USGA PROGRESS REPORT - 1986

Turfgrass Cultural Practices and Their Interactive Effects on Rooting

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Executive Summary

Joint agreement for this research project was reached on 19 April 1985 between the USGA and UN-L. Initiation funding occurred with a grant-in-aid of $4,000 in 1984. In 1985 $23,000 was granted for project support. This was followed by $20,000 in 1986. Total support to date for this project is $47,000.

1. ACCOMPLISHMENTS TOWARD USGA PROJECT GOALS: The USGA has set goals of 50% reduction in turfgrass water use and 50% lower maintenance costs. Results from the irrigation frequency x potassium nutrition study conducted during 1986 demonstrated that decreasing irrigation frequency and increasing potassium nutrition levels resulted in equal or better putting green conditions than turfs receiving frequent daily irrigation. Snow mold (Typhula blight) incidence decreased with increasing potassium. A 60% reduction in disease incidence was found between treatments of 4 and 8 lbs K/ 1000 ft^2/ season. These results indicate a strong potential to reduce maintenance cost by manipulating irrigation frequency and potassium nutrition, particularly on sand growing media.

2. OTHER RESEARCH ACCOMPLISHMENTS: The interaction of turfgrass species root growth and distribution was investigated under drought stress conditions. Species were eliminated when root growth ceased and permanent wilt symptoms were expressed. Tall fescue, creeping red fescue, perennial ryegrass and creeping bentgrass produced roots to 1220 mm to 1520 mm. Rough bluegrass ranked intermediate in root production, but wilted very early in the drought stress cycle since approximately 50% of its rooting was in the upper 0 to 150 mm of the profile. Sixteen Kentucky bluegrasses were investigated for intraspecific responses in root growth and distribution, top growth, and amount of root growth supporting top growth. Cultivars were found to vary by as much as 50% to 56% in these characteristics. Ram I, Touchdown and Eclipse had high percentages of root growth supporting top growth.

Potassium nutrition studies on creeping bentgrass and Kentucky bluegrass demonstrated that drought avoidance characteristics increased with K nutrition. Wilting tendency decreased as K nutrition was increased from 0 to 8 lbs K/1000$^f t^2$. Turfgrass wear tolerance increased with increasing K rates.

3. OTHER UN-L CONTRIBUTIONS: Studies were initiated in the JSA Turfgrass Rhizotron to investigate growing media and microenvironment. An ERDAS system was purchased to be used as a means to quanitate turfgrass root growth in the rhizotron and in other rooting studies. An additional 10,000 ft^2 Of creeping bentgrass green area was established for research purposes. This additional green brings the total area to approximately 56,000 ft^2. A creeping bentgrass cultivar study was initiated September 1986. Plots were designed to incorporate cultural practice on the replicated cultivar study.

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USGA RESEARCH PROJECT PROGRESS REPORT (1986)- TURFGRASS CULTURE

The studies reported are part of an on-going research project supported jointly by the USGA and the University of Nebraska Department of Horticulture. Studies have been conducted with nine, cool-season turfgrass species, 16 Kentucky bluegrass cultivars, and potassium nutrition. These studies have investigated inter- and intraspecific differences in turfgrass root growth, top growth and their interrelated responses under limited and nonlimiting moisture conditions. Similarly, potassium nutrition responses on rooting and drought stress have been investigated using creeping bentgrass and Kentucky bluegrass.

Cool-Season Turfgrass Root Growth And Distribution Under Drought Stress

This study was conducted in the greenhouse, using the procedures described in the following paragraphs. The study is presently being repeated. A report of the initial findings of this study will be given at the Agronomy Society of America meetings which will be held in New Orleans in late November. Root growth and distribution patterns of hard fescue, chewings fescue, creeping red fescue, rough bluegrass, Kentucky bluegrass, perennial ryegrass, tall fescue, and creeping bentgrass were studied under drought stress conditions. Plants were grown in PVC tubes (100 mm dia. x 1525 mm length) that were designed to allowed sub-irrigation at 305 mm intervals under greenhouse conditions. The growing media was fritted clay. Sub-irrigation allowed manipulation of soil water in the profile and the opportunity to maintain soil drought stress conditions in the upper portion of the profile with adequate quantities at lower levels. Plants were mowed every 5 days at the species optimum height and clippings were collected and dried. Plants received 201 ml of a modified Hoagland's solution injected with daily irrigation. Species were eliminates when permanent wilt symptoms were observed or upon reaching the last sub-irrigation interval in the drought stress cycle. Analysis was performed between species on top growth, root organic matter production at segment, total root weight, and maximum root depth. Total root weight was of little value (Table 1). Creeping bentgrass had low total root weight, but produced roots to 1160 mm and plants did not show signs of permanent wilt during the course of this study. Tall fescue as a species had 1525 mm rooting depth and the largest top growth production (Table 1). Mustang, a turftype cultivar demonstrated the greatest root redistribution with 21% of its roots in the last segment and K-31, a forage-type cultivar supported greater topgrowth than Mustang with only 8.1% of its total root production found in the deepest portion of the profile (Table 2). Hard fescue and rough bluegrass wilted early in the drought stress cycle due to their lack of rooting depth and distribution. Turfgrasses grown under these conditions show an ability to distribute roots to avoid drought stress.

Table 1. Total top and root growth of nine cool-season turfgrasses grown under progressive drought stress.

Species	Top growth (g)z	Root growth (g)y
K-31 tall fescue	35.7 ax	22.6 a
Mustang tall fescue	27.7 b	11.6 bc
Creeping red fescue	14.6 c	13.9 b
Perennial ryegrass	14.4 c	11.1 bc
Creeping bentgrass	13.1 c	3.3 d
Chewings fescue	11.3 cd	11.5 bc
Rough bluegrass	10.9 cd	7.7 cd
Kentucky bluegrass	6.9 d	5.5 d
Hard fescue	6.4 d	4.1 d

zTop growth equals verdure plus total clipping yield. Values are means of 4 replications.

yRoot growth expressed as ashed weights and are means of 4 replications.

xMeans followed by the same letter are not significant at the 5% level, as determined by the Duncan's new multiple range test.

