# USGA PROGRESS REPORT - FALL 1990

## Cultural Practice Interactions on Golf Course Turf

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D. PROCEEDINGS

Riordan, T.P. Low Maintenance Alternative Species for Golf Course Roughs. Proceeding of the 61st International Golf Course Conference and Show. February 1990, p. 9.

de Shazer, S.A., T.P. Riordan, R.C. Shearman and D.C. Rundquist. Development of Spatial Relationships Between Digitally Analyzed and Manually Traced Turfgrass Root Images on in situ Root Length and Area. Proceedings of the Nebraska Academy of Science. April 1990, p. 5.

E. ABSTRACTS

Riordan, T.P. Low Maintenance Turfs Recommended For Roughs. Landscape Management. April 1990, p.16.

F. THESIS

Browning, S.J. Buffalograss Sex Expression and Correlation with Turf-Type Charactertistics.Master of Science, 1990, 139 pages.

Schwarze, D.J. The Influences of Prerooting of Plugs on the Establishment of Buffalograss. Master of Science, 1989, 96 pages.

# EXECUTIVE SUMMARY

## CULTURAL PRACTICE INTERACTIONS OF GOLF COURSE TURF

**CREEPING BENTGRASS FAIRWAY MANAGEMENT:** The fairway management study is being conducted to determine effects of irrigation frequency, clipping removal or return, nitrogen nutrition, and traffic on Penncross creeping bentgrass competition with annual bluegrass and maintenance of fairway quality. Turfgrass quality and color ratings increased with high nitrogen application in both traffic conditions. Responses to fairway playing conditions for load bearing capacity, divot tolerance and divot recovery, and ball speed in 1990 were similar to those reported in 1989. Leaf nitrogen content increased with frequent irrigation, clipping return, and high nitrogen treatment. A general trend was that soil nitrogen content decreased with frequent irrigation, clipping return, and high nitrogen rate under both traffic conditions. Low nitrogen application produced less thatch than high nitrogen application. Perennial-biotype verdure spread of annual bluegrass decreased with low nitrogen application in traffic and nontrafficked conditions. Attempts to infest this research area with annual-biotype annual bluegrass have failed. Perhaps indicating a strong competitive advantage toward the bentgrass fairway culture.

**VERTICAL MOWING FREQUENCY AND MOWING HEIGHT EFFECTS ON PUTTING GREEN QUALITY AND PLANT STRESS:** This project continues to study the effects of vertical mowing frequency and mowing height on putting speed, rooting, and stress resistance. Grooming by vertical mowing at 28 and 14 day intervals did not influence putting speed, under conditions of this study. Mowing height did influence putting speed. Mean ball roll for 1990 was 7% greater at 1/8 (3.2 mm) than at 5/32 (4.0 mm) and 15% greater at 1/8 than at 3/16 (4.8 mm) inch mowing heights. Vertical mowing intervals did not influence average monthly visual color and quality ratings. Mowing height did influence visual color and quality with the 5/32 inch having up to 49% greater quality than 1/8 inch mowing height in July 1990. Color ratings at 3/16 inch were up to 40% greater than 1/8 inch mowing height in July 1990. Vertical mowing frequency did not influence the vegetation index as measured by light reflectance.

**SYRINGING ON A CREEPING BENTGRASS GREEN:** A syringing study has been initiated to study interactive effects of nitrogen and potassium nutrition. The study was designed so treatment modifications over time would allow investigation of amount of water applied during syringing, and of application timing effects on syringing treatments. Very limited data were collected during 1990 due to weather and scheduling conflicts. However, the data collected do indicate a significant canopy turfgrass cooling influence from mid-day syringing. Now that another project leader had filled one of the vacant staff positions, greater emphasis will be directed toward this project. Currently, design and implementation aspects of this research project are under evaluation.

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## I. CREEPING BENTGRASS FAIRWAY MANAGEMENT

The Penncross creeping bentgrass fairway management study was conducted second-year to determine the effects of irrigation frequency, clipping removal or return, nitrogen nutrition and traffic or no traffic on a competition with annual bluegrass. Bentgrass was mowed at 13mm (1/2 inch) 4 times per week with fall vertical mowing. In addition to nitrogen nutrition treatments, the turf received 5g P / $m^2$ / season (1 lb. P / 1000 $ft^2$) and 15g K / $m^2$ / season (3 lbs. K / 1000$ft^2$). Pesticides were applied as needed. Annual and perennial biotypes of annual bluegrasses were introduced. Annual biotypes were attempted to be introduced using topdressing materials obtained from local golf courses that were known to be contaminated with Poa annua var. annum. Topdressing was applied after the coring cultivation in spring and fall. Perennial-type annual bluegrass (Poa annua var. reptans) was obtained from University of Minnesota, propagated in the greenhouse; and was transplanted to the research area in fall of 1989 and spring of 1990.

Treatments were arranged in a split-split plot design with irrigation frequency as main plots, clipping treatments as sub-plots and nitrogen levels as sub-subplots (Table 1, page 23). Treatments were replicated 3 times in a completely randomized design. Irrigation was based on potential evapotranspiration(ETp) rate using the Nebraska modified Penman equation. The irrigation scheduled at 80% ETp rate was changed weekly to simulate light frequent (7x) and heavy infrequent (1x) application. The clipping treatments were divided into clippings return (C+) and clippings removal (C-). The nitrogen levels were applied at 5, 15, and 25g N / $m^2$ / season (1, 3 and 5 lbs. N / 1000 $ft^2$). The irrigation, clipping, and nitrogen interaction treatments were divided so half the plots received traffic. Traffic was applied twice weekly with the traffic simulator over the trafficked areas during the season. Studies have been separately conducted under trafficked area and nontrafficked area since 1989.

