Nitrogen Utilization Efficiency of Creeping Bentgrass Genotypes

Y. Kuo
D. J. Wehner
T. W. Fermanian
J. M. Swiader

ABSTRACT. A greenhouse study was conducted in a hydroponic system to determine the nitrogen (N) utilization efficiency (NUE) of 14 creeping bentgrass cultivars. There were significant differences among cultivars in plant tissue dry weight, tissue N content, root absorption efficiency (RAE), and NUE. Considering all plant tissue (whole plant), 'Penncross' accumulated the highest N accompanied with the highest whole plant dry weight (WPDW), while 'Allure' accumulated the lowest total N and WPDW than all the other cultivars. The proportion of WPDW and total N partitioned to shoots was higher than partitioned to roots in each cultivar. On a whole plant basis, 'Regent' had the highest NUE while 'Allure' had the lowest NUE. N absorption efficiency values were comparatively higher in 'Allure' than any of the other cultivars, while 'Forbes' had the lowest RAE. The RAE value of the cultivars was not a response to the NUE indicating that differences in RAE was not a critical factor involved in genotypic differences in NUE. Differences in NUE among most cultivars were correlated to plant dry weight in a second experiment. Solution systems have the potential for

Y. Kuo is affiliated with the Chinese Culture University, Department of Landscape Architecture, 55 Hwa-Ken Road, Yang Ming Shan, Taipei, Taiean, ROC.

D. J. Wehner is affiliated with the College of Agriculture, Cal Poly State University, San Luis Obispo, CA 93407.

T. W. Fermanian and J. M. Swiader are affiliated with the Department of Natural Resource and Environmental Science, University of Illinois, 1102 South Goodwin Avenue, Urbana, IL 61801.

Please address correspondence to T. W. Fermanian at the above address (E-mail: fermo@uiuc.edu).

Contribution from the Illinois Agricultural Experiment Station, Urbana.

This study was partially supported by the Illinois Turfgrass Foundation.

an effective means of screening the NUE of creeping bentgrass cultivars.

KEYWORDS. Creeping bentgrass cultivars, nitrogen utilization, root absorption efficiency

ABBREVIATIONS. NUE, nitrogen utilization efficiency; RAE, root absorption efficiency; WPDW, whole plant dry weight

Creeping bentgrass (*Agrostis palustris* Huds.) is one of the most important cool season turfgrasses. Mowing heights of 0.5 to 1.3 cm are preferred, so it is widely used as the surface of golf course putting greens (Turgeon, 1998) and fairways. The nitrogen (N) fertility requirement varies from 8 to 20 g m^{-2} per year depending on the mowing height (Turgeon, 1998).

Nitrogen is considered to be the most important nutrient element affecting the quality of turfgrass. It represents 3 to 6% of the plant on a dry-weight basis. Too much N can cause poor root and shoot growth, greater disease incidence, reduced carbohydrate reserves, reduced tolerance to environmental stress, and potentially ground water pollution (Agnew, 1992). NO_3^- is the form most commonly used by plants. It is highly mobile in soil and is not stored in the soil on cation exchange sites. Golf course putting greens are composed of a high percentage of sand and receive frequent irrigation, thus, it is very susceptible to leaching (Geron et al., 1993).

Commonly, N efficiency (NE) in plants is expressed as biomass produced per unit of N supplied. Genotypic differences in NE have been demonstrated in several crops, including maize (Moll et al., 1982), rice (DeDatta and Broadbent, 1988), and pumpkin (Swaider et al., 1994). Causes of genotypic variation in NE relate to two main components; N absorption efficiency (NAE, total plant N accumulated per unit of N supplied) and N utilization efficiency (NUE, the quantity of dry matter produced per unit of plant N). Of these two components, NUE is considered more influential to NE under low N supply, whereas under high N supply, genotypic differences in NE were due mainly to NAE (Moll et al., 1982). Other plant parameters, such root absorption efficiency (RAE, total plant N accumulated per unit of root dry weight) may also affect NE in plants (Kolek and Kozinka, 1991).

Genotypic evaluation for NE is usually conducted at low N supply levels, commonly < 1.0 mM N (Sander et al., 1987). The water potential, oxygen level, and N concentration are easier to maintain in a hydroponic culture than in soil culture (Howard and Watschke, 1984). Research using hydroponic culture to detect NUE of Kentucky bluegrass was recently reported by Bertauski (1993). This work showed that there is a possibility of improving NUE in turfgrasses through genotype selection. However, little information is available on the importance of adjusting N applications to match the fertilizer efficiency of a specific cultivar.