Table 2. Ashed root weights (g) of nine cool season turfgrasses exposed to drought stress.

	Root Product					
Species	0-150mm[y]	150-300mm	300-610mm	610-910mm	910-1220mm	1220-1520mm
K-31 tall fescue	3.9 bc	3.1 a	5.3 a	4.8 a	3.8 a	1.8 a
Mustang tall fescue	2.0 de	1.4 bcd	1.8 cd	1.91 b	2.0 b	2.4 a
Creeping red fescue	4.7 ab	2.6 ab	3.5 b	2.2 b	0.8 c	0.1 b
Perennial ryegrass	3.8 bc	2.3 abc	3.3 bc	1.44 bcd	0.3 c	0.1 b
Creeping bentgrass	1.3 e	0.6 d	0.7 d	0.53 cde	0.2 c	0.1 b
Chewings fescue	4.1 abc	2.6 ab	3.1 bc	1.52 bc	0.2 c	--
Rough bluegrass	5.5 a[z]	1.7 abcd	0.5 d	--	--	--
Kentucky bluegrass	3.2 bcd	1.3 bcd	0.8 d	0.22 de	0.1 c	--
Hard fescue	2.6 cde	1.0 cd	0.5 d	--	--	--

[z]Values are means of 4 replications. Values at a soil depth followed by the same letter are not significant at the 5% level as determined by the Duncan's new multiple range test.

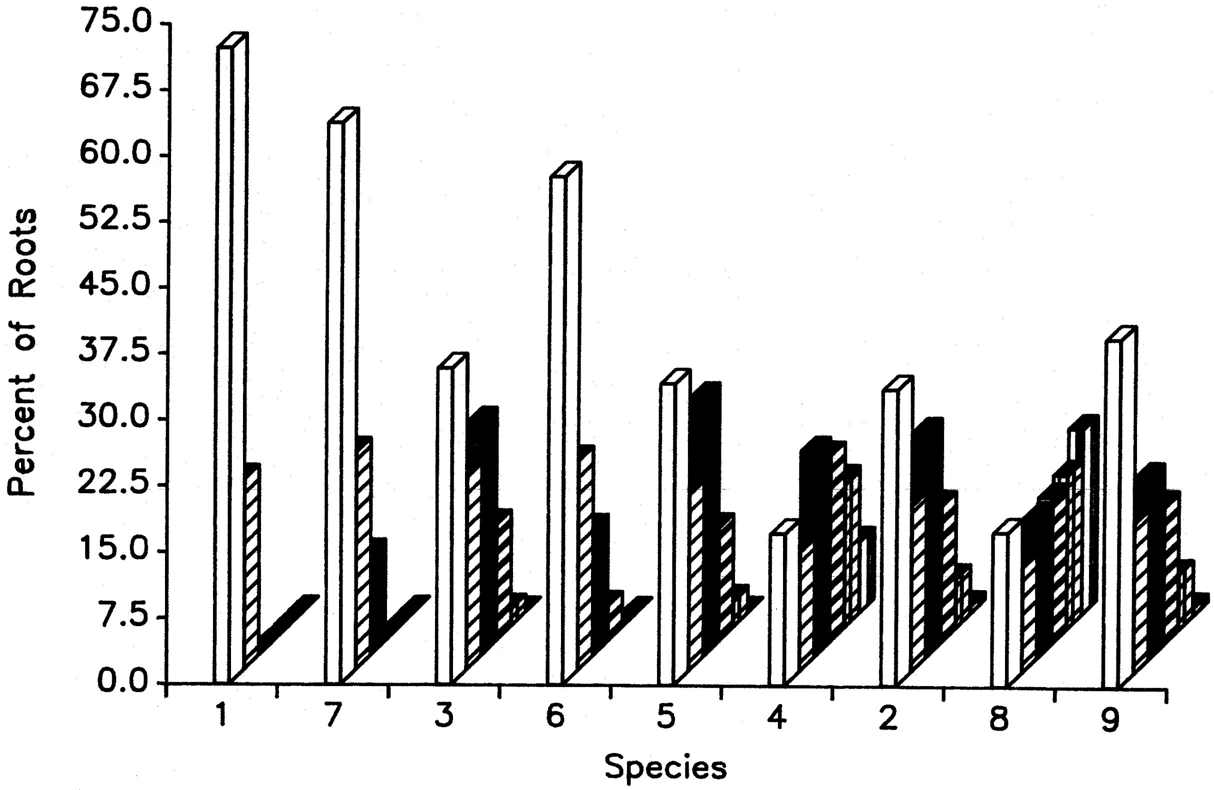
[y]Dashed line indicates species did not reach that soil depth.

[z]Means followed by the same letter are not significant at the 5% level as determined by the Duncan's new multiple range test.

Figure 1. Root distribution of nine cool-season turfgrasses over six soil profile levels after exposure to drought stress (1 = Rough bluegrass, 2 = Creeping red fescue, 3 = Chewings fescue, 4 = K-31 Tall fescue, 5 = Perennial ryegrass, 6 = Kentucky bluegrass, 7 = Hard fescue, 8 = Mustang tall fescue, and 9 = Creeping bentgrass).

6.

Percent Root Distribution



Kentucky Bluegrass Cultivar Root Growth and Distribution

This study was conducted in the greenhouse and was repeated over time. Procedures used in conducting these experiments are detailed in the subsequent text. A report on this study will be given at the ASA Meetings in New Orleans in late November.

