Turfgrass

2000 Research & Information Report

From the

University of Missouri-Columbia Turfgrass Research Center

Experiment Station ■ University Extension
Missouri Valley Turfgrass Association

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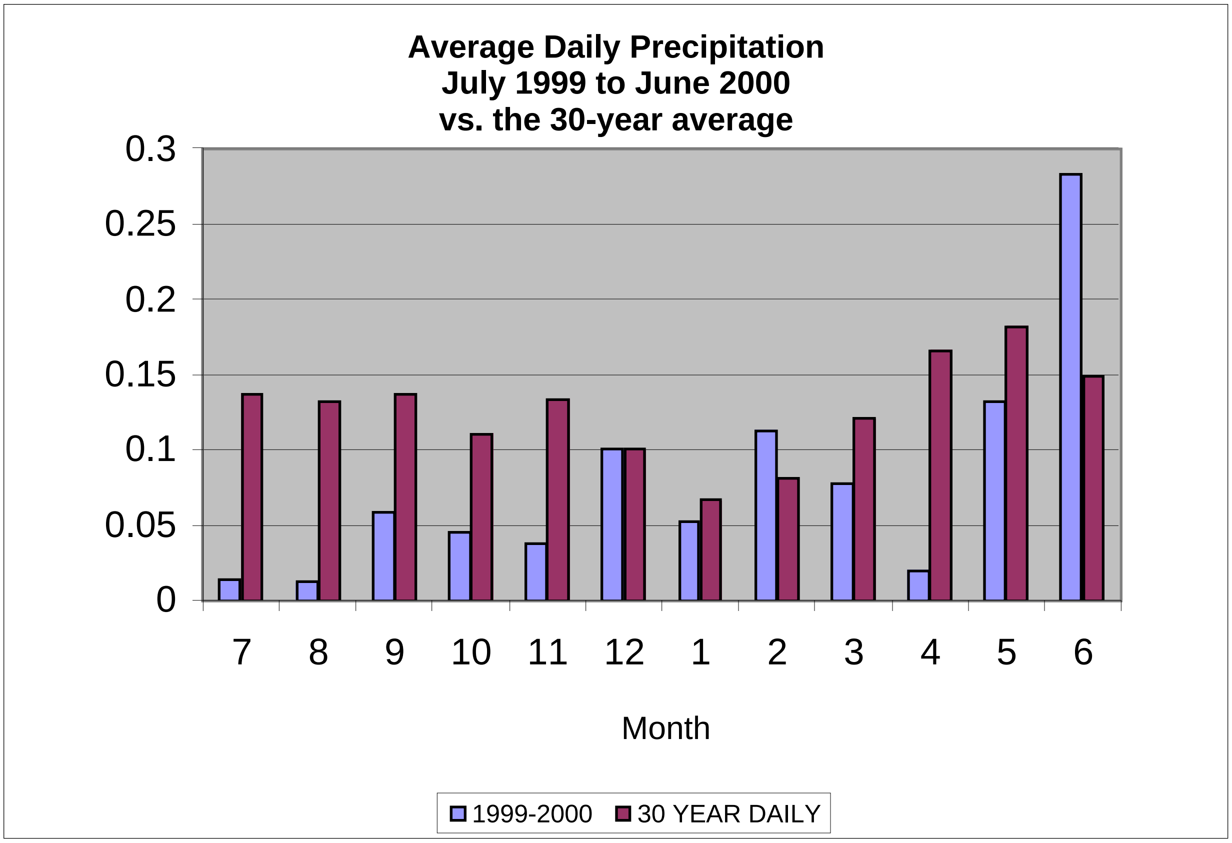
By October 1999, our irrigation pond level was too so low we could no longer irrigate.


Average Daily Precipitation
July 1999 to June 2000
vs. the 30-year average
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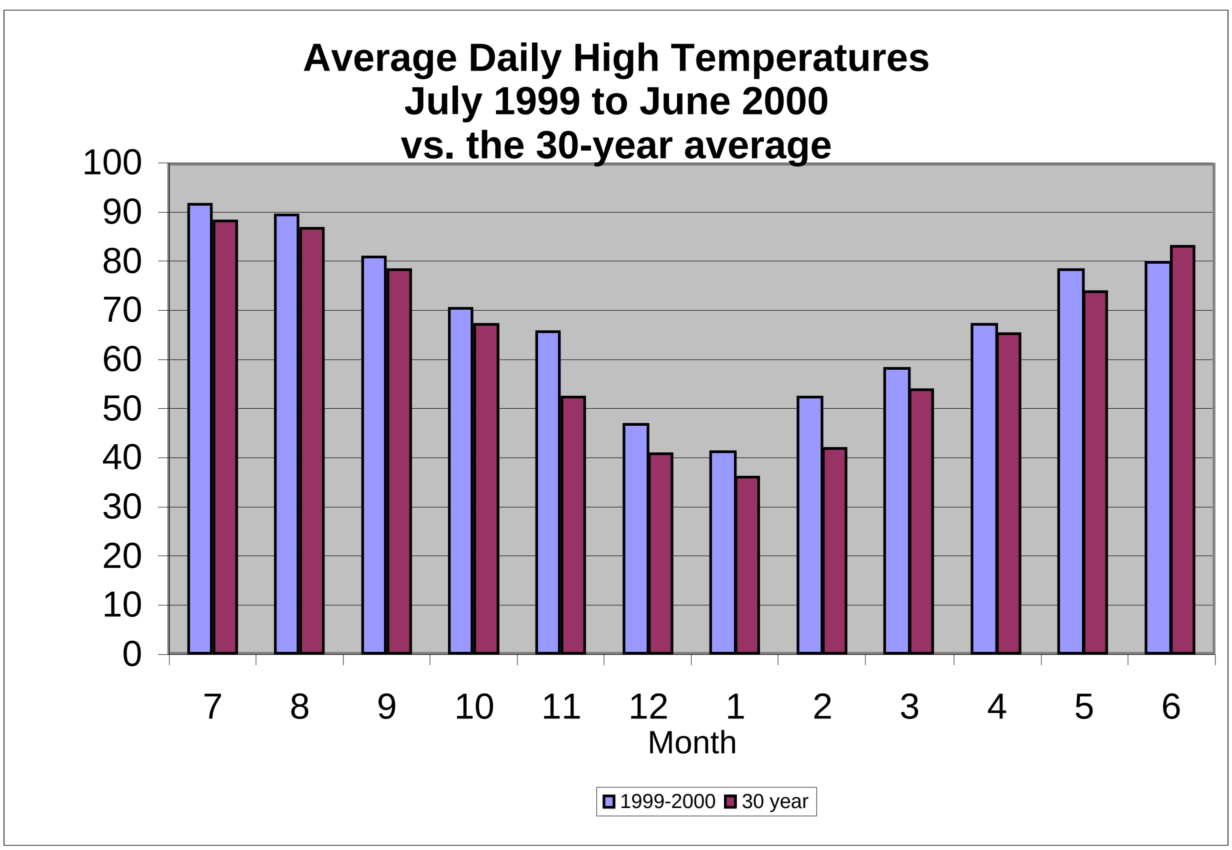
Month
1999-2000
30 YEAR DAILY


Average Daily High Temperatures
July 1999 to June 2000
vs. the 30-year average
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80
70
60
50
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20
10
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9
10
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6
Month
1999-2000
30 year

Amendments and construction systems for improving the performance of sand-based greens

Erik H. Ervin, Changho Ok, Brad S. Fresenburg

Many sands are ideal physical root zone media for creeping bentgrass (*Agrostis palustris Huds.*) putting greens due to particle sizes and distributions that provide a firm surface that remains highly permeable. However, sands have low moisture and nutrient retention properties. Organic and inorganic amendments are added to sand-based root zones to improve moisture and nutrient retention and decrease bulk density.

Although peat does fulfill the above three functions, it has some potential shortcomings. First, peats are not permanent root zone additions as they decompose over time. Second, the addition of peats to sand-based mixes reduces aeration porosity and they are of limited effectiveness in reducing nitrate leaching.

The use of inorganic amendments for putting green root zone mixtures such as calcine clays and zeolites may offer a number of benefits for improving sand-based root zones. These materials possess high cation exchange and water holding capacities without reducing air-filled pore space (Table 1). Superior establishment rates and reduced nitrate leaching and increased nitrogen use efficiency have been reported for zeolite amended sand-based rootzones. Additionally, calcine clays and zeolites are more permanent additions to the root zone, demonstrating good stability in weathering, impact, and abrasion tests. Given such properties, these inorganic materials may be superior replacements for peat as amendments for sand-based putting greens.

An increasing number of courses are also building greens in a California-style (cutting costs by establishing a 10- to 12-inch sand layer over native soil and drains). During humid Midwest summers, the extra moisture potentially available in USGA perched water table greens may not be a positive feature. Water acts as an insulator, resulting in root zones with high relative soil temperatures that increase during the heat of the day, but fail to fall significantly with cooler night temperatures. The extra water stored in perched water table greens also implies less air-filled porosity. Higher relative soil temperatures and less air imply greater root stress, and, most likely, more summer bentgrass decline.

Procedures and Objectives

A study is underway at the MU Turfgrass Research Center to compare three amendments and three systems of green constructions: USGA, California, and a modified California profile. The USGAtreatment consists of 90 percent sand and 10 percent Dakota reed sedge peat by volume, with a 12-inch root zone mix over a 5-inch pea gravel layer (0.10”-0.25” diameter) over a drain. The sand / peat mix was blended at the supplier, Capitol Sand, Jefferson City, MO. There are two modified California profile green treatments, each consisting of a 10-inch root zone mix over a 7-inch layer of silt loam with a drain at the top of the silt loam layer. The first modified profile consists of 82 percent sand, 15 percent porous ceramic (Profile™), and 3 percent humate; the second modified profile consists of 85 percent sand and 15 percent zeolite (ZeoPro™). These two mixes were blended at the Turf Research Center with a small cement mixer. Last, the California system treatment consists of 12-inch of 100 percent sand over a 5-inch layer of silt loam with a drain at the top of the silt loam layer. Two sands were used for the different rootzone mixes in this study: a coarse mason sand was blended with Dakota reed sedge peat for the USGA treatment and a fine mason sand was used in the three California-style treatments. Their particle size analyses are presented in Table 1.

