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# TURFGRASSES FOR THE 1980's[1]

PHILIP BUSEY
*IFAS, Agricultural Research Center,
University of Florida,
3205 S.W. 70th Ave.,
Fort Lauderdale, FL 33314*

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*Abstract.* **Turfgrass breeding at Fort Lauderdale applies the general principles of plant adaptation to the humanistic goal of improving turfgrasses for the 1980's. A germplasm resource of approximately 600 accessions has been established as the foundation for new cultivars. Breeding and selection procedures place priority on genotypes requiring smaller inputs of energy, pesticides, water, and fertilizer, in order to maintain an attractive and durable cover for urban areas. A breeding philosophy is presented that considers the need for long-term field-level adaptation and turf quality, but is cautious regarding single-character evaluations. These procedures are part of an ongoing program designed to respond to changing conditions in the turfgrass environment of the future.**

Turfgrasses became an increasingly important part of the urban environment, with the development of suburbs, and the single-family home. Expansion of parks and recreational facilities also gave turfgrasses an important part in our way of life, such that turf is a major industry in Florida, involving expenditures exceeding half a billion dollars (4). The widespread use of pesticides was a change not foreseen a few decades ago, but this was a change that revolutionized turfgrass management. Among changes foreseen for the 1980's is that many of today's pesticides will no longer be produced. In some cases, they will be replaced by safer and more effective chemicals. In other cases, undoubtedly, there will be no other substitute available—except genetic resistance. We are now considering the genetic design of turfgrasses for the 1980's, and it is appropriate to study the directions established in the past.

## Evolution and Adaptation

Grasslands evolved under the hooves and grazing of vast herds, and were repeatedly swept by flames. Grasses have developed well the ability to grow from the base, instead of from the aerial portions. Except in flowering, most grasses have stems near the ground; when grazed, only the distal portions of the leaves are removed. Intercalary meristems at the base of grass leaves permitted continued growth after cutting. Furthermore, the tightly intertwined stems of sod-forming grasses formed a cushion that protected the soil in the root zone from compaction and erosion.

Evolution proceeded by means of natural selection, mutation, and hybridization, to develop the species of grasses cultivated for turf in Florida. For natural selection to continue, there must be genetic diversity. The turfgrass breeder must apply what is known about the evolutionary milieu of our turfgrasses to speed up or to redirect natural selection towards humanistic goals. Evolution is proceeding by means of artificial selection at the Fort Lauderdale Agricultural Research Center, and at other turfgrass laboratories across the country.

Through millenia of natural selection, certain grasses became adapted to do particularly well in rich, unstable environments—they survived the heavy grazing forced on by primitive herdsmen, and thrived in the nutrients recycled through cattle. Bermudagrass (*Cynodon dactylon* [L.] Pers.) is an excellent example. Bermudagrass thrives under conditions of disturbance (7). Bermudagrasses developed for pastures and for turf respond to very high levels of N. This response is in the form of high net assimilation rates, and resulting high growth rates. Rapid growth permits bermudagrass to outgrow traffic damage and frequent cutting, more than any other grass. Although evolutionary divergence and interspecific hybridization have also been involved in certain turf-type bermudagrasses, thousands of years of natural selection in the savannahs of Africa and southern Asia were primarily responsible.

At the opposite extreme is centipedegrass (*Eremochloa ophiuroides* [Munro] Hack.). Centipedegrass originated in southern Asia and China. Infertile soils may have been brought about by thousands of years of cultivation, particularly in the monsoon region of southeast Asia. As a result, centipedegrass became adapted as a grass requiring low fertility levels. Although centipedegrass is slow-growing, it can predominate and outcompete other grasses in conditions of low fertility.

The contrast between bermudagrass and centipedegrass points out another aspect of turfgrass breeding. Adaptation, the ability of a genotype to do well in a given environment, is the key to better turfgrasses. New turfgrasses will be grown in a certain range of environments. The only appropriate criterion of their acceptability is how well they are fitted to the conditions under which they will be grown. Because a turfgrass cultivar looks beautiful in some carefully maintained experimental plots is no consolation for the homeowner whose front lawn is killed by chinchbugs, or left ragged because of improper mowing. For all management environments, the responsibility falls both on the plant breeder and on the turf manager to find a solution. In almost all cases, either better breeding or better management can be applied successfully, depending on the situation.