The objectives of this study were to evaluate bentgrass cultivars for their adaptation to low N growing conditions, and to compare the differences in N accumulation and partioning, NUE, and RAE among cultivars of creeping bentgrass genotypes.

MATERIALS AND METHODS

Solution Culture

Seeds of 14 bentgrass cultivars (Table 1) were sown in plastic trays (25×52 cm^2) containing medium-grade vermiculite and covered with a thin layer of the same medium to reduce desiccation. After 16 to 18 d, seedlings were removed from the vermiculite and any media attached to the roots was washed off with distilled water. Uniform sized seedlings (root length about 2.5 cm) were placed in the center of a sterilized Dispo plug (Scientific Products Co., San Jose, CA) (10 mm in height $\times$ 20 mm in diameter) for physical support. The Dispo plugs with the seedlings were placed in a hole cut in a styrofoam sheet ($30 \times 43 \times 2.5$ cm^3) that floated on the surface of 15 l of 10% v/v modified Pellet and Roberts' solution (Pellett and Roberts, 1963) containing 10 ppm of N in plastic aerated tanks with the roots submerged in the solution. The plants were allowed to acclimate in the tanks for 5 d before transplanting to the final screening system. Seedlings of uniform size were removed from the tank and placed into PVC pots (20 cm in height $\times$ 10 cm in diameter). A thin-knock out cap (10 cm in diameter) served as the lid. Four holes, the size of the Dispo plugs

TABLE 1. The entries and source of the bentgrass (bent) cultivars used in the experiments.

Entry No.	Name	Species	Source
1	BR 1518	dryland bent	USGA Green Section
2	Allure	colonial	Willamette Seed Co.
3	Egmont	browntop bent	Olsen-Fennell Seed Co.
4	Bardot	colonial	Barenburg USA
5	National	creeping	Pickseed West
6	Lopez	creeping	Finelawn Research Corp.
7	SR 1020	creeping	Seed Research of Oregon
8	Putter	creeping	Jacklin Seed Co.
9	Regent	creeping	Barenburg USA
10	Penneagle	creeping	Tee-2-Green Crop.
11	Carmen	creeping	Advanta Seeds West, Inc.
12	Forbes 29-12	creeping	Forbes Seed & Grain
13	Providence	creeping	Seed Research of Oregon
14	Penncross	creeping	Tee-2-Green Crop.

were drilled in each lid. Three of the holes were used to support the seedlings and the fourth one was used as access for an aeration tube. Each pot contained 1.6 l of solution. The solution contained 50% Pellet and Roberts's solution with a low level of N (3 ppm) substituted for the normal N concentration. During the experimental period, KNO_3 was added to maintain the desired N level by spectrophotometer (Beckman DU-65) at 210 nm. Desired solution level was maintained with distilled water to replace water lost through evapotranspiration. Solution pH was adjusted between 5.5 to 6.5 (pocket pH meter, Analytical Measurements Inc. Model 107) by addition of 0.5 N HCl. Solutions were renewed every wk after the first 2 wks since the nutrient uptake rate was slow.

Data Collection and Analysis

Plants were harvested after four wks. The dry matter in shoots and roots were dried separately in an oven at 80°C for 72 hrs. Sample tissues were kept in the oven before grinding. All samples were ground to pass a 40 mesh screen with a Wiley-Thomas Mill grinder. The ground tissue was used to measure tissue N by Micro-kjeldahl method (Cataldo et al., 1974).

Treatments and Experimental Design

Two experiments (EXP1 and EXP2) were conducted in the greenhouse in December, 1993 and February, 1994. In EXP2, N was adjusted to its desired level twice each day after two weeks, and pots were rotated once per wk. A complete randomized design with five replications of each cultivar was used in both experiments. The cultivars evaluated are shown in Table 1. High pressure sodium vapor lights were applied at a 14/10, day/night photoperiod. Light intensity from lamps ranged from 600 μmol m^{-2} s^{-1} in the middle of the bench to 290 μmol m^{-2} s^{-1} at the edges for the EXP1 and 400 μmol m^{-2} s^{-1} in the middle of the bench to 190 μmol m^{-2} s^{-1} at the edges for the EXP2 (measured by Li-1776 solar monitor, Li-Cor Instruments, Inc.) Data were subjected to an analysis of variance. Significant differences among cultivars were evaluated using Fisher's protected least significant difference (LSD) test.

RESULTS

Experiment 1 (EXP1)

There were significant differences in root dry weight (RDW), shoot dry weight (SDW), and whole plant dry weight (WPDW) among the 14 cultivars (Table 2). The proportion of WPDW partitioned to the shoots was generally higher than partitioned to the roots. 'Lopez' had a SDW:RDW ratio significantly higher than all the other cultivars, except 'National'.