Data on turfgrass quality, turfgrass color, ball speed, load bearing capacity, divoting tolerance, divot recovery, thatch accumulation, annual bluegrass encroachment, nitrogen nutrient analysis, and soil bulk density were collected. Data were subjected to analysis of variance and means were separated, using Least Significant Difference at the 5% probability level.

**Turfgrass Quality and Color:** Color and quality responses were related to nitrogen application in trafficked and nontrafficked studies. The high nitrogen rate (5 lb/ M / S) provided the highest quality and color ratings, with the exception of September. The light, frequent irrigation treatment produced better visual quality and color ratings than the heavy, infrequent irrigation treatment, during the summer. However, infrequent irrigated treatments appeared to be more tolerant of early July high temperatures and had better visual quality and color ratings than frequently irrigated treatments (Table 2, page 24). Interactions of irrigation by clippings in June and August and irrigation by nitrogen in August and September occurred under nontrafficked conditions. Under trafficked conditions there was an irrigation, clippings, and nitrogen interaction for color rating in June and September.

**Fairway Playing Conditions:** Ball speed varied with irrigation frequency, clippings and nitrogen rates. Responses to ball speed and load bearing capacity or ball holding characteristics of the turf were similar under both trafficked and nontrafficked conditions. Ball speed increased with reduced irrigation frequency, clipping removal and reduced nitrogen nutrition (Table 3, page 25). Ball holding characteristic of the turf was greater under infrequent irrigation, clippings removed, and low nitrogen level when compared to contrasting treatments. Overall treatment results in 1990 were similar to those obtained in 1989.

**Divot Tolerance:** Divoting was applied 3 times (May, July, and August) during the season. Divot injury under trafficked and nontraficked areas was highly associated with soil moisture content when divoting was given. Treatments subjected to infrequent irrigation and clippings removal were more tolerant to divoting than their counterpart treatments. Divot tolerance increased with high nitrogen rate in early summer but decreased again in late summer under both areas. Interaction among irrigation, clippings, and nitrogen treatments was observed under nontrafficked area in May-divoting application.

**Divot Recovery:** The same responses to divot-return (D+) recovery were observed under trafficked and nontrafficked areas. Divot injured areas recovered more rapidly under frequent irrigations. High nitrogen application produced rapid divot recovery in July-divoting application but slower recovery after the August-divoting application when compared with low nitrogen application. Frequent irrigation and high nitrogen produced better recovery after divot-removal (D-) than their counterpart applications. Under trafficked conditions, better recovery rating was observed in clippings removed treatments. Interaction between irrigation and nitrogen was found only under nontrafficked conditions of May-divoting treatment. Similar responses to divot tolerance and divot recovery were recorded in the 1989 research.

**Nitrogen Nutrient Analysis:** Plant tissue and soil nitrogen analysis for 1990 have not been completed, therefore 1989 analysis results will be reported. Under nontrafficked conditions, leaf N content increased with frequent irrigation, clippings return, and high nitrogen rate. But under trafficked conditions, leaf N content increased with clippings return and high nitrogren nutrition rate, with contrasting irrigation response. Leaf N content increased with frequent irrigation in July and August but decreased with it in June and September. Interactions of irrigation frequency by nitrogen rates were observed under trafficked conditions of June and August and under nontrafficked conditions of July. A general trend was that soil N content decreased with frequent irrigation, clippings returned, and high nitrogen rate under both traffic conditions.

**Annual Bluegrass Competition:** Number of perennial-biotype panicles were counted in May on plugs transplanted in fall of 1989. Under trafficked conditions, panicle counts increased with frequent irrigation, clippings return and high nitrogen level. But under nontrafficked conditions panicle counts increased with infrequent irrigation, clippings return and high nitrogen level and interaction of irrigation by nitrogen was observed. Lateral verdure growth measurements were also made in July and September as 4 perpendicular vectors per plug. Annual bluegrass verdure spread increased with high nitrogen application under trafficked and nontrafficked conditions. An estimation on annual-biotype population of annual bluegrass were made but no comparison data are available since there was not sufficient infestation.

**Thatch Accumulation:** Thatch depth was measured 3 times (May, July, and September) during the season. Significant differences in thatch depth were found in nitrogen treatments over the season. The low nitrogen level accumulated less thatch than high nitrogen level. There was a general trend that frequent irrigation and clippings return had more thatch accumulation than their counterpart treatments. Interactions due to irrigation frequency by nitrogen under trafficked area and clippings by nitrogen under nontrafficked area were observed in May.

**Soil Bulk Density:** Soil bulk density was measured 3 times (May, July, and September) through the season. No statistical significance was found in soil bulk density. But there was such tendency that infrequent irrigation and clippings removal offered less soil compaction than their contrasting treatments.

**Overall Summary:** Turfgrass quality and color ratings increased with high nitrogen application in both traffic conditions. Responses to such fairway playing conditions as ball speed, load bearing capacity, divot tolerance, and divot recovery in 1990 were similar to those reported in 1989. Leaf nitrogen content increased with frequent irrigation, clippings returned, and high nitrogen treatments. Perennial-biotype verdure spread of annual bluegrass decreased with low nitrogen application in trafficked and nontrafficked conditions. Low nitrogen application produced less thatch depth than high nitrogen application. Attempts to infest this research area with annual-biotype annual bluegrass have failed. Perhaps indicating a strong competitive advantage toward the bentgrass fairway culture.

