FERTILITY EFFECTS ON CREEPING BENTGRASS, PEST, WATER, AND ROOT RELATIONSHIPS

UNIVERSITY OF GEORGIA
Griffin, GA
1992 Research Grant: $5,940
(Final year of support)

Dr. Robert N. Carrow
Principal Investigator

Creeping bentgrass (Agrostis palustris Huds.) is the preferred species for golf greens in the upper South. However, the hot, humid environment of the Southeast results in substantial high temperature and disease stress on this cool-season species. Dr. Milt Engelke, Texas A&M, has an extensive bentgrass breeding program targeted to developing bentgrass cultivars that will exhibit improved adaptation to summer stresses. The objectives of this project were to compare three of Dr. Engelke's experimentals with two industry standards for a) root growth and water extraction patterns in the summer months, b) shoot growth, and c) disease and insect tolerances as pest stresses were observed. The five bentgrasses were: Penncross, Pennlinks, SYN-1-88, SYN-3-88 and SYN-4-88.

To define appropriate cultural regimes, two nitrogen fertility programs and two fungicide programs were included for each species. The annual fertility programs were 3.5 lb N and 7.0 lb N per 1000 ft^2; while the two fungicide programs were preventative and curative. The preventative program was based on use of a number of fungicides applied on a preventative (to prevent disease appearance) schedule. For the curative program substantial disease development was allowed before curative rates of a fungicide were applied. This allowed disease infection and recovery from disease to be monitored. Mowing height was 5/32 inch with clippings removed. The site was a 5 year old USGA specification golf green at Griffin, GA. Establishment of the bentgrasses was in September 1990.

Conclusions.

1. SYN-3 and SYN-4 exhibited significantly better visual quality and shoot density than Penncross, and these differences became greater over time. As the summer progressed, both cultivars maintained better shoot density and visual quality. Turf color of all cultivars were, in general, similar.

2. Relative to Penncross: SYN-1 was much more susceptible to brown patch; SYN-3 was very susceptible to dollar spot; all cultivars were more susceptible to the "Curvularia" yellow spot symptoms.

3. SYN-1 and SYN-4 often exhibited a greater ability to extract soil moisture than Penncross in the early to mid-summer period, which could lessen the effects of indirect high temperature stress over the summer.

4. Until 1992 root data are available, conclusions on rooting differences cannot be made.

5. SYN-4 was the only cultivar that did not exhibit a greater deterioration in quality/shoot density by late summer at high N versus low N. This indicates that SYN-4 could withstand higher N when needed without adversely affecting late summer performance.

6. Except for SYN-4, the annual N program of 7.0 lb N/1000 ft^2 was excessive, while 3.5 lb N/1000 ft^2 appeared to be a minimal acceptable rate.

Nov. 1992

Annual Progress Report

FERTILITY EFFECTS ON CREEPING BENTGRASS, PEST, WATER, AND ROOT RELATIONSHIPS

UNIVERSITY OF GEORGIA
Griffin, GA
1992 Research Grant: $5,940
(Final year of support)

Dr. Robert N. Carrow
Principal Investigator

Creeping bentgrass (Agrostis palustris Huds.) is the preferred species for golf greens in the upper South. However, the hot, humid environment of the Southeast results in substantial high temperature and disease stress on this cool-season species. Dr. Milt Engelke, Texas A&M, has an extensive bentgrass breeding program targeted to developing bentgrass cultivars that will exhibit improved adaptation to summer stresses. The objectives of this project were to compare three of Dr. Engelke's experimentals (Table 5) with two industry standards for a) root growth and water extraction patterns in the summer months, b) shoot growth, and c) disease and insect tolerances as pest stresses.

To define appropriate cultural regimes, two nitrogen fertility programs and two fungicide programs were included for each species. The annual fertility programs were 3.5 lb N and 7.0 lb N per 1000 ft^2; while the two fungicide programs were preventative and curative. The preventative program was based on use of a number of fungicides applied on a preventative (to prevent disease appearance) schedule. For the curative program substantial disease development was allowed before curative rates of a fungicide were applied. This allowed disease infection and recovery from disease to be monitored. Treatment schedules for fertility and fungicide programs are in Tables 1-2 and Tables 3-4, respectively.

Mowing height was 5/32 inch with clippings removed. The site was a 5-year old USGA specification golf green at Griffin, GA. Establishment of the bentgrasses was in September 1990. Ratings reported are visual quality, color, shoot density, clipping yield, verdure, brown patch incidence, and dollar spot incidence. Rating dates and scales are presented in the tables. The AUDPC rating for brown patch and Curvularia bears additional explanation. Plots were visually assessed for the severity of disease (% necrotic area per plot) by Dr. Lee Burpee over several weeds while the disease developed. Values were used to calculate an area under the disease progress curve (AUDPC) for each plot using the formula: **$\Sigma[(Y_i+Y_{i+1})\ (t_{i+1}-t_i)/2]$ for i=1,2,3,...,n-1, where y_i is the amount of disease and t_i the time at the ith rating.**

The analysis of variance (ANOVA) for each data set is included in the table with the data. The experimental design was a randomized complete block with treatments in a 5 (Cultivar) x 2(N-Programs) x 2(Fungicide Programs) factorial arrangement. Single degree of freedom contrasts were used to compare all cultivars versus Penncross as a standard. Since main effect interactions were rare, contrasts were normally made across N levels within a fungicide program. When important interactions did occur, the full data set is presented. Results are discussed below:

Visual Quality. Comparison of the grasses under the preventative fungicide program is the most related to current golf course situations. In 1991, SYN-3 and SYN-4 exhibited similar visual quality compared to Penncross in the June through August period but higher quality in the cooler months (Table 5). Visual quality of SYN-1 was similar to Penncross, but with lower quality in early August of 1991. On most ratings dates from 9 April through 6 October 1992, SYN-3 and SYN-4 performed significantly better than

Penncross under the preventative fungicide regime (Table 6). Pennlinks and SYN-1 demonstrated higher visual quality than Penncross in May and June, but not afterwards.

A comparison of the overall visual quality values of the 5 grasses between June to September 1991 and 1992 reveals that Penncross ratings tended to decline, while the SYN cultivars were more stable (Tables 5-6). Average visual quality ratings over this period were:

Cultivar	1991	1991	% change
Penncross	7.46	6.82	- 9.1
Pennlinks	7.34	7.02	- 4.4
SYN-1	7.12	7.03	- 1.3
SYN-3	7.44	7.53	+ 1.0
SYN-4	7.54	7.42	- 1.6

With the curative fungicide program, disease pressures were allowed to become severe before fungicide application. In 1991, Penncross often showed better quality than the three SYN grasses. Many of these differences were due to dollar spot infection of the SYN materials (Table 14).

As anticipated, the preventative fungicide program often resulted in higher quality ratings than the curative program, regardless of cultivar or N-program (Tables 5-6). Only when disease pressure was very low were no differences between fungicide programs apparent. The significant CxF interaction that occasionally occurred was a magnitude response (i.e., cultivars responding differently in magnitude or strength of a response) and not a trend response (where cultivars exhibit different trends with fungicide (Table 7). FxN interactions were also magnitude in mature (Table 7).

The CxN interactions of $P < 0.20$ all occurred in the July to September period and were trend responses (Table 7). Penncross and Pennlinks exhibited several instances within this period of higher visual quality at low N than at high N. In a previous study at this location using Penncross creeping bentgrass, we found increasing quality up to 6.0 lb N/1000 ft^2/yr but a decline in late summer quality at above 6.0 lb N. This would suggest that high N enhances the indirect high temperature stress these grasses are exposed to in the summer months. SYN-3 exhibited a similar CxN interaction in late summer of 1992, and SYN-1 a minor instance on 9 July 1992. SYN-4, however, did not show a CxN interaction which suggests a) SYN-4 has an inherently greater high N tolerance, and/or b) it has a greater indirect high temperature tolerance.

It should be noted that differences between low and high N on all cultivars were less prevalent and less in magnitude in the late July through September period (Tables 5-6). Thus, with continued high temperature stress, application of high N did not compensate, and as discussed in the previous paragraph, actually increased stress in some cases.