Many options are available to the turfgrass manager. Pesticides, topdressing, fertilizer, and mowers are commercially available, and do not involve replacement of the grass. But few options are immediately available to the turfgrass breeder in the way of resistant grasses, or grasses that require less maintenance. Many years of research are necessary to develop and release a new cultivar; at present we have only three acceptable St. Augustinegrasses, and only two bahiagrasses available in Florida.

Climate is an aspect of the turfgrass environment that cannot be controlled. Although irrigation can be used in the dry season, and mowing and fertilization practices can be altered to meet the season, ambient temperature and sunlight are virtually inflexible. In Florida, only a handful of warm-season turfgrasses can be depended on for most situations. The same warm-season turfgrasses that do well farther north are beset here by additional life cycles of insects, and nematode species of less importance farther north. Cultivars such as 'Meyer' zoysiagrass and 'Common' bermudagrass do not do well in Florida. Common bermudagrass types are heavily attacked by the bermudagrass mite (*Eriophyes cynodoniensis* Sayed) in Florida. However, there are common genotypes, such as FB-119, that may be resistant to the bermudagrass mite (J. A. Reinert, personal

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communication). In the case of zoysiagrass, there are 7 genotypes in the Fort Lauderdale breeding program that perform significantly better ($P<0.001$) than either 'Meyer' or 'Emerald.' These experimental strains will be considered for release as new cultivars.

These examples point out another aspect of turfgrass adaptation. Although climate and management are environmental factors pertinent to selecting the best grass for any condition, no single variable can be isolated. In the case of the bermudagrass mite, an interaction exists with temperature and management. No single environmental variable can be considered by itself. Rather, the turfgrass environment is a complicated multiple interaction of all factors, acting in concert. In some cases (e.g., gray leafspot disease of St. Augustinegrass) high fertility increases the incidence of disease (5). However, in the case of Cercospora leaf spot disease of St. Augustinegrass, high fertility diminishes the problem (9). In both examples, genetic resistance is known and can be applied as an alternative solution. In other cases, such as mole cricket damage in bahiagrass, resistance is not known, but should be looked for.

## Genetic Resources

Breeders of major food crops such as corn and wheat have available to them collections of tens of thousands of genotypes. Should a new and virulent disease appear, the corn breeder can immediately begin screening the entire world's collection for resistance. This is not true for turfgrasses, particularly the warm-season species. During 1976-1977 we have accumulated about 600 accessions in the germplasm resource base at Fort Lauderdale (Table 1). Accessions are being maintained in pots, to lessen the opportunity for contamination that would occur in field plots. Vavilov theorized in 1926 that more genetic diversity could be obtained at the center of origin for various crops (16). However, less than 200 of the turfgrass accessions available to us have been obtained from the centers of origin of different turf species; the rest have been continental-U.S. collections. This suggests that there may be duplications and gaps in the germplasm collection, and that additional introductions from the centers of origin would be useful. Among some of our African accessions, we have found several bermudagrasses with outstanding competitive ability to weeds (Fig. 1).

Table 1. Numbers of turfgrass and groundcover accessions in the germplasm resource base at Fort Lauderdale.

| Genus or species | Number of accessions | |
|---|---|---|
| Axonopus spp. (carpetgrass) | | 6 |
| Cynodon | | 202 |
| C. dactylon (common bermudagrass) | 63 | |
| C. X magenissii (hybrid bermudagrass) | 5 | |
| C. transvaalensis (African bermudagrass) | 25 | |
| C. spp.. | 109 | |
| Eremochloa ophiuroides (centipedegrass) | | 65 |
| Paspalum | | 95 |
| P. distichum (siltgrass) | 10 | |
| P. notatum (bahiagrass) | 69 | |
| P. spp. | 16 | |
| Stenotaphrum secundatum (St. Augustinegrass) | | 109 |
| Zoysia | | 118 |
| Z. japonica | 15 | |
| Z. matrella | 85 | |
| Z. tenuifolia | 8 | |
| Z. spp. | 10 | |
| Miscellaneous genera (Dichondra, Hemarthria, Indigofera Wedelia). | | 26 |
| | | 621 |