Table 1. Treatments for Penncross creeping bentgrass fairway management study designed by split-split plot.

| Treatment No. | Irrigation Frequency | Clippings | Nitrogen Rates ( lbs. N / 1000 ft$^2$ / season ) |
|---|---|---|---|
| 1 | 1x[z] | C+[y] | 1[x] |
| 2 | 1x | C+ | 3 |
| 3 | 1x | C+ | 5 |
| 4 | 1x | C- | 1 |
| 5 | 1x | C- | 3 |
| 6 | 1x | C- | 5 |
| 7 | 7x | C+ | 1 |
| 8 | 7x | C+ | 3 |
| 9 | 7x | C+ | 5 |
| 10 | 7x | C- | 1 |
| 11 | 7x | C- | 3 |
| 12 | 7x | C- | 5 |

[z]Irrigation frequency: 7x means light, frequent application and 1x means heavy, infrequent application with the same amount of 80% ETp.

[y]Clippings: C+ means clippings return and C- means clippings removal after mowing.

[x]Nitrogen rates: 1, 3 and 5 represent 1, 3 and 5 lbs. nitrogen per 1000 ft$^2$ per season.

Table 2. The quality evaluation of Penncross creeping bentgrass maintained as a fairway turf under nontrafficked conditions during the 1990 growing season.

| Treatment No. | Apr.17 | May14 | June28 | July9 | Aug.5 | Sep.5 | Mean |
|---|---|---|---|---|---|---|---|
| 1. 1x C+ 1N | 3.3[z] | 4.0 | 5.3 | 6.0 | 7.3 | 6.3 | 5.4 |
| 2. 1x C+ 3N | 3.7 | 4.7 | 7.0 | 7.3 | 7.0 | 5.3 | 5.8 |
| 3. 1x C+ 5N | 5.0 | 6.0 | 8.0 | 8.3 | 8.0 | 4.7 | 6.7 |
| 4. 1x C- 1N | 3.6 | 4.3 | 5.7 | 6.0 | 6.7 | 6.3 | 5.4 |
| 5. 1x C- 3N | 4.0 | 4.0 | 6.3 | 6.7 | 7.0 | 6.0 | 5.7 |
| 6. 1x C- 5N | 4.7 | 5.0 | 7.7 | 8.0 | 8.0 | 4.3 | 6.3 |
| 7. 7x C+ 1N | 2.7 | 4.0 | 6.7 | 5.7 | 6.0 | 7.0 | 5.3 |
| 8. 7x C+ 3N | 3.3 | 3.7 | 7.3 | 6.7 | 8.0 | 7.0 | 6.0 |
| 9. 7x C+ 5N | 5.3 | 5.7 | 8.3 | 6.7 | 8.0 | 6.3 | 6.7 |
| 10. 7x C- 1N | 3.3 | 3.7 | 7.3 | 6.3 | 7.0 | 7.7 | 5.9 |
| 11. 7x C- 3N | 3.7 | 5.0 | 8.3 | 7.3 | 8.3 | 8.0 | 6.8 |
| 12. 7x C- 5N | 4.3 | 4.7 | 8.7 | 7.3 | 8.7 | 8.0 | 6.9 |
| **Irrigation frequency**[y] | | | | | | | |
| 1x | 4.1 | 4.7 | 6.7b | 7.1 | 7.3 | 5.5b | 5.9 |
| 7x | 3.8 | 4.4 | 7.8a | 6.7 | 7.7 | 7.3a | 6.3 |
| LSD(.05) | ns | ns | 0.9 | ns | ns | 0.6 | ns |
| **Clippings**[x] | | | | | | | |
| C+ | 3.9 | 4.7 | 7.1 | 6.8 | 7.4 | 6.1b | 6.0 |
| C- | 3.9 | 4.4 | 7.3 | 6.9 | 7.6 | 6.7a | 6.2 |
| LSD(.05) | ns | ns | ns | ns | ns | 0.6 | ns |
| **Nitrogen rates**[w] | | | | | | | |
| 1 | 3.3b | 4.0b | 6.3b | 6.0b | 6.8b | 6.8a | 5.5b |
| 3 | 3.7b | 4.3b | 7.3ab | 7.0a | 7.6a | 6.6a | 6.1ab |
| 5 | 4.8a | 5.3a | 8.2a | 7.6a | 8.2a | 5.8b | 6.7a |
| LSD(.05) | 0.7 | 0.7 | 1.1 | 1.0 | 0.7 | 0.7 | 0.6 |

[z]Visual quality was made on a 1-9 scale with 1 = poorest quality and 9 = best quality.

[y]Irrigation frequency: 7x means light, frequent application and 1x means heavy, infrequent application with the same amount of 80% ETp.

[x]Clippings: C+ means clippings return and C- means clippings removal after mowing.

[w]Nitrogen rates: 1, 3 and 5 represent 1, 3 and 5 lbs. nitrogen per 1000 $ft^2$ per season.

Table 3. The fairway speed of Penncross creeping bentgrass maintained as a fairway turf under trafficked conditions during the 1990 growing season.