Table 1: Particle size analysis of the two sands used in this experiment

Particle size	Diameter (mm)	USGA recommends (%)	90/10 peat (%)	Fine mason sand (%)
gravel	> 2	< 3	0.9	0.1
v. coarse sand	1 - 2	< 7	3.4	2.3
coarse sand	0.5 - 1	60%	19.9	13.0
medium sand	0.25 - 0.5	minimum	49.1	49.9
fine sand	0.1 - 0.25	< 20	23.7	31.6
v. fine sand	0.05 - 0.1	< 5	2.4	1.9
silt and clay	0.05 or less	< 8	0.6	1.2

Treatments were established in 4' by 4' wooden boxes equipped so that drainage leachate may be monitored. The four treatments are arranged in a randomized complete block with four replications. The amended and unamended root zones were installed in August and 'Penncross' creeping bentgrass was seeded on September 27, 1998 at 1 lb / M (M=1000 ft^2). From seeding through May 1999, each plot was supplied with 6 lbs N / M, 2 lbs P / M, and 15 lbs K / M, either from granular fertilizer or, in the case of the ZeoPro amended plots, as nutrients estimated to be available from the nutrient-charged ZeoPro (0.1-0.05-0.6). From June 1999 through June 2000 all plots have received 3.75 lbs N / M, 0.82 lbs P / M, and 5 lbs K / M. The green was initially mowed at 0.5", then 0.375", then 0.25", and is now being mowed at 0.156". Mowing occurs four times weekly. Irrigation is applied every two days based on atmometer estimated evapotranspiration.

The research plan is to compare these amendments and systems of greens construction in terms of short and long term performance and resource efficiency by measuring responses such as: establishment rate, quality and color, root mass, soil physical and chemical properties, oxygen diffusion rates, nitrogen, phosphorus, and potassium leaching, and drought avoidance.

Table 2:Color ratings of bentgrass sand/amendment root zone study (1999-2000)

Color ratings:1 - 9

Amendment (subsurface)	1999				2000		
	4/26	6/14	8/19	10/22	12/23	4/28	5/29
None (soil)	5.0 b	7.1 ab	6.8 b	6.5 b	4.4 bc	4.4 b	4.6 bc
Peat (pea gravel)	4.8 b	6.8 b	6.4 b	6.0 b	4.1 c	4.6 b	3.9 c
Profile (soil)	5.3 b	6.9 ab	6.8 b	6.4 b	4.6 ab	5.3 a	4.9 b
ZeoPro (soil)	7.3 a	7.3 a	8.1 a	7.5 a	4.9 a	5.3 a	6.3 a
LSD (0.05)	**1.2**	**0.4**	**0.6**	**0.6**	**0.3**	**0.5**	**0.8**

Table 3:Quality ratings of bentgrass sand/amendment root zone study (1999-2000)

Quality ratings:1 - 9

Amendment (subsurface)	1999				2000		
	6/14	8/19	9/21	10/22	12/23	4/28	5/29
None (soil)	6.9 b	6.6 b	6.6 bc	6.6 b	4.5 b	4.1 b	4.1 c
Peat (pea gravel)	6.6 b	6.1 b	6.4 c	6.1 c	4.4 b	3.9 b	3.8 c
Profile (soil)	6.4 b	6.6 b	7.0 b	6.8 b	4.8 b	5.0 a	5.0 b
ZeoPro (soil)	7.5 a	8.0 a	8.0 a	7.4 a	5.3 a	5.1 a	6.3 a
LSD (0.05)	**0.5**	**0.5**	**0.6**	**0.4**	**0.4**	**0.4**	**0.5**

Results

(June 1999 to June 2000)

From June 1999 to May 2000, ZeoPro-amended plots had higher color and quality ratings (Tables 2, 3). The Profile-amended plots had greater color and quality than the other two treatments in April and May of 2000 only. The peat and 100 percent sand treatments have performed similarly throughout the study.

Root mass measurements have been variable, making it difficult to reach any meaningful conclusions (Table 4).

All amendments increased the capillary porosity of the mixtures in relation to the 100 percent sand treatment, resulting in greater water retention at field capacity (Table 5). The peat mixture had the lowest saturated hydraulic conductivity with highest capillary porosity in lab tests of the mixture without the gravel layer (Table 5). However, early measurements (7 / 99) of saturated field infiltration rates demonstrated the flushing action that occurs when a root zone saturation occurs on a USGAperched water table profile (Table 6). The USGA / peat system had a very high Ksat along with the modified-CA / ZeoPro system. The high Ksat of the modified-CA / ZeoPro profile can be attributed to its high air-filled porosity (28.5 percent). All field Ksat rates have dropped as the plots have matured, with the USGA / peat system declining the most and the modified-CA / ZeoPro system remaining the highest (Table 6).

All three amendments have higher CEC relative to the 100 percent sand plots (Table 7). The ZeoPro plots possess more available P and K than the others, while the Profile plots also contain high amounts of available P, Ca, and Mg relative to the peat and 100 percent sand plots. Greater nutrient retention due to ZeoPro and Profile addition correlates well with higher average quality and color ratings over the last two years. These results indicate that substituting Profile or Zeopro for peat may allow for the maintenance of high quality bentgrass with less fertilizer inputs.

Peat treatments had the highest nitrate leachate concentration at the November 1998 sampling (Table 8). However, 18-24 months after planting, the results show that there were no significant nitrate leaching differences among the treatments. ZeoPro, with its high affinity for K, has consistently had the lowest K^+ leachate concentration, whereas peat has had the highest measured losses. Higher losses through the peat profiles may be more associated with large flushing events through the gravel layer rather than with the peat itself.

Both oxygen diffusion rates and soil moisture content were not significant among treatments. There was less correlation (0.74) between oxygen diffusion rate and soil moisture con-

Table 4:Root mass of bentgrass sand/amendment root zone study (1999-2000)

Root mass :2.5"x 4"depth (grams)

Amendment (subsurface)	1999 4/27	2000 8/4	2000 4/27
None (soil)	0.87a	1.57a	1.19ab
Peat (pea gravel)	0.67ab	1.63a	0.99b
Profile (soil)	0.55b	1.20ab	1.39a
ZeoPro (soil)	0.71ab	0.87b	1.38a
LSD (0.05)	**0.31**	**0.57**	**0.29**

Table 5:Root zone physical analysis at establishment:September 1998

Amendment (subsurface)	Ksat (lab)*	Non-capillary (air-filled)	Capillary (water-filled)	Water retention at field capacity
	in/hr	percentage		
None (soil)	22.8	26.3	13.1	8.1
Peat (pea gravel)	11.2	16.3	21.7	13.3
Profile (soil)	23.2	26.2	18.9	13.2
ZeoPro (soil)	24.3	28.5	14.8	9.9

*Analysis performed by Tifton Physical Soil Testing Laboratory: Ksat = Saturated hydraulic conductivity of the sand-based root zone mix, without subsurface pea gravel or silt loam layer, in the lab.

Table 6:Saturated field infiltration rate as green matures

Amendment (subsurface)	Ksat (in/hr): Saturated field infiltration rate 7/1999	10/1999	5/2000
None (soil)	28.2 b	22.7 b	16.4 b
Peat (pea gravel)	37.3 a	30.2 a	15.1 c
Profile (soil)	29.8 b	32.7 a	20.0 b
ZeoPro (soil)	38.8 a	36.6 a	22.2 a
LSD (0.05)	**7.0**	**6.6**	**2.2**

Table 7:Soil chemical properties of bentgrass sand/amendment root zone study:6/2000

Amendment (subsurface)	pH	CEC (meq/100g)	Organic Matter %	P (lb/A)	Ca (lb/A)	Mg (lb/A)	K (lb/A)
None (soil)	6.8 a	2.2 b	0.45 b	37.0 c	701.0 b	89.3 bc	129 b
Peat (pea gravel)	6.9 a	2.7 a	0.70 a	39.0 c	882.3 a	113.0 a	129 b
Profile (soil)	6.9 a	3.1 a	0.58 ab	51.0 b	975.8 a	5.3 a	183 b
ZeoPro (soil)	6.9 a	3.0 a	0.58 ab	71.5 a	871.8 a	95.5 ab	345 a
LSD (0.05)	**0.2**	**0.5**	**0.2**	**11.6**	**146.4**	**19.4**	**64.7**

tent because soil moisture contents were not significant among mean comparison of treatments (Table 9). Further measurements will be taken during this summer's dry-down cycle to determine if differences in air-filled pore spaces will influence root zone oxygen diffusion rates.

Table 8:Nitrate, phosphorous and potassium leachate concentration from bentgrass sand/amendment root zone study during establishment

Amendment (subsurface)	NO^{3-} (mg L–1) 1998-99			P^{-} (mg L–1) 1998-99			K^{-} (mg L–1) 1998-99		
	11/09	6/18	9/02	11/09	6/18	9/02	11/09	6/18	9/02
None (soil)	44.1b	0.25a	0.20a	0.16a	0.32a	0.47a	14.70ab	33.38b	38.85b
Peat (pea gravel)	64.6a	0.23a	0.18a	0.22a	0.66a	0.35ab	18.63a	84.53a	49.30a
Profile (soil)	11.2c	1.90a	0.45a	0.12a	1.00a	0.15b	13.18b	19.00bc	35.75b
ZeoPro (soil)	46.5b	2.93a	0.34a	0.10a	0.23a	0.31ab	13.11b	10.50c	4.58c
LSD (0.05)	**11.91**	**3.02**	**0.28**	**0.16**	**1.30**	**0.22**	**4.64**	**21.94**	**10.31**

Table 9: Oxygen diffusion rates with soil moisture content of sand/amendment study

Amendment (subsurface)	Oxygen diffusion rates (mg/cm2/min)	Soil moisture content (%)
	6/13/2000	
None (soil)	14ab	24.24a
Peat (pea gravel)	0.09b	22.85b
Profile (soil)	0.15a	25.70ab
ZeoPro (soil)	0.14ab	25.95ab
LSD (0.05)	**0.05**	**3.31**
Correlation (oxygen,moisture)	**0.74**	

Root-zone blends for safe and effective sandpbased athletic fields, 2000

C.C. Follis, B.S. Fresenburg, E.H. Ervin, C.H. Ok

As athletic field maintenance continues to grow and become a more recognized profession, the emphasis placed on field managers has increased as well. This pressure can also be seen in the field where more and more athletic fields are being established with a sand-base, to optimize its benefits such as percolation, infiltration, and reduced compaction.

The glaring problems of sand-based fields are a lack of stability and a recognized standard of soil amendments to maximize root growth. This has lead to the development of many varying root-zones across the nation. With such diverse variables problems arose with some blends once sodding was completed. Field managers reported problems with poor establishment or poor continued growth and recovery once minimal establishment was achieved. Safety concerns have also been discussed. With the lack of established rooting players have complained of inadequate surface stability leading to a detetoriating-playing surface. Fields are then resodded early in their lives leading to added cost and embarassment for these facilities.