Sixteen Kentucky bluegrass cultivars were grown hydroponically in a greenhouse to determine root production and distribution under decreasing water levels. The nutrient solution was allowed to drop according to evapotranspiration demand. The solution was changed weekly to prevent salt buildup in solution and to maintain nutrient levels. Plants were mowed every five days at 6.4 mm and the clippings were collected. The study was terminated after ten weeks and plant material harvested and dried at 70 C for 72 hours and weighed.

Cultivars differed in topgrowth, root growth, and distribution (Tables 3, 4, and 5). Topgrowth and root growth varied by 31% and 32%, respectively (Table 3). Touchdown had the highest percentage of root growth supporting the topgrowth (Table 4). Touchdown, Dormie, Baron, and Ram I had a higher production of topgrowth and percentage of supporting root growth. Eclipse, Kenblue, and Park also had a higher percentage of root growth supporting the plant but had a lower amount of overall topgrowth. Aspen, Nassau and NE 8088 had a higher amount of topgrowth but a lower percentage of root growth supporting the topgrowth.

Kentucky bluegrass is a widely grown turfgrass species which has been used in many golf course tees and fairways throughout the cool-humid and semi-arid regions of the United States. To meet the needs of water and energy conservation, Kentucky bluegrass cultivars with deep, extensive root systems are needed. These results demonstrate that this potential exists (Figure 1).

Table 3. Verdure, clipping yield, and total topgrowth of 16 Kentucky bluegrass cultivars grown in a hydroponic solution

Cultivar	Verdure(g)	Clipping Yield(g)	Topgrowth(g)[z]
Glade	4.1 a[y]	3.3 abc	7.4 a
Baron	4.1 a	3.6 abc	7.7 a
Aspen	3.9 a	3.8 a	7.8 a
America	3.8 ab	3.1 abc	7.0 ab
Dormie	3.8 ab	4.0 a	7.8 a
Challenger	3.8 ab	2.7 cd	6.6 ab
Mystic	3.7 ab	3.6 abc	7.3 a
Nassau	3.6 abc	2.9 bcd	6.5 ab
Touchdown	3.5 abcd	3.7 ab	7.2 a
NE 8088	3.4 abcd	2.8 bcd	6.3 ab
Eclipse	3.3 abcd	2.1 d	5.4 b
Georgetown	3.3 abcd	3.2 abc	6.5 ab
Ram I	3.2 abcd	2.9 bcd	6.1 ab
Birka	2.9 bcd	3.2 abc	6.1 ab
Kenblue	2.7 cd	2.8 bcd	5.5 b
Park	2.6 d	2.9 cd	5.4 b

[z] Verdure + clipping yield

[y] Mean separation within columns by Duncan's multiple range test, 5% level

Table 4. Total root growth and percent supporting root growth (SRG) of 16 Kentucky bluegrass cultivars grown in hydroponic solution

Cultivar	Root Growth (mg)[z]	SRG (%)[y]
Dormie	1121 a[x]	15.5 abcd
Ram I	1037 ab	19.2 abc
Park	955 abc	22.0 ab
Kenblue	923 abc	17.2 abcd
Mystic	920 abc	13.0 abcd
Glade	918 abc	11.7 abcd
Challenger	904 abc	10.4 bcd
Aspen	891 abc	7.3 d
Baron	889 abc	17.5 abcd
Nassau	872 abc	7.3 d
NE 8088	866 abc	8.8 cd
Eclipse	863 abc	18.2 abcd
Georgetown	830 bc	15.2 abcd
Birka	823 bc	20.2 abc
America	782 bc	12.9 abcd
Touchdown	767 c	24.0 a

[z] Mean total root growth of four replications
[y] Percentage of total root mass in contact with nutrient solution
[x] Mean separation within columns by Duncan's multiple range test, 5% level

Table 5. Total root production and distribution of 16 Kentucky bluegrass cultivars grown in a hydroponic solution.

	Root Production (mg)[z]				
Cultivar	0-150 mm[y]	150-300 mm	300-450 mm	450-600 mm	600-750 mm
NE 8088	452 a[x]	292 abc	116 bc	6 c	---
Nassau	446 a	315 abc	103 c	9 c	---
Glade	435 a	312 abc	146 abc	18 bc	7 a
Challenger	412 a	322 abc	124 bc	34 abc	23 a
Dormie	404 a	346 ab	256 a	89 a	34 a
Aspen	398 a	324 abc	149 abc	18 bc	5 a
Mystic	392 a	266 bc	197 abc	56 abc	11 a
Kenblue	386 ab	311 abc	156 abc	57 abc	12 a
Park	376 ab	323 abc	190 abc	53 abc	12 a
Ram I	375 ab	377 a	224 ab	52 abc	9 a
Georgetown	359 ab	282 abc	149 abc	49 abc	6 a
America	342 ab	250 bc	154 abc	30 abc	7 a
Birka	336 ab	277 abc	136 bc	60 abc	25 a
Eclipse	324 ab	322 abc	167 abc	41 abc	11 a
Baron	314 ab	276 abc	190 abc	78 ab	32 a
Touchdown	253 b	232 c	181 abc	74 ab	27 a

z Values are mean of four replications.
y Root distribution broken down in five 150 mm segments.
x Mean separation within columns by Duncan's multiple range test, 5% level.

Figure 2. Root Distribution of three Kentucky bluegrass cultivars exposed to decline available moisture.