| Treatment No. | May17 | June25 | July16 | Aug.13 | Sep.5 | Mean |
|---|---|---|---|---|---|---|
| 1. 1x C+ 1N | 197.0[z] | 198.0 | 215.0 | 204.7 | 236.7 | 210.3 |
| 2. 1x C+ 3N | 179.7 | 159.3 | 179.3 | 173.3 | 243.3 | 187.0 |
| 3. 1x C+ 5N | 195.3 | 145.7 | 177.0 | 170.7 | 246.3 | 187.0 |
| 4. 1x C- 1N | 207.0 | 195.0 | 222.0 | 223.0 | 257.0 | 220.8 |
| 5. 1x C- 3N | 182.3 | 165.7 | 183.0 | 190.3 | 239.3 | 192.1 |
| 6. 1x C- 5N | 176.3 | 147.3 | 182.7 | 199.7 | 246.7 | 190.5 |
| 7. 7x C+ 1N | 194.0 | 191.7 | 203.0 | 194.0 | 198.7 | 196.3 |
| 8. 7x C+ 3N | 182.7 | 165.0 | 165.3 | 161.3 | 201.0 | 175.1 |
| 9. 7x C+ 5N | 161.7 | 130.7 | 169.3 | 165.7 | 193.7 | 164.2 |
| 10. 7x C- 1N | 192.3 | 193.3 | 195.0 | 188.3 | 200.3 | 193.9 |
| 11. 7x C- 3N | 173.0 | 181.3 | 180.7 | 189.3 | 208.7 | 186.6 |
| 12. 7x C- 5N | 170.7 | 158.0 | 182.0 | 169.3 | 217.0 | 179.4 |
| **Irrigation frequency**[y] | | | | | | |
| 1x | 189.6a | 168.5 | 193.2a | 193.6a | 244.9a | 198.0a |
| 7x | 179.1b | 170.0 | 182.6b | 178.0b | 203.2b | 182.6b |
| LSD(.05) | 9.1 | ns | 9.8 | 10.3 | 10.5 | 7.2 |
| **Clippings**[x] | | | | | | |
| C+ | 185.1 | 165.1 | 184.8 | 178.3b | 219.9 | 186.6b |
| C- | 183.6 | 173.4 | 190.9 | 193.3a | 228.2 | 193.9a |
| LSD(.05) | ns | ns | ns | 10.3 | ns | 7.2 |
| **Nitrogen rates**[w] | | | | | | |
| 1 | 197.6a | 194.5a | 208.8a | 202.5a | 223.2 | 205.3a |
| 3 | 179.4b | 167.8b | 177.1b | 178.6b | 223.1 | 185.2b |
| 5 | 176.0b | 145.4c | 177.8b | 176.3b | 225.9 | 180.3b |
| LSD(.05) | 11.2 | 15.8 | 12.0 | 12.6 | ns | 8.8 |

[z]The fairway speed (cm) was determined by the mean of 8 measurements which were measured by two in every direction using a modified stimpmeter.
[y]Irrigation frequency: 7x means light, frequent application and 1x means heavy, infrequent application with the same amount of 80% ETp.
[x]Clippings: C+ means clippings return and C- means clippings removal after mowing.
[w]Nitrogen rates: 1,3 and 5 represent 1,3 and 5 lbs. nitrogen per $1000ft^2$ per season.

## II. MOWING HEIGHT AND VERTICAL MOWING FREQUENCY EFFECT ON PUTTING GREEN QUALITY

Many cultural practices are involved in managing creeping bentgrass (Agrostis palustris Huds.) putting greens. A golf course superintendent must use practices that increase putting speed and maintain a high quality turf. Lowering mowing heights increases putting speed, but adds to turfgrass environmental and physiological stress. Effects of cultural practices on putting green quality and playability have not been fully evaluated.

This study was conducted to evaluate the interactive effects of vertical mowing and mowing height on putting green quality and playability. Interactive effects of mowing height and vertical mowing frequency on putting speed, overall quality, visual color, and canopy reflectance were studied. Soil temperature, canopy temperature, and root production data also was collected but will not be presented in this report.

### Materials and Methods

The study was conducted on a 'Penncross' creeping bentgrass (Agrostis palustris Huds.) green, established on a 508 mm (20 in) sand base in 1986. A split-block experimental design was used with three mowing heights and three vertical mowing frequencies, replicated three times. Mowing heights were 3.2, 4.0, and 4.8 mm (1/8, 5/32, and 3/16 inch, respectively). Vertical mowing (VM) intervals were no VM, 28, and 14 days. Mowing was applied 5-6 days week$^{-1}$, in four directions rotated daily. Vertical mowing was applied early morning at treatment frequencies. Topdressing applications of 0.8 mm (0.1 yd$^{3}$) were applied biweekly following vertical mowing. Fertilization was 20, 10, 20 g N P K m$^{-2}$ season$^{-1}$. Daily irrigation was based on replacement of 80% potential ET on a three day accumulation.

Data was collected during the 1989 and 1990 growing seasons. Only 1990 data presented in this report. Ball roll was used to gauge putting speed using the USGA Stimpmeter. Ball roll measurements were taken 0, 4, and 8 days after vertical mowing. Visual quality ratings were based on 1 to 9 scale with 1 = least desirable and 9 = most desirable putting green quality. Color ratings were based on a 1 to 9 scale with 1 = straw brown, 6 = light green, and 9 = dark green. Color and quality ratings were taken 0, 2, 4, 6, and 8 days after vertical mowing. An Exotech Model 100-A spectral radiometer was used to measure reflected radiation in multispectral scanner (MSS) bands 5, and 7 (0.6-0.7, 0.8-1.1 $\mu$m), from which reflectance factors were calculated. Measurements were taken over a period 15 minutes prior to and after solar noon on clear days. A normalized difference vegetation index (NIR - RED)/(NIR + RED) was used as an indication of vegetation greenness.