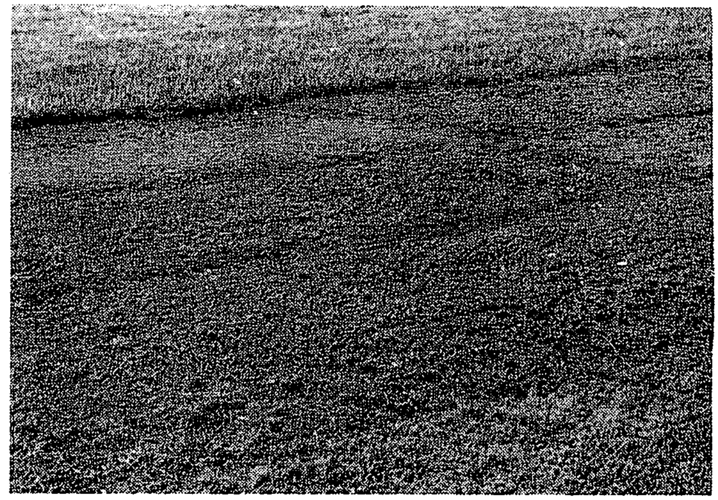

Fig. 1. Bermudagrass plots at Fort Lauderdale. In the absence of pesticides, most plant introductions did poorly in competition with weeds. The plot in the upper left, however, withstood the stresses of minimal maintenance. This was of a plant introduction from Rhodesia.

In the case of St. Augustinegrass, the worldwide distribution of wild relative species (13) is in a narrow, transoceanic band. This band extends from southern Africa and Madagascar to Ceylon, and from there across southern Asia and into the islands of the south Pacific. Only in this region would we expect to find St. Augustinegrass to be accumulating genetic diversity through the process of introgressive hybridization (1). The distribution of wild relative species suggests that St. Augustinegrass originated in the Old World, centering around the Indian Ocean. This implies that St. Augustinegrass introduced to the New World may be a genetic subsample of the total variation in the species. A study of 87 genotypes showed that substantial genetic variation exists (10), even though there were only a few exotic collections. Therefore, considerable genetic variation has accumulated in the United States, since the original introductions of St. Augustinegrass sometime before 1800.

Harlan (6) stated that centers of diversity can be created, away from the center of origin of a crop. As a result, new genes may accumulate in those secondary centers, and be valuable to plant breeders. Therefore, we have continued to assemble warm-season turfgrasses found along roadsides, in home lawns, and golf courses throughout the South. On a recent Gulf Coast collection trip, I discovered an accession of bahiagrass that is highly self-sterile, possibly male-sterile. Such an accession may be useful in our attempts to develop a better bahiagrass for Florida highways.

For most of the warm-season turfgrasses, present germplasm resources are inadequate. Bahiagrass and bermudagrass are important forages, and a number of major collections have been established for these species. For St. Augustinegrass, centipedegrass, and the zoysiagrasses, available genetic diversity is limited and additional collecting abroad is needed. As primarily vegetatively propagated grasses, these three species are more difficult to bring through quarantine, and few living collections exist.

Only 8 introductions of centipedegrass to the United States were indicated between 1903 and 1974 (15). The first introduction (PI 46415) arrived in 1918 by sheer accident. The great plant explorer Frank Meyer had been returning from an expedition to Honan Province, China, carrying with him collections of beans, fruiting trees, and vegetables. One morning Mr. Meyer was found missing from the steamer and, it was presumed, had drowned in the Yangtze river. Once the boat reached Shanghai, the American

Consul found some seeds in Mr. Meyer's baggage, and forwarded them on to the United States (15). Later collections of centipedegrass were made and given Plant Introduction numbers, but it is not known what became of any of these. It is likely that all centipedegrass in the United States goes back to a few collections. We have seen, as in the 1970 epiphytotic of southern corn leaf blight, the seriousness of placing "all of the eggs in the same basket."

