position of the nutrient in the nutrient ratios presented in lines 350 through 370, and the sign identifies whether the nutrient is in the numerator (+) or the denominator (–) of the nutrient ratio. For example, the numbers 1, 2, and 3 in line 600 indicate that A(1), A(2), and A(3) in line 350 each have N in the numerator. The numbers –4, –7, and –13 in line 600 indicate that A(4), A(7), and A(13) each have N in the denominator. By making changes in these three locations in the program, allowance can be made for changes in the data set. Somewhat more extensive modification is needed if nutrients other than the ones used in this analysis are to be examined. In addition to the obvious changes that will be needed in the portions of the program that control input and output functions, and any increases in the dimension statement (line 30) made necessary because of an increase in the number of nutrients considered, the value of "T" in line 110 must be changed to correspond to the number of nutrients used in the analysis (9 in the present example). The program also calculates the "absolute sum" (line 690), which is a measure of the overall imbalance among nutrients. A lower absolute sum indicates reduced imbalance among nutrients. The number of X's listed in line 690 must correspond to the number of nutrients in the analysis. With these simple changes, the program can be modified to suit various data sets.

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TURFGRASS PROVING GROUNDS

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Abstract. **New turfgrass varieties must provide acceptable consumer quality and permanence in the landscape, and field evaluation is essential in their assessment. Public and private sectors are working together on field evaluation of new varieties. Sod variety trials have provided data as well as plant material used in urban trials. Such tests simulate in pilot scale the typical economic path of a new grass. A study was recently initiated to obtain regional cold tolerance data on 5 St. Augustinegrasses in 34 Florida counties. Under the sponsorship of the National Turfgrass Evaluation Program at Beltsville, MD, the University of Florida has distributed genetic material for 25 grasses in the National St. Augustinegrass Test—1989, installed at 15 locations from California to South Carolina, with 4 more locations pending. The purpose of these tests is to better assess the risks and potentials of present and future turf varieties, over a range of conditions, so that better value can be assured for the consumer.**

The testing of turfgrass varieties can help the consumer in the same way as do evaluations of other products. Knowledgeable prediction of benefits and risks allows for the selection of a turfgrass satisfying individual needs and resources. Knowledge of turfgrass variety response to different environments allows for the tailoring of management options to best utilize a particular turf variety. While the turf field test is often conducted during new variety development, it is also an ongoing process which can provide useful knowledge for previously-released varieties. Unfortunately, turfgrass field tests are but surrogate end-points for evaluating perennial grasses designed for 10- to 20-year life expectancies. Another limitation in the design of traditional field tests is an emphasis on statistical precision at the expense of practical relevance. This paper discusses turfgrass field evaluation and shows how to improve the testing process.

The Traditional Field Trial

Most turfgrass product evaluations involve a comparison of treatments applied in relatively small plots at a single field location. Sufficient number of replications and local control (blocking of replications) ensures that unexplained variability (error variance) is minimal, and that error variance and treatment means are accurately measured. Treatment means are compared relative to a standard. For a

Florida Agricultural Experiment Stations Journal Series No. N-00064. I thank Cooperative Extension Service Faculty throughout Florida, members of the Turfgrass Producers Association of Florida, and colleagues throughout the southern United States, for participation in regional tests. The National St. Augustinegrass Test is coordinated by the National Turfgrass Evaluation Program; the Florida Department of Agriculture and Consumer Services, Division of Plant Industry cooperated with phytosanitary inspections; and the South Florida Water Management District sponsored its distribution. A special thanks to Bonnie L. Coy and Mickey A. Stanaland, for their expert technical help in propagation and distributing these tests.

variety evaluation, experimental grasses are compared relative to the best available commercial varieties. A relatively conservative approach is accepted (1) regarding the seriousness of Type I errors (e.g., 5% probability of incorrectly recommending a falsely superior variety), but at the expense of reducing the power of the test (the ability to correctly detect real treatment differences, if they exist).

The traditional approach in most turfgrass product evaluations is applied to varieties, fertilizer products and rates, pesticide efficacy, etc. Its apparent advantages are that it concentrates resources on the testing of hypotheses, error variance is minimized, and simple statistical tests generally result in a rejection of the null (no variety differences) hypothesis. Plots are easily managed and conveniently located, usually at an experiment station. This approach is frequently the basis for turf extension recommendations over a broad region.

Implicit in the design and interpretation of single-location field trials is that the results are applicable only to a single location. When results are interpreted to a region, one must consider the varying response of varieties to different environments (e.g., shade level, parasitic nematodes, and temperature). We already know from many studies of crops other than turfgrass that genotype X environment interactions are critical in variety performance. If a damaging stress were absent at the central test site, then variety vulnerability might be missed.