To help solve these problems, soil amendments have been incorporated into the root-zones at installation and as a topdressing later in the fields life. Soil amendments can be instrumental in improving the suitability of the root-zone and unlocking all the benefits to a healthy, active root-zone. Both organic and inorganic amendments have been used in various amounts to improve soil factors such as CEC, water holding capacity, and help alleviate compaction. Many of the most common amendments used in today's athletic fields are peats, soils and inorganic materials such as calcined clays, zeolite, and turf grids. All of these materials will benefit the root-zone, but the optimal blend is not known.

The **overall objective** of this project is: 1) to determine a root-zone blend that provides optimal root growth, 2) to provide proper surface stability without compromising the known benefits of a sand-based root-zone and 3) to provide an inexpensive alternative for native soil athletic fields at the high school and/or parks and recreation levels. By developing a deep fibrous root mass, a dense vigorous turfgrass cover is more easily maintained. Good turfgrass cover correlates to better play ability and safety for athletes. We propose to construct a simulated athletic field of various root zone blends in a replicated trial to answer these questions.

Rationale

With the bar being raised on a daily basis for athletic field maintenance, some level of uniformity needs to be established for the industry at an economical price. The "witches brew" method of sand-soil, or sand-soil-amendment root-zones needs to be standardized. The work that has been done up until now has been positive and has moved the industry forward. However the few primary root-zones being utilized were actually derived form the golf course industry. While these developments have been adapted to the sports turf industry with some level of success, stability, which leads to safety is still a concen. This research will benefit managers at all levels, budgets, and experience.

The expansion of this project on previous research would provide a starting point for any facility looking at renovation, construction or improvement over time through topdressing.

Much like Henry Ford unified the wayward Industrial Revolution, his assembly line lead to the development of interchangeable parts while each car maintained its own personality. A standard in root-zone blends could do the same for the athletic field industry.

Materials and Methods

A proposed list of root-zone blends (Table 1) have been compiled with approximately 0.02 cubic meters of each treatment being blended for some preliminary laboratory testing. Most treatments in this list were based on information from newly constructed athletic fields across the country over the past five years. Some treatments were added to test the extremes and some "what if" questions that have been raised. This list is attempting to look at more economical solutions for establishing high-quality fields at the high school/and or parks and recreation levels. Prior to establishment of field plots, the physical and chemical properties of each root zone blend have been tested for: pH, percent organic matter by weight, CEC, macro nutrients, particle size analysis, K-saturation, bulk density, total porosity and water retention. Field plots have been constructed with a 6”root-zone cap in 8’ X 8’replicated blocks, with Kentucky bluegrass sod being installed following completion. Standard athletic field irrigation and drainage were present before initial construction. Planned field tests consist of infiltration, sod strength, dry root weight, soil and tissue testing, Clegg impact testing, and Shear testing.

Table 1. Treatment List.

Root-zone blends	Ratio	Components
1.	90/10	Sand/Peat
2.	90/10	Sand/Peat/Fibers
3.	90/10	Sand/Soil
4.	85/15	Sand/Soil
5.	80/20	Sand/Soil
6.	70/30	Sand/Soil
7.	100	Native soil
8.	85/10/5	Sand/Peat/Calcine Clay
9.	85/10/5	Sand/ Peat/Zeopro
10.	85/10/5	Sand/Calcine Clay/Soil
11.	85/5/10	Sand/Calcine Clay/Soil
12.	85/10/5	Sand/Zeopro/Soil
13.	85/5/10	Sand/Zeopro/Soil
14.	80/10/10	Sand/Calcine Clay/Soil
15 .	80/10/10	Sand/Zeopro/Soil
16.	85/7.5/7.5	Sand/Calcined Clay/Zeopro
17.	70/15/15	Sand/Calcine Clay/Soil
18.	70/15/15	Sand/Zeopro/Soil
19.	70/20/5	Sand/Soil/Compost
20.	85/15	Sand/Compost

Quality, density, and thatch comparisons of Bentgrass cultivars on the NTEP / GCSAA / USGA trial green at the Missouri Bluffs Golf Club

Erik H. Ervin, Scott Frame,
Adam Smith and Alan Zelko

The Missouri Bluffs Golf Club is one of 16 nationwide locations that are hosting a national on-site putting green trial. This five year project is jointly sponsored by the United States Golf Association Green Section, the Golf Course Superintendents Association of America, and the National Turfgrass Evaluation Program. The greens in this national program are in-play as practice putting greens. Having a trial located in the Mississippi Valley is a great opportunity for area superintendents and course officials to get a first hand look at cultivar performance under real world conditions. Superintendent Alan Zelko applies the same management practices on this research green as on the rest of the course.

Management inputs for the 1999 season included: 4.7 pounds N / 1000 ft^2 from granular and liquid sources, a preventive fungicide program, light sand topdressing every seven to ten days (April-November), turfgroomers six days a week (April-June), hydro-jecting once in July, and a mowing height of 0.145 inches. This practice green has not been core cultivated since establishment in October 1997.

Many of the cultivars in this trial may be considered the 3rd generation of seeded creeping bentgrasses. The 1st generation began in the early 1920s when 'Seaside' creeping bent-grass was first commercially produced. In 1954, Dr. H.B. Musser at Penn State developed the first synthetic cultivar of creeping bentgrass by crossing the vegetative cultivar 'PennLu' with two other vegetative strains from the USGA / USDAcollection. The result was 'Penncross': finer textured, dense, more aggressive, and disease-resistant than Seaside. Further selections from segregated patches on Penncross greens from across the country in the 70s and 80s have yielded the 3rd generation of cultivars. With the release of each new cultivar we are seeing reductions in leaf texture, increased density, and increased upright growth. 'Pennlinks' was released in 1986, followed by 'Cobra' and 'SR1020' in 1987, 'Providence' in 1988, 'Southshore' in 1991, 'Cato' and 'Crenshaw' in 1993, and 'L-93' and the Penn A and G series in 1995. 'Century', 'Imperial', and 'Backspin' are more recent releases. All of these newer cultivars are denser than Penncross, with the Penn A and G series being 30 to 50 percent denser than all others.

Our objective was to quantify potential density and thatch accumulation differences on nine of the 18 entries in the on-site NTEP bentgrass test at the Missouri Bluffs Golf Club.

Increased density allows these bents to outperform Penncross at lower mowing heights, but also raises concerns with increased potential thatch accumulation. Our objective was to quantify potential density and thatch accumulation differences on nine of the 18 entries in the on-site NTEP bentgrass test at the Missouri Bluffs Golf Club.

Results

Penn A-4 had the greatest density and the most thatch accumulation 2.5 years after establishment. It should be noted that, statistically, Penn A-4 possessed greater thatch depth only in comparison to Penncross. All of these thatch levels are greater than the standard recommended level of <0.5 inches. This is not surprising given the lack of core cultivation practiced on this green.

Cultivars with the highest tiller densities such as Penn A-4 and Century also displayed consistently high quality.

Tiller Density, Thatch Depth, and Average Quality of Nine Creeping Bentgrass Cultivars on the NTEP Green at the Missouri Bluffs Golf Club.

Cultivar	Tiller density (per 4.25"or dm^2)	Thatch depth (inches)	Ave. quality 1999
Penn A-4	2422	0.64	7.8
Penn G-1	2095	0.62	7.3
Century	2036	0.58	7.5
SR 1119	1923	0.55	7.2
Providence	1899	0.55	6.9
Backspin	1833	0.63	7.6
L-93	1768	0.58	7.2
Crenshaw	1726	0.58	7.1
Penncross	1629	0.56	6.1
LSD (0.05)	**325**	**0.07**	**0.4**

*Tiller density and thatch depth measurements taken on April 22, 2000

Evaluation of PGRs to speed turf establishment and increase sod strength

Erik H. Ervin, Brent Rockwell,
Chad Follis and Changho Ok

Many superintendents have experienced the pressures of growing in new or renovated turf areas. Management, investors and golfers alike are eager to open these areas quickly. Assuming adequate soil and seed quality, seeding uniformity and seed to soil contact, irrigation, sunlight, and temperature conditions, what practices might the superintendent employ to speed establishment?

Two practices commonly thought to speed establishment are the use of higher than recommended seeding and nitrogen rates. While higher seeding rates will increase initial stand density, tightly packed seedlings tend to remain in a juvenile state for an extended period of time. Juvenile seedlings are weak, spindly and characterized by a lack of adventitious root, leaf, tiller, and lateral stem (stolon and rhizome) development. Significant seedling mortality (self-thinning) must occur before the remaining plants have the space and resources required for proper development. Often, due to the weak state of the seedlings and increased duration of canopy wetness, much of this self-thinning is related to greater disease incidence. A turfgrass stand of sufficient maturity to open for play must be actively producing tillers, lateral stems, and adventitious roots so that it possesses the leaf area and stored energy necessary to withstand and recover from traffic and environmental stress.

Nitrogen is needed for adequate turfgrass growth and development, but excess N will promote shoot growth at the expense root growth. Rhizome and lateral stem development will be reduced, the need for mowing will be increased, and the potential for disease will be increased. A moderate N fertility program (0.5 to 1.0 lb N / 1000 ft^2 / month) will provide adequate green color and a consistent rate of growth to favor maturation of the whole plant.

Frequent mowing with sharp and well-adjusted equipment should begin when the developing turf first reaches the upper limit of the ⅓ leaf removal rule. For example, if the stand is to be maintained at two inches, mowing should commence when the seedlings have reached a height of three inches.

Although allowing the turf to grow taller will initially produce more leaf area for greater photosynthate production, tillering may be disfavored due to increased shading from neighboring plants. It has been shown that neighboring plants "sense" each other's presence via changes in the light environment which causes greater absorption of far-red radiation; this, in turn, signals greater leaf elongation at the expense of tillering.

Simply using proper seeding rates, practicing moderate fertilization and mowing frequently at the intended height may be all that is needed for rapid turfgrass maturation. However, as turf scientists and managers we are always open to ideas that may improve our success. One such idea has its roots in the physiological basis of frequent mowing. If mechanical mowing helps reduce shading from neighboring plants resulting in faster relative tillering, what about chemical mowing with plant growth regulators (PGRs)?