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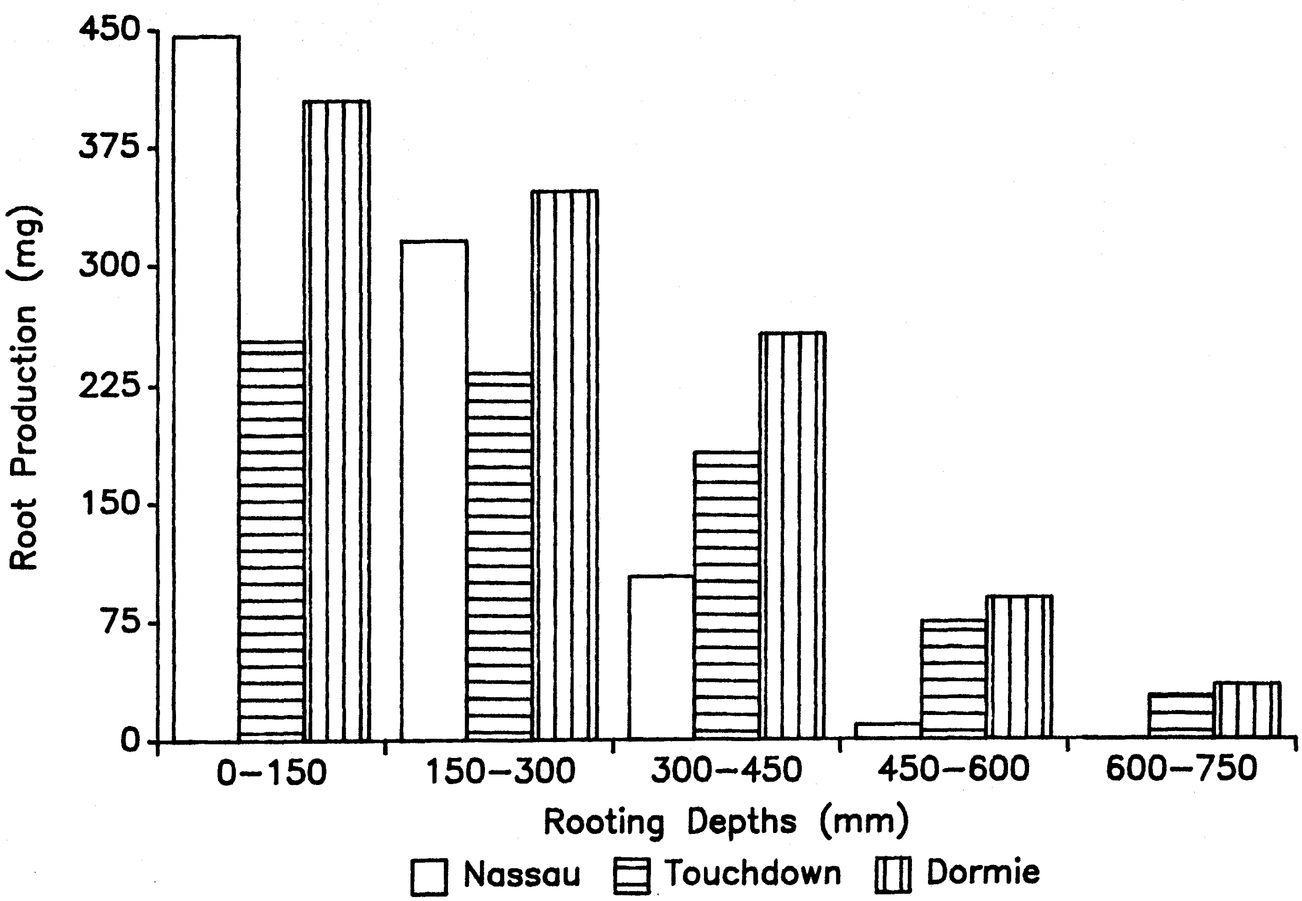

Root Production (mg)
450
375
300
225
150
75
0
0–150
150–300
300–450
450–600
600–750
Rooting Depths (mm)
Nassau
Touchdown
Dormie

Sixteen Kentucky bluegrass cultivars were grown hydroponically in a greenhouse to measure root production and distribution under decreasing water levels. The study was repeated over time in 1985 and 1986. The nutrient solution was allowed to drop according to evapotranspiration demand. Nutrient solutions were changed weekly to maintain nutrient availability and to prevent salt buildup. Plants were mowed to a uniform height every five days and the clippings collected. The plants were allowed to equilibrate in solution for one week. The study was terminated five weeks after initiation of treatments. Topgrowth and root growth were harvested and dried at 70 C for 72 hours and weighed. Cultivars differed in topgrowth, root growth, root distribution, and percentage of root growth supporting the plant. Total topgrowth and root growth varied among cultivars by 50% and 56% (Table 6). Ram I, and Eclipse had the highest percentage of root growth supporting the plant (Table 7). Ram I, Park, Eclipse, and Touchdown had a low total topgrowth with a high percentage of supporting root growth. Georgetown and Aspen had a high amount of topgrowth with a low percentage of supporting root growth.

Table 6. Verdure, clipping yield, and total topgrowth of 16 Kentucky bluegrass cultivars grown in a hydroponic solution.