The Regional Trial

The regional trial consists of a series of experiments linked by the same or similar treatments, and with systematic observations across locations. The main advantage is that an estimate of genotype X environment variance can be used to make confident performance predictions across the region. When this interaction is significant (it usually is), refined recommendations can be made most accurately for individual locations. Regional recommendations can still be made at an accurate, but lower, degree of confidence. In some cases, performance at individual locations can be predicted with greater accuracy through the combined knowledge of neighboring locations. Of considerable additional value, recommendations can be extended to locations not specifically tested, if they were part of the population from which the test sites had been sampled. This is a large advantage over the traditional test, in which regional performance is primarily guesswork. The disadvantages of regional trials are their greater cost and complexity. When testing resources are limited, probably the greatest information can be gained by experiments replicated across locations, in which only a single plot per treatment exists at any one location.

Regional trials have been applied infrequently in warm-season turfgrasses. Regional data was obtained for bermudagrass varieties (2) but the available data were fairly incomplete. Beginning in 1986, the National Turfgrass Evaluation Program (NTEP) distributed the National Bermudagrass Test. This was followed in 1989 by the National St. Augustinegrass Test (Fig. 1 and Table 1). The goals of the NTEP are to develop and coordinate uniform evaluation trials of turfgrass varieties and promising experimentals in the United States and Canada. This can be used to determine the adaptation of a variety. A wealth of useful information has been obtained from NTEP-sponsored

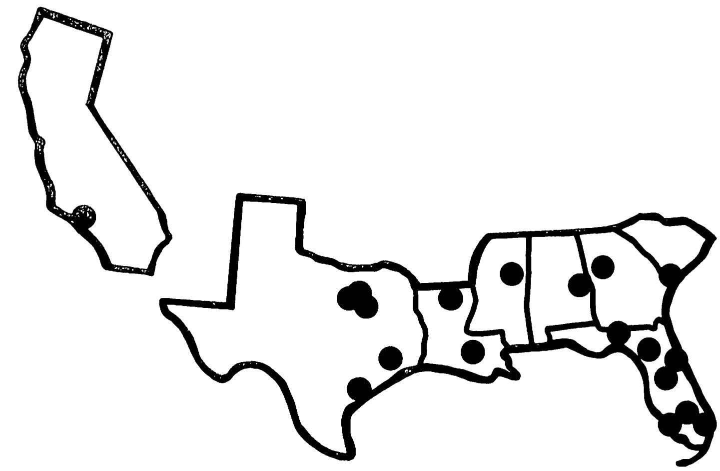

Fig. 1. Locations to which the National St. Augustinegrass Test—1989 was distributed. There are 25 genotypes represented at 19 locations (15 were installed as of November 1989). This regional trial is coordinated by the National Turfgrass Evaluation Program, Beltsville, MD, with cooperation from the Southern Region Agricultural Experiment Stations and the Cooperative Extension Service, and private contributors.

trials. This data covers advanced experimental lines and already released varieties. Without the leadership of the NTEP, it would have been difficult to get all of this germplasm assembled in one place for national distribution.

One of the challenges of regional tests has been to increase and distribute healthy, genetically pure plant material to various locations simultaneously, so that measured differences among genotypes are not simply propagation effects. Some early experiences suggested that a concentrated effort would be needed. As a result, one location (Fort Lauderdale Research and Education Center) was selected for the distribution of the National St. Augustinegrass Test (Fig. 2). The same approach may be used

Table 1. List of entries and sponsors in the National St. Augustinegrass Test.

Entry	Sponsor
DALSA8401	Texas A & M University
FX-10	University of Florida—IFAS
FX-261	University of Florida—IFAS
FX-313	University of Florida—IFAS
FX-33	University of Florida—IFAS
FX-332	University of Florida—IFAS
M1	Milberger Turf Farms Company
MSA-2	Mississippi State University
MSA-11	Mississippi State University
MSA-20	Mississippi State University
S-6-71-138	O. M. Scott & Sons
S-6-72-107	O. M. Scott & Sons
S-6-71-2090	O. M. Scott & Sons
S-6-71-770	O. M. Scott & Sons
TR 6-10 (DD-II)	David Doguet/Quality Turf, Inc.
TR 6-3 (DD-I)	David Doguet/Quality Turf, Inc.
Bitterblue	Standard
Delmar (S-6-72-99)	Ross Elsberrry
Floralawn	Standard
Floratam	Standard
Jade (S-6-72-82)	Turfgrass Associates, Inc.
Mercedes	Patten Seed
Raleigh	Standard
Seville	Standard
Sunclipse (S-6-72-130)	Pacific Sod

Fig. 2. Packaging of experimental grasses for the National St. Augustinegrass Test—1989, Fort Lauderdale Research and Education Center. Pre-rooted, 18-plugged trays were shipped to cooperators for immediate field planting.