Shade induced changes in growth such as increased leaf elongation and reduced tillering have been shown to be substantially reversed by application of antigibberellin PGRs, particularly, Primo. Previous research on a mature stand of Kentucky bluegrass in full sun has indicated an increase in tillering due to successive Primo applications. The hypothesis is that photosynthetic energy, not employed for leaf elongation, is re-directed to the crown where it is used for the production of more tillers that are reduced in size. In 1997 and 1999, a growth chamber and then a field experiment were conducted to test whether PGR application to developing turf stands would increase tillering of cool-season grasses and speed establishment.

Growth Chamber Study

Perennial ryegrass (Prizm) seedlings were grown in a growth chamber set for a 14 hour light period at 72°F and a 10 hour dark period at 64°F. Primo was applied at 26 oz / A at three and six weeks after germination (WAG).

Tiller initiation from mother plants began at three to four weeks after germination. As expected, Primo reduced leaf growth by 30-40 percent. While no root mass differences were measured, Primo did increase tiller number per plant compared to the untreated controls at nine weeks after germination. It was this increase in tiller number per plant that suggested the possibility of employing PGRs to increase establishment rate and prompted the following field test.

Field Study

This study was seeded into a prepared area from which all vegetation had been killed with two applications of glyphosate. The dead vegetation was verticut and debris was removed. A blend of three turf-type tall fescues (Titan, SR8200 and SR8300) were planted on April 13, 1999 with a slit seeder in two directions at a rate of six pounds pure live seed per 1000 ft^2. Tupersan was applied at seeding for crabgrass control. The soil is a silt loam with a pH of 6.6 and adequate test levels of P, K, C, and Mg.

Fertilizer applied consisted of 1 pound N per 1000 ft^2 as 13-13-13 on April 15, 1 pound N per 1000 ft^2 as 20-3-20 on May 10, 0.5 lb N per 1000 ft^2 as 18-3-12 on June 11, and 1.5 pounds N per 1000 ft^2 as 24-4-12 on September 15. Manage was applied for control of yellow nutsedge on June 9 and Mach 2 for white grub control on June 11. No other pesticide applications were needed.

Treatments were arranged in a randomized complete block design with three replications. Each plot was 10 feet by 10 feet. Plant growth regulator treatments were as follows: Turf Enhancer 2SC (paclobutrazol) at 16 oz / A; Primo Liquid 12%EC (trinexapac-ethyl) at 26 oz / A; and Proxy (ethephon) at 174 oz / A. Applications were made at two, five, and eight WAG on May 14, June 3, and June 25.

Mowing was initiated when the developing turf had reached a height of three inches and was cut to a height of two inches, twice a week, with a rotary mulching mower. Irrigation was applied as needed to maintain active growth.

At 12 WAG (Aug. 4) two cup cutter plugs (4.25 inch diameter) per plot were taken and individual tillers were counted. Tiller density per plot is the average of these two plugs. On October 21 two sod strips (18 x 28 inches) were cut per plot at a 0.75 inch soil depth. The force required to tear the sod apart was measured using a simple sod strength device.

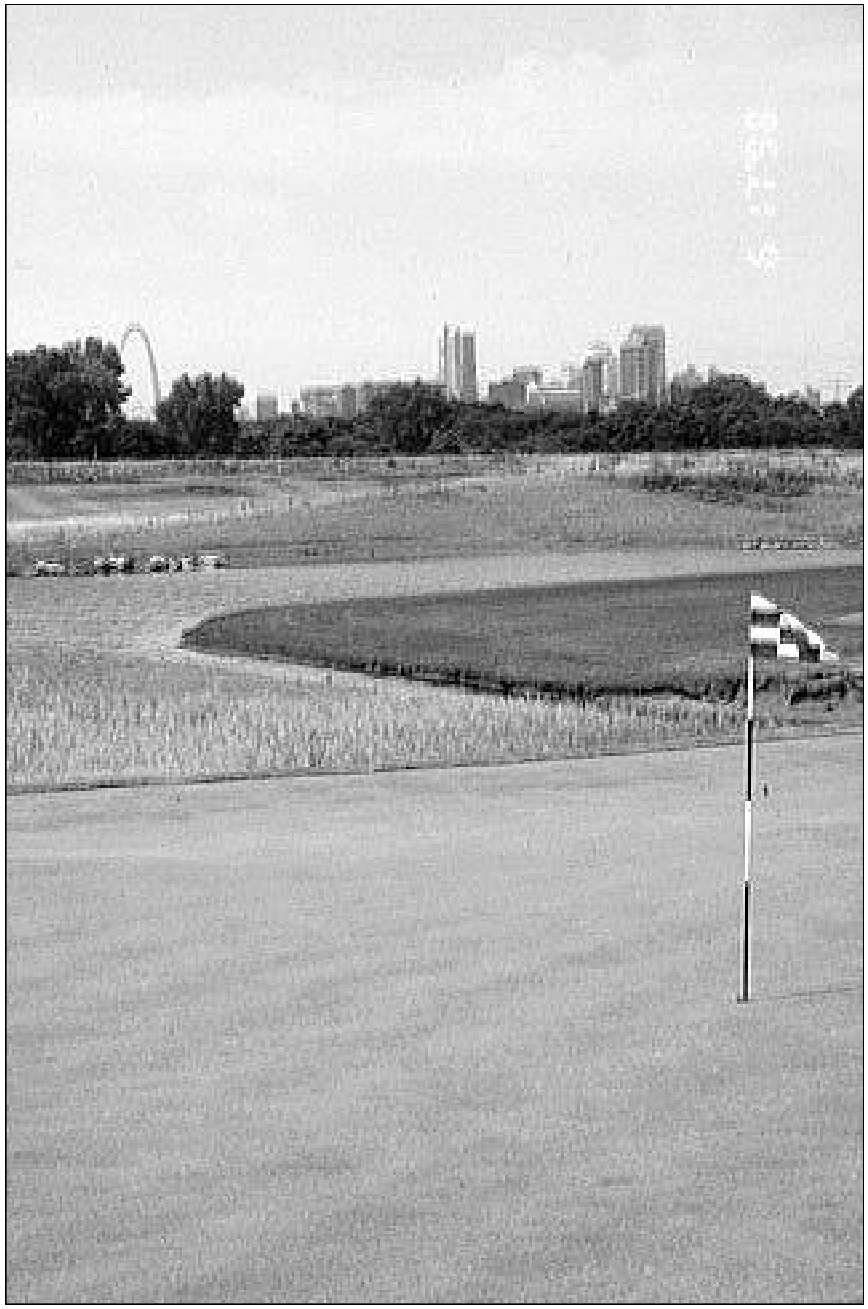
Results

Grow-in quality of the turf-type tall fescue was very similar among treatments until approximately the second PGR application at five WAG when Proxy-treated plots began to exhibit

lower visual density. While no phytotoxicity was observed due to the application of any of the PGRs to the developing tall fescue, the quality of Proxy-treated plots was lower relative to the other treatments at 12 and 23 WAG. Lower visual quality was associated with decreased tiller density of Proxy-treated plots at 12 WAG relative to those treated with Turf Enhancer.

Increased sod strength is associated with greater tiller, rhizome, and root density. One tall fescue cultivar used in this study, Titan, is noted for the production of short rhizomes and was included specifically for the purpose of improving sod strength. At harvest, we were able to cut tall fescue that held together as sod, but we did not measure any statistically significant differences in sod strength due to PGR treatment.

In summary, the results of this field study indicate that, given proper cultural practices, application of various PGRs to developing stands of tall fescue do not increase establishment rate. Perhaps the only significant advantage to the use of PGRs during establishment would be to sustain turfgrass maturation with chemical mowing rather then mechanical mowing in wet springs.



Primo for sustaining Zoysiagrass quality in the shade

Erik H. Ervin, Changho Ok, Brad S. Fresenburg, John H. Dunn, and Scott Dunn

It is estimated that 20 to 25 percent of turfgrasses are grown under low light conditions. 'Meyer' zoysiagrass is the premier warm-season turfgrass for golf course tees and fairways in the Missouri transition zone because of its dense growth habit, tolerance of low mowing heights, cold, traffic, and drought tolerance, and relative lack of insect and disease problems. Unfortunately, Meyer zoysiagrass is not very shade tolerant. In Missouri, a considerable amount of time and money are spent by golf course superintendents in an effort to maintain zoysiagrass in shade. Too often, the effects of traffic and shade reduce zoysiagrass quality to the point where the zoysia must be resodded or replaced entirely with a more shade-tolerant species which, unfortunately, does not offer the same functional or aesthetic performance.

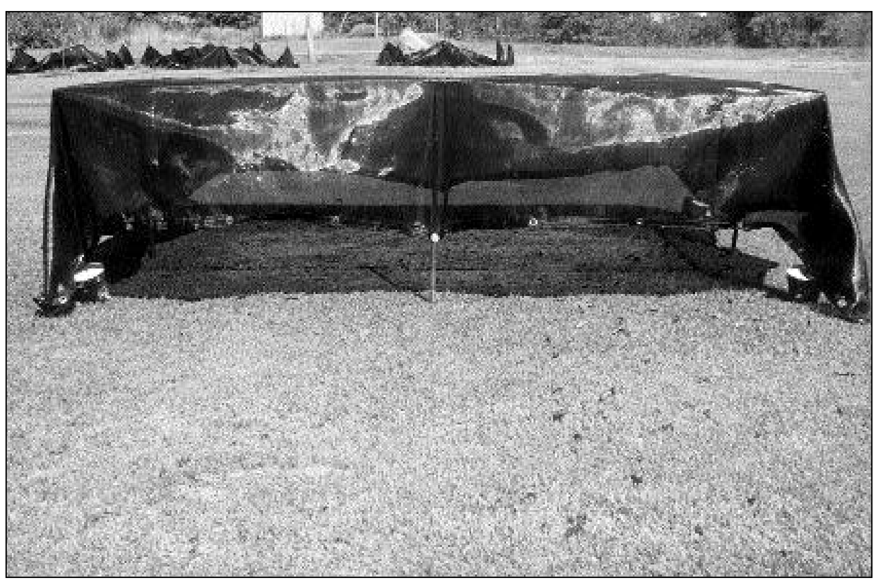
Shade causes a number of morphological and physiological changes to occur in turfgrasses. For instance, leaf length and plant heights increase most likely due to the inactivation of phytochrome by far-red light and the production of excessive levels of gibberellic acid. Gibberellic acid is a plant hormone that is primarily responsible for leaf blade elongation. Elongated leaves are thinner and have higher tissue moisture contents. Photosynthesis is decreased in shade resulting in decreased carbohydrate reserves and reduced root, rhizome, and tiller growth. The overall result is thin, poor quality turf that will not stand up to traffic and other stress.