Cultivar	Verdure(g)	Clipping Yield(g)	Topgrowth(g)[z]
America	6.9 a[y]	3.8 a	10.7 a
Baron	5.9 ab	3.4 abc	9.3 ab
Georgetown	5.9 ab	3.6 ab	9.4 ab
Aspen	5.8 abc	3.6 ab	9.3 ab
Glade	5.6 bc	2.9 abcd	8.5 bc
Mystic	4.8 bcd	3.3 abc	8.1 bcd
Birka	4.6 cd	2.4 cde	7.0 cde
Challenger	4.3 de	1.6 e	5.9 e
Dormie	4.2 de	2.1 de	6.3 de
Eclipse	4.1 de	2.1 de	6.1 e
NE 8088	3.7 def	2.1 de	5.8 e
Touchdown	3.6 def	2.8 bcd	6.4 de
Ram I	3.6 def	2.1 de	5.8 e
Nassau	3.5 def	2.2 de	5.7 e
Park	3.2 ef	2.7 bcd	5.9 e
Kenblue	2.5 f	2.8 abcd	5.3 e

z Verdure + clipping yield
y Mean separation within columns by Duncan's multiple range test, 5% level

Table 7. Total root growth and percent supporting root growth (SRG) of 16 Kentucky bluegrass cultivars grown in hydroponic solution

Cultivar	Root Growth (mg)[z]	SRG (%)[y]
Mystic	1887 a[x]	14.1 bcd
Georgetown	1863 a	8.8 d
Ram I	1647 ab	30.3 a
Eclipse	1628 ab	33.6 a
Birka	1622 ab	21.6 abcd
Baron	1616 ab	14.6 bcd
Glade	1604 ab	17.2 abcd
Park	1585 ab	24.6 abc
America	1577 ab	14.3 bcd
Dormie	1513 abc	18.7 abcd
Aspen	1490 abc	12.0 cd
Touchdown	1472 abc	29.0 ab
Challenger	1353 bc	14.7 bcd
NE 8088	1245 bc	8.7 d
Kenblue	1240 bc	18.3 abcd
Nassau	1063 c	20.3 abcd

[z] Mean total root growth of six replications
[y] Percentage of total root mass in contact with nutrient solution
[x] Mean separation within columns by Duncan's multiple range test, 5% level

Table 8. Total root production and distribution of 16 Kentucky bluegrass cultivars grown in hydroponic solution

	Root Production (mg)[z]				
Cultivar	0-150 mm[y]	150-300 mm	300-450 mm	450-600 mm	600-700mm
Georgetown	867 a[x]	708 a	252 abc	40 ab	5 c
Park	766 ab	660 ab	241 abc	47 ab	5 c
NE 8088	721 ab	437 cd	76 d	10 b	7 bc
Dormie	721 ab	539 abcd	185 bcd	69 ab	21 abc
Ram I	714 ab	607 abc	239 abc	69 ab	21 abc
America	702 ab	480 bcd	294 ab	86 a	16 abc
Kenblue	700 ab	370 d	128 cd	40 ab	19 abc
Mystic	697 ab	640 abc	334 a	80 a	16 abc
Glade	681 ab	621 abc	243 abc	49 ab	13 abc
Challenger	673 ab	516 abcd	127 cd	44 ab	22 abc
Aspen	650 ab	511 abcd	272 ab	51 ab	9 abc
Eclipse	610 b	566 abcd	322 ab	76 a	34 ab
Baron	574 b	653 ab	304 ab	71 ab	14 abc
Touchdown	549 b	527 abcd	273 ab	98 a	25 abc
Birka	546 b	540 abcd	284 ab	93 a	35 a
Nassau	530 b	368 d	124 cd	43 ab	10 abc

[z] Values are mean of six replications
[y] Root distribution broken down in five 150 mm segments
[x] Mean separation within columns by Duncan's multiple range test, 5% level

Potassium Nutrition Versus Turfgrass Rooting and Stress Tolerance

Potassium nutrition studies were conducted in the field at the John Seaton Anderson Turfgrass Research Facility located on the University of Nebraska ARDC near Mead. One Study was conducted on creeping bentgrass and the other on Kentucky bluegrass. Both studies were initiated prior to receipt of the USGA grant, but research efforts were expanded by the added support. A great deal of interest has been generated by these studies. Golf course superintendents are interested in potassium nutrition and stress management, particularly where high sand-content growing media (i.e. sand greens and light, frequent sand topdressing).

Fylking Kentucky Bluegrass Study. This study was initiated in 1976 on a Sharpsburg, silty-clay loam (Typic Argiudoll) with a pH of 7.3, phosphorus level of 27 kg/ha, potassium level of 350 kg/ha, and an organic matter content of 2.8%. Soil potassium levels were considered very high according to soil test recommendations.

A randomized complete block design with five nitrogen and five potassium treatments arranged factorily was used. Treatments were replicated three times. The nitrogen source was urea (45 N-0-0) and the potassium source was potassium sulphate (0-0-41.5 K). Treatments included 0, 10, 20, 30, and 40 g/m^2/season for each of nitrogen and potassium. Fertilizer applications were made mid-May, mid-June, late-July, early-September, late-October and mid-November each year. Application rates were divided evenly over the 6 application dates. The turfs were mowed 3 times weekly at 22 mm and clippings were removed. Irrigation was supplied at 25 mm to 44 mm based on estimated ET, using a modified Penman with a crop coefficient of 0.80. Irrigation and precipitation were excluded during periods of moisture stress evaluation.

There was no nitrogen times potassium interation for turfgrass color and quality ratings when the turf was not under moisture stress. Nitrogen enhanced turfgrass quality and color ratings on a seasonal basis (Data not shown). Potassium significantly influenced color and quality only when turfs were subjected to stress or during periods of recovery after stress (Data not shown). There was a significant interaction of N x K for soil pH levels (i.e. high N and low K decreased soil pH). Soil pH ranged from 7.0 to 7.2 in potassium treatments and from 7.3 to 7.0 in nitrogen (Tables 9 and 10). Potassium treatments had no effect of soil phosphorus levels, but did cause a linear increase in soil K levels based on application rate (Table 9). Nitrogen applications ranging from 0 to 40 g/m^2/season drove soil P and K levels down on a linear basis. Soil P levels declined to 46% of that in the control at the 40 g/m^2 treatment (i.e. 27 to 12 kg/ha). Soil K declined with added N, but the decline was to only 92% of that found in the low N treatments (Table 10). Turfgrass verdure was not influenced by K but increased linearly on a dry weight basis with nitrogen treatments ranging from 0 to 40 g/m^2. Root organic matter content increased with increasing K levels for all soil depths examined (Table 12). There was a 3 fold increase in root mass between 20 g/m^2 and 40 g/m^2. Increasing nitrogen rates decreased rooting overall soil depths (Data not shown). There was a significant N x K interaction for turfgrass wilting tendency when the turfs were exposed to moisture stress (Figure 3). Wilting tendency was greater at 40 g/m^2 than at 10 g/m^2, but wilting declined linearly with added K.