### Results and Discussion

No mowing height by vertical mowing frequency interaction was found with respect to ball roll on all dates measured in 1990. Ball roll measurements were averaged over the whole year in 1990 to evaluate the yearly trend across vertical mowing frequencies (Figure 1, page 28). Ball roll was not affected by frequency of vertical mowing, but was affected by mowing height (Figure 2, page 29). Mean ball roll for 1990 was 7% greater at 3.2 mm than at 4.0 mm and 15% greater at 3.2 mm than at 4.8 mm (Figure 2, page 29). No differences were observed among vertical mowing intervals for average monthly visual color and quality ratings in 1990 (Figure 3, page 30). Differences were observed among mowing heights for monthly color and quality ratings in 1990. Quality ratings at the 4.0 mm mowing height were up to 49% greater than at 3.2 mm in July 1990 (Figure 4, page 31). Color ratings at the 4.8 mm mowing height were up to 40% greater than at 3.2 mm in July 1990 (Figure 4, page 31). Canopy reflectance measurements were taken a total of nine times in 1990. Significant mowing height by vertical mowing frequency interaction for the normalized difference vegetation index was observed on one of the nine measurement dates. The interaction plot for that specific date is not shown in this report. Frequency of vertical mowing did not significantly affect the vegetation index (Figure 5, page 32). Differences were observed among mowing heights for the vegetation index with largest values associated with higher mowing heights. When averaged across mowing heights, these differences were significant.

Grooming by vertical mowing at 28 and 14 day intervals did not influence putting speed, under conditions of this study. Since rotation of mowing direction and light frequent topdressing may have played a role in eliminating vertical mowing treatment effects, efforts to control putting speed must focus on several cultural practices. Color and quality increased from no vertical mowing compared to vertical mowing at 28 day intervals. The slight differences in color and quality would not warrant the use of grooming at the frequencies studied.

Many turf managers utilize reel mowers with groomer attachments and groom their greens every time they mow. Others utilize groomers on a scheduled basis only, ranging from every other day to the frequencies studied here. Additional research is needed over a wider range of vertical mowing intervals to determine optimum frequency.

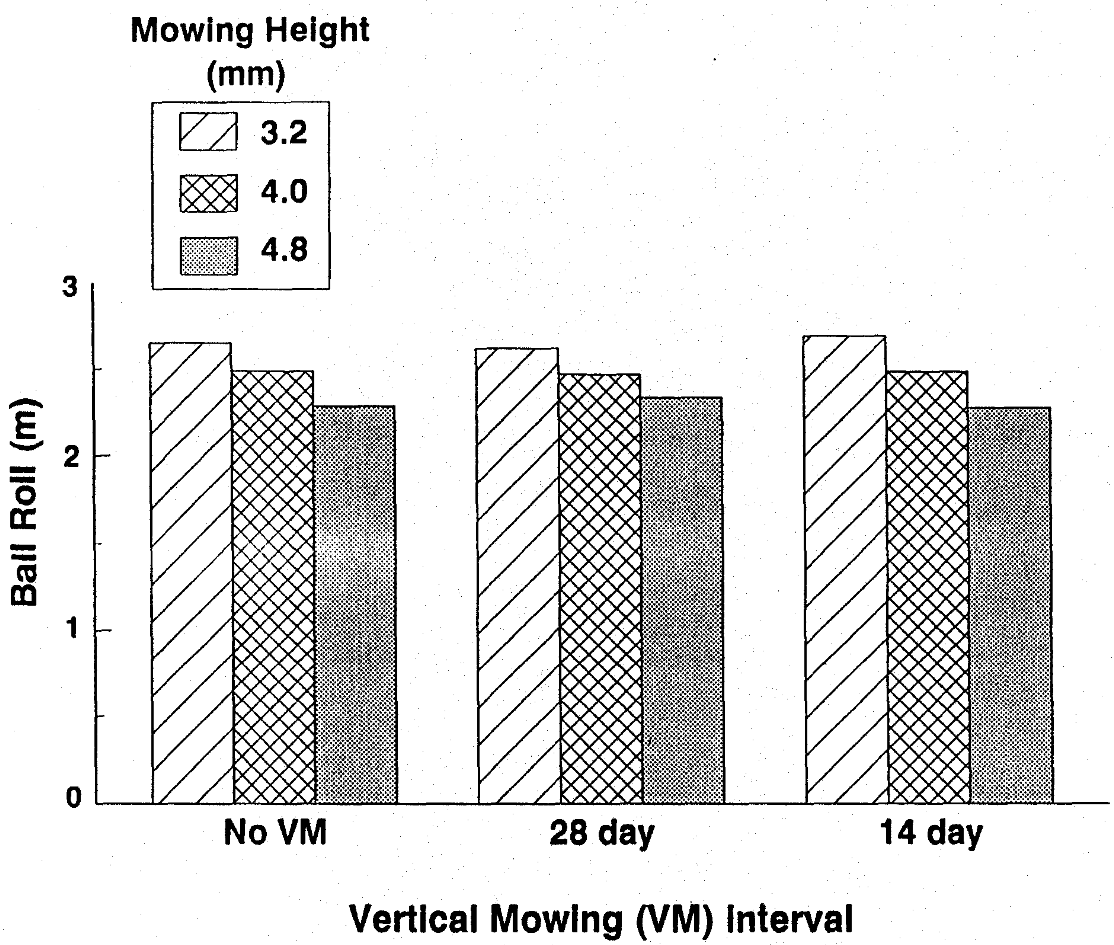
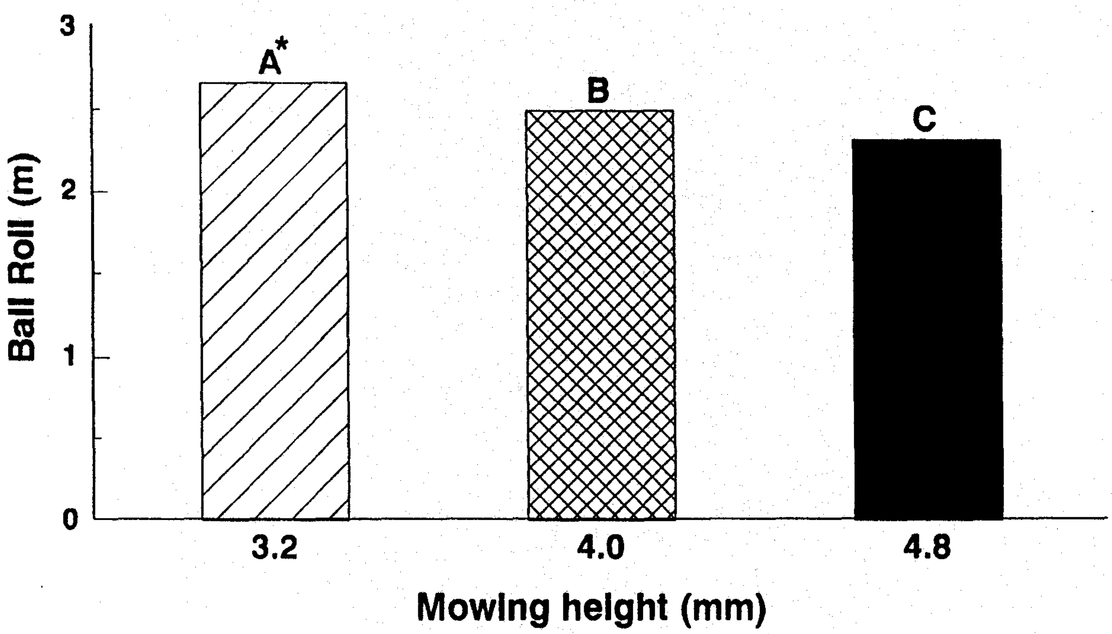