Shoot Density. Under both fungicide regimes, SYN-3 and SYN-4 tended to demonstrate better shoot density than Penncross over the duration of the study (Tables 8-9). SYN-1, however, had lower shoot density than Penncross in 1991 but similar in 1992, as did Pennlinks.

Shoot density was the best under the preventative fungicide program and high N program; however, by late summer, plots under low N had shoot densities similar to those at high N.

In July and August 1992, a significant CxN interaction for shoot density occurred, which would affect visual quality (previously discussed) (Table 10). Except for SYN-4, the cultivars were exhibiting the same or lower shoot density at high N compared to low N.

Turfgrass Color. Color differences were not great in magnitude among the cultivars (Tables 8-11). Considering both fungicide programs, out of 20 ratings SYN-3 had 5 better and 2 lower than Penncross, while SYN-4 had 4 better and 2 lower. SYN-3 showed 6 lower color ratings than Penncross and none better. Higher N resulted in better color, especially in cooler periods. Color differences by late summer between N-programs were minimal. In general, the preventative fungicide program resulted in somewhat better color; however, after a curative fungicide application in late August 1991 and early October 1992 the reverse trend was noted. Apparently, residual N not used by the grass under stress was available on curative plots once a fungicide was applied.

Growth. Periodic clipping yields were collected and late August verdure to access relative growth responses under the preventative fungicide program. While some cultivar differences occurred no consistent trend was apparent over time (Table 12). Verdure in late summer was similar for all cultivars.

Disease. Climatic conditions were conducive in both years for brown patch (Rhizoctonia solani) and in 1991 for dollar spot (Sclerotina homoecarpa). Concerning brown patch, disease severity was greatest under the curative fungicide program (Table 13). SYN-1 and Pennlinks were most susceptible to brown patch. The AUDPC data suggests that with a preventative fungicide program SYN-1 was less responsive to fungicides, while Penncross was most responsive - AUDPC value under a preventative program for SYN-1 was 74 to 78% of curative and for Penncross it was 23 to 30% of curative. Brown patch infection was not significantly influenced by N-programs.

Dollar spot infection was greatest on SYN-3, followed by SYN-4 (Table 14). The sensitivity of SYN-3 to dollar spot would require a rigorous preventative fungicide program for this disease. The preventative program reduced dollar spot infection and infection tended to be somewhat less severe at higher N.

Symptoms occurred in both years of yellow to yellow-green, round spots of 3 to 6-inch diameter. These areas did not enlarge nor did stand thinning occur. With advent of cooler weather, the symptoms faded. Dr. Lee Burpee was able to find very high levels of Curvularia associated with these areas within the study, as well as on local golf courses. Thus, this has been termed "Curvularia" awaiting further clarification of the problem. All cultivars exhibited these symptoms, but based on the AUDPC data of Dr. Burpee in 1992, Penncross appears to be least susceptible, while SYN-4 was most (Table 13). Since all cultivars exhibited higher AUDPC values than Penncross even under a preventative fungicide program, this suggests that this problem may increase as other bentgrasses are used in place of Penncross. Symptoms were reduced under the preventative program (indicating fungicide control may be possible) and with higher N.

Other Pests. Purple cudweed (Gnaphalium purpureum L.) occurred on the research area and the degree of invasion was rated in April 1992 (Table 15). While high N tended to reduce infestation, the preventative fungicide plots also had less cudweed either due to competition and/or a herbicidal action on the cudweed from one or more of the fungicides. SYN-1 had the highest quantity of cudweed of the bentgrasses.

Sod webworm counts in October 1992 are listed in Table 15. Webworms were higher in the preventative fungicide plots. All cultivars exhibited more sod webworms than Penncross.

Rooting. Under low N, few cultivar rooting differences were observed (Table 16). SYN-1 did have higher root length density (RLD) in the upper 10 cm soil profile in early July but not in late summer.

At high N, Penncross produced very high RLD's in the July sampling at the 3 to 10 cm zone, but no cultivar differences were apparent in this zone by late August. Such high RLD values in the surface 10 cm zone for Penncross have been noted by the author in other studies, but other bentgrass cultivars were not present. In fact, the reason for discarding the 0 to 3 cm root mass was due to this observation. This would suggest that Penncross may produce an excessive root mass within the surface few inches which could lead to interference with water infiltration/percolation - since such a dense root mass fills most of the surface pore space. Water extraction data obtained in July demonstrated no difference in water extraction from this zone among cultivars. Thus, such a high RLD did not improve water uptake.

Interestingly, in early July all SYN cultivars had lower RLD's than Penncross within the 10 to 20 cm root zone. However, by late summer, Penncross's RLD declined to 0.04 $cm \cdot cm^{-3}$, while SYN-3 increased from 0.07 to 0.27 $cm \cdot cm^{-3}$ and SYN-1 remained constant. All cultivars exhibited loss of RLD in the surface zone as the summer progressed. While SYN-4 RLD's did not decrease in the 10 to 20 cm zone as much as Penncross, a decrease was apparent. Thus, maintenance of deeper roots through the late summer period appears to be better for Pennlinks, SYN-3 and SYN-1 relative to Penncross.

Total root length over all depths is reported in Table 16. The higher RLD's in the surface 3 to 10 cm root zone tends to dominate this value. However, under the high N program, the decrease in Penncross rooting in both zones caused a dramatic shift in these values in the 12 July to 27 August period. SYN-1 and SYN-3 had higher total root length than Penncross under the High N regime. Root growth under high N was better over all grasses within the surface zone in July and for total root length in July. Roots were sampled in late June and early September in 1992. They are presently being washed and analyzed.

Water Extraction/Evapotranspiration. Water extraction data for 1991 are presented by soil depth for each day of a 2-day dry-down period (Tables 18-19). Totaling water extraction for both depths allows calculation of evapotranspiration (ET) for each day. In the cases of total ET and water extracted at a depth, greater water use/extraction would be viewed as beneficial on bentgrass grown on a high sand media. Data on day 1 of a dry-down would be representative of a turf manager irrigating every day, while day 2 would illustrate plant response if irrigation was omitted for two consecutive days. At low N, all SYN cultivars had higher water extraction from the upper 0 to 10 cm profile than Penncross on day 1 in July 1991 (Table 16). Also, ET on day 1 was higher for SYN-1 and SYN-3 compared to Penncross. In June 1992, all cultivars exhibited higher ET on day 1 than Penncross, but only SYN-4 had higher water extraction from a particular soil zone - i.e., SYN-4 showed greater water extraction from the 10 to 20 cm zone on day 1 (Table 20).

At high N in early to mid-summer, SYN-1 demonstrated greater 10 to 20 cm water extraction in July 1991 but no cultivar differences in ET on day 1 were noted (Table 18). In June 1992, SYN-1 again had better 10 to 20 cm water extraction and SYN-1 and SYN-4 demonstrated higher ET rates on day 1 than Penncross (Table 20). On this date, Pennlinks extracted only 0.30 mm water from the 10 to 20 cm zone, while ET was significantly less than Penncross.

On day 2 after irrigation and under the low N regime in July 1991, SYN-4 had lower 0 to 10 cm water extraction and SYN-3 lower 10 to 20 cm water extraction (Table 18). In terms of ET (day 2), the only cultivar difference was for a lower ET for SYN-3 versus Penncross. Only June 1992, rainfall prevented extending the dry-down a full 48 hours. However, over the first 32 hrs SYN-3 and SYN-4 had the highest 10 to 20 cm water extraction and all SYN cultivars exhibited higher ET than Penncross (Table 20).

Results on day 2 under high N revealed greater water extraction at 0 to 10 cm than Penncross for Pennlinks, SYN-1 and SYN-4; and better 10 to 20 cm water extraction for SYN-3 and SYN-4 (Table 18).

This resulted in higher ET (day 2) at high N for all SYN cultivars versus Penncross. In 1992, over the first 32 hrs at high N, Pennlinks and SYN-4 extracted more water at 0 to 10 cm and SYN-1 at 10 to 20 cm relative to Penncross (Table 20). Pennlinks exhibited less 10 to 20 cm water extraction. The overall effect on ET (32 hrs) was higher ET for SYN-1 and lower for SYN-3.