It is of interest to note that the K responses observed in this study occurred at soil levels in excess of those considered high by soil test recommendations.

Table 9. Soil pH, phosphorus and potassium levels as influenced by potassium treatment.

Potassium		Soil		
(lbs. K/1000 sq ft/season)	(gK/m^2/season)	pH	Phosphorus (kg/ha)	Potassium (kg/ha)
0[z]	0	7.0[y]	18	431
2	10	7.0	19	854
4	20	7.1	18	1134
6	30	7.1	19	1516
8	40	7.2	18	1933
	LSD (0.05) =	0.1	ns	79
	Rate (1)[x] =	ns	ns	*

[z] Potassium treatments were applied in May, June, July, Sept., Oct., and Nov.

[y] pH values were converted to - log [H^+] for analysis.

[x] Rate (1) indicates rate comparison based on orthogonal contrast.
* indicates significance at 5% probability level, and ns indicates nonsignificant

Table 10. Soil pH, phosphorus and potassium as influenced by nitrogen treatments.

Nitrogen		Soil		
(lbs. N/1000 sq ft/season)	(gN/m^2/season)	pH	Phosphorus (kg/ha)	Potassium (kg/ha)
0[z]	0	7.3[y]	27	1209
2	10	7.2	21	1197
4	20	7.1	16	1174
6	30	7.1	16	1167
8	40	7.0	12	1119
	LSD (0.05) =	0.1	6	53
	Rate (1) =	ns	*	*

z Nitrogen treatments were applied in May, June, July, Sept., Oct. and Nov.

y pH values converted to - log [H+] for analysis.

x Rate (1) indicates rate comparisons based on orthogonal contracts.
* indicates significance at 5% probability level, and ns indicates nonsignificance.

Table 11. 'Fylking' Kentucky bluegrass verdure treated with nitrogen and potassium.

Nitrogen (lbs. N/1000 sq. ft.)	(gN/m²)	Verdure (kg/m²)[z] Fresh Wt.	Dry Wt.
0[y]	0	1.9	0.7
2	10	1.9	0.8
4	20	2.4	0.9
6	30	2.1	0.9
8	40	2.2	1.0
	LSD (0.05) =	0.4	0.2
Potassium (lbs. K/1000 sq. ft.)	**(gK/m²)**		
0	0	2.1	0.9
2	10	2.0	0.8
4	20	2.2	0.9
6	30	2.0	0.8
8	40	2.0	0.9
	LSD (0.05) =	ns	ns
	N-Rate (l) =	ns	*
	N-Rate (q) =	*	ns
	K-Rate (l) =	ns	ns
	N-Rate (q) =	ns	ns

[z]Verdure values are means of four subsamples and three replications per treatment.

[y]Treatments were applied in May, June, July, Sept. Oct. and Nov.

[x]Rate (l) or Rate (q) indicates linear or quadratic response to treatment based on orthogonal comparisons.

*, ns indicate significance and nonsignificance at 5% probability level.

Table 12. Rooting response of 'Fylking' Kentucky bluegrass treated with potassium (K).

Potassium		Root Organic Matter (mg)[z]		
(lbs. K/1000 sq. ft.)	(gK/m^2)	0-100 mm	100-200 mm	200-300 mm
0[y]	0	261	13	-
2	10	321	60	-
4	20	373	63	13
6	30	383	67	28
8	40	420	113	40
	LSD (0.05) =	32	27	3
	Rate (1)[x] =	*	*	*

[z]Root mass expressed on root organic matter basis. Values are means of four subsamples and three replications per treatment.

* indicates significance at the 5% probability level.

Figure 3. Influence of nitrogen and potassium on wilting tendency of 'Fylking' Kentucky bluegrass. Wilting tendency was based on a 1 to 9 scale with 1 = no wilt and 9 = 90 to 100% of turf wilted.

