Research *You Can Use*

Developing Annual Bluegrass Cultivars for Putting Greens

Work continues at Penn State University to tame this highly variable species.

BY DAVID R. HUFF

Poa annua L., the Latin name for annual bluegrass, has long been recognized for providing high quality turf of fine texture and high shoot density that is uniform and tolerant of close mowing.[1] In 1927, legendary USDA agronomists Piper and Oakley[14] described the value and high quality of *Poa annua* for golf course putting greens. More recently, Warwick[16] observed that if grown in a monoculture, *Poa annua* provides an excellent putting surface.

However, not everyone reached the same conclusion concerning the utility of *Poa annua*. While some turfgrass agronomists have encouraged the use and cultivation of *Poa annua* as turf,[7,15,17] others have focused on its eradication as a weed.[2,12] In fact, most instances of *Poa annua* literature describe the grass as an invasive weed whose eradication should be pursued at all costs. This article focuses on the utility and genetic improvement of *Poa annua* for use as putting surfaces.

VARIABLE WITH A WORLDWIDE DISTRIBUTION

Poa annua is one of the world's most widely distributed invasive weed species and, in all its forms, is found on every continent. The mechanisms that enable this grass species to disseminate its progeny so widely and enable it to survive, adapt, and persist in such a wide range of environmental conditions are currently not known. One thing we do know is that *Poa annua* is a highly variable species. It contains forms that behave as annuals and other forms that behave as long-lived perennials.

Traits typically associated with either annual or perennial forms are listed in Table 1. Basically, 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.

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 that contributes to the appearance of a rather tight turf. The perennial biotype of annual bluegrass also is more restricted in the timing of seed formation than the annual form, and it allocates more of its resources (photosynthates) into vegetative growth rather than seed production. As a result, the perennial form is almost exclusively found growing in closely mowed turfs such as old, established golf greens. Thus, one's perception of whether it is a weed (either

Table 1
Comparison of characteristics typically associated with either the annual or perennial forms of *Poa annua*

"Annual" Annual Bluegrass	"Perennial" Annual Bluegrass
Favored by constant surface disruption	Favored by surface stability (little disruption)
Produces lots of seed	Produces little to no seed
Dominates soil seed bank	Scarce in the soil seed bank
Quick to germinate, quick to flower	Slower to flower
Extremely sensitive to environmental stresses (heat, cold, drought)	Likely more tolerant of environmental stresses (heat, cold, drought)
Easier to kill with chemicals, although numerous reports of evolved resistance	More likely to tolerate herbicides
Individuals reproduce throughout a growing season	Individuals reproduce during a specific period during a season (typically spring only)
Most individuals die within a season	Most individuals live multiple seasons and perhaps some are long-lived
Lots of small lime-green tufts on a golf green	Lots of variable-size, variable-color patches on a golf green
Tolerates close mowing heights	Adapted to close mowing heights
Low shoot density, course texture, tall stature	High shoot density, fine texture, short stature
Ugly, bad	Beautiful, good

Table 2
Number of daughter tillers produced at the time of flowering (anthesis) of the parent tiller

Source of *Poa annua*	Number of Daughter Tillers
Rough	1-3
Fairway	4-8
Greens	> 9

annual or perennial forms) or a valuable putting surface (a highly evolved perennial form) depends on which form is present in the turf.

ANNUAL OR PERENNIAL?

The problem in designating an annual bluegrass plant as either an annual or a perennial is that there is a range or spectrum of variability of what ecologists call "life-history characteristics" that exists within the species. One way to measure the perennial nature of a particular *Poa annua* plant is to determine if it grows faster than it dies. In other words, one needs to consider if a growing shoot (also known as a tiller, the basic unit of a grass plant) replaces itself before it flowers, because once a tiller flowers, it dies. And if it does, how many replacements does it produce?

If a tiller replaces itself with just a single daughter tiller before it flowers (i.e., a one-to-one replacement), that would seem to be a precarious position for a perennial to be in because any number of mishaps or events could easily eliminate the one vegetative offspring. In addition, most of the tiller's energy would be invested in seed versus a single vegetative tiller offspring, and so the parent tiller would likely be survived by its seed progeny and not by its only vegetative tiller. This tiller would be behaving as an annual plant. However, if a tiller were to produce many tillers before it flowered (i.e., many-to-one replacement), it would be behaving as a perennial plant.