Fig. 4. Locations (solid circles) of the Florida St. Augustinegrass Test—1989, representing 5 varieties and experimentals (FX-10, FX-33, FX-261 and Floratam and Seville); and locations (solid triangles) of other past and present turf variety trials in Florida.

for the proposed National Zoysiagrass Test (1991) and the National Centipedgrass Test (1993).

Additional regional test work has been done by individual breeding programs in the evaluation of proposed releases. Since 1984, a very active program has been conducted in Florida on experimental St. Augustinegrasses. This has involved a partnership between the public and private sectors. Members of the Turfgrass Producers Association of Florida have conducted on-farm sod variety trials for the University of Florida. Sod produced from those tests has been distributed to urban test locations, at which public and private evaluators have participated (Fig. 3). In a more recent example, the Florida St. Augustinegrass Test was distributed in 1989 to IFAS Extension Faculty in 33 counties, with 1 more location pending (Fig. 4). Some of the logistic challenges of these trials include: timing, avoidance of variety contamination, and shipping method.

The Pilot Market Test

At some point in the development of a turfgrass variety, it will be applied to lawn-sized areas without internal replication, and without a standard control or comparison variety. In this respect the pilot market test accepts all turf sites as the population to be sampled. In this ultimate road

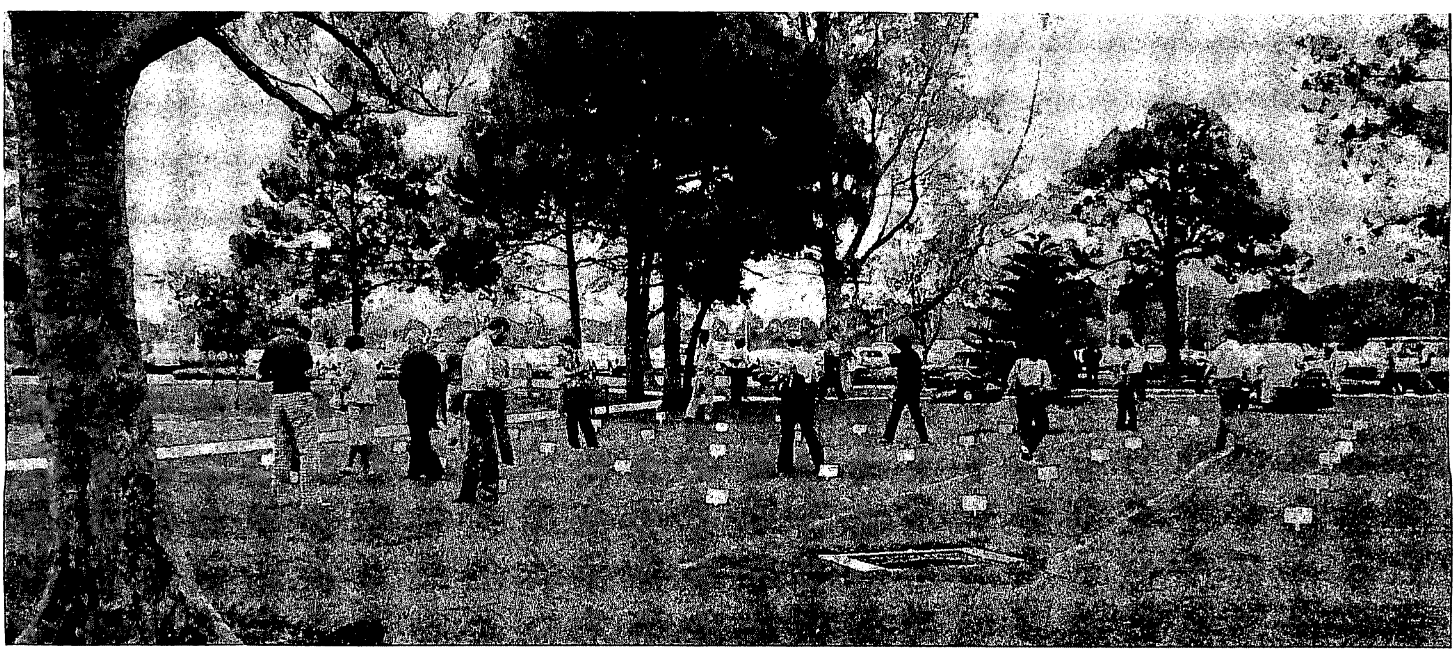

Fig. 3. Evaluation of sodded, replicated St. Augustinegrasses genotypes in an experiment at Palm Beach Gardens Community Center. The identity of individual entries is coded in order to protect the impartiality of the turf judges.