Thus, in terms of the ability of the SYN materials to obtain soil moisture relative to Penncross in the early to mid-summer period when rooting should be optimal:

a) Day 1 after irrigation at low N. In both years SYN-1 and SYN-3 had greater ET, while SYN-4 and Pennlinks exhibited higher ET in 1992 only.

b) Day 1 after irrigation at high N. Cultivar differences occurred only in 1992 where SYN-1 and SYN-4 had greater ET rates, but SYN-3 had lower than Penncross.

c) Day 2 after irrigation at low N. SYN-3 had lower ET than Penncross in 1991 but all SYN cultivars had higher ET in 1992 over the 32-hr period.

d) Day 2 after irrigation at high N. SYN-1 plots had higher ET than Penncross in both years, SYN-4 higher ET in one year, while SYN-3 had higher ET one year but low the second.

e) Overall. When viewed over both days and both N-programs, which would include 8 observations per cultivar: SYN-1 had 6 higher ET ratings than Penncross; SYN-4 had 4 higher ratings; SYN-3 exhibited 4 higher and 3 lower ET values.

The late August and early September water extraction data and ET values would reflect a period after considerable root deterioration would occur from indirect high temperature stress. On day 1 with low N, Pennlinks and SYN-1 had greater 10 to 20 cm water extraction in 1991, and the ET rate for Pennlinks was greater. In 1992, Pennlinks and SYN-1 exhibited higher water extraction from 0 to 10 cm but less extraction at 10 to 20 cm for Pennlinks and SYN-4. ET rates on day 1 were less than Penncross for Pennlinks, SYN-3 and SYN-4.

Day 1 at high N revealed better 0 to 10 cm water extraction versus Penncross for SYN-1 in both years and SYN-4 in 1991 only. In 1992 SYN-3 had greater deep water extraction. For ET rates SYN-4 was higher in 1991, while SYN-3 was in 1992.

On Day 2 under low N, Pennlinks exhibited less 0 to 10 cm water extraction than Penncross in 1991, while all SYN materials had higher extraction in 1992. At the 10 to 20 cm depth, SYN-1 and SYN-4 had lower extraction in 1992. The only differences in ET rates were lower ET for Pennlinks and higher for SYN-4 in 1991.

At high N on day 2, Pennlink plots had greater 10 to 20 cm extraction in 1991 but lower 0 to 10 cm extraction in 1992, while SYN-3 also had lower 0 to 10 cm extraction in 1992. Water uptake as revealed in ET showed higher ET than Penncross for Pennlinks and SYN-3 in 1991, while in 1992 SYN-3 and SYN-4 had lower ET.

Therefore, a summary of late summer water relations when root viability would be low is:

a) Fewer differences occurred among cultivars in terms of water extraction by depth and daily ET compared to the early to mid-summer period.

b) Over the 8 observation periods (i.e., days 1 and 2 at low and high N):SYN-3, SYN-4, and Pennlinks had 2 higher ET values and 2 lower than Penncross; SYN-1 did not differ from

Penncross. Thus, ET for late summer does not reveal an advantage over Penncross for any of the cultivars in terms of water relations. However, since SYN-1 and SYN-4 appeared to have an advantage in the early to mid-summer period, this would aid in reducing the severity of indirect high temperature stress.

Stimpmeter. Two stimpmeter readings were obtained in 1992 with ball roll up a 2% slope (Table 21). In general, most significantly different values were for less stimpmeter values.

Conclusions.

1. SYN-3 and SYN-4 exhibited significantly better visual quality and shoot density than Penncross, and these differences became greater over time. As the summer progressed, both cultivars maintained better density and quality. Turf color of all cultivars were, in general, similar.

2. Relative to Penncross: SYN-1 was much more susceptible to brown patch; SYN-3 was very susceptible to dollar spot; all cultivars were more susceptible to the "Curvularia" yellow spot symptoms.

3. SYN-1 and SYN-4 often exhibited a greater ability to extract soil moisture than Penncross in the early to mid-summer period, which could lessen the effects of indirect high temperature stress over the summer.

4. Until 1992 root data are available, conclusions on rooting differences cannot be made.

5. SYN-4 was the only cultivar that did not exhibit a greater deterioration in quality/shoot density in late summer at high N versus low N. This indicates that SYN-4 could withstand higher N when needed without adversely affecting late summer performance.

Table 1. Annual fertility programs (low, high) on five creeping bentgrasses in 1991.

Date	Low N		High N	
	lbs N/1000 ft^2	Carrier	lbs N/1000 ft^2	Carrier
Jan.	-		-	
Feb.	0.30	22-0-16	0.61	22-0-16
March	0.12	22-0-16	0.50	22-0-16
March	0.33	12-24-14	0.33	12-24-14
April	0.30	22-0-16	0.60	22-0-16
May	0.30	12-24-14	0.60	12-24-14
June	0.25	6-2-0	0.50	6-2-0
July	0.25	22-0-16	0.50	22-0-16
Aug.	0.25	22-0-16	0.50	22-0-16
Sept.	0.25	22-0-16	0.50	22-0-16
Oct.	0.40	12-24-14	0.80	12-24-14
Nov.	0.40	12-24-14	0.80	22-0-16
Dec.	0.40	22-0-16	0.80	22-0-16
Total N =	3.51		7.04	
P_2O_5 =	2.28		3.63	
K_2O -	2.64		5.32	

Table 2. Annual fertility programs (low, high) on five creeping bentgrasses in 1992.

Date	Low N		High N	
	lbs N/1000 ft^2	Carrier	lbs N/1000 ft^2	Carrier
Jan.	0.25	31-3-10	0.50	31-3-10
Feb.	0.33	20-0-15	0.66	20-0-15
March	0.33	12-24-14	0.66	12-24-14
April	0.33	12-24-14	0.66	29-0-0
May	0.33	22-0-16	0.66	22-0-16
June	0.33	6-2-0	0.66	6-2-0
July	0.25	22-0-16	0.50	22-0-16
Aug.	0.25	22-0-16	0.50	22-0-16
Sept.	0.25	18-4-10	0.50	18-4-10
Oct.	0.33	22-0-16	0.66	29-0-0
Nov.	0.33	22-0-16	0.66	22-0-16
Dec.	0.33	22-0-16	0.66	22-0-16
Total N =	3.64		7.28	
P_2O_5 =	1.51		1.70	
K_2O -	1.56		3.88	

Table 3. Fungicide programs for five creeping bentgrasses in 1991.

Date of Application	Preventative Treatment		Curative Treatment	
	Fung.	oz/1000 ft^2	Fung.	oz/1000 ft^2
May 7[a]	Chip 26019	2[b]	-	
May 21	Banner	4	Banner	4
	Aliette 80W	8	Aliette 80WP	8
June 3	Chipco 26019	2	-	
	Subdue 2EC	2	-	
June 17	Rubigan 1EC	1.5	-	
	Banol 6S	3	-	
July 3	Subdue 2EC	2	-	
	Chipco 26019	2	-	
July 15	Rubigan 1EC	1.5	-	
	Aliette 80W	8	-	
July 29	Chipco 26019	2	-	
	Pace	6.4	-	
Aug 8	Aliette 80WP	8	Aliette 80WP	8
	Chipco 26019	2	Chipco 26019	2
Aug 13	Tersan 1991	2	Tersan 1991	2
	Pace	6.4	Pace	6.4
Aug 26	Subdue 2EC	2	-	
	Rubigan 1EC	1.5	-	
Sept. 10	Chipco 26019	2	-	
	Pace	6.4	-	
Sept. 20	-		Chipco 26019	2
	-		Subdue 2EC	2
Sept. 26	Subdue 2EC	2	-	
	Rubigan 1EC	1.5	-	
Oct. 8	Chipco 26019	2	-	
Oct. 22	Bayleton 25WP	2	-	
Dec. 6	Bayleton 25W	2	-	-

[a]Prior to May 7, a preventative program was applied on all plots.

[b]All fungicides applied at 1.0 gal/1000 ft^2 until 1 July and then increased to 1.9 gal water/ 1000 ft^2.

Table 4. Fungicide programs for five creeping bentgrasses in 1992.