Primo (trinexapac-ethyl) is a plant growth regulator that reduces leaf elongation by directly inhibiting the production of gibberellic acid (GA) in the plant. Our hypothesis is that Primo, by inhibiting shade-induced GAproduction and unneeded leaf growth, will conserve photosynthate and result in increased zoysiagrass shade tolerance. Our objective is to determine if monthly applications of trinexapac-ethyl to an actively growing zoysiagrass experimental fairway will enhance quality under two levels of dense shade.

Methods

This project is being conducted on a mature 'Meyer' zoysiagrass experimental fairway maintained at $\frac{5}{8}$ inch and irrigated once a week to replace 100 percent of evapotranspiration. Uniform applications of 1 lb N / 1000 ft^2 (urea) were applied in August 98 and May 99. The study consists of two factors and four replications arranged in randomized complete blocks. The two factors are: light level and Primo. There are three light levels: full sun, 73 percent shade cloth, and 92 percent shade cloth. Such dense shade levels are common in nature. Each shade structure covers a plot area of 35 ft^2. Each plot is separated from its neighbor by 5 foot borders to the east and west and 3 foot borders on the north and south. Shade and Primo treatments began on 14 August 1998. Three rates of Primo (0.0, 0.125 and 0.25 oz / 1000 ft^2) were applied on 14 August and 13 September 1998. The shade structures were removed after leaf fall and replaced in May 1999 when monthly Primo treatments were again initiated on May 28, 1999. Weekly golf cart traffic pressure (10 passes / plot) was initiated in June over the entire study.

Data collected included mid-day



light levels, visual turf quality, tiller density and weekly clipping production.

Results

Average irradiance levels measured in full sun and under the supposed 73 percent and 92 percent shade cloths from 11 am to 2 pm on a cloud free day (14 June 1999) were 1665 μ mol m^{-2} s^{-1} (0 percent shade), 351 μ mol m^{-2} s^{-1} (79 percent shade), and 130 μ mol m^{-2} s^{-1} (92 percent shade).

The clipping production data demonstrate three predictable responses of zoysiagrass to Primo, shade, and their combination. First, Primo does reduce vertical shoot growth. In full sun the 1/4 oz/M rate of Primo reduced clipping production by 30 to 40 percent over each four week application cycle, while the 1/8 oz/M rate reduced clippings by only about 1 to 18 percent (Table 1). Second, shade increases vertical shoot growth probably due to increased GA biosynthesis induced by the reduced light conditions. The 79 percent and 92 percent shade treatments without Primo applied had increased clipping production relative to the untreated full sun plots (8 to 54 percent). Third, Primo's inhibition of GA production functioned to overcome or counteract most shade-induced increases in vertical shoot growth. Clipping production of the shaded plots treated with Primo were either just slightly above or slightly below that of the full-sun untreated control. Such a response of Primo-treated zoysia in the shade most likely implies a conservation of energy relative to shaded zoysia that has not been treated with Primo. The 3 oz rate gave the most consistent reduction of shoot growth at both shade levels. This rate was also most effective during periods of vigorous zoysia growth (Aug-Sept. 98 and June 99).

Table 1:Clipping production response of Meyer zoysiagrass to shade and Primo

Treatment	14 Aug to 13 Sept 1998	13 Sept to 11 Oct 1998	28 May to 25 June 1999
	Percentage above or below untreated full-sun control (4 week average)		
0% shade: 1/4 oz Primo	-38	-36	-30
0% shade: 1/8 oz Primo	-17	-18	-1
79% shade: no Primo	+42	+18	+20
79% shade: 1/4 oz Primo	-9	-31	-0
79% shade: 1/8 oz Primo	+10	-13	+5
92% shade: no Primo	+54	+8	+8
92% shade: 1/4 oz Primo	-11	-16	-16
92% shade: 1/8 oz Primo	-4	-15	+23

Prior to shade and Primo treatment initiation (13 Aug. 1998) there were no tiller density differences measured between plots (Table 2). At the beginning of the shade and Primo treatments in 1999 (02 June), there were also no tiller density differences measured. However, following two months of treatments, large differences became apparent with the 1/4 oz treatments providing the greatest maintenance of tiller density.

Energy conservation in the shade due to Primo should result in the retention of higher quality (or a slower loss in quality) relative to shaded zoysia not treated with Primo over time. The quality ratings in Table 3 indicate that this is, in fact, the case. They also indicate that the 3 oz rate provided the best quality under both levels of shade. By 18 July 1999, zoysia thinning under 92 percent was severe with almost no grass left on plots not treated with Primo and those that only receive 1/8 oz each month. At the end of the trial (29 September 1999), no quality differences were apparent on the unshaded plots, while the 1/4 oz rate under 79 percent shade had resulted in the greatest maintenance of quality when compared to all other shaded plots.

This study has shown that greater zoysia quality and density can be maintained under dense shade with monthly applications of Primo at 1/4 oz/M. It must be stressed that this is a preventive treatment. Primo will not necessarily help to fill-in zoysia that has already been thinned by shade and traffic, but it will slow down the thinning process. Depending on the level of shade and the amount of traffic, Primo's effects may enable a fairway or tee area to remain playable for another season or indefinitely. Superintendents may wish to experiment with more frequent applications of the same or lower rates tested in this study.

Table 2:Tiller density response of Meyer zoysiagrass to shade and Primo

Treatment	17 August 1998	02 June 1999	09 August 1999
	Tiller density		
0% shade: no Primo	204.8	227.6	301.0b
0% shade: 1/4 oz Primo	244.0	232.8	338.0a
0% shade: 1/8 oz Primo	222.5	256.4	270.3b
79% shade: no Primo	251.6	231.4	45.4d
79% shade: 1/4 oz Primo	211.3	207.9	89.3c
79% shade: 1/8 oz Primo	231.4	203.4	63.3cd
92% shade: no Primo	241.1	222.0	3.3e
92% shade: 1/4 oz Primo	231.8	199.8	30.6de
92% shade: 1/8 oz Primo	232.9	249.6	9.3e
LSD (0.05)	**NS**	**NS**	**36.1**

Table 3:Visual Quality response of Meyer zoysiagrass to shade and Primo

Treatment	09 October 1998	18 June 1999	18 July 1999	29 Sept. 1999
	Quality rating (1-9, 9=best)			
0% shade: no Primo	7.5a	6.9a	6.0a	6.9a
0% shade: 1/4 oz Primo	7.4a	6.8a	6.3a	6.9a
0% shade: 1/8 oz Primo	7.5a	6.9a	5.6a	7.0a
79% shade: no Primo	5.1de	4.9c	3.3c	2.3c
79% shade: 1/4 oz Primo	6.5b	5.8b	4.5b	4.0b
79% shade: 1/8 oz Primo	6.3bc	5.1bc	3.4c	3.9b
92% shade: no Primo	4.3e	4.5c	1.6e	1.0d
92% shade: 1/4 oz Primo	6.4b	5.3bc	2.5d	1.6cd
92% shade: 1/8 oz Primo	5.6cd	5.0bc	1.9de	1.3cd
LSD (0.05)	**0.8**	**0.8**	**0.6**	**1.1**

1999 Crabgrass demonstration trial

B.S. Fresenburg and E.H. Ervin

This study was conducted on a stand of 'Nassau' Kentucky bluegrass at the MU Turfgrass Research Center. Soil classification is a 'Mexico' silt loam with pH of 6.1 and 1.8 percent organic matter. The 'Nassau' Kentucky bluegrass was established in the fall of 1987, overseeded as needed, fertilized with 3 to 4 lbs of nitrogen per 1,000 square feet per year and mowed twice a week at 2.5 inches. Moisture levels were maintained to prevent wilt. The entire block was seeded with large crabgrass (*Digitaria sanguinalis*) at a rate of one quart per 1,000 square feet using an Olathe model 84 slit-seeder on 14 April.

Treatments were initiated on 14 April with Pre 1 applications being watered in with approximately 0.5 inches of irrigation. Some Pre 1 applications had sequential applications made on 28 May. Post-emergence applications were made on 24 June at a 1 to 3 leaf stage of crabgrass. A sequential application of MSMA was made on 6 July.

Treatments were applied with a CO2 backpack sprayer, walking 3 mph, using TeeJet XR8008 tips delivering 56 gpa at 20 psi.

Evaluations for phyto were taken on 21 April, 4 June and 28 June. Evaluations for phyto were taken on a scale of 1 to 9, with 9 showing no phyto. Data for color was taken on 5 May and 4 June. Evaluations for color were taken on a scale of 1 to 9, with 9 being equal to the darkest green color. Percent control of crabgrass was taken on 24 June, 21 July and 9 August. Percent control was taken on a scale of 0 to 100, with 100 being equal to total control of crabgrass.

Results for all treatments are indicated in the following table.

Crabgrass demonstration trial, 1999

Treatments	Rate lbs ai/A	Timing	Phyto 21 April	Color 5 May	Phyto 4 June	Color 21 June	% Control 24 June	Phyto 28 June	%Control 21 July	% Control 9 August
Control	—	—	9	7	9	7	0	9	0	0
Blank fertilizer	—	Pre 1	9	8	9	8	100	9	99	95
Dimension	0.19	Pre 1								
Dimension	0.19	Pre 2								
Dimension FG	0.19	Pre 1	9	8	9	8	100	9	98	95
Dimension FG	0.19	Pre 2								
Blank fertilizer	—	Pre 1	9	9	9	7	100	9	98	94
Dimension	0.50	Pre 1								
Dimension FG	0.50	Pre 1	9	8	9	9	100	9	98	94
Pendimethalin	1.50	Pre 1	9	7	9	7	99	9	94	88
Pendimethalin	1.50	Pre 2								
Ronstar G	4.00	Pre 1	9	7	9	7	100	9	99	96
Ronstar G	2.00	Pre 1	9	7	9	7	100	9	100	99
Ronstar G	2.00	Pre 2								
Barricade	0.65	Pre 1	9	7	9	7	100	9	100	98
Balan	1.50	Pre 1	9	7	9	7	97	9	95	89
Balan	1.50	Pre 2								
Team	1.50	Pre 1	9	7	9	7	97	9	93	86
Team	1.50	Pre 2								
Daconate	1.00	1-3 leaf	9	7	9	7	0	8	87	81
Daconate	1.00	14 leaf								
Dimension	0.50	1-3 leaf	9	7	9	7	0	9	98	97
X-77	0.50%									
Acclaim Extra	0.05%	1-3 leaf	9	7	9	7	0	9	96	91
Drive	0.75	1-3 leaf	9	7	9	7	0	9	100	96
COC	1 pint									
LSD (0.05)=	**—**	**—**	**0**	**0**	**0**	**0**	**2**	**0**	**3**	**5**

Shade adaptation study: 1999 to 2000

Erik H. Ervin, Christopher J. Starbuck, John H. Dunn, and Brad S. Fresenburg

This shade adaptation study was established in the fall of 1998 to evaluate the performance of 16 species and cultivars grown under a maturing stand of American Sweetgums (*Liquidambar styraciflua*). The species include creeping red fescue (*Festuca rubra L. rubra*) = CRF; Chewings fescue (*F. rubra L. commutata Gaud.*) = CF; hard fescue (*F. longifolia Thuill.*) = HF; sheep fescue (*F. ovina L.*) = SF; blue fescue (*F. ovina L. glauca Lam.*) = BF; turf-type tall fescue (*F. arundinacea Schreb.*) = TF; and Kentucky bluegrass (*Poa pratensis L.*) = KB.