In experiments conducted at Penn State University, we measured a range of annual bluegrasses for this trait by counting the number of daughter tillers produced at the first sign of flowering (anthesis) of the parent tiller. The results are presented in Table 2 and indicate that *Poa annua* plants evolve an increasingly perennial nature as the level of turfgrass management increases. This process continues on the golf green until eventually plants become entirely perennial and lose the ability to set viable seed altogether. It is these later classes of evolutionary products, those that still set viable seed and are highly perennial and those that do not set viable seed and are entirely vegetative, that have served as the raw material for cultivar development in the Penn State *Poa annua* breeding program.

PENN STATE'S BREEDING PROGRAM

When the annual bluegrass breeding program was initiated in July 1994 thousands of *Poa annua* samples were collected from existing golf course greens. To date, the project has collected and evaluated tens of thousands of *Poa annua* plants. 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. Subsequent collections have yielded similar variability.

Improvements to these initial collections have been achieved by successfully applying several fundamental principles of plant breeding. Primarily, the breeding process has improved turf quality regarding not only shoot density, color, and uniformity of appearance, but also in increased tolerance to several biotic (disease) and abiotic (environmental) stresses.

After an effluent water line broke at one of the trial sites and the plots went unwatered for ten days, plot differences were evident. The Penn State annual bluegrass (back right) was better able to handle the lack of water when compared to the local, native annual bluegrass plot (back left).

Currently, the breeding program has designated a set of the "top-12" cultivars. These cultivars currently are being evaluated on various golf courses and university research facilities around the world. The encouraging news from preliminary reports is that these cultivars are performing well, even better than expected. For instance, at a trial established at Barwon Heads G.C., located on the southern coast of Victoria, Australia, half the plots were irrigated with potable (drinkable) water, while the other half were irrigated with high-salinity effluent water. Planted along with the Penn State annual bluegrasses were plots of the local, native *Poa annua* and several cultivars of creeping bentgrass, including Penn A-4, Seaside II, Mariner, and Penncross. *Poa annua* is known for its inability to tolerate high saline conditions, whereas bentgrasses are known for their ability to tolerate high saline conditions.

The first year's data from this multiple-year study (courtesy of J. Neylan, Australian Golf Course Superintendents Association) indicates that the Penn State annual bluegrasses are not only surviving the high salinity of the effluent water source, but they are demonstrating higher turf quality than bentgrasses in many instances. Moreover, during the late summer of 2004 (February-March), the effluent water line broke and the plots were unwatered for 10 days. The Penn State annual bluegrasses fully recovered, while the local native annual bluegrasses died, demonstrating improved drought resistance in some strains of this highly variable species.

STRESS TOLERANCE

Stress tolerance is an important factor that contributes to perenniality. After all, does it really matter how much better turf quality specific selections may have if the plants have little or no inherent ability to tolerate environmental and biological stress? In order to be perennial, turfgrasses must be able to survive and persist month after month, season after season, year after year, through all kinds of heat, cold, disease, and traffic stresses, whereas plants with annual life cycles can simply die and survive these stressful periods as seed.

Most of what we know about *Poa annua* is based on the annual or less-evolved perennial types. For example, both high and low temperatures represent the major environmental limitations to distribution and growth of *Poa annua*. It is generally believed that this lack of tolerance to extreme temperatures makes *Poa annua* a weak turf for at least some part of the year in most locations. Despite this general observation, strains of *Poa annua* have been observed to perform well in irrigated turf areas subjected to the desert heat of Arizona (D. Kopec, 1998, pers. com.). Duff[4] also reported significant differences among strains for heat tolerance. At the other temperature extreme, Dionne et al.[3] reported finding significant differences among strains for tolerance to freezing temperatures.

Poa annua also is widely known for its susceptibility to many turfgrass diseases, including dollar spot (*Sclerotinia homoeocarpa*), anthracnose (*Colletotrichum graminicola*), and pink snow mold (*Monographella nivalis*). However, the *Poa annua* breeding program at Penn State has identified strains exhibiting excellent field resistance to anthracnose and dollar spot.[6,8] Thus, while most scientific efforts regarding *Poa annua* have been directed towards its eradication, control, or lack of stress tolerance, those research efforts aimed at determining and identifying strains possessing improved stress tolerances have generally been successful.