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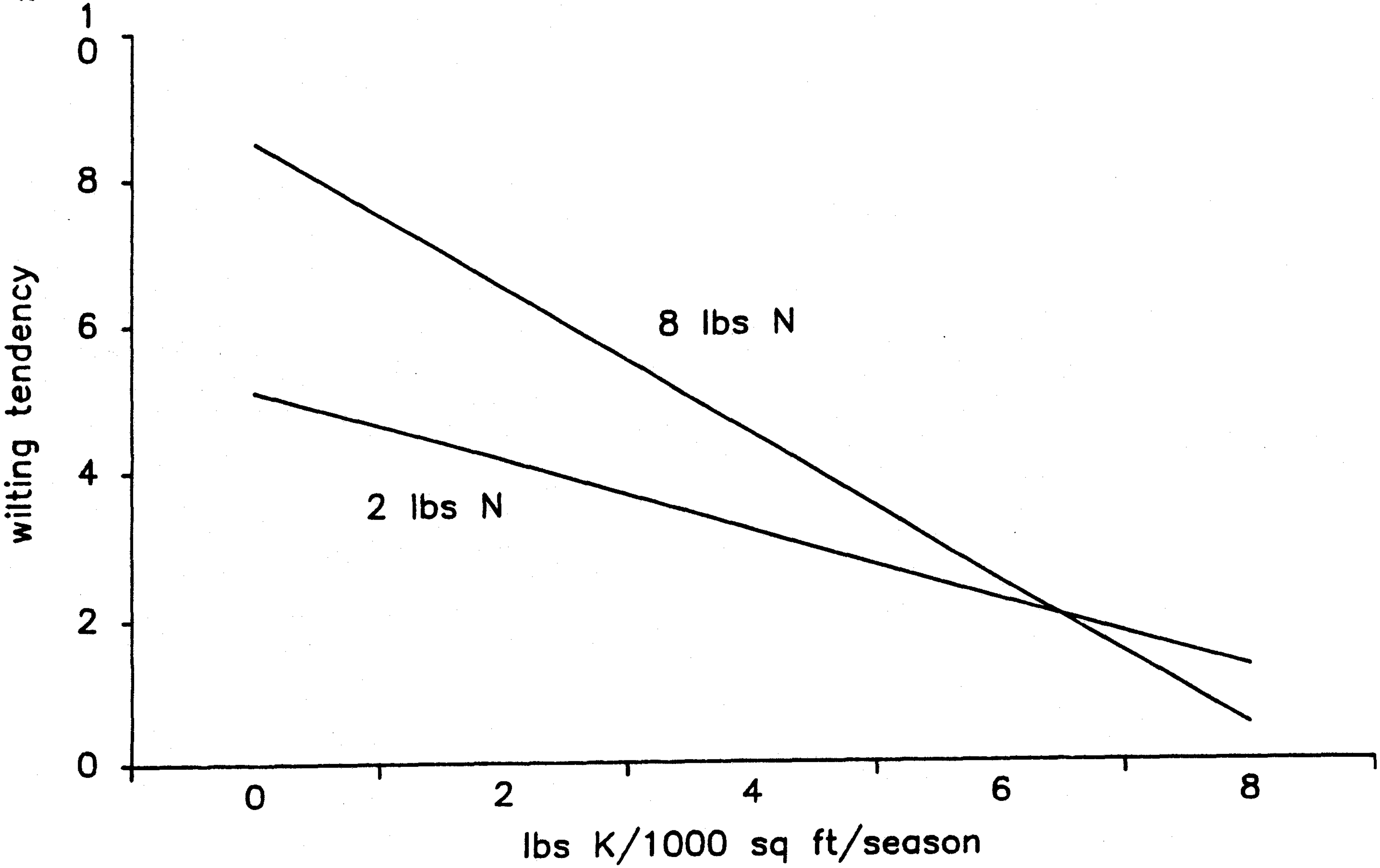

wilting tendency
10
8
6
4
2
0
8 lbs N
2 lbs N
0
2
4
6
8
lbs K/1000 sq ft/season

Seaside Creeping Bentgrass Study.

This study was initiated in April 1981 on a sand green construction that had no soil or peat added. Sand depth was 525 mm. Particle size distribution was highest in the coarse to medium sand range with only 14% in the fine to very fine categories (Table 13). Soil test results indicated a pH of 7.9, phosphorus at 5 ppm, and potassium at 50 ppm. Soil organic matter was nonexistent.

A split-plot design was used with irrigation frequency as the main plot and K treatments as the subplots. Irrigation frequency consisted of daily and twice weekly watering. The amount of irrigation applied was based on a modified Penman equation and a crop coefficient of 0.80. Turfs received the same amount of water. They were mowed 5 to 6 times per week at 3 mm and clippings were removed. Vertical mowing or grooming was done every 7 to 10 days throughout the growing season. Greens were topdressed with light applications of the sand every 2 to 3 weeks, during the growing season. Pesticides were applied on a preventative basis.

Potassium rates were 0, 10, 20, 30, and 40 g/m^2/season. Nitrogen was supplied at 30 g/m^2/season. Phosphorus was supplied at 10 g/m^2/season. Potassium sulphate was used as the K source, urea as the N source, and treble superphosphate as the P source. K and N were applied bi-weekly as liquids in 105 ml/m^2/ application of water. Phosphorus was applied May, June, July and September at 2.5 g/m^2/ application.

Color and quality were not influenced by the interaction of irrigation frequency and potassium nutrition (Data not Shown), unless the turfs were exposed to moisture stress. Soil potassium levels increased with K fertilization under both irrigation frequencies, but at the highest rate of application (i.e. 40 g/m^2/ season) reached only the medium level of availability based soil test recommendations (Table 14). Putting green quality increased with K nutrition (Table 15). However, putting speed (Stimpmeter) declined with added K when turfs were exposed to moisture stress (Tables 16 and 17). Potassium treatments decreased visual wilt symptoms. Thus the more turgid turfs resisted ball roll more than the wilted or non-turgid ones. Turfgrass root density was increased by infrequent irrigation as opposed to daily irrigation. Potassium nutrition increased root density (Table 18). Turfgrass wear tolerance was enhanced by K nutrition. There was no interaction between irrigation frequency and potassium nutrition for wear injury (Table 19).

Potassium Source Study.

A potassium source study has been initiated to investigate the following sources: 1) Potassium sulphate, 2) Muriate of potash (KCl), and 3) Potassium nitrate. These sources are commonly available to the turfgrass industry. This study was initiated in September 1986 and constitutes two experiments. One being conducted on a USGA green construction with Penncross creeping bentgrass and the other on a Baron Kentucky bluegrass turf maintained at fairway height of cut. This study should give insight into potential benefits and concerns that might arise from high K rates in turfgrass nutrition programs.

Table 13. Particle size distribution used for sand green construction.

Description	Size (mm)	Percentage (%)
Very coarse	2.0 - 1.0mm	23.8
Coarse	1.0 - 0.5mm	36.0
Medium	0.5 - 0.25mm	26.0
Fine	0.25 - 0.10mm	12.2
Very fine	0.10 - 0.05mm	2.0

Table 14. Soil potassium levels in a 'Seaside' creeping bentgrass turf growing on sand and receiving two irrigation frequencies.