There were significant differences in plant tissue RN, SN and WPN content, NUE, and RAE among the 14 cultivars (Table 3). RN content indicated that 'Bardot' accumulated the most N among all the cultivars, while 'Forbes' and 'Egmont' accumulated less WPN than the other cultivars. This might have been one of the reasons that 'Bardot' produced significantly more RDW than the other cultivars. The proportion of whole plant total N partitioned to shoots was higher than partitioned to roots in each cultivar.

On a whole plant basis, 'Egmont' had the highest NUE, with the exception of 'Carmen'. There were no significant differences in RAE among the cultivars.

TABLE 2. Root dry weight (RDW), shoot dry weight (SDW), and whole plant dry weight (WPDW) accumulation and partitioning 14 bentgrass cultivars in EXP1 and EXP2.

Cultivars	EXP1						EXP2					
	RDW		SDW		WPDW		RDW		SDW		WPDW	
	mg	%[†]	mg	%	mg	S/R[‡]	mg	%	mg	%	mg	S/R
BR1518	1.48	38.8	2.32	61.2	3.81	1.61	0.81	36.0	1.34	64.0	2.22	1.75
Allure	1.21	41.2	1.73	58.8	2.94	1.51	0.73	33.0	1.48	67.0	2.21	2.09
Egmont	1.60	44.8	1.97	55.2	3.57	1.42	1.22	39.0	1.91	61.0	3.13	1.66
Bardot	1.96	41.7	2.74	58.3	4.70	1.42	1.20	37.5	2.00	62.5	3.20	1.71
National	0.95	25.6	2.77	74.4	3.71	3.35	0.83	22.9	2.79	77.1	3.62	3.59
Lopez	1.01	23.8	3.23	76.2	4.24	4.60	1.12	28.1	2.86	71.9	3.98	3.27
SR1020	1.18	27.4	3.13	72.6	4.31	2.67	1.03	25.4	3.01	74.6	4.05	3.00
Putter	1.24	30.5	2.83	69.5	4.06	2.30	0.73	10.2	3.38	89.8	4.11	5.59
Regent	1.45	27.5	3.83	72.5	5.28	2.68	1.06	23.9	3.37	76.1	4.44	2.75
Penneagle	1.46	26.8	4.00	73.2	5.45	2.83	1.04	23.0	3.48	77.0	4.52	3.52
Carmen	1.58	30.8	3.55	69.2	5.13	2.27	1.15	25.2	3.42	74.8	4.56	3.20
Forbes	0.77	30.0	1.79	70.0	2.57	2.50	1.33	28.9	3.27	71.1	4.60	2.48
Providence	1.34	26.7	3.68	73.3	5.02	2.75	1.15	23.6	3.74	76.4	4.88	3.27
Penncross	1.33	30.2	3.07	69.8	4.40	2.34	1.31	25.7	3.78	74.3	5.09	2.98
$LSD_{0.05}$	0.41		0.67		0.91	1.58	0.33		0.38		0.59	1.18

[†] Percent of RDW, SDW, and WPDW.
[‡] RDW + SDW.

Experiment 2 (EXP2)

There were significant differences among the 14 cultivars in RDW, SDW, and WPDW (Table 2). 'Penncross' had the highest SDW, but was statistically the same has 'Penneagle', 'Carmen', 'Forbes' and 'Providence'. 'Penncross' also had the highest WPDW, but was statistically the same has 'Penneagle', 'Carmen' 'Forbes' and 'Providence'. The proportion of WPDW partitioned to shoots was generally higher than that partitioned to roots. 'Putter' had a S/R ratio that was significantly highest among the cultivars. The bunch-type cultivars had relatively lower S/R ratios than the creeping-type cultivars due to their relatively lower SDW.

There were significant differences in RN, SN, WPN content, NUE, and RAE among the 14 cultivars (Table 3). N content of shoots indicated that 'BR1518' and 'Allure' accumulated significantly less SN man the other cultivars. From a whole plant basis, 'Penncross' accumulated the highest WPN accompanied with the highest WPDW. The

TABLE 3. Root N (RN), shoot N (SN), and whole plant N (WPN) accumulation and partitioning, and N utilization efficiency (NUE) and root absorption efficiency (RAE) of bentgrass cultivars in EXP1 and EXP2.

