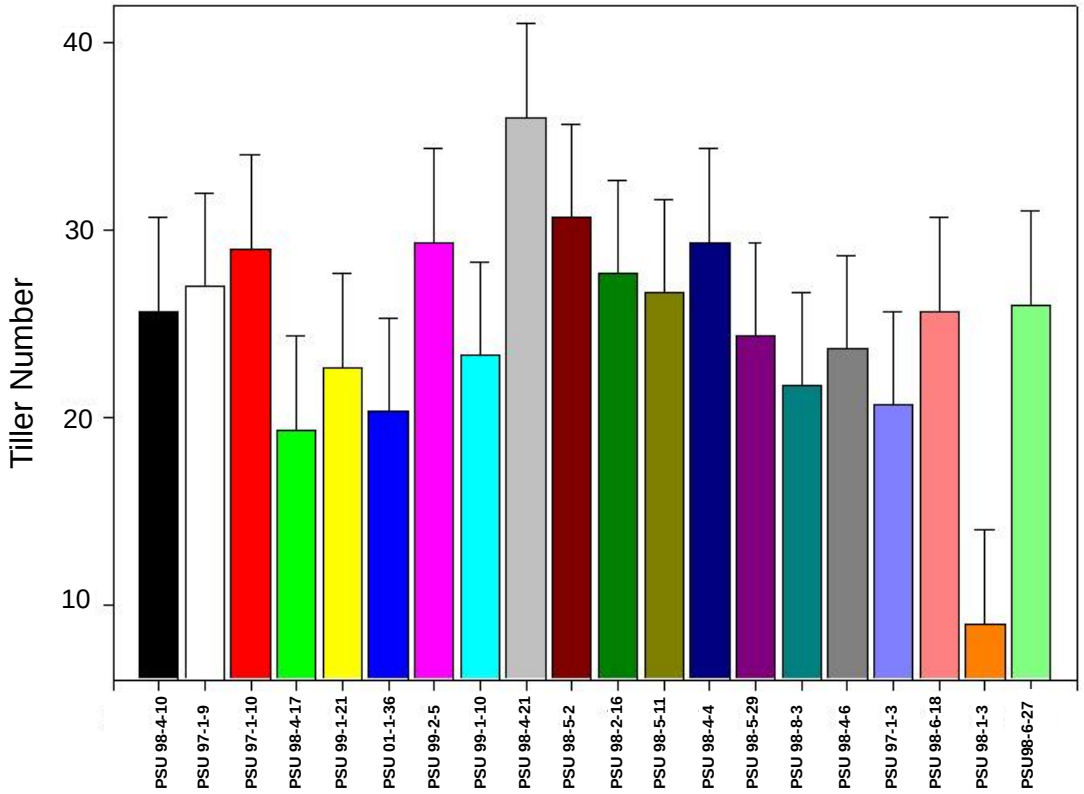

Figure 4. The tiller numbers were counted 10 months after seeding. Some of the *Poa annua* cultivars like PSU 98-4-21 had a lot of tillers while PSU 98-1-31 had very low tiller numbers.

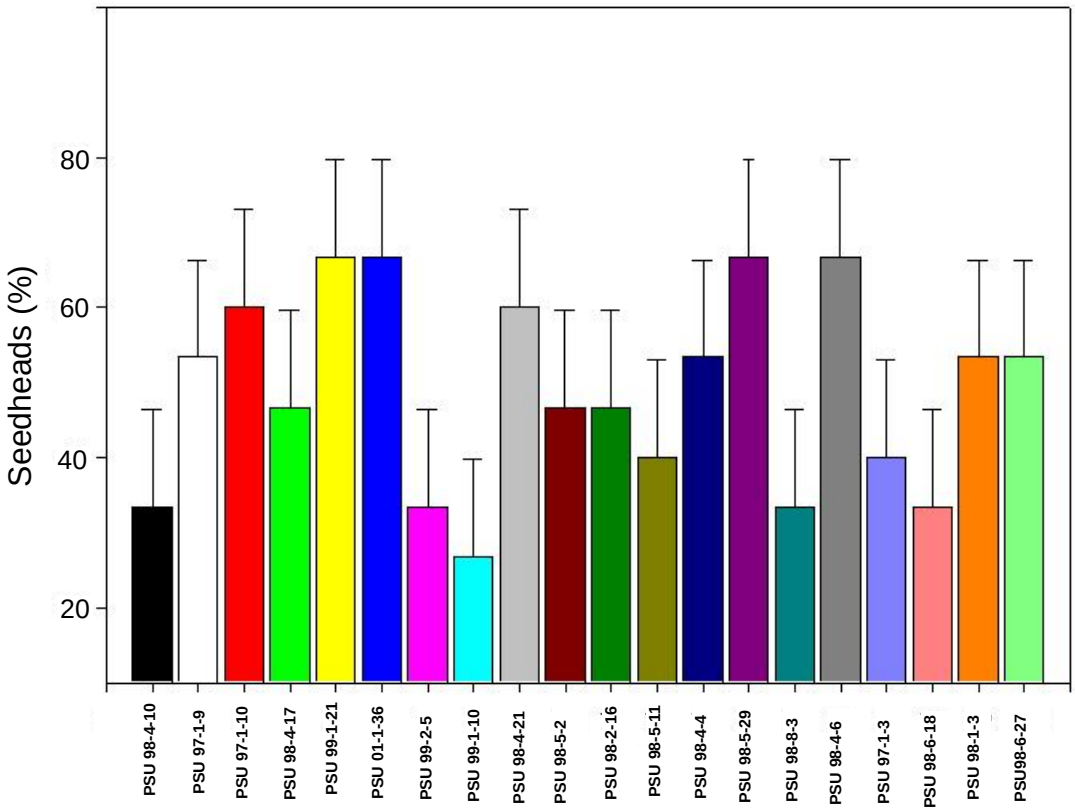

Figure 5. Percentage rating of *Poa annua* seedheads as observed one year after seeding. The plots were rated on a 1 through 5 scale. Plots where 20% of the *Poa annua* plants had seedheads were given a rating of 1, while plots where 100% of the *Poa annua* had seedheads were given a rating of 5. The numbers were then converted to percentages.

PSU 98-4-17 had the lowest R/NIR ratio (Figure 3). Overall comparing the NDVI and R/NIR ratio of the all the cultivars PSU 99-1-10, PSU 98-4-21, and PSU 97-1-3 had the best color, quality, growth, and development.

Tiller numbers were counted 10 months after seeding when they had all established well in all the plots. PSU 98-4-21 had the highest number of tillers followed by PSU 98-4-21, PSU 99-2-5, and PSU 98-4-4 (Figure 4). *Poa annua* produces a huge number of seeds and often produces seedheads in the evening after the green has been mowed in the morning. Due to the excessive growth of *Poa annua* during spring and fall, golf course superintendents experience a reducing in speed of their greens. Hence a *Poa annua* variety suitable for golf course putting greens should have less seedheads. PSU 99-1-10, PSU 99-2-5, PSU 98-8-3, PSU 97-1-3, and PSU 98-6-18 had lower number of seedheads compared to the other *Poa annua* cultivars (Figure 5).

Overall, though there were some variations in germination, percent coverage, turf color, quality, tiller numbers, and number of seedheads among the *Poa annua* cultivars, some of the varieties have a great potential to be used on golf course putting greens even when grown under warmer growing conditions like southern California.

Acknowledgements

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