Date of Application	Preventative Treatment		Curative Treatment	
	Fung.	oz/1000 ft^2	Fung.	oz/1000 ft^2
Feb. 5[a]	Bayleton 25WP	2	Bayleton 25WP	2
Feb. 28	Bayleton 25WP	2	Bayleton 25WP	2
Apr. 9	Bayleton 25WP	2	-	
Apr. 28	Banner	4	Banner	4
	Banol 6S	3	-	
May 13	Subdue 2EC	1.5	-	
	Rubigan 1EC	1.5	-	
May 27	Bayleton 25WP	1	-	
	Banol 6S	2	-	
June 10	Chipco 26019	1.5	-	
	Aliette 80WP	4	-	
June 23	Rubigan 1EC	1.5	Rubigan 1EC	1.5
July 8	Banner	4	-	
	Subdue 2EC	2	-	
July 22	Banol 6S	3.0	-	
	Rubigan 1EC	1	-	
July 30	Chipco 36019	2	Chipco 26019	2
Aug 14	Banol 6S	3	-	
	Formec 80WP	3	-	
Aug 18	Subdue 2EC	2	-	
	Chipco 26019	2	-	
Aug 31	Formec 80WP	3	Formec 80WP	3
Sept. 11	Daconil 2787	6	Daconil 2787	6
Oct. 1	Bayleton 25W	2		

[a]All fungicides applied at 1.9 gal/1000 ft^2.

Table 5. Turfgrass visual quality main treatment effects in 1991.

Contrast or Main Effect	Turf Quality 16 May	7 Jun	15 Jul	9 Aug	29 Aug	17 Sep	24 Oct
	----------9 = ideal density, color, uniformity; 1 = no live turf----------						
Contrast at Cur. Fung.‡							
Penncross versus	6.9	7.3	6.0	5.6	7.5	6.6	7.4
Pennlinks	7.1	7.3	6.0	5.2	7.3	6.0*	6.9**
SYN-1-88	6.7	6.7*	6.7	4.6**	7.0†	5.8**	6.9**
SYN-3-88	7.4**	5.9**	4.5**	4.6**	7.5	6.4	7.5
SYN-4-88	7.2*	6.7*	4.8**	4.9*	7.6	6.6	7.2
Contrast at Prev. Fung.‡							
Penncross versus	7.2	7.2	7.5	7.6	7.4	7.6	7.5
Pennlinks	7.4	7.2	7.1	7.4	7.4	7.6	7.4
SYN-1-88	7.0	6.8	7.1	7.0†	7.2	7.5	7.4
SYN-3-88	7.6**	6.8	7.3	7.6	7.5	8.0†	7.8†
SYN-4-88	7.6**	7.2	7.1	7.9	7.5	8.0†	7.8†
Fungicide							
Curative	7.1	6.8	5.5	5.0	7.4	6.3	7.2
Preventative	7.4**	7.0*	7.2**	7.5**	7.4	7.8**	7.6**
Annual N							
171 kg ha^{-1}	7.2	6.8	6.2	6.2	7.3	7.0	7.0
342 kg ha^{-1}	7.3	7.0*	6.5*	6.3	7.5	7.1	7.8**
CV(%)	4	8	11	9	6	7	5
ANOVA							
Cultivar (C)	**	**	**	**	†	**	**
Fungicide (F)	**	*	**	**	.90	**	**
Nitrogen (N)	.19	*	*	.47	.63	.75	**
C x F	.98	.16	*	†	.99	.43	.36
C x N	.98	.79	.96	.20	.55	.91	.94
F x N	.25	.81	.43	.41	.63	.31	.78

†,*, ** Significant at the 0.10, 0.05, 0.01 probability levels, respectively.

‡ Contrasts are across N levels. Cultivars significantly different from Penncross within a column are denoted by †, *, ** for 0.10, 0.05, and 0.01 probability levels, respectively.

Table 6. Turfgrass visual quality main treatment effects in 1992.

Contrast or Main effect	Turf Quality 9 Apr	29 Apr	25 May	16 Jun	26 Jun	9 Jul	31 Jul	24 Aug	3 Sep	6 Oct
	9 = ideal density, color, uniformity; 1 = no live turf									
Contrast at Cur. Fung.‡										
Penncross versus	7.3	8.2	7.0	7.2	7.1	6.8	6.0	6.1	6.6	7.3
Pennlinks	6.9*	7.2	7.0	7.0	7.1	6.8	6.3	6.2	6.4	7.5
SYN-1-88	7.3	6.7†	6.8	6.7*	6.9	6.9	6.1	6.7†	6.8	7.5
SYN-3-88	7.5*	6.6†	7.3†	7.5	7.7**	7.5**	6.5	6.4	6.6	6.5*
SYN-4-88	7.4	7.3	7.3†	7.1	7.5*	7.3**	5.8	6.8*	6.9	7.6
Contrast at Prev. Fung.‡										
Penncross versus	7.6	7.4	7.0	7.3	7.0	6.9	6.8	6.7	6.2	7.1
Pennlinks	7.7	8.0†	7.4†	7.8*	7.5*	7.0	6.9	6.8	6.3	7.3
SYN-1-88	7.6	7.6	7.5*	7.6†	7.5*	6.9	6.7	6.9	6.6	7.3
SYN-3-88	7.9**	7.9	8.0**	8.0**	8.0**	7.6**	7.4†	7.2†	7.0*	7.4
SYN-4-88	7.8*	7.9	7.5*	7.8**	7.7**	7.7**	7.2	7.2†	6.9*	7.4
Fungicide										
Curative	7.3	7.0	7.1	7.1	7.2	7.0	6.2	6.5	6.7	7.3
Preventative	7.7**	7.8**	7.5**	7.7**	7.6**	7.3**	7.0**	7.0**	6.6	7.3
Annual N										
171 kg ha^{-1}	7.1	7.0	6.7	7.1	7.1	7.0	6.6	6.6	6.6	7.3
342 kg ha^{-1}	7.9**	7.8**	7.9**	7.8**	7.7**	7.3**	6.6	6.9*	6.6	7.3
CV(%)	2	8	5	6	5	4	10	8	8	8
ANOVA										
Cultivar (C)	**	.15	**	*	**	**	.24	†	*	.24
Fungicide (F)	**	**	**	**	**	**	**	**	.67	.74
Nitrogen (N)	**	**	**	**	**	**	.90	*	.92	.87
C x F	.48	.25	†	†	.28	.56	.62	.78	.61	†
C x N	.50	.88	.79	.89	.64	.21	.43	*	†	.96
F x N	.66	.42	†	†	*	†	.41	.70	.96	.61

†, *, ** Significant at the 0.10, 0.05, 0.01 probability levels, respectively.

‡ Contrasts are across N levels. Cultivars significantly different from Penncross within a column are denoted by †, *, ** for 0.10, 0.05, and 0.01 probability levels, respectively.

Table 7. Data for turfgrass visual quality on dates where significant treatment interactions occurred in 1991 and 1992.

