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Breeding Disease-Resistant Cool-Season Turfgrass Cultivars for the United States

There has been a great increase in breeding cool-season turfgrass cultivars for improved characteristics since the Plant Variety Protection (P.V.P.) Act was signed into law in December of 1970. This law, which is similar to the Plant Patent Law except that it covers sexual and asexual species, permits the developer of a new cultivar to exclude other persons from any unauthorized reproduction or marketing. This does not exclude plant breeders from using protected cultivars in further breeding work.

At present, approximately 5 U.S. universities, 14 U.S. companies, and 10 foreign companies are involved in the improvement of cool-season turfgrasses through breeding. Kentucky bluegrass (*Poa pratensis* L.), perennial ryegrass (*Lolium perenne* L.), tall fescue (*Festuca arundinacea* Schreb.), Chewings fescue (*F. rubra* L. subsp. *commutata* Gaud.), slender creeping fescue (*F. rubra* L. subsp. *trichophylla* Guad.), creeping or spreading fescue (*F. rubra* L. *rubra* Guad.), hard fescue (*F. longifolia* Thuill.), and creeping bentgrass (*Agrostis palustris* Huds.) are the most important cool-season turfgrasses. All these species reproduce sexually and are cross-pollinated except for Kentucky bluegrass, which reproduces mainly by means of apomixis.

A new turfgrass cultivar must be distinct, uniform, and stable during its reproduction process in order to be protected under the P.V.P. Act. The P.V.P. objective description form for bluegrasses has 15 questions regarding environmental reactions; 14 questions regarding disease, insect, and nematode reactions; and other questions regarding plant morphology and turf-forming abilities. All this information is considered by P.V.P. officials in determining the distinctness of a new cultivar. From a practical standpoint, a new cultivar must be easy to establish and an economically efficient seed yielder.

The following discussion is about the development of new, unique cultivars by incorporating disease resistance into cool-season turfgrasses. Most of the screening and selection work in the field and turf plots was conducted where the diseases occur naturally.

Kentucky Bluegrasses

Kentucky bluegrass is the most important turfgrass in the northern half of the United States. All the cultivars used before 1970 were derived from composites collected from naturalized stands in the Midwest or individual apomictic clones found in old turf areas. Merion Kentucky bluegrass originated from a single plant collected in 1936 from Ardmore, Pennsylvania (8). This was the first cultivar with a real turf-type low growth habit and improved resistance to leaf spot caused by *Drechslera poae* (Baudys.) Shoem. or *Bipolaris sorokiniana* (Sacc. in Sorok.) Shoem. (1,4,10). All other cultivars available until the late 1960s were highly susceptible to leaf spot when maintained at close mowing and high fertility.

Hybridization. Kentucky bluegrasses produce seed both sexually and asexually by a process called apomixis. Seed formed by apomictic reproduction is genetically identical to the mother plant. Apomixis is therefore an excellent means of maintaining the genetic purity of a cultivar from one generation to the next. It also makes the crossing and subsequent selection of Kentucky bluegrasses a difficult process.

Clones of Kentucky bluegrass vary as to level of apomixis. Merion has a level of apomixis of 96% or more and A-20 has an apomixis level of around 25% or less. Merion's high level of apomixis makes stable reproduction possible. A-20 has been increased mainly by vegetative means because of its high level of sexuality (8).

The greatest breakthrough in the breeding of Kentucky bluegrass occurred at Rutger's University in the late 1960s (9). C. Reed Funk and associates developed a crossing technique in the greenhouse, using clones with various levels of sexuality, that resulted in many F_1 hybrids. They found that most Kentucky bluegrasses opened their flowers and shed pollen between 1:00 and 4:00 a.m. and that foreign pollen had to be applied during this period to obtain the maximum number of hybrids. Each individual hybrid was planted in a field as an isolated plant and the seed of each individual hybrid was collected. The seed of each hybrid was then used for turf evaluation and uniformity tests as spaced plants. Fortunately, 14% of these F_1 hybrids had recovered the apomictic mode of reproduction. In the same study, approximately 16% of the clones collected from old turf areas were considered highly apomictic (9).

In our crossing work with the above technique we have used the cultivar Shasta, which has excellent resistance to stripe rust (*Puccinia striiformis* West.), as a male parent on stripe rust-susceptible female plants. Progeny of these crosses have resulted in F_1 hybrids with excellent resistance to stripe rust (13) (Fig. 1).