The study area receives a very low level of maintenance. It is mowed weekly to a three inch height, receives only 1 lb. N / 1000 ft^2 in the fall, and receives no irrigation or pesticides. Light levels throughout the study area vary from 80 to 95 percent shade.

Monthly quality data are collected from March through October (Tables 1 and 2). Visual quality is based on a scale of 1 to 9: 9 = best quality, 6 = good shade quality, 4 = lowest acceptable quality, 1 = completely dead or dormant turf.

Results and Discussion

The Chewings fescue, hard fescue, and tall fescue cultivars displayed the greatest post-establishment quality in May and June of 99. A large incidence of brown patch throughout July 99, followed by extended drought, weakened the two tall fescue entries to quality averages of 1.5 in September. Alamo (E), however, displayed a much greater ability to recover than the Arid blend, finishing the season with a 5.0 rating. The combination of powdery mildew, shade, and extended drought thinned the two Kentucky bluegrass cultivars so considerably in 1999, that they have failed to adequately recover by June 2000.

All fine leaved fescue species display best persistence in shaded sites where soil moisture and fertility is low. Fine fescues may thin considerably in wet soils under shade due to an increased incidence of summer patch, dollar spot, brown patch, and powdery mildew. Considerable drought-induced summer dormancy

Table 1.1999 Visual quality data for turfgrass cultivars in dense shade

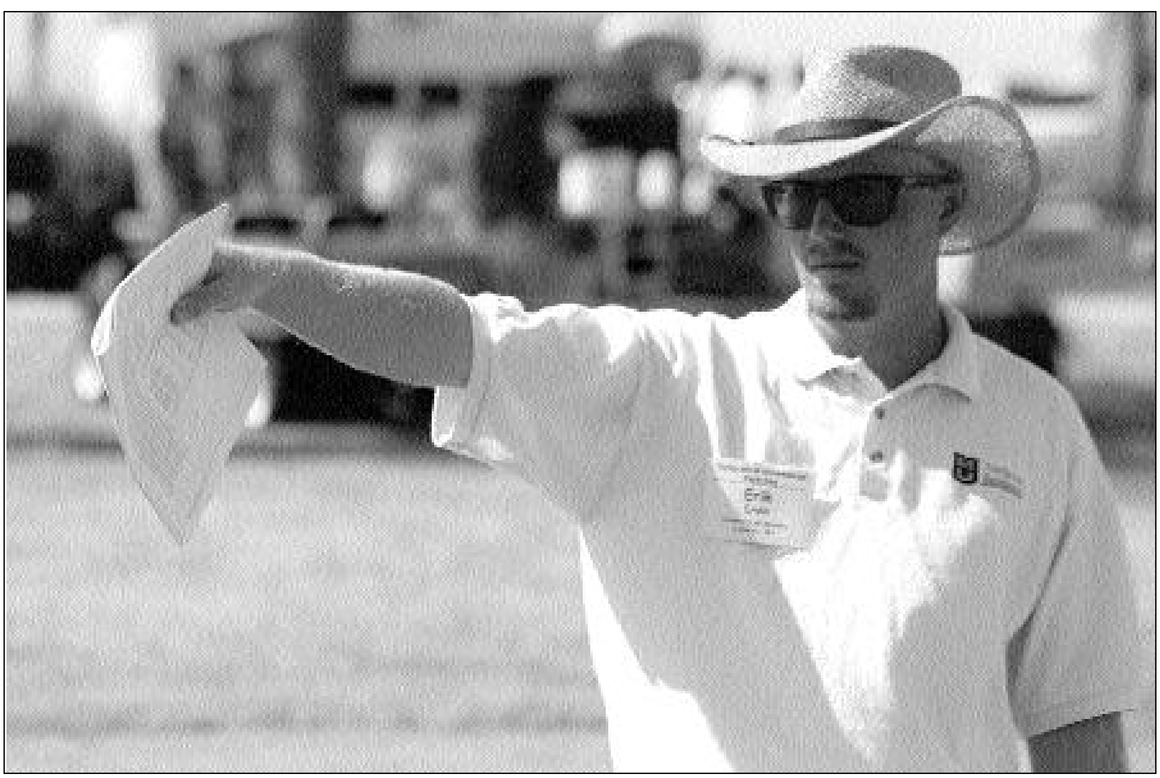
Cultivar/Species	May 99	June 99	July 99	Aug.99	Sept.99	Oct.99
	Quality Rating (9 = best)					
SR5100 (CF)	6.0	6.0	6.5	4.0	2.7	5.7
Rescue (HF)	4.7	5.3	5.7	4.3	3.0	5.3
EcoStar (HF)	4.3	5.5	5.7	4.7	3.0	4.0
Alamo (E) (TF)	5.3	5.8	5.0	4.0	1.5	5.0
Shadow II (CF)	4.7	6.3	6.5	3.7	1.8	4.3
Tiffany (CF)	5.0	6.0	6.2	3.7	1.7	4.0
Jamestown II (CF)	5.3	6.0	5.5	3.7	1.7	4.0
SR3200 (BF)	4.0	5.2	5.2	3.7	2.5	4.0
SR3100 (HF)	4.3	5.5	5.3	4.0	2.0	3.3
SR5LAV (CRF)	6.0	5.7	5.3	3.0	1.5	3.0
Shademaster II (CRF)	5.3	5.3	5.5	3.3	2.2	3.3
Arid II and III (TF)	5.7	6.3	4.8	3.0	1.5	3.3
Nassau (KB)	3.7	5.5	5.7	3.0	1.5	3.7
Reliant II (HF)	4.0	4.5	4.3	3.0	2.2	3.3
MX86AE (SF)	4.7	4.0	3.8	2.7	1.7	2.7
NuGlade (KB)	3.3	3.8	4.3	3.0	1.3	2.7
LSD (0.05)	**1.2**	**1.3**	**1.3**	**1.3**	**0.6**	**1.9**

reduced the quality of all the fine fescue entries, rather than disease, from July to September 1999. Thus, considerable recovery occurred in October 1999, most notably for SR5100 Chewings and Rescue hard fescue. This recovery continued through the relatively dry and warm spring of 2000 resulting in these two cultivars being the highest rated for the duration of this trial. In all, six of the top seven cultivars are Chewings or hard fescues.

These results are similar to those of two long-term shade adaptation studies at Iowa State University, where cultivars such as SR5100 (CF), Shadow (CF), Jamestown (CF), SR3000 (HF), and Waldina (HF) have been the top performers.

Table 2.2000 Visual quality data for turfgrass cultivars in dense shade

	March 00	April 00	May 00	June 00	July 00	99-00
Cultivar/Species	Quality Rating (9 = best)					Ave.
SR5100 (CF)	5.0	5.0	5.7	5.3		5.2a
Rescue (HF)	5.0	5.0	5.3	5.3		4.9b
EcoStar (HF)	4.3	4.7	4.8	5.8		4.7c
Alamo (E) (TF)	4.3	5.0	5.3	5.3		4.7c
Shadow II (CF)	4.7	4.3	5.0	5.3		4.7c
Tiffany (CF)	4.3	4.3	5.0	4.7		4.5d
Jamestown II (CF)	4.0	4.0	5.2	5.0		4.4de
SR3200 (BF)	4.3	4.3	4.8	5.3		4.3e
SR3100 (HF)	4.0	3.7	4.7	4.8		4.2f
SR5LAV (CRF)	3.7	3.3	4.5	4.7		4.1fg
Shademaster II (CRF)	3.3	3.0	4.7	4.5		4.1g
Arid II and III (TF)	3.3	3.3	4.3	4.5		4.0g
Nassau (KB)	2.7	2.0	2.8	4.0		3.4h
Reliant II (HF)	2.7	3.0	4.0	3.3		3.4h
MX86AE (SF)	2.7	3.3	4.0	4.3		3.4h
NuGlade (KB)	2.0	2.3	3.2	3.7		3.0i
LSD (0.05)	**1.7**	**1.7**	**1.4**	**1.3**		**0.11**



Rubber tire particle topdressing trial on turf pathways in Gladney Rose Garden at the Missouri Botanical Garden

Erik H. Ervin and Scott Stelling

The U.S. discards about 300 million tires a year. At least 25 states now prohibit these tires from landfills and 46 states, including Missouri, have legislated government funding toward recycling efforts. This usually means the tire must be broken down into very small pieces and separated from the metal / steel component. While the metal in the tire are easily sold, finding a market for crumb rubber particles ($\frac{1}{4}$ inch and less) has been more challenging. Increasingly, crumb rubber is being used for fuel, pavement stabilization, and as a playground surface.

Research, beginning at Michigan State in 1990, and later at Iowa State, has indicated that crumb rubber topdressing can reduce soil compaction and protect the turfgrass crown resulting in greater traffic tolerance and recovery. Best results were obtained when a $\frac{3}{4}$ inch crumb rubber layer was accumulated by topdressing at $\frac{1}{4}$ inch (600 lbs / 1000 ft^2) or less increments over a three to four month period. Applying more than a $\frac{1}{4}$ inch layer at one time was not recommended due to problems with working the particles into the turfgrass canopy and possible excess surface temperatures.

Crumb rubber is composed primarily of iron, sulfur, and zinc. Reports from Michigan State indicate iron and zinc soil levels have increased from 1990 to 1995, but have not approached levels of concern. At no time have they reported any toxicity to the turfgrass plant during their studies.