			Turf Quality								
			1991		1992						
Cultivar	Fung.	Annual Fertility	15 Jul	29 Aug	25 May	16 Jun	26 Jun	9 Jul	24 Aug	3 Sep	6 Oct
		kg ha^{-1}	9 = ideal density, color, uniformity; 1 = no live turf								
Penncross	Cur.	171	5.7	5.9	6.2	6.8	6.5	6.4	6.3	6.7	7.3
Penncross	Cur.	342	6.2	5.4	7.7	7.6	7.6	7.1	6.0	6.5	7.2
Penncross	Pre.	171	7.2	7.5	6.3	6.9	6.7	6.7	6.9	6.4	7.2
Penncross	Pre.	342	7.7	7.6	7.7	7.6	7.4	7.1	6.5	6.1	7.1
Pennlinks	Cur.	171	6.1	5.5	6.4	6.4	6.6	6.6	6.2	6.6	7.5
Pennlinks	Cur.	342	5.9	4.9	7.7	7.6	7.5	6.9	6.2	6.1	7.5
Pennlinks	Pre.	171	6.7	7.3	7.0	7.7	7.4	7.0	6.7	6.6	7.4
Pennlinks	Pre.	342	7.5	7.6	7.8	7.9	7.7	7.0	6.9	6.1	7.3
SYN-1-88	Cur.	171	6.1	4.2	6.0	6.3	6.3	6.5	6.4	6.5	7.4
SYN-1-88	Cur.	342	6.3	5.1	7.5	7.2	7.5	7.3	6.9	7.0	7.6
SYN-1-88	Pre.	171	6.8	6.7	7.1	7.4	7.4	7.0	6.7	6.5	7.3
SYN-1-88	Pre.	342	7.5	7.4	8.0	7.9	7.6	6.9	7.1	6.7	7.3
SYN-3-88	Cur.	171	4.5	4.6	6.6	7.3	7.4	7.5	6.5	6.8	6.3
SYN-3-88	Cur.	342	4.7	4.7	8.0	7.8	8.0	7.5	6.3	6.4	6.8
SYN-3-88	Pre.	171	7.2	7.3	7.5	7.8	7.8	7.7	6.9	6.9	7.4
SYN-3-88	Pre.	342	7.4	7.6	8.5	8.2	8.2	7.6	7.4	7.0	7.4
SYN-4-88	Cur.	171	4.6	4.8	6.7	6.7	7.2	7.1	6.3	6.6	7.6
SYN-4-88	Cur.	342	4.9	5.0	7.9	7.6	7.8	7.5	7.4	7.3	7.5
SYN-4-88	Pre.	171	7.0	7.7	6.7	7.4	7.4	7.5	6.7	6.6	7.4
SYN-4-88	Pre.	342	7.2	8.0	8.2	8.2	8.0	8.0	7.7	7.2	7.3
CV (%)			11	9	5	6	5	4	8	8	8
ANOVA											
Cultivar			**	**	**	*	**	**	†	*	.24
Fung.			**	**	**	**	**	**	**	.67	.74
Nitrogen (N)			*	.47	**	**	**	**	*	.92	.87
Cult. x Fung.			*	†	†	†	.28	.56	.78	.61	†
Cult x N			.96	.20	.79	.89	.64	.21	*	†	.96
Fung. x N			.43	.41	†	†	*	†	.70	.96	.61

**, *, † Significantly different F-test at 1, 5, and 10% levels, respectively.

Table 8. Turfgrass shoot density and color main treatment effect responses in 1991.

Contrast or Main Effect	Shoot Density[§] 29 Aug	17 Sep	24 Oct	Turf Color 16 May	9 Aug	29 Aug	24 Oct
				---------9 = dark green; 1 = no green---			
Contrast at Cur. Fung.[‡]							
Penncross versus	7.9	7.7	7.6	6.5	7.7	8.2	7.8
Pennlinks	7.8	7.4*	7.4*	7.2[†]	7.6	8.1*	7.5*
SYN-1-88	7.7[†]	7.2**	7.3*	6.8	7.3**	8.0**	7.4**
SYN-3-88	8.0	7.6	7.8	7.3*	7.6	8.1[†]	7.6[†]
SYN-4-88	8.2*	7.8	7.5	7.4*	7.5*	8.2	7.5*
Contrast at Prev. Fung.[‡]							
Penncross versus	7.8	7.9	7.8	7.4	7.5	7.9	7.9
Pennlinks	7.8	7.8	7.7	7.2	7.6	7.8	7.5**
SYN-1-88	7.8	7.7	7.7	6.7[†]	7.5	7.7*	7.5**
SYN-3-88	8.0*	8.3**	8.0*	7.3	7.8**	7.9	7.8
SYN-4-88	8.2**	8.3**	7.9	7.5	7.8**	7.8[†]	7.8
Fungicide							
Curative	7.9	7.5	7.5	7.0	7.5	8.2	7.6
Preventative	7.9	8.0**	7.8**	7.2	7.7*	7.9**	7.7**
Annual N							
171 kg ha^{-1}	7.8	7.7	7.5	7.0	7.6	7.9	7.4
342 kg ha^{-1}	8.0*	7.8	7.9**	7.2	7.6	8.0**	7.9**
CV(%)	3	3	3	9	3	2	3
ANOVA							
Cultivar (C)	**	**	**	†	*	**	**
Fungicide (F)	.76	**	**	.23	*	**	**
Nitrogen (N)	*	.14	**	.19	.21	**	**
C x F	.83	.17	.69	.34	*	.95	.78
C x N	.37	.74	.88	.32	.38	.68	.94
F x N	.31	.31	.74	.30	.67	.92	.56

†, *, ** Significant at the 0.10, 0.05, 0.01 probability levels, respectively.

‡ Contrasts are across N levels. Cultivars significantly different from Penncross within a column are denoted by †, *, ** for 0.10, 0.05, and 0.01 probability levels, respectively.

§ Shoot Density: 9 = ideal, 1 = no live turf.

Table 9. Turfgrass shoot density main treatment effect responses in 1992.

Contrast or Main Effect	Shoot density 9 Apr	29 Apr	25 May	16 Jun	26 Jun	9 Jul	31 Jul	24 Aug	6 Oct
	9 = ideal, 1 = no live turf								
Contrast at Cur. Fung.‡									
Penncross versus	8.0	8.0	7.7	7.6	7.3	7.2	7.0	7.3	7.7
Pennlinks	7.9	8.1	7.8	7.5	7.5	7.2	7.0	7.3	7.9†
SYN-1-88	7.9	7.9	7.7	7.4	7.3	7.3	7.2	7.5	7.8
SYN-3-88	8.0	8.3*	8.1**	7.9†	7.9**	7.8**	7.3†	7.7**	8.2**
SYN-4-88	8.0	8.4*	8.0*	7.6	7.6**	7.7**	7.0	7.7**	8.3**
Contrast at Prev. Fung.‡									
Pencross versus	8.2	8.2	7.8	7.5	7.3	7.3	7.4	7.5	7.6
Pennlinks	8.3	8.4*	7.8	8.0**	7.6*	7.5	7.3	7.4	7.4
SYN-1-88	8.2	8.2	7.8	7.8*	7.6*	7.3	7.4	7.6	7.6
SYN-3-88	8.4*	8.5*	8.2**	8.2**	8.0**	7.8**	7.7†	7.8**	7.9*
SYN-4-88	8.4*	8.5*	8.1**	7.9**	7.9**	8.0**	7.6	7.8**	7.8
Fungicide									
Curative	8.0	8.1	7.9	7.6	7.5	7.5	7.1	7.5	8.0
Preventative	8.3**	8.4**	8.0*	7.9**	7.7**	7.6*	7.5**	7.6*	7.8**
Annual N									
171 kg ha^{-1}	7.8	7.9	7.6	7.5	7.4	7.4	7.3	7.5	7.8
342 kg ha^{-1}	8.4**	8.6**	8.2**	8.0**	7.8**	7.6**	7.3	7.6	7.9
CV (%)	2	2	3	4	3	3	4	2	3
ANOVA									
Cultivar (C)	.13	**	**	**	**	**	*	**	**
Fungicide (F)	**	**	*	**	**	*	**	*	**
Nitrogen (N)	**	**	**	**	**	**	.69	.40	.46
C x F	.34	.36	.93	.14	.45	.45	.49	.97	.35
C x N	.34	.62	.28	.74	.38	†	.23	*	.71
F x N	.41	.37	.20	.71	.17	*	.76	.89	.64

†, *, ** Significant at the 0.10, 0.05, 0.01 probability levels, respectively.
‡ Contrasts are across N levels. Cultivars significantly different from Penncross within a column are denoted by †, *, ** for 0.10, 0.05, and 0.01 probability levels, respectively.

Table 10. Turfgrass shoot density on dates where significant treatment interactions occurred in 1992.