Improved turf-type cultivars. The cultivars Adelphi, Bristol, Bonnieblue, Eclipse, Galaxy, Majestic, and America have resulted from the hybridization work at Rutger's University. Touchdown, Columbia, Glade, Plush, Ram I, and Brunswick are cultivars developed

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cooperatively by Rutger's University and other organizations. Nugget, A-34, Baron, Victa, Cheri, Birka, Parade, Pennstar, Fylking, Sydsport, and Shasta were collections from old turf areas developed by other U.S. and European companies.

All the above-mentioned cultivars are low-growing cultivars with resistance to leaf spot comparable to that of Merion and with resistance to stripe smut better than that of Merion (8). The cultivars Baron, Cheri, and Galaxy were originally thought to have good resistance to stripe smut in New Jersey tests but after years of testing were found to be moderately susceptible (8). Determining the level of stripe smut resistance of a new Kentucky bluegrass cultivar adds 3–4 years to the development time needed for a new cultivar.

Common types. Park, Arobretum, Palouse, S-21, Geary, Kenblue, Delta, Common, Delft, Troy, South Dakota, and Piedmont are erect cultivars with a rapid vertical growth rate and high susceptibility to leaf spot caused by *D. poae*. Newport, Prato, and Cougar are moderately low-growing cultivars susceptible to leaf spot caused by *D. poae* (8). All the above cultivars perform better when mowed at 6 cm or higher. The common bluegrass purchased on the market is usually one of these cultivars.

Park and Kenblue are the most genetically diverse cultivars and will perform better under low maintenance conditions than the other common types or the new turf-type cultivars.

Fusarium blight. Fusarium blight caused by *F. roseum* f. sp. *cerealis* or *F. tricinctum* f. sp. *poae* (2) can cause severe damage to Kentucky bluegrass cultivars that are resistant or susceptible to leaf spot and stripe smut. This disease is most serious under conditions of drought stress, high nitrogen fertility, and heavy thatch accumulation.

The cultivars showing the best resistance to Fusarium blight tend to be the less aggressive sod formers. In tests in southern California and New Jersey (6), the cultivars Adelphi, Columbia, Parade, Rugby, Banff, and Sydsport have shown improved resistance, while Park, Fylking, and Pennstar have been most susceptible.

In our breeding scheme the most promising cultivars are seeded in southern California where Fusarium blight is usually an annual occurrence. The reaction to Fusarium blight can be observed within 8 months after planting.

Low-maintenance diseases. All the rust diseases and dollar spot (*Sclerotinia homeocarpa* T. Bennett) are the most serious low-maintenance diseases of Kentucky bluegrass. Nugget is very susceptible and Merion, Glade, Sydsport, Touchdown, Baron, Victa, Cheri, and Ram I are moderately susceptible to dollar spot (8). Majestic, Bristol, Kenblue, Plush, Adelphi, and Columbia have shown moderate or better resistance to dollar spot. Dollar spot could become quite serious on susceptible cultivars in the future if the level of nitrogen fertility continues to decline.

In the Midwest, Northeast, and southern California, stem rust (*P. graminis*) can seriously damage Merion, Birka, Nugget, Touchdown, and Baron grown under conditions of low fertility (4,8). Adelphi, Majestic, Columbia, Bristol, Eclipse, and Plush have good stem rust resistance (8).

In the Pacific Northwest and northern California, stripe rust is the most serious disease of Kentucky bluegrass in seed production fields and low-maintenance turf. Shasta is the most resistant and Touchdown the most susceptible cultivar.

Specialty uses. Many of the turf areas in the northern United States are partially shaded. Powdery mildew (*Erysiphe graminis* DC) and leaf spot are the most serious diseases in shade (1). A-34, Glade, Nugget, Touchdown, and Birka have shown good resistance to some of the races of powdery mildew (8) and perform better in the shade than other cultivars.

When Kentucky bluegrasses are maintained at short cutting heights and managed intensely as a golf course tee or fairway, only Touchdown, A-34, and Brunswick are able to compete with *P. annua* (14). These are very aggressive cultivars with high competitive abilities. They can dominate other cultivars in blends, and if managed at higher, nondemanding cutting heights, they can develop thatch at a rapid rate.

Regional cultivars. Certain regions of the northern United States require cultivars that may not be as useful in other areas. Shasta is more useful for the Pacific Northwest. Vantage is a unique cultivar in the mid-Atlantic area because its performance during heat and drought stress is better than that of other cultivars. In the Rocky Mountain region, cultivars must have resistance to iron chlorosis and drought, with little or no demand for resistance to the diseases prevalent in humid areas.