The Gladney Rose Garden at the Missouri Botanical Garden consists of narrow (2.5 to 4 feet wide) turfed pathways between the rose plantings. The turf consists primarily of turf-type tall fescue and a small amount of Kentucky bluegrass maintained at three inches. The soil is a clay loam. Rose night is an annual event in late May that attracts 1,500 to 2,000 people to view the rose selections in peak bloom. Such an intense traffic event on narrow turf pathways inevitably wears much of

Rubber vs. no rubber at the Missouri Botanical Gardens

Response	Rubber	No rubber	Response	Rubber	No rubber
Quality May 17, 1999	6.3	6.5			
Quality June 01, 1999	4.6	4.5			
Quality June 28, 1999	4.8	4.6	Hardness June 28, 1999	64	70
Quality March 17, 2000	6.3	6.3	Hardness March 17, 2000	60	65
Quality May 17, 2000	5.4*	4.9			
Quality June 14, 2000	4.3*	3.7	Hardness June 14, 2000	56	68*

*significantly different at a 95% probability level;all other mean comparisons are not different.

Quality was rated on a 1 to 9 scale, 9 = best.Surface Hardness was measured with a Clegg impact meter with a 2.5 kg hammer and is reported as the peak deceleration value (gmax).

Rubber buffings were applied to the plots in 1/4 inch increments on three dates:May 17, 1999; October 15, 1999;and March 17, 2000.

the turfgrass foliage to the ground, leaving many bare areas for the duration of the summer. Core cultivation and re-seeding must occur each September. Our objective was to determine if rubber topdressing would increase traffic tolerance and reduce the need for yearly re-establishment.

Methods

Rubber buffings were applied to the plots in 1/4 inch increments on three dates with a drop spreader at its maximum opening: May 17, 1999, October 15, 1999, and March 17, 2000. Six 2.5 feet by 12 feet paths received rubber and six did not. Each plot was in the highest traffic areas, immediately adjacent to the sidewalk.

Quality ratings were taken on three dates in 1999 and 2000. The June 01, 1999 and June 14, 2000 ratings followed the intense Rose Night traffic events. Only a 1/4 inch layer was present for the 1999 ratings, while the full 3/4 inch layer was present for the 2000 ratings. Impact absorption or surface hardness readings were taken with a Clegg Impact Meter on one date in 1999 and two dates in 2000.

Results

No quality differences were apparent at the beginning of the trial when the first 1/4 inch layer was applied on May 17, 1999. Quality decreased significantly in June 1999 following the intense traffic of Rose Night; the addition of rubber did not improve post-traffic quality or decrease surface hardness. Turf quality was increased due to the 3/4 inch rubber layer in May 2000 and in June 2000, following the intense traffic of Rose Night. Surface hardness was also reduced by the rubber in June 2000. Although loss of turf quality was mitigated by the rubber topdressing, it may not be enough in this intense traffic situation to eliminate the need for annual fall renovation.

Evaluation of fungicides for management of Brown Patch on Bentgrass greens, 1999

B.S. Fresenburg, E.H. Ervin, and B.S. Corwin

This study was conducted on a 'Penncross' bentgrass green at the MU Turfgrass Research Center. The green profile is a 10 inch base of 90/10 sand and peat blend over drains in sub-grade. The 'Penncross' was established in the fall of 1992.

The green was mowed on Monday, Wednesday and Friday of each week at 3⁄16 to 5⁄32 of an inch. Fertility levels were maintained at a high level with 0.38 lbs of nitrogen per 1,000 square feet being applied every three weeks. Moisture levels were maintained at optimum levels with thorough, but infrequent, watering plus daily syringes as needed. During hot weather moisture levels were increased to promote high humidity levels insuring better infection conditions for brown patch. Fungicide treatments were initiated 9 June and sequentially applied on 23 June, 30 June, 7 July and 21 July based on the recommended application intervals for each treatment. Plots were 5 feet by 5 feet replicated four times in a randomized, complete block.

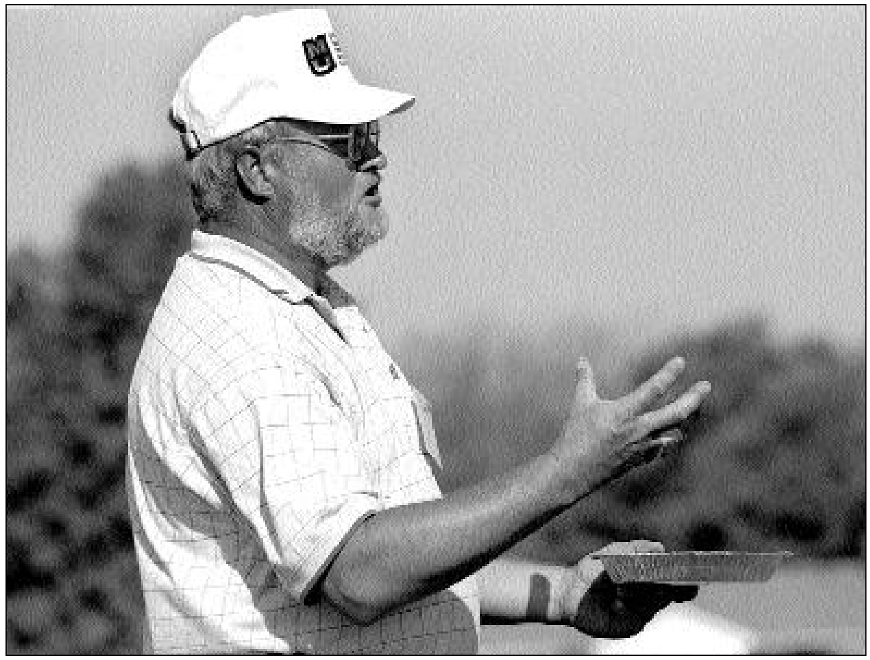
Treatments were applied with a CO2 backpack sprayer, walking speed of 3 mph, using TeeJet XR8008 tips delivering 56 gpa at 20 psi.

Brown patch symptoms were starting to become visible on 9 June by natural infection. The first applications were made at that time. Early evaluations observed a high infection of dollar spot is these plots and data was taken for percent infection, percent control and quality on 18 June and 30 June. Similar evaluations were taken on 15 July and 22 July for a moderate brown patch infection.

Treatment	Rate oz/1000	Interval	18 June Dollar Spot %Infection	18 June Dollar Spot % Control	18 June Bentgrass Quality	30 June Dollar Spot %Infection	30 June Dollar Spot % Control	30 June Bentgrass Quality
Control	—	—	36	0	3	43	0	3
Compass+	0.10+	14	2	95	7	0	100	8
Banner	0.50							
Compass+	0.15+	14	2	96	7	0	100	9
Banner	0.50							
Heritage	0.20	14	15	55	5	24	40	4
Heritage	0.40	28	25	32	4	38	21	4
Chipco 26GT	4.0	14	5	87	6	3	95	7
Daconil Ultrex	3.8	14	5	88	6	3	94	7
Bayleton	0.25	14	6	83	6	1	98	7
Sentinel	0.16	21	6	81	6	5	88	7
Banner MAXX	2.0	21	6	83	6	3	94	7
Prostar	3.0	21	23	36	4	33	25	3
Eagle	0.60	21	6	86	6	7	84	6
Model-Ervin	3.8	14	6	84	6	2	96	7
Model-Shaffer	3.8	14	36	0	5	12	70	5
LSD (0.05) =		**8**	**17**	**1**	**11**	**19**	**1**	**4**

Percent infection and percent control were taken on a scale of 0 to 100, with 100% infection being total coverage of the plot with brown patch, while 100% control showing no infection at all. Quality was taken on a scale of 1 to 9, with 9 being equal to the best quality.

Control plots were showing 36 and 43% infection for dollar spot on 18 and 30 June, respectively. Brown patch infection ranged from 34 down to 23% on 15 and 22 July. Control of dollar spot and brown patch by various treatments is outlined in the following table.



15 July Brown Patch %Infection	15 July Brown Patch % Control	15 July Bentgrass %Infection	22 July Brown Patch %Infection	22 July Brown Patch % Control
34	0	4	23	0
0	100	8	0	100
0	100	8	0	100
2	94	6	0	100
1	96	7	1	98
1	97	7	1	98
3	91	7	2	86
1	98	7	0	100
0	100	9	0	100
0	100	9	2	93
9	73	4	2	92
0	100	8	0	99
6	82	6	7	67
19	45	4	2	91
4	**9**	**1**	**4**	**18**

Evaluation of fungicides for management of Dollar Spot on Bentgrass greens, 1999

B.S. Fresenburg, E.H. Ervin, and B.S. Corwin

This study was conducted on a 'Penncross' bentgrass green at the MU Turfgrass Research Center. The green profile is a 10 inch base of 90/10 sand and peat blend over drains in sub-grade. The 'Penncross' was established in the fall of 1992.

The green was mowed on Monday, Wednesday and Friday of each week at $3/16$ to $5/32$ of an inch. Fertility levels were maintained at a moderate level with 0.38 lbs of nitrogen per 1,000 square feet being applied every four weeks. Lower fertility levels favor dollar spot, therefore we were trying to insure a high level of natural infection. Moisture levels were maintained at optimum levels with thorough, but infrequent, watering plus daily syringes as needed. Fungicide treatments were initiated 13 May and sequentially applied on 27 May, 3 June, 10 June, 24 June and 8 July based on the recommended application intervals for each treatment. Plots were 5 feet by 5 feet replicated four times in a randomized, complete block.

Treatments were applied with a CO_2 backpack sprayer, walking speed of 3 mph, using TeeJet XR8008 tips delivering 56 gpa at 20 psi.

Dollar spot symptoms were becoming visible on 13 May by natural infection. The first applications were made at this time. After a week or so, infection rates were very high and data taken included percent infection, percent control and quality on 8 June, 18 June and 24 June.

Percent infection and percent control were taken on a scale of 0 to 100, with 100 percent infection being total coverage of the plot with dollar spot, while 100 percent control showing no infection at all. Quality was taken on a scale of 1 to 9, with 9 being equal to the best quality.

Control plots were averaging 46, 53 and 51 percent infection on 8 June, 18 June and 24 June, respectively. Control of dollar spot, by various fungicide treatments, is outlined in the following table.