Warm-season turfgrasses are grown as a monoculture. To permit the same narrow group of genotypes to be grown over millions of home lawns leaves us especially vulnerable to new and virulent pathogens and insects. The majority of golf course areas in Florida are planted to 2 cultivars, that are genetically similar. Certified St. Augustinegrass in Florida constitutes only 2 genotypes, that are also genetically related. Genetic diversity is necessary not only in a breeding program; it is a natural resource that provides both richness in the kinds of ornamental plants available, and in the flexibility to develop new plants for the changing landscape environments of the 1980's.

### Manipulation of Genetic Variation

New introductions can be screened for their usefulness as turfgrasses. Old variations can be reassembled through mutation or hybridization, and pushed back through the screening and selection process. Turfgrasses provide a unique opportunity to use hybrids, as well. Because many turfgrasses are vegetatively propagated, fertility is not a desirable characteristic. As with other vegetatively propagated plants, hybridization assumes a much greater importance (14). The benefits of hybridization for turfgrasses are in the area of combining desirable characteristics from genetically dissimilar genotypes.

The hybrid bermudagrass cultivar 'Tifgreen' arose as a triploid ($2n=27$) progeny of common bermudagrass ($2n=36$) and African bermudagrass (*Cynodon transvaalensis* Burtt-Davy, $2n=18$). The latter species imparted a more dwarfed habit to 'Tifgreen,' and a measure of resistance against the bermudagrass mite. The fact that the hybrid is sterile is an advantage for maintaining genetically pure stands, as well as a relief for hay fever sufferers—because it is a triploid, it sheds no pollen. Ongoing investigations show us that a number of St. Augustinegrass cultivars are also triploids, and intentional schemes to produce such triploid hybrids are now being developed. To do this, we are combining chromosome studies with efforts to describe patterns of genetic variation in St. Augustinegrass.

In contrast to most warm-season turfgrasses, bahiagrass is primarily seed-propagated. The use of an all-$F_1$ hybrid bahiagrass would involve similar complications as are involved in corn, onions, and tomatoes. We are attempting a series of hybrids in bahiagrass to identify good-combining parents for production of a nonflowering progeny population (3). Hybrids may not be nonflowering, especially if made from closely related parents, but once a desirable combination is identified, it can be repeated by propagating the intended parents vegetatively, and crossing them in blocks. Burton (2) had originally proposed a recurrent restricted phenotypic selection system for increasing forage yields of bahiagrass—we are considering a similar system for developing outstanding turf types. Bahiagrass is not only primarily self-incompatible, but a highly self-sterile (possibly male-sterile) type has been recognized. The self-sterile plant could be used as a "universal female" tester, in a simple recurrent selection procedure, until an outstanding hybrid combination is recognized. A nonflowering bahiagrass would reduce the millions of dollars spent annually to mow Florida roadsides—it is primarily the seed heads that are removed in mowing.

Mutation breeding can create new genetic variations. This is particularly advantageous in improving an already outstanding genotype. In a vegetatively propagated plant, these mechanisms can be based on heterozygous combinations, that would be grossly mixed up in meiosis and seed production. As a result, a unique set of quality characteristics can be developed in a warm-season turfgrass genotype—for example, the hybrid bermudagrasses, specially selected for good golf playing qualities. For various reasons, the fact that these are also triploids increases the efficacy of mutation breeding (11). A number of turf cultivars of bermudagrass arose as natural mutations.

Our work in mutation breeding has been focused on a dwarf type St. Augustinegrass with many outstanding turf qualities. Hundreds of stolon pieces were irradiated with gamma rays. After several months of growth and recovery, 190 of these were planted in a replicated design under uniform conditions (Fig. 2). Desirable variations to be sought include sod webworm resistance and freedom from thatch accumulation. A number of morphologic variants have already been recognized, and these hold the promise of being tied to underlying behavioral differences.

Fig. 2. St. Augustinegrass clones being transferred to miniature field plots. These clones had been treated with gamma rays, to induce mutations. Some morphologic variants have been noticed, that suggest behavioral differences might also be present.