INVADE AND ADAPT

The evolution of *Poa annua* from wild, weedy, annual forms to the perennial forms adapted to golf, lawn, and athletic field turf has been documented by plant ecologists and plant evolutionists as a classic example of rapid micro-evolution.[10,11,13] When *Poa annua* first invades a turf area, it typically does so as seed of the annual form. The seedlings become established in damaged or weakened open areas of turf, and through phenotypic plasticity they adapt to the given management conditions of that particular turf (i.e., mowing height, moisture availability, and fertility).

Poa annua exhibits a range of perenniality as shown by the number of daughter tillers produced at the time of first flowering of the parent tiller. Early in the breeding program the initial collections of *Poa annua* exhibited a wide range of genetic variation in nearly every imaginable trait.

Poa annua has a unique ability to adjust the height of its flowering culms so that it is capable of flowering and setting seed under nearly any mowing height (i.e., as low as 0.10 inch). Cross-pollination events among annual bluegrass parents produce a range of genetically based morphological variation. Turf management programs act as powerful selection forces. Over time, subsequent generations of *Poa annua* begin to take on the characteristics of a perennial form and ultimately adapt to the particular turfgrass management program. Thus, with every generation, *Poa annua* evolves and adapts in response to the specific cultivation and management practices of a given turf.

On old golf course putting greens this evolutionary process results in strains of highly evolved perennial annual bluegrasses that are becoming known as greens-type *Poa annua*.[3,6] These greens-type *Poa annua* strains are perennials that possess a short stature and extremely high shoot densities, and are vegetatively aggressive. Seedhead production may be a fact of life in any

future commercial cultivar of greens-type *Poa annua*. The main problem, currently, is not the production of seedheads, but rather the *lack* of any seed supply of an improved *Poa annua* for golf green use.

Greens-type *Poa annua* may begin to appear on golf greens as young as 10 years old. Such a rapid evolutionary event is an indication of the extreme selection forces existing on golf greens (primarily mowing height and wear). The selection pressures of the green environment are so intense that on greens as young as 60 years old, it is common to observe a special type of *Poa annua* known as dihaploids. Dihaploids occasionally produce a flower stalk, but they are absolutely seed sterile and thus exist entirely as vegetative perennials. Such dihaploids represent some of the densest, finest, and highest-quality turf strains yet observed.[8]

REALIZING THE POTENTIAL

Over the years and throughout the world, turfgrass scientists and geneticists have described the potential to breed improved strains of *Poa annua* for the golf industry.[4,10] This is due to the high turf quality and the enormous amount of morphological variation present in the perennial forms of *Poa annua*. However, the main obstacles that need to be overcome for the successful cultivation of *Poa annua* seed for the commercial market are 1) low seed yield, 2) the indeterminacy of seed maturity, and 3) the control of undesirable forms of *Poa annua* within seed production fields.

Overcoming the first two obstacles has been among the goals of the Penn State breeding program, with limited success to date. Overcoming the third obstacle through reliance on chemical control may only delay the problem, as several herbicide-resistant strains have been reported among plants of the annual form.[5,9] We have thus been researching production practices (i.e., rotating seed production fields on an annual cycle) that will reduce this obstacle to an acceptable level.

Without doubt, the cultivars of perennial greens-type *Poa annua* will have their share of unforeseen problems, and our breeding program will continue its search for genetic solutions. Our focus is to develop commercial seed supplies for golf courses that have or would like to have annual bluegrass greens. Currently, golf courses that have annual bluegrass greens do not have an adequate seed source for use in routine maintenance, renovations, or new construction. The ulimate goal of Penn State's greens-type *Poa annua* breeding program is not to replace creeping bentgrass as a golf green putting grass, but rather to offer an alternative for situations where annual bluegrass is simply a better choice.

Editor's Note: More about this research and other USGA-funded research projects can be found on the USGA's Turfgrass and Environmental Research Online at: *http://usgatero.msu.edu*.

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DAVID R. HUFF, PH.D., *is an associate professor of turfgrass breeding and genetics at the Pennsylvania State University.*