The 1980 national bluegrass test included 84 entries to be planted throughout the northern United States. After the performance data from this test are evaluated, better information about regional adaptation of cultivars should be available.

Perennial Ryegrasses

All the perennial ryegrasses available before 1960 were developed for forage rather than for turf. In 1967, Manhattan perennial ryegrass was released as the first improved turf-type cultivar. It is fine textured, leafy, and persistent in turf, with improved mowability (Fig. 2). Pennfine was released later and performed better than Manhattan during the summer but was less cold hardy (5). Citation, Birdie, Derby, Fiesta, Dasher, Regal, Delray, and Pennant were released later and have shown better summer performance and improved resistance to brown patch (*Rhizoctonia solani* Kühn). Omega, Belle, Blazer, Yorktown, Yorktown II, and Diplomat possess improved brown patch resistance, good winter performance, and resistance to leaf spot caused by *D. siccans* (Drechs.) Shoem. (5).

Because ryegrasses are a cross-pollinated species, recurrent selection can be used to develop cultivars with improved disease resistance. This has been done to improve the level of resistance in perennial ryegrass populations to brown patch (5). In our breeding work, we have been able to use recurrent selection in conjunction with single plant turf progeny tests to improve resistance to leaf spot caused by *D. siccans* in perennial ryegrass populations.

Pythium blight is a serious disease of perennial ryegrasses, especially under poor drainage conditions; no resistance has been reported. Fortunately, the new turf-type cultivars have the ability to recover rapidly from disease damage.

Dollar spot, crown rust (*P. coronata* Cda.), and red thread (*Corticium fusiforme* (Berk.) Wakef.) can severely damage perennial ryegrasses grown under low fertility. Citation, Birdie, Pennfine, Regal, and Pennant have shown some resistance to a few strains of dollar spot and red thread (5). Elka, Loretta, Pennant, Yorktown II, Blazer, Fiesta, and Birdie have shown resistance to crown rust in tests, whereas Regal and Derby have been susceptible (5).

Seed production. Stem rust (*P. graminis* Pers.) is the most serious disease of seed production fields of perennial ryegrass in western Oregon (Fig. 3). Fungicide applications are required from April through July to prevent seed yield losses of up to 93%.

Collections of perennial ryegrass from old turf areas in St. Louis, Missouri, and Washington, D.C., in 1975 have shown good resistance to stem rust. These resistant clones were not turf-type plants and had to be used in crosses with turf-type cultivars. After four cycles of selection for rust resistance, seed-yielding abilities, and turf performance, synthetics have been made that are turf-type, stem rust-resistant cultivars. Progeny tests from crosses indicate that the stem rust resistance in this material is being controlled by multiple genes.

The cycles of selection are done by inoculating seedlings with the stem rust fungus during the summer. The seedlings with limited or no pustule development are then planted in the fall as spaced plants. In the spring, the clones susceptible to rust are defoliated by stem rust in 3–4 weeks. Only those plants with little or no rust are allowed to interpollinate. All plants are harvested individually and then evaluated in turf

progeny tests. Seed of the most promising turf-type plants is then used to start the next cycle of selection. Figure 4 shows the difference between a stem rust-resistant and a stem rust-susceptible plant.

The turf-type perennial ryegrasses are unique in that they have never been reported to form thatch. They are also useful in mixtures with Kentucky bluegrass to reduce the incidence of Fusarium blight. In our tests in southern California, the addition of 15–20% turf-type perennial ryegrass to Kentucky bluegrass mixtures effectively controlled Fusarium blight (Fig. 5).

Fine Fescues

The Chewings, slender creeping, creeping or spreading, and hard fescues are the predominant species included in the open-pollinated fine fescue group. They form a very fine, dense turf and maintain this density at low fertility. They tolerate infertile, droughty, and acid soil conditions, moderate shade, and tree root competition. They will not tolerate wet soils or perform well in open sun at high nitrogen fertility and irrigation because of severe leaf spot damage caused by *B. sorokiniana* and *D. dictyoides* (1,7).

Chewings fescues. This very low-growing species produces only basal tillers and no rhizomes. Chewings fescues perform best in cooler regions of the United States and tolerate close mowing. Jamestown and Banner are improved cultivars with better heat tolerance than older cultivars (7). In the shade, these cultivars can be damaged by powdery mildew. Shadow is a new cultivar with improved resistance to powdery mildew. All the new cultivars need better resistance to red thread and dollar spot. They are very dense, aggressive turf formers. This can be a disadvantage when they are mixed with Kentucky bluegrass; they are too competitive, and thatch accumulates rapidly.