test, an appropriate null hypothesis is that, "Grass XYZ survives and provides acceptable turf benefits within acceptable maintenance requirements." By repeatedly using a new grass in actual turfgrass situations, knowledge can be gained to test the foregoing hypothesis. Experienced producers and managers of turfgrass have a kind of internal "check" or comparison (the sum of their past experience with other turfgrasses) which can be helpful in accepting or rejecting the null hypothesis. The testimonial of experienced individuals will go much further in deciding the fate of a new variety than all the data developed previously. The repeated testing of the new grass at a number of sites would be necessary to develop a confidence estimate which is based on a sample from that variable population of all turfgrass applications. The null hypothesis would be rejected if the proposed new variety failed to survive or failed to provide acceptable turf benefits, within acceptable maintenance, at a significant proportion of sites.

The scientific disadvantages of this method are that the alternative hypothesis (absence of the new variety) is not specifically defined, and other controls are relaxed. The practical disadvantage of the market test is that it may be more expensive, in total resources, than all previous research and development, and thus it must be restricted to a small number of promising candidates. Despite these disadvantages, the strong advantage of the pilot market test is that it can capture a sample of problems that a new variety might experience in widespread use. This would be accomplished by encompassing representative turfgrass sites where turf is generally grown (lawns, golf courses, ball fields, parks, and highways) as a defined population worthy of sampling. In contrast, field plot methods generally create a new population of environments different from areas where turfgrass is actually used. Some unrealistic situations (e.g., alleyways) are created in the traditional field plot set-up. Other environmental variables (e.g., tree shade, traffic, and disturbed soils) are generally absent in experiment station turf plots, but could be easily included in pilot market tests. Within-yard variability, present in typical turf sites, is virtually non-reproducible in field plots.

It could easily be argued that a pilot market test is a logical stage which any variety must go through before it can be readily recommended. From 1980 through 1989 a number of new varieties have been introduced (Tifgreen-II, Tifway-II, and Vamont bermudagrasses; AU Centennial centipedegrass; Delmar, Floralawn, Jade, Mercedes, Raleigh, Seville, and Sunclipse St. Augustinegrasses; and Belair, Cashmere, and El Toro zoysiagrasses). In each case actual success or failure was (or continues to be) a function of market experiences, and is barely discernible (even in hindsight) from traditional statistical field plot evaluations. If these grasses had had an earlier entry into turf-sized applications, it is likely that some (e.g., Tifgreen-II) would have been rejected earlier, and research efforts could have been redirected to more successful pathways. It is interesting to speculate whether there might have been promising experimentals which had been rejected at the field plot stage, but which might have been advanced further had they been given a chance to be tried out in pilot market tests.

Discussion

Considerable progress has been made in developing new turfgrasses for Florida. We must strive to understand this progress in a way which is both scientific and practical. A balance of approaches is needed in developing, testing, and recommending turf varieties for Florida. Of the three types of tests which have been covered, none is without advantages and disadvantages. Traditional Experiment Station field plots can rapidly collapse a germplasm, which is desirable in early selection. Regional trials and pilot market tests address the broader stability of performance of turfgrass varieties, once a narrower germplasm has been obtained.

In contrast to these field approaches, there is at present no way to predict from the laboratory whether a grass will do well in the field. In the case of an acute damaging stress (e.g., chinch bugs), laboratory screening has been shown to be highly efficient in addressing vulnerability, probably much more so than would field evaluation. This is because of the uneven distribution of field damage by chinch bugs. In the instance of some chronic stresses (e.g., nematodes), a good laboratory screening would also be highly valuable, because nematode stresses are normally observed after years of culture in the field. Even if a breeding program were to be highly dedicated to laboratory screening tests, there would be no more likely place to generate useful hypotheses than exploratory field testing. There is also no simpler place to test for combined resistance to a number of adaptive stresses acting together than the field of application.

There are over 50 released varieties of warm-season turfgrasses, but only 9 varieties predominate in Florida (Argentine and Pensacola bahiagrass; Floratam and Bitterblue St. Augustinegrass; Tifway, Tifgreen, and Tifdwarf bermudagrass; Common centipedegrass; and Emerald zoysiagrass). To compete in the market with those successful varieties, a new grass must offer substantially greater consumer value, compared with existing products. The apparent failure of new grasses to penetrate this market is evidence for the superiority of varieties already introduced and the continuing great challenge to develop sturdy grasses for general purpose turf. While the fate of turfgrass varieties is sometimes obvious based on past experience, its scientific prediction is only emerging.

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