Treatment			Shoot Density 1992	
Cultivar	Fung.	Annual Fertility	9 July	24 August
		kg ha^{-1}		
Penncross	Cur.	171	7.0	7.4
Penncross	Cur.	342	7.4	7.3
Penncross	Pre.	171	7.2	7.6
Penncross	Pre.	342	7.5	7.4
Pennlinks	Cur.	171	7.1	7.3
Pennlinks	Cur.	342	7.4	7.3
Pennlinks	Pre.	171	7.5	7.5
Pennlinks	Pre.	342	7.5	7.4
SYN-1-88	Cur.	171	7.1	7.4
SYN-1-88	Cur.	342	7.6	7.5
SYN-1-88	Pre.	171	7.5	7.6
SYN-1-88	Pre.	342	7.2	7.6
SYN-3-88	Cur.	171	7.8	7.7
SYN-3-88	Cur.	342	7.3	7.7
SYN-3-88	Pre.	171	7.9	7.8
SYN-3-88	Pre.	342	7.8	7.8
SYN-4-88	Cur.	171	7.6	7.5
SYN-4-88	Cur.	342	7.9	7.8
SYN-4-88	Pre.	171	7.8	7.6
SYN-4-88	Pre.	342	8.2	8.0
CV (%)			3	2
ANOVA				
Cultivar			**	**
Fung.			*	*
Nitrigen (N)			**	.40
Cult. x Fung.			.45	.97
Cult. x N			†	*
Fung. x N			*	.89

**, *, † Significantly different F-test at 1, 5, and 10% levels, respectively.

Table 11. Turfgrass color main treatment effect responses in 1992.

Contrast or Main Effect	Turf Color 9 Apr	25 May	31 Jul	24 Aug	3 Sep	6 Oct
	9 = dark green; 1 = no green					
Contrast at Cur. Fung.‡						
Penncross versus	7.7	7.7	7.4	7.5	7.4	7.5
Pennlinks	7.7	7.5	7.4	7.3	7.4	7.5
SYN-1-88	7.6	7.5	7.4	7.4	7.4	7.5
SYN-3-88	7.8	7.9*	7.5	7.4	7.4	7.6
SYN-4-88	7.9*	7.6	7.2	7.5	7.4	7.5
Contrast at Prev. Fung.‡						
Penncross versus	7.8	7.6	7.7	7.7	7.3	7.5
Pennlinks	8.0*	7.7	7.6	7.5	7.4	7.5
SYN-1-88	7.8	7.7	7.6	7.5	7.3	7.4
SYN-3-88	8.0*	7.9*	7.7	7.5	7.4	7.5
SYN-4-88	8.1*	7.8	7.6	7.6	7.4	7.5
Fungicide						
Curative	7.8	7.6	7.4	7.4	7.4	7.54
Preventative	7.9**	7.7†	7.6**	7.6**	7.3	7.47**
Annual N						
171 kg ha^{-1}	7.4	7.4	7.5	7.5	7.4	7.47
342 kg ha^{-1}	8.3**	8.0**	7.5	7.5	7.4	7.54**
CV(%)	2	3	2	2	1	1
ANOVA						
Cultivar (C)	**	**	*	**	.31	.39
Fungicide (F)	**	†	**	**	.19	**
Nitrogen (N)	**	**	.17	.15	.99	**
C x F	.72	.395	†	.68	.67	.45
C x N	.75	.80	.97	.75	.74	.96
F x N	.23	*	**	.99	.19	.27

†, *, ** Significant at the 0.10, 0.05, 0.01 probability levels, respectively.
‡ Contrasts are across N levels. Cultivars significantly different from Penncross within a column are denoted by †, *, ** for 0.10, 0.05, and 0.01 probability levels, respectively.

Table 12. Relative clipping yield and verdure data in 1991 and 1992.

Contrast or Main Effect	Relative Clipping Yield[§] 1991 5 Jun	15 Jul	21 Aug	24 Sep	1992 1 Jun	24 Jul	19 Aug	Verdure 1991 29 Aug	1992 26 Aug
	% control							g m^{-2}	
Contrast at Low N[‡]									
Penncross versus	100	100	100	100	100	100	100	37.2	37.4
Pennlinks	110	135†	75*	87	104	89	89	30.3	34.9
SYN-1-88	124	43†*	72*	111	127†	109	97	36.7	33.0
SYN-3-88	123	132†	92	122	91	97	93	32.5	42.6
SYN-4-88	117	73	71*	102	78	103	79*	32.9	38.1
Contrast at High N[‡]									
Pencross versus	163	53	93	115	170	119	93	40.0	37.2
Pennlinks	147	59	89	114	173	93*	100	39.5	38.9
SYN-1-88	189	65	106	126	200†	108	89	35.6	32.1
SYN-3-88	159	60	89	147*	155	110	79†	39.2	39.9
SYN-4-88	103	84	81	115	185	105†	86	28.7	42.6
Annual N									
171 kg ha^{-1}	115	97	82	104	100	100	92	33.9	37.2
342 kg ha^{-1}	152	64*	92	123†	177**	107	89	36.6	38.1
CV (%)	63	46	22	24	22	14	17	21	25
ANOVA									
Cultivar (C)	.90	.30	.43	.29	.27	.26	.46	.51	.56
Nitrogen (N)	.23	*	.20	†	**	.20	.70	.35	.79
C x N	.92	†	.39	.98	.77	.79	.58	.55	.96

†, *, ** Significant at the 0.10, 0.05, 0.01 probability levels, respectively.

‡ Contrasts are in the Preventative Fungicide program. Cultivars significantly different from Penncross within a column are denoted by †, *, ** for 0.10, 0.05, and 0.01 probability levels, respectively.

§ Relative to Penncross at the low N rate.

Table 13. Brown patch and Curvularia infection in 1991 and 1992.

Contrast or Main Effect	Brown Patch Infection 1991 15 Jul	1991 9 Aug	1991 17 Sep	1992 16 Jun	Brown Patch AUDPC§ 1991	Brown Patch AUDPC§ 1992	Curvularia 1991 15 Jul	Curvularia AUDPC§ 1992
	% plot				% plot		% plot	
Contrast at Cur. Fung.‡								
Penncross versus	17.6	22.7	32.5	22.5	734	499	17.3	51
Pennlinks	16.7	44.2**	56.5*	35.0	409**	459	21.5	340**
SYN-1-88	9.7*	51.7**	71.7**	40.0†	423**	473	14.6	411**
SYN-3-88	9.3*	27.5	36.7	30.0	482*	377	14.7	238*
SYN-4-88	15.3	30.3	36.7	35.0	622	557	17.5	429**
Contrast at Prev. Fung.‡								
Pencross versus	4.2	1.5	0.8	0	220	114	6.1	7
Pennlinks	7.0	7.7	4.7	0	187	179	7.8	94
SYN-1-88	3.5	20.5*	7.0	4.5	332	350*	5.0	94
SYN-3-88	3.2	4.7	1.7	0	151	145	9.2	127
SYN-4-88	6.4	1.7	0	0	225	224	7.8	140†
Fungicide								
Curative	13.7	35.2	46.8	32.5	535	474	17.1	294
Preventative	4.8**	7.2**	2.8**	0.9**	224**	202*	7.1**	80*
Annual N								
171 kg ha^{-1}	8.6	22.3	24.4	18.9	395	313	12.5	223
342 kg ha^{-1}	9.9	20.1	25.1	14.5	362	363	11.7	152†
CV (%)	77	66	71	99	57	68	70	84
ANOVA								
Cultivar (C)	.18	**	**	.59	.24	.49	.77	**
Fungicide (F)	**	**	**	**	**	**	**	**
Nitrogen (N)	.48	.53	.87	.31	.56	.41	.73	†
CxF	.70	.66	.13	.85	.17	.68	.80	.24
CxN	.23	.29	.69	.99	.96	.98	.78	.32
FxN	.87	.97	.70	.22	.92	.88	.98	.76

†, *, ** Significant at the 0.10, 0.05, 0.01 probability levels, respectively.

‡ Contrasts are across N levels. Cultivars significantly different from Penncross within a column are denoted by †, *, ** for 0.10, 0.05, and 0.01 probability levels, respectively.

§ AUDPC = area under the disease progress curve. Higher values reflect a more rapid rate of infection by the disease.

Table 14. Dollar spot ratings in 1991 and 1992.