Potassium[z] (lbs. K/1000 sq ft/season)	Soil Potassium Levels (kg/ha) Watered Daily	Watered 2X/Week
0 (0)	34	36
2 (10)	43	43
4 (20)	40	51
6 (30)	61	68
8 (40)	168	200
LSD (0.05) =	18	18
Rate (1) =	*	**

[z]Potassium treatments received 6 lbs. N/1000 sq. ft. (30g/m²)/ growing season. Values in parenthesis are g k/m²/season.

*,** indicate significance at 0.05 and 0.01 probability levels, respectively.

Table 15. Putting green quality of 'Seaside' creeping bentgrass, growing on a fine-sand with two irrigation frequencies and varying potassium nutrition.

Potassium[z] (lbs. K/1000 sq. ft.)	Turfgrass Quality[y] Watered Daily	Watered 2X/Week
0 (0)	5.3	5.9
2 (10)	6.1	6.2
4 (20)	6.7	6.3
6 (30)	6.9	7.3
8 (40)	7.3	7.5
LSD (0.05) =	0.2	0.2
Rate (1) =	*	**

[z]Potassium treatments received 6.0 lbs. N/1000 sq. ft. (30g K/m^2)/growing season. Values in parenthesis are g K/m^2.

[y]Turfgrass quality was based on a 1 to 9 scale with 1 = poorest, 6 = acceptable, and 9 = best. Values are means of 5 monthly assess ments (May-September 1985) and 3 replications per treatment.

*, ** indicates significance at the 0.05 and 0.01 probability levels, respectively.

Table 16. Wilting tendency of 'Seaside' creeping bentgrass as influenced by irrigation frequency and potassium nutrition.

Potassium[z] (lbs K/1000 ft^2/season)	Wilting Tendency[y] Irrigated Daily 24 hr	48 hr	72 hr	Watered 2x/week 24 hr	48 hr	72 hr
0 (0)	4.9	5.7	9.0	3.5	4.0	7.2
2 (10)	4.0	4.9	8.3	3.0	3.2	5.7
4 (20)	3.3	4.0	6.5	1.3	3.2	3.3
6 (30)	1.0	3.3	3.3	1.0	1.8	1.8
8 (40)	1.3	1.8	2.3	1.0	1.3	1.0
LSD (0.05) =	0.7	0.4	0.8	0.4	0.7	0.4
Rate (l) =	*	*	*	ns	*	*

[z]Potassium treatments received 6.0 lbs N/1000 ft^2/season (30 g/m^2/season). Values in parenthesis are g K/m^2/season.

[y]Wilting tendency was based on 1 to 9 scale with 1 = no wilt and 9 = 90-100% of turf wilted. Wilt was assessed at 2:00 p.m. on 16, 17, and 18 July 1986. Potential ET was 10.3mm, 11.3mm, and 8.8mm, respectively. Irrigation was withheld 15 to 18 July 1986.

*, or ns indicates significance or non-significance at the 5% probability level.

Table 17. Influence of potassium nutrition on ball roll (i.e. Stempmeter) measured under non-stress moisture and stress conditions.

Potassium[z] (lbs K/1000 ft^2/season)	Golf Ball Roll[y] Non-stress[x] (inches)	Golf Ball Roll[y] Stress (inches)
0 (0)	85	87
2 (10)	83	85
4 (20)	86	83
6 (30)	84	82
8 (40)	85	78
LSD (0.05) =	ns	3
Rate (1) =	ns	*

[z]Potassium treatments received 6.0 lbs N/1000 ft^2/season (30 g/m^2/season. Values in parenthesis are g K/m^2/season.

[y]Ball roll values were assessed using the USGA Stimpmeter at 2:00 p.m. Values are means of 16 measurements per treatment and were rounded to the nearest inch.

[x]Non-stressed and stressed are based on visual wilt symptoms. Data are from 15 July and 18 July, 1986 on treatments receiving daily irrigation. Irrigation was withheld from 8:00 a.m. 15 July to 4:00 p.m. 18 July.

Table 18. 'Seaside' creeping bentgrass root density responses to potassium nutrition for turfs growing on sand and receiving two irrigation frequencies.

Potassium[z] (lbs. K/1000 sq. ft.)	Root Density (mg/L)[y] Watered Daily	Watered 2X/Week
0 (0)	265	237
2 (10)	277	323
4 (20)	336	356
6 (30)	372	478
8 (40)	469	618
LSD (0.05) =	6.4	6.4
Rate (1) =	**	**

[z]Potassium treatments received 6.0 lbs. N/1000 sq. ft. (30g/m^2)/growing season. Values in parenthesis are g K/m^2/season.

[y]Root density were expressed as mg dry wt/L. Values in a column are means of 4 subsamples and 3 replications per treatment.

** indicates significance at the 0.01 probability levels.

Table 19. Wear tolerance responses for 'Seaside' creeping bentgrass growing on a fine-sand and receiving two watering regimes with varying potassium levels.

Potassium[z] (lbs. K/1000 sq. ft.)	Wear Tolerance[y] Watered Daily	Watered 2X/Week
0 (0)	328	303
2 (10)	404	385
4 (20)	431	449
6 (30)	604	606
8 (40)	625	623
LSD (0.05) =	25	25
Rate (1) =	*	*

[z]Potassium treatments received 6.0 lbs. N/1000 sq. ft. (30g K/m²)/growing season. Values in parenthesis are g K/m².

[y]Wear tolerance was based on number of revolutions by wear machine necessary to wear-away verdure leaving exposed soil and shoots and no green vegetation.

*indicates significance at the 0.05 probability level.