**Figure 1. Effects of vertical mowing frequency and mowing height on yearly average ball roll for 1990, on a creeping bentgrass putting green.**




* = DMRT (0.05)

**Figure 2. 1990 mean ball roll measurements for a creeping bentgrass putting green at three mowing heights (mm).**

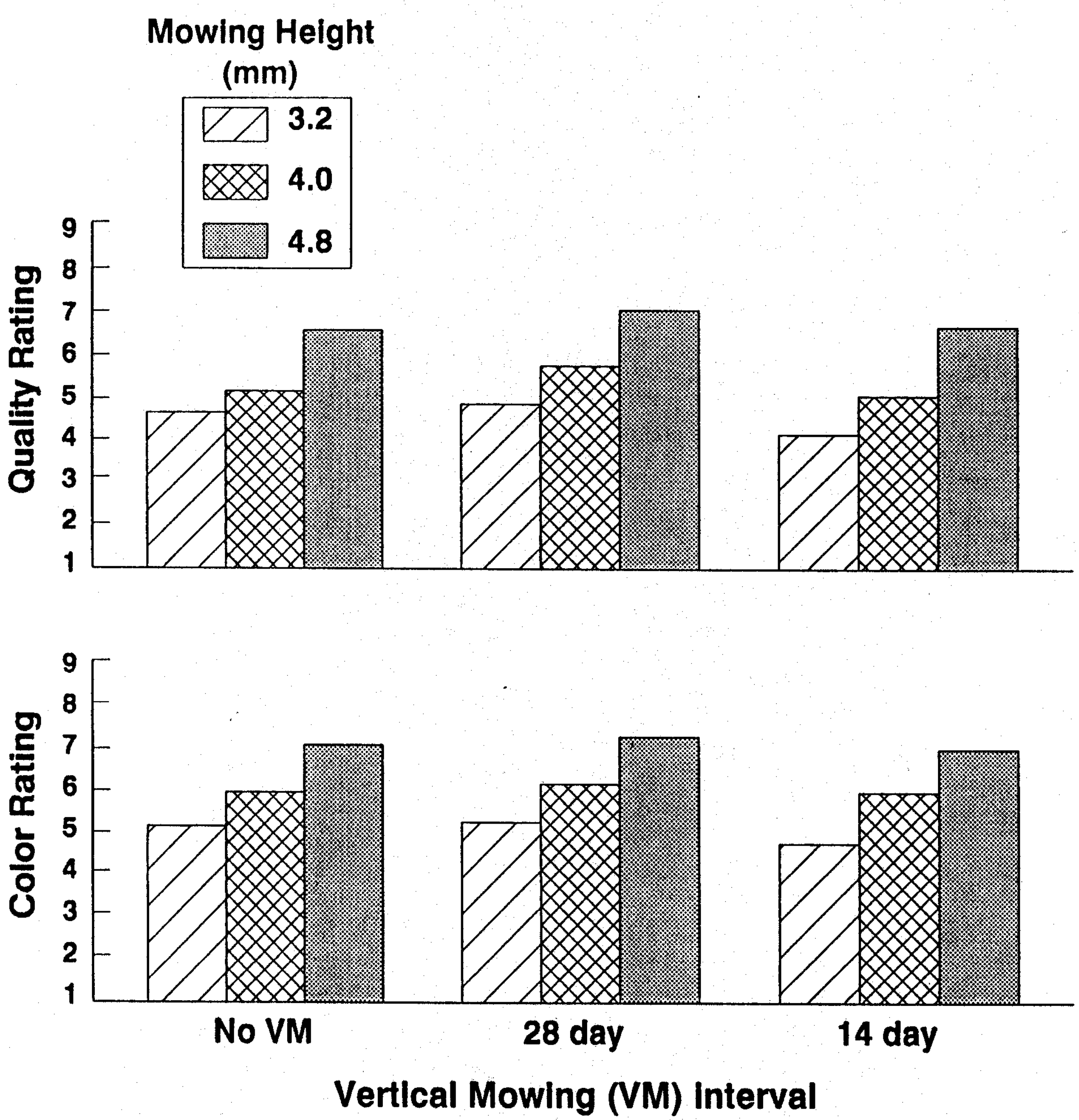



**Figure 3. Effects of vertical mowing frequency and mowing height on mean quality and color ratings for July 1990 on a creeping bentgrass putting green.**