Treatment	Rate oz/1000	Interval	8 June Dollar Spot %Infection	8 June Dollar Spot % Control	8 June Bentgrass Quality	18 June Dollar Spot %Infection	18 June Dollar Spot % Control	18 June Bentgrass Quality	24 June Dollar Spot %Infection	24 June Dollar Spot % Control
Control	—	—	46	0	3	53	0	3	51	0
Daconil Ultrex	3.8	14	4	92	6	2	97	8	6	87
Heritage[+]	0.2[+]	14	1	98	7	1	98	8	3	94
Daconil Ultrex	3.8									
Chipco 26 GT	4.0	14	2	96	7	1	99	8	1	98
Chipco Signature	8.0	14	26	42	4	31	43	4	35	38
Chipco 26GT[+]	4.0[+]	14	1	99	8	0	100	9	0	100
Chipco Signature	8.0									
Chipco Triton	0.5	14	0	99	7	0	100	8	0	100
Chipco Triton	1.0	14	0	100	8	0	100	8	0	100
Sentinel	0.16	21	0	99	7	0	100	8	0	100
Eagle	1.2	28	5	90	6	2	97	7	0	100
Banner MAXX	1.0	14	0	100	7	0	100	8	0	100
Bayleton	0.25	14	1	99	7	1	99	8	0	100
Lynx[+]	0.28[+]	14	0	100	8	0	100	9	0	100
Daconil Ultrex	1.8									
Lynx[+]	0.28	14	0	100	8	0	100	8	0	100
Bayleton[+]	0.25[+]	14	4	83	7	2	96	8	2	97
Daconil Ultrex	1.8									
Model										
Daconil Ultrex	3.8	14	10	85	5	8	85	6	14	78
LSD (0.05) =			**8**	**20**	**2**	**8**	**11**	**1**	**12**	**18**

Evaluating annual herbacious ornamentals for performance in Missouri

David Trinklein and Amy Riesselman

Colorful beds of annual flowering plants have become an important component of the created landscape. This is true for public areas as well as private residences. Sales of annual flowering plants increase in scope each year by double-digit figures, with no end in sight. Many annual herbaceous plants carry the stigma of being somewhat difficult to grow, especially under severe heat and water stress conditions typical of Missouri's summers. This fact has, in certain cases, prevented them from being more widely used in large-scale planting such as those typical of color beds on golf courses, surrounding commercial buildings, etc. Plant improvement via introduction and breeding provides us with many new cultivars of ornamentals each year. Unfortunately, the ability of these new cultivars to tolerate the heat and humidity typical of a Missouri summer is, for the most part, unknown. The purpose of this trial was to evaluate a number of new herbaceous ornamental cultivars for their summer performance in Missouri.

Table 1. 2000 Ornamental Plant Evaluation.

Asclepias 'Red Butterfly'	Nicotiana 'Avalon Bright Pink'
Canna 'Pretoria'	Pentas 'Butterfly Red'
Capsicum 'Jigsaw'	Pentas 'Lavender Light'
Celosia 'New Look'	Petunia 'Madness Star Rose'
Celosia 'Red Glow'	Petunia 'Tidal Wave Rose'
Coleus 'Alabama Sunset'	Portulaca 'Margarita Rosita'
Coleus 'Gold Bound'	Salvia 'Strata'
Coleus 'Pineapple'	Salvia 'Vista Salmon'
Cuphea 'Bat Face'	Strobalinthus 'Persian Shield'
Helianthus 'Del Sol'	Tithonia 'Del Sol'
Ipomea 'Blackie'	Verbena 'Mauve Twilight'
Ipomea 'Tri-Color'	Vinca 'Raspberry Red Cooler'
Lagerstroemia 'Dwarf Crepe Myrtlette'	Zinnia 'Short Stuff'
Marigold 'Sweet Cream'	Zinnia 'Profusion White'

Twenty-eight cultivars of annual herbaceous ornamental plants (Table 1) were grown under garden conditions at demonstration plots located at the University of Missouri Turf Research Center located on the University's South Farm which is near Columbia, Mo. The plants were started from seed or received as established plants in February and cultured to transplantable size in the greenhouse. On May 16, 2000 they were planted in the outdoor plots which had been amended with .5 pounds of 4-12-12 per 100 square feet of soil. Plants were hand-watered until established and then supplied with one and one-half inches of water per week. Weed control was accomplished using Preen and hand-weeding, when needed.

Data will be collected for early performance, mid-summer performance, and late season performance; evaluation will be preformed by a panel of judges using a numerical rating scale.

Using the Missouri Gravel Bed to extend the planting season for bare root trees and shrubs

Christopher Starbuck

The Missouri Gravel Bed (MGB) is a system, developed at the MU Horticulture and Agroforestry Research Center (HARC), allowing trees and shrubs to be planted bare root twelve months of the year. Dormant, bare root plants are placed with their roots in a drip-irrigated bed of gravel in the spring. Slow release fertilizer raked into the gravel under the drip lines maintains a fairly consistent concentration of nutrients in the root zone. Research at HARC has shown that many species of trees and shrubs can be taken from the gravel and planted bare root, in full leaf throughout the summer with a survival rate comparable to those of container-grown or balled and burlapped (B&B) plants.

Based on work at HARC over the past 15 years, river rock with a particle size of 0.5 inch or less, containing approximately 10 percent sand (passing a #10 screen) works well for most plant species. This provides excellent drainage while providing some water holding capacity and lateral movement of drip irrigation. Using this type of gravel, drip lines with 1 gph emitters on 1 foot centers maintains uniform moisture throughout the bed. During June, July and August, four to six 5-minute irrigation cycles during the daylight hours are sufficient to keep most trees and shrubs from coming under undue water stress. After the foliage has hardened in late summer, the irrigation frequency can be reduced. Current research is evaluating the effectiveness of a re-circulating irrigation system.

There are a number of advantages inherent in planting bare root trees and shrubs. Since production and shipping costs are lower than for B&B and container stock, bare root plants are economical. Bare root plants can also be harvested with a larger root

system and, when they are planted, the roots are in direct contact with the backfill soil. There is no soil ball to dry out and, in the case of Missouri Gravel Bed plants, root tips begin taking up water from the surrounding soil immediately. Before MGB the major limitation to planting bare root trees and shrubs was the short planting season. Now it is possible to reap the benefits of bare root twelve months of the year.

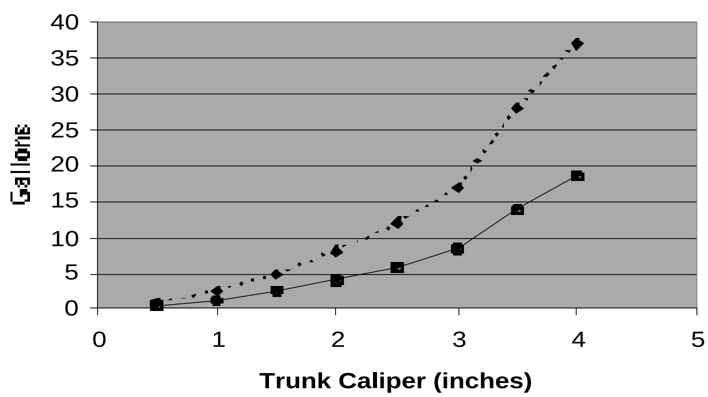
Maintenance of Newly Planted Trees to Increase Survival

A tree can not be considered "established" after planting until it can survive without irrigation for two weeks during a summer drought. Establishment requires extensive root growth from the original soil ball into the backfill soil. Often this does not occur for two seasons following planting. Until it is established, a tree may require special care to ensure survival.

The most common cause of mortality of newly planted trees is improper watering. Until significant root growth has occurred into the backfill, the tree is entirely dependent upon the roots present in the original soil ball to supply water to its transpiring leaves. With both container grown and balled and burlapped (B&B) trees, water does not move freely from the backfill into the soil ball. Therefore, the new tree must be watered frequently with small volumes of water to keep the soil ball moist. Over-watering can be just as fatal as under-watering. Since roots need oxygen to take up water, saturated soil during hot, windy conditions can be a deadly combination. When trees are planted in clay soil and watered with an automatic turf irrigation system, they often drown in their own individual bathtubs.

Some form of drip irrigation is most effective at keeping the root ball of a new tree moist without waterlogging. A very practical, temporary drip system is the "Gator Bag". This device, a reinforced plastic bag that zips around the tree trunk, drips a measured volume of water directly into the soil ball of a new tree over a period of hours. A leaky bucket or a sophisticated drip system can achieve the same end result. Regardless of the method used, it is better to water a new 2-inch-caliper tree with 5 gallons of water three times per week than with 15 gallons once per week. As roots grow into the backfill, the irrigation frequency can be decreased and the volume increased. Figure 1 shows the approximate number of gallons of water held by soil ball of trees with different trunk calipers, grown in clay loam soil. A new tree should be watered when half of the soil moisture reserve in the ball has been depleted. During hot, windy, low humidity weather, this may take only one or two days. Under more moderate conditions in mid-summer, irrigation every four or five days will generally keep new trees from suffering undue stress.

Figure 1.Approximate volume of water held by the soil balls of trees of various trunk calipers grown in clay loam soil ((diamonds) and the amount required to irrigate when half of the soil moisture is depleted ((circles).



In addition to proper watering, mulching can greatly improve the chances of transplanting success. A three- or four-inch layer of mulch promotes tree root growth by conserving moisture, moderating soil temperature and reducing competition with turf roots. However, an excessively thick layer of mulch can contribute to transplanting stress by shedding water or retaining too much water during rainy weather. Also, when mulch is too deep, tree roots grow into the mulch and are subsequently killed when drought conditions occur.

Companies and Organizations that contributed to the 1999-2000 Turfgrass Research Program

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Turf and Ornamental Faculty and Staff

Dr. Erik Ervin
Assistant Professor of Horticulture and Director of Turfgrass Research Center

Dr. John Dunn
Professor of Horticulture Turfgrass Teaching, Research and Extension

Mr. Brad Fresenburg
Turfgrass Research and Extension Associate

Dr. Barbara Corwin
Extension Assistant Professor Plant Pathology

Dr. Lewis Jett
Assistant Professor of Horticulture and Vegetables

Dr. Bruce Barrett
Associate Professor of Entomology

Dr. Patricia Donald
Research Assistant Professor Plant Pathology

Dr. Chris Starbuck
Associate Professor of Horticulture

Dr. David Trinklein
Associate Professor of Horticulture

Dr. Michele Warmund
Associate Professor of Horticulture

Mr. Changho Ok
Ph.D. Candidate, Turf

Mr. Chad Follis
M.S. Candidate, Turf

Ms. Kim Fresenburg
Field Technician

Mr. Michael Fresenburg
Field Technician

Mr. Casey Hairston
Field Technician

Amy Riesselman
Horticulture Student

Mr. Scott Dunn
Research Specialist, Horticulture

Mrs. Rita Gerke, Secretary of
Horticulture and Entomology

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