### Selection

The process of favoring one genotype over another is accomplished in nature, but can be vastly speeded up artificially, and directed to emphasize characteristics desirable to people. Selection is speeded up by the use of special tools to improve predictability, such as replication, testing in different environments, and progeny testing. Laboratory tests have been designed to measure specific aspects of turf quality and adaptation, in order to reduce the errors inherent in strict visual evaluations. This is well suited to simply inherited characters, such as resistance to black stem rust disease of wheat. A problem arises in determining the relative weight to give to such indirect measurements, however. The importance of lignin in thatch build-up has been demonstrated (8), and selection of genotypes with lower lignin content may be a convenient way of selecting new turfgrasses that accumulate less thatch. However, lignin has also been shown to be positively related to mechanisms of resistance to fungi in grasses (12). Therefore, strict adherance to laboratory procedures could yield contradictory results, and other, related, genetic characteristics involved with thatch or disease susceptibility would be ignored. The goal of selection is to improve field-level adaptation and turf quality, that is, the ability of a strain to hold up in the larger laboratory of the outside environment. For selecting field-level adaptation and quality, genotypes must be given the test of time. In some cases, the genotype that survives best will turn out to have resistance to a number of pests, and be competitive with weeds (G. W. Burton, personal communication).

In view of these concerns, the turfgrass breeding program at ARC-Fort Lauderdale emphasizes selection techniques. Since adaptation is genetically determined, and environment is the multiple impingement of management and climatic variables, it should be possible to model these factors, and use them to improve the predictability of selection. One of the important problems for plant breeders is in determining what degree of a stress factor is optimal for selecting genotypes resistant or tolerant to that stress. Methods presently being used by us include: (a) greater reliance on quantitative measurements (such as growth rate as a response to environmental stress); (b) the use of incomplete block designs for visually evaluated experiments; (c) establishment of minimal management plots for long-term adaptation studies; and (d) multivariate analysis of variance procedures to relate long-term adaptation to specific characteristics.

## Conclusions

Turfgrasses are an important part of our expanding urban environment. The 370,000 ha of turf in Florida helps moderate urban areas against such dangers as hurricanes, as well as contributes to the beauty and usefulness of landscape environments. The turfgrass industry is also a major contributor to Florida's economy (4). Better grasses are rated as a high priority for Florida; only one new grass has been released in Florida in the past 15 years. The climate of Florida is unique, turfgrasses developed elsewhere in the South sometimes perform poorly here, and more grasses specifically tailored to Florida are needed.

To keep step with future changes, a germplasm resource base has been developed that is available for testing against new and virulent biotypes of diseases and insects. An ongoing program may be a better way of meeting future challenges than crash programs directed to solve the next major biological catastrophe to hit ornamental plants. Hopefully, we can develop enough information on the genetic structure of warm-season turfgrasses, so that the challenge of a new pest problem can be met by a diverse breeding population with resistance to the problem.

Turfgrasses of the 1980's will not look much different from those of today. New conditions in the availability of pesticides, fertilizer, and water will be considered in developing new grasses. Priority in the breeding program at ARC-Fort Lauderdale is placed on the recognition of genotypes requiring smaller inputs of energy, in order to maintain an attractive and durable cover for our urban areas. In addition, it is our plan to provide a greater range of options in the kinds of turfgrasses available.

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# PETIOLE INJECTION OF COCONUT PALM, A METHOD TO PREVENT PERMANENT TRUNK INJURY DURING ANTIBIOTIC TREATMENT FOR LETHAL YELLOWING[1]

Randolph E. McCoy
*IFAS, Agricultural Research Center,*
*Fort Lauderdale, FL 33314*

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*Abstract.* **Treatment of coconut palms with trunk injections of the antibiotic oxtetracycline-HCl has come under widespread use for control of the lethal yellowing disease in Florida. The principal drawback to the treatment methods currently in use is that a permanent injury is made to the trunk at the site of injection. An alternative method of injecting the bases of leaf petioles was found to be of definite therapeutic value in diseased palms, even though high overall tissue concentrations of antibiotic were found only in the treated fronds.**

Antibiotic treatment of coconut palms (*Cocos nucifera* L) with oxytetracycline-HCl (OTC) has been extensively utilized since 1974 in Florida as a control measure for lethal yellowing (LY), a disease associated with a mycoplasmalike organism. The only treatment method found to produce con-

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