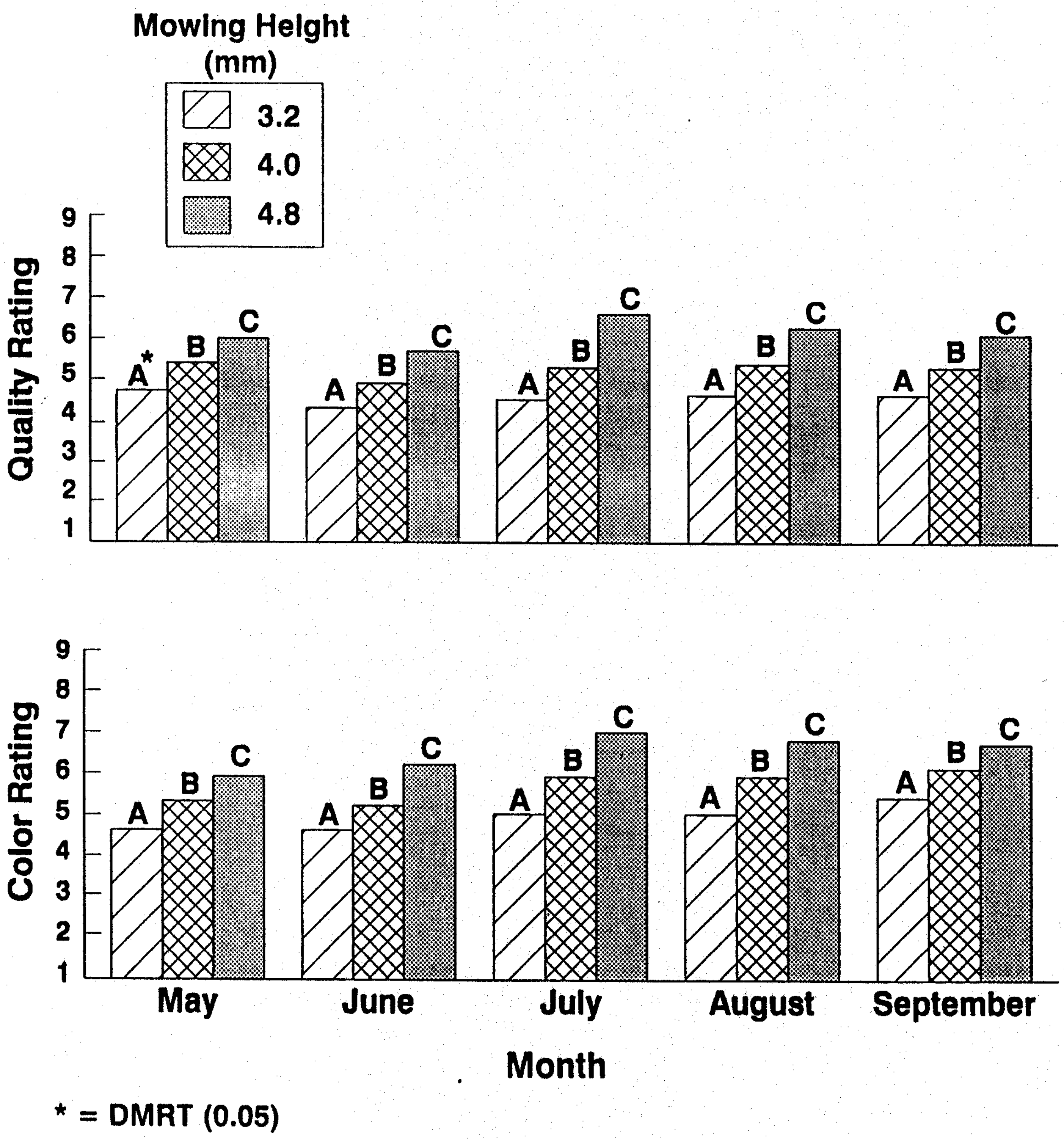



**Figure 4. 1990 monthly quality and color rating means for a creeping bentgrass putting green at three mowing heights (mm).**