Contrast or Main Effect	Dollar spot				
	1991			1992	
	16 May	7 Jun	15 Jul	29 Apr	6 Oct
	% plot				
Contrast at Cur. Fung.‡					
Penncross versus	0.3	0.5	3.9	0.3	0
Pennlinks	0.2	0.5	2.2	0	0
SYN-1-88	1.8	1.9	5.5	0	0.2
SYN-3-88	6.5**	7.8**	23.9**	5.2	5.2
SYN-4-88	1.8	2.4	13.9**	0.5	0.7
Contrast at Prev. Fung.‡					
Pencross versus	0.1	0.2	0	0	0.2
Pennlinks	0	0.2	0	0	0
SYN-1-88	0	1.7	0.5	0	0
SYN-3-88	0.7	2.9*	0.5	0	0.2
SYN-4-88	0	0.3	0.2	0	0
Fungicide					
Curative	4.3	2.7	9.8	1.2	1.2
Preventative	0.3**	1.0**	0.2**	0*	0.1*
Annual N					
171 kg ha^{-1}	2.5	2.1	5.3	0.6	0.6
342 kg ha^{-1}	2.1	1.6	4.8	0.6	0.7
CV (%)	164	117	111	99	98
ANOVA					
Cultivar (C)	**	**	**	*	*
Fungicide (F)	**	**	**	*	*
Nitrogen (N)	.65	.41	.75	.91	.92
CxF	**	*	**	*	*
CxN	.68	.33	.99	.99	.99
FxN	.81	.99	.65	.91	.93

†, *, ** Significant at the 0.10, 0.05, 0.01 probability levels, respectively.
‡ Contrasts are across N levels. Cultivars significantly different from Penncross within a column are denoted by †, *, ** for 0.10, 0.05, and 0.01 probability levels, respectively.

Table 15. Weed and insect data on bentgrasses in 1992.

Contrast or Main Effect	Cudweed 29 Apr	Sod webworm Counts 10 Oct
	-% plot-	-------m^2------
Contrast at Cur. Fung.‡		
Penncross versus	2.5	0.17
Pennlinks	2.8	0.33
SYN-1-88	5.0**	0.33
SYN-3-88	1.8	0.67
SYN-4-88	3.2	0.67
Contrast at Prev. Fung.‡		
Penncross versus	0.8	0.67
Pennlinks	0.5	3.17**
SYN-1-88	1.2	3.15**
SYN-3-88	0.3	2.50*
SYN-4-88	0.7	1.50*
Fungicide		
Curative	3.1	.43
Preventative	0.7**	2.43**
Annual N		
171 kg ha^{-1}	2.5	1.57
342 kg ha^{-1}	1.2**	1.30
CV (%)	80	91
ANOVA		
Cultivar (C)	*	†
Fungicide (F)	**	**
Nitrogen (N)	**	.43
CxF	.36	.19
CxN	.58	*
FxN	†	.84

†, *,**Significant at the 0.10, 0.05, 0.01 probability levels, respectively.

‡Contrasts are across N levels. Cultivars significantly different from Penncross within a column are denoted by †, *, ** for 0.10, 0.05, and 0.01 probability levels, respectively.

Table 16. Influence of fungicide and N-Program treatments on rooting of five bentgrass cultivars in 1991.

Contrast or Main Effect	Root Length Density 12 Jul 3 to 10 cm	Root Length Density 12 Jul 10 to 20 cm	Root Length Density 27 Aug 3 to 10 cm	Root Length Density 27 Aug 10 to 20 cm	Total Root Length 3 to 20 cm 12 Jul	Total Root Length 3 to 20 cm 27 Aug	Percent change in total root length 12 Jul to 27 Aug
	cm • cm^{-3}				cm • cm^{-2}		%
Contrast at Low N‡							
Penncross versus	.99	.11	.82 (-17)§	.03 (-73)§	8.04	6.06	- 25
Pennlinks	.63	.12	1.15 (+83)	.12 (0)	5.54	9.26*	+ 67
SYN-1-88	1.99*	.16	.59 (-70)	.06 (-63)	15.61*	4.69	- 70
SYN-3-88	.90	.14	.69 (-23)	.09 (-36)	7.65	5.76	- 25
SYN-4-88	1.64	.13	.50 (-70)	.03 (-77)	11.51	3.79*	- 67
Contrast at High N‡							
Penncross versus	4.58	.21	.58 (-87)	.04 (-81)	34.25	4.50	- 87
Pennlinks	1.30*	.17	.58 (-55)	.15* (-12)	10.81*	5.52	- 49
SYN-1-88	1.08*	.07*	.98 (-9)	.07 (0)	8.28*	7.54*	- 9
SYN-3-88	2.56*	.07*	.67 (-71)	.27* (+286)	18.67*	7.37*	- 61
SYN-4-88	1.32*	.10*	.36 (-73)	.06 (-40)	10.28*	3.14	- 69
Annual N							
171 kg ha^{-1}	1.23	.13	.75 (-39)	.07 (-46)	9.67	5.90	- 39
342 kg ha^{-1}	2.17**	.13	.64 (-71)	.12 (- 7)	16.46*	5.61	- 66
CV (%)	34	65	75	106	79	87	
ANOVA							
Cultivar	**	.76	.68	†	*	.39	
Nitrogen	**	.83	.55	.16	*	.82	
CxN	**	.27	.61	.52	**	.53	

†, *,**Significant at the 0.10, 0.05, and 0.01 probability levels, respectively.

‡Contrasts are in the Preventative Fungicide program. Cultivars significantly different from Penncross within a column are denoted by †,*,** for 0.10, 0.05, and 0.01 probability levels, respectively.

§Percent change from the 12 July RLD values.

Table 18. Root water extraction by soil depth and ET in July 1991.

Contrast or Main Effect	Root Water Extraction by Soil Depth (8:00 am to 8:00 am)						Evapotranspiration		
	22 to 23 Jul		23 to 24 Jul		22 to 24 Jul				
	0 to 10 cm	10 to 20 cm	0 to 10 cm	10 to 20 cm	0 to 10 cm	10 to 20 cm	22-23 Jul	23-24 Jul	22-24 Jul
	mm						mm d^{-1}		
Contrast at Low N‡									
Penncross versus	2.77	3.70	2.33	2.30	5.10	6.00	6.47	4.63	5.55
Pennlinks	3.66	4.63	2.80	2.50	6.46†	7.13	8.30	5.30	6.80*
SYN-1-88	4.63*	4.83	2.27	2.03	6.90*	6.87	9.47**	4.30	6.88*
SYN-3-88	4.87*	4.47	1.83	1.13*	6.70*	5.60	9.33*	2.97*	6.15
SYN-4-88	4.80*	3.67	1.36†	3.03	6.17	6.70	8.47	4.40	6.43†
Contrast at High N‡									
Penncross versus	3.37	3.37	1.83	1.90	5.20	5.27	6.73	3.73	5.23
Pennlinks	2.50	4.17	2.60†	2.37	5.10	6.53	6.67	4.97	5.82
SYN-1-88	2.83	5.23*	4.03**	1.43	6.86*	6.67†	8.07	5.47*	6.77*
SYN-3-88	3.67	3.57	2.46	3.60*	6.13	7.17*	7.23	6.07*	6.65*
SYN-4-88	2.73	4.07	2.63†	2.73†	5.37	6.80*	6.80	5.37*	6.08†
Annual N									
171 kg ha-1	4.15	4.26	2.12	2.20	6.27	6.49	8.41	4.32	6.36
342 kg ha-1	3.02**	4.08	2.71†	2.41	5.73	6.46	7.10	5.12	6.11
CV (%)	32	40	42	46	25	23	30	34	17
ANOVA									
Cultivar	.35	.60	.26	.44	.34	.62	.57	.85	.24
Nitrogen	**	.77	†	.60	.34	.96	.14	.19	.51
C x N	.33	.95	.28	†	.91	.69	.92	.27	.81

†,*,**Significant at the 0.10, 0.05, 0.01 probability levels, respectively.

‡Contrasts are in the Preventative Fungicide program. Cultivars significantly different from Penncross within a column are denoted by †,*,** for 0.10, 0.05, and 0.01 probability levels, respectively.

Table 19. Root water extraction by soil depth and ET in August 1991.