Slender creeping fescues. Dawson is the popular example of this group. It forms short, thin rhizomes and looks like Chewings fescue. Dawson is more susceptible to dollar spot and more resistant to leaf spot caused by *D. dictyoides* than most other fine fescues. It has performed better than other fine fescues for the overseeding of dormant bermudagrass, with a very good establishment rate.

Creeping or spreading fescues. These fescues have wider leaves than other fine fescues and produce long rhizomes. They will not tolerate a close cut but have very good seedling vigor. Fortress, Ruby, and Ensylva are creeping types with less leaf spot, red thread, and dollar spot resistance than the best fine fescues (7). These cultivars have a more open growth habit and are more compatible in mixtures with Kentucky bluegrass than the other fine fescues.

Hard fescues. Biljart (C-26), Scaldis, and Waldina are improved hard fescues. They are similar in appearance to the better Chewings fescues but have a slower rate of vertical growth and improved heat tolerance. They have good resistance to red thread and leaf spot caused by *D. dictyoides* and improved tolerance to dollar spot. Their rate of establishment is slower than that of the other fine fescues. The limited commercial availability of hard fescues has been caused by their lack of burning tolerance in seed production, which limits the productive life of fields to 2 or 3 years. Breeding work is being done to select clones for use in synthetics that can sustain good seed head formation over a longer period of time in the absence of field burning.

Fig. 1. Center plant is a F_1 stripe rust-resistant hybrid derived from a susceptible female crossed with Shasta Kentucky bluegrass. Other plants illustrate the rust susceptibility of asexual derivatives.

Fig. 2. Leafy, dense, attractive growth habit of parents of Manhattan turf-type perennial ryegrass growing in a breeder seed isolation nursery.

Tall Fescues

Tall fescue is a cool-season grass best adapted to the transition zone of the United States. This species can also do well in the Great Plains and Rocky Mountains when irrigated and is well adapted to the Pacific Northwest and California. The tall fescues require less irrigation to maintain active growth than the Kentucky bluegrasses and perennial ryegrasses.

Alta and Kentucky 31 were the first cultivars developed for forage and turf uses (11). They both form a coarse, moderately open turf with a rapid rate of leaf elongation. Fawn was a later forage development with poorer turf quality than that of Alta or Kentucky 31. Kentucky 31 has shown better tolerance of brown patch and leaf spot caused by *D. dictyoides* than Alta and Fawn, which are quite susceptible.

Fig. 3. Stem rust of perennial ryegrass in western Oregon.

Fig. 4. Preharvest perennial ryegrass plants resistant (left) and susceptible (right) to stem rust.

Fig. 5. Turf in southern California consisting of Kentucky bluegrass with 20% perennial ryegrass (left) and without ryegrass (right) illustrates how mixing perennial ryegrass with susceptible Kentucky bluegrass cultivars controls Fusarium blight.

Rebel, Falcon, and Olympic are new, moderately low-growing, leafy cultivars developed for turf purposes (12). They have softer leaves and produce a denser, more persistent turf than the older cultivars. They have shown improved resistance to brown patch and a faster recovery rate from disease damage. Olympic has displayed better resistance to leaf spot during establishment than other cultivars (12). Olympic and Falcon were screened for resistance to crown rust before the final selection of parents in the breeder seed production field in western Oregon.

Creeping Bentgrass

Penneagle creeping bentgrass was released in 1978 by the Pennsylvania Agricultural Experiment Station (3). This cultivar was developed after testing

parental material for 15 years. The objective in developing this new putting green bentgrass was to have a broad genetic base without gross segregation of off-types, improved putting green quality, enough vigor to compete with *P. annua* invasion, and good disease resistance. In comparison tests with Penncross, Seaside, and Emerald, Penneagle looks like an improved disease-resistant putting green grass for the northern United States.

Needs and Demands

There is an increasing demand for turfgrasses that require less energy and other natural resources for maintenance, including reduced mowing, irrigation, and fertilization. Cultivars are also needed that require less pesticide usage by being at least tolerant to serious diseases and insect problems and competitive with weedy species. There is a great need to eliminate diseases in seed fields through breeding work to improve the economics of seed production.

It is now well known that no single cultivar is sufficiently well adapted and disease-resistant to be used in home lawn-type turf in a monoculture. Blends and mixtures of Kentucky bluegrasses, improved turf-type perennial ryegrasses, and fine and tall fescues are now commonly used for new seedings and sod production. This trend places added demands on the turfgrass breeder to determine the compatibility of a new cultivar for blending and mixing with other cultivars and species to attain optimum long-term turf performance.

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