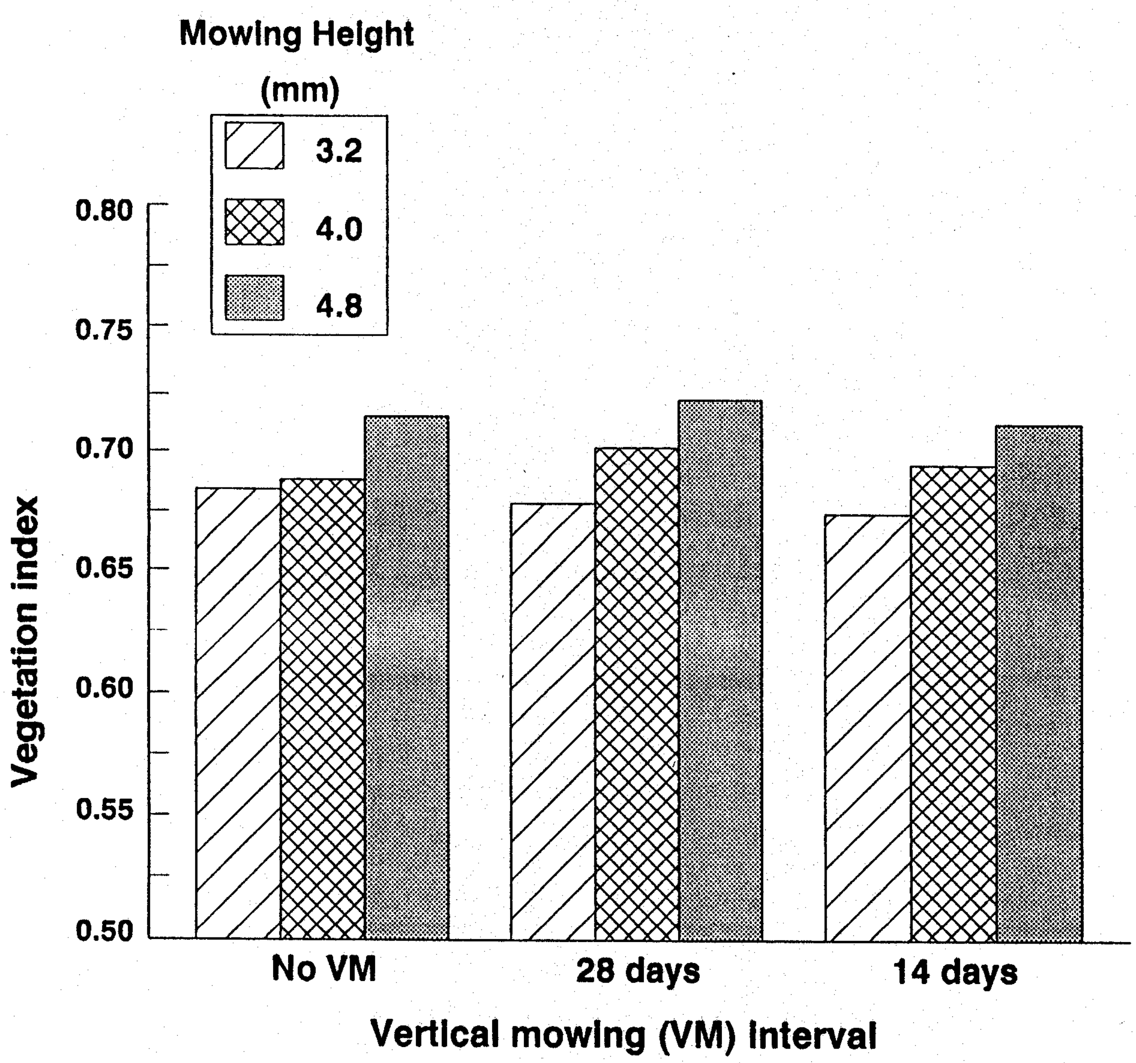



**Figure 5. Effects of vertical mowing frequency and mowing height on the normalized difference vegetation index [(NIR-RED)/(NIR+RED)] on July 3, 1990.**

## III. PROJECT LEADER TRANSITION ACTIVITIES

**Organic Fertilizer Research** - Renewed interest in turfgrass and turfgrass systems response to natural organic based fertilizers has prompted initiation of several field studies. These studies are designed to provide information on turfgrass color, quality, and topgrowth response to date and rate of application and nutrient source base. Overall the natural organic based fertilizers look promising as an alternate turfgrass nutrition source.

**Rhizotron Research** - Soil column boxes in the south wing of the rhizotron have been modified to accommodate collection of soil extracts for analysis of nutrient movement is soil profiles. Initially, these modifications will allow monitoring the fate and movement of fertilizer nutrients such as nitrogen from fertilizer sources. Rhizotron modifications for this research initiative have now been successfully completed and tested. Penncross creeping bentgrass maintained at putting green height has been established as the initial turfgrass test species.

**Spectroradiometer Research** - This summer the Turfgrass Science Team initiated use of a 252 band spectroradiometer, sensitive to light reflected over the range of 300 to 1100 nm. This instrument is currently being adapted and tested for turfgrass quality evaluations in the field. Initial evaluation of reflectance and vegetation index data from buffalograss advanced selections indicate this likely is another tool which may be used to differentiate and quantify genetic potential. We also anticipate use of this instrument and procedure to objectively quantify turfgrass quality and color responses to many studies such as: 1) natural organic fertilizers, 2) rhizotron studies, 3) creeping bentgrass fairway management, 4) mowing height and vertical mowing interactions, 5) national turfgrass evaluation trials, 6) turfgrass establishment studies.

**Irrigation, Drought Resistance, and Water Quality Research** - Irrigation scheduling, drought resistance, water quality, and turfgrass water use have constituted major portions of my research programs in the past. Coordination of the successful completion of these studies in Texas has almost been accomplished. Overall, two of these studies have established minimum water requirements for maintenance of bermudagrass in the southwest. In addition, one study documented the successful use of soil moisture sensors (Cummings Sensors) as an instrument to control irrigation application and significant water savings over conventional irrigation control systems.

Advanced long term studies have been planned here to further define the use dimensions of soil sensors to control irrigation of cool and warm season grasses under mid-western environment conditions. Use of linear gradient irrigation as a turfgrass breeding selection tool and for basic physiological studies is in the feasibility planning stage. Water quality investigations coincident with turfgrass cultural systems have been initiated in the rhizotron. Expanded research direction on interactions of turfgrass systems and the environment have been initiated through research grant proposals.

## IV. PRESENTATIONS

### A. POSTERS

Salaiz, T. Mowing Height and Vertical Mowing Frequency Effects On Putting Green Quality. American Society of Agronomy. October 1990.

Horst, G.L. Bermudagrass Quality Response to Deficit Irrigation. American Society of Agronomy. October 1990.

### B. PRESENTATIONS

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