Contrast or Main Effect	Root Water Extraction by Soil Depth						Evapotranspiration		
	28 to 29 Aug		29 to 30 Aug		28 to 30 Aug				
	0 to 10 cm	10 to 20 cm	0 to 10 cm	10 to 20 cm	0 to 10 cm	10 to 20 cm	28-29 Aug	29-30 Aug	28-30 Aug
	cm						cm•d^{-1}		
Contrast at Low N‡									
Penncross versus	3.70	2.97	2.97	1.97	6.67	4.93	6.67	4.93	5.80
Pennlinks	4.03	4.46*	1.67*	2.03	5.70	6.50	8.50†	3.70†	6.10
SYN-1-88	3.73	4.37†	3.23	1.97	6.97	6.33	8.10	5.20	6.65
SYN-3-88	3.33	3.30	2.50	1.30	5.83	4.60	6.63	3.80	5.22
SYN-4-88	2.87	3.40	3.53	2.80	6.40	6.20	6.27	6.33*	6.30
Contrast at High N‡									
Penncross versus	3.40	4.40	2.03	1.80	5.43	6.20	7.80	3.83	5.81
Pennlinks	3.47	4.13	2.77	3.20*	6.23	7.33	7.60	5.97*	6.78
SYN-1-88	4.60*	4.37	2.70	2.10	7.30*	6.47	8.97	4.80	6.88†
SYN-3-88	3.63	3.90	2.83	2.10	6.47	6.00	7.53	4.93†	6.23
SYN-4-88	5.60**	5.23	1.70	1.77	7.30*	7.00	10.83**	3.47	7.15*
Annual N									
171 kg ha-1	3.53	3.70	2.78	2.01	6.31	5.71	7.23	4.79	6.01
342 kg ha-1	4.14	4.41	2.41	2.19	6.55	6.60	8.55†	4.60	6.57
CV (%)	29	37	39	51	22	31	26	27	19
ANOVA									
Cultivar	.69	.82	.77	.63	.53	.54	.59	.85	.44
Nitrogen	.15	.22	.32	.65	.66	.22	†	.68	.23
C x N	.13	.70	.15	.46	.72	.98	.25	*	.94

†,*,**Significant at the 0.10, 0.05, 0.01 probability levels, respectively.

‡Contrasts are in the Preventative Fungicide program. Cultivars significantly different from Penncross within a column are denoted by †,*,** for 0.10, 0.05, and 0.01 probability levels, respectively.

Table 20. Root water extraction by soil depth and ET in June 1992.

Contrast or Main Effect	Root Water Extraction: 23(8:00 hr) to 24(8:00 hr) Jun, 0 to 10 cm	Root Water Extraction: 23(8:00 hr) to 24(8:00 hr) Jun, 10 to 20 cm	Root Water Extraction: 23(8:00 hr) to 24(4:00 hr) Jun, 0 to 10 cm	Root Water Extraction: 23(8:00 hr) to 24(4:00 hr) Jun, 10 to 20 cm	Evapotranspiration: 23(8:00 hr) to 24(8:00 hr) Jun	Evapotranspiration: 23(8:00 hr) to 24(4:00 hr) Jun
	mm		mm		mm	
Contrast at Low N‡						
Penncross versus	4.57	1.97	4.83	3.43	6.54	8.26
Pennlinks	4.47	4.73	5.13	5.80	9.20†	10.93
SYN-1-88	4.90	4.63	5.97	5.23	9.53*	11.20†
SYN-3-88	5.37	4.17	5.60	6.00†	9.54*	11.60*
SYN-4-88	4.53	5.27*	4.87	6.80*	9.80*	11.67*
Contrast at High N‡						
Penncross versus	4.67	2.87	5.23	5.37	7.54	10.60
Pennlinks	6.23	0.30†	7.10†	1.23**	6.53	8.83
SYN-1-88	5.00	6.53*	5.60	7.73†	11.53*	13.33†
SYN-3-88	3.43	0.70	4.73	1.07**	4.13*	5.80*
SYN-4-88	6.03	3.97	7.37*	5.17	10.00†	12.54
Annual N						
171 kg ha-1	4.77	4.15	5.28	5.45	8.92	10.73
342 kg ha-1	5.07	2.87	6.01	4.11	7.95	10.22
CV (%)	41	95	37	64	36	29
ANOVA						
Cultivar	.95	.19	.83	.20	†	†
Nitrogen	.56	.17	.36	.15	.29	.40
C x N	.70	.25	.60	*	.15	*

†,*,**Significant at the 0.10, 0.05, 0.01 probability levels, respectively.

‡Contrasts are in the Preventative Fungicide program. Cultivars significantly different from Penncross within a column are denoted by †,*,** for 0.10, 0.05, and 0.01 probability levels, respectively.

Table 21. Root water extraction by soil depth and ET data for September 1992.

Contrast or Main Effect	Root Water Extraction						Evapotranspiration		
	9(8:00 hr) to 10(8:00 hr) Sep		10(8:00 hr) to 11(14:00 hr) Sep		9(8:00 hr) to 11(14:00 hr) Sep				
	0 to 10 cm	10 to 20 cm	0 to 10 cm	10 to 20 cm	0 to 10 cm	10 to 20 cm	9(8:00 hr) to 10(8:00 hr) Sep	10(8:00 hr) to 11(14:00 hr) Sep	9(8:00 hr) to 11(14:00 hr) Sep
	mm						mm		
Contrast as Low N‡									
Penncross versus	3.13	7.00	1.43	4.43	4.57	11.43	10.13	5.87	16.00
Pennlinks	4.67†	2.80**	2.20	3.47	6.87*	6.27	7.47†	5.67	13.13
SYN-1-88	4.56†	6.37	2.67†	1.20†	7.23*	7.57	10.93	3.87	14.80
SYN-3-88	3.13	4.00*	3.27*	3.53	6.40†	7.53	7.13*	6.80	13.93
SYN-4-88	3.67	3.87*	4.77**	0.43*	8.43*	4.30	7.53†	5.20	12.73†
Contrast at High N‡									
Penncross versus	3.23	4.63	3.00	4.47	6.23	9.10	7.87	7.47	15.33
Pennlinks	2.56	4.97	1.83†	4.03	4.40†	9.00	7.53	5.87	13.40
SYN-1-88	4.73†	2.47	2.53	5.80	7.26	8.26	7.20	8.33	15.50
SYN-3-88	4.23	7.10†	2.60	0**	6.80	7.10	11.33*	2.60*	13.93
SYN-4-88	4.20	3.20	2.37	2.10	6.57	5.30	7.40	4.46*	11.87†
Annual N									
171 kg ha^{-1}	3.83	4.81	2.87	2.61	6.26	7.42	8.64	5.48	14.12
342 kg ha^{-1}	3.79	4.47	2.47	3.28	6.70	7.75	8.26	5.75	14.01
CV (%)	41	63	54	116	33	66	32	52	30
ANOVA									
Cultivar	.61	.59	.40	.45	.38	.47	.64	.73	.64
Nitrogen	.94	.75	.46	.60	.58	.85	.71	.80	.94
CxN	.49	.23	.27	.38	.48	.92	.17	.17	.99

†, *, **Significant at the 0.10, 0.05, and 0.01 probability levels, respectively.

‡Contrasts are in the Preventative Fungicide program. Cultivars significantly different from Penncross within a column are denoted by †, *, ** for 0.10, 0.05, and 0.01, respectively.

Table 22. Stimpmeter readings in 1992 rolling up a 2% slope.

Contrast or Main Effect	Stimpmeter	
	27 Mar	14 May
	m	
Contrast as Low N‡		
Penncross versus	2.12	1.70
Pennlinks	2.02	1.81
SYN-1-88	1.89†	1.76
SYN-3-88	1.96	1.71
SYN-4-88	2.12	1.88
Contrast at High N‡		
Penncross versus	2.02	1.63
Pennlinks	1.81†	1.72
SYN-1-88	1.74*	1.85†
SYN-3-88	1.76*	1.56
SYN-4-88	1.94	1.74
Annual N		
171 kg ha^{-1}	2.02	1.78
342 kg ha^{-1}	1.85*	1.70
CV (%)	10	12
ANOVA		
Cultivar	.18	.43
Nitrogen	.035	.31
CxN	.99	.90

†,*,**Significant at the 0.10, 0.05, and 0.01 probability levels, respectively.

‡Contrasts are in the Preventative Fungicide program. Cultivars significantly different from Penncross within a column are denoted by †,*,** for 0.10, 0.05, and 0.01 probability levels, respectively.