Cultivars	EXP1							EXP2						
	RN		SN		WPN	NUE[†]	RAE[‡]	RN		SN		WPN	NUE	RAE
	mg	%	mg	%	mg	mg	%	mg	%	mg	%	mg	mg	%
BR1518	28.68	20.1	113.13	79.9	141.82	26.95	26.47	14.80	27.8	38.24	72.2	53.04	43.74	26.87
Allure	26.62	23.7	85.43	76.3	112.05	25.67	42.05	17.51	30.9	39.07	69.1	56.58	42.74	31.14
Egmont	26.73	30.1	63.20	69.9	89.93	40.37	22.76	16.93	26.3	47.34	73.7	64.28	45.90	19.99
Bardot	37.48	25.6	112.39	74.4	149.87	31.23	16.51	14.80	22.2	51.62	77.8	66.42	45.89	19.94
National	18.77	17.0	91.15	83.0	109.92	33.52	60.66	16.76	24.5	52.23	75.5	68.99	55.60	23.06
Lopez	21.70	13.7	134.34	86.3	156.05	27.17	50.59	14.15	19.6	58.36	80.4	72.50	53.78	18.88
SR1020	23.70	15.6	129.00	84.4	152.70	28.39	30.84	15.84	22.7	54.21	77.3	70.05	57.54	17.85
Putter	27.52	20.3	108.26	79.7	135.78	26.91	27.26	15.15	19.4	63.44	80.6	78.58	55.79	28.63
Regent	28.32	17.7	132.50	82.3	160.82	32.72	22.09	14.26	20.5	55.69	79.5	69.95	63.30	15.65
Penneagle	29.12	17.2	139.84	82.8	168.96	32.12	23.55	14.19	18.9	61.40	81.1	75.59	59.89	17.40
Carmen	28.76	21.1	108.69	78.9	137.45	37.85	24.63	16.34	23.3	57.82	76.7	74.16	62.92	15.38
Forbes	18.32	18.7	80.20	81.3	98.50	26.16	58.99	13.57	17.7	62.99	82.3	76.55	56.86	14.38
Providence	24.75	15.5	141.11	84.5	165.86	31.67	24.63	16.21	20.6	62.41	79.4	78.63	60.49	15.22
Penncross	29.01	19.2	122.61	80.8	151.52	29.09	27.52	15.13	17.4	71.98	82.6	87.10	55.99	15.72
$LSD_{0.05}$	6.60		23.03		8.02	6.64		2.65		8.50		8.57	9.18	7.76

[†] NUE = WPDW/WPN.
[‡] RAE = WPN/mg root dry weight.

proportion of WPN partitioned to shoots was higher than to roots in each cultivar. On a whole plant basis, none of the bunch-type cultivars were as efficient in utilizing N (NUE) as any of the creeping-type cultivars. RAE was significantly higher in 'Allure', 'Putter' and 'BR1518' than all the other cultivars. The RAE value of the cultivars were not a response to the NUE, just as the results of EXP1.

DISCUSSION

The overall WPDW, WPN, NUE, and RAE production in EXP2 was lower than EXP1 because the cultivars were grown under a different set of conditions including greenhouse lamps (different bench in greenhouse) that provided less light. Another reason was on the initial size of the seedlings. Larger seedlings were chosen for EXP1 than the seedlings used in EXP2. The average RDW and SDW was 17.0 mg and 46.9 mg for EXP1, respectively. However, in EXP2 the average RDW and SDW was 5.4 mg and 13.8 mg, respectively.

In EXP1 the NUE did not completely correlate to dry matter production because the N depletion was very rapid after the second wk. At that time the N level was only maintained once a day. N uptake and utilization might have been influenced by the light gradient. In order to overcome this obstacle, N was brought to a desired level twice a day. Pots were also rotated every wk in the EXP2. The results of EXP2 were more consistent. The differences in NUE among cultivars was similar to the difference in WPDW in EXP1. Generally the bunch-type cultivars had lower SDW, WPDW, S/R ratio, SN, WPN, and NUE than creeping-type cultivars. The RAE values of the cultivars were not a response to the NUE, so the RAE was probably not a critical factor in genotypic differences in NUE. This agrees with Swiader et al. (1994), who found the same results in pumpkin hybrids. Other factors such as N assimilatory capacity may be more important in the regulation of N utilization.

Some low NUE cultivars, such as bunch-types bentgrass, may not be efficient in the absorption, translocation, assimilation, and redistribution of N. High NUE cultivars can grow under the conditions of N deficiency. Golf course managers may fertilize these cultivars too much. The low NUE cultivars may not be good N assimilators. Solution systems may be used as an effective means of evaluating creeping bentgrass cultivars for their NUE. However, additional NUE evaluations should be conducted under field conditions.

REFERENCES

Agnew, M.L. 1992. Natural organic nitrogen sources. Golf Course Management March:70-75.

Bertauski, A.F. 1993. M.S. thesis. University of Illinois.

Cataldo, D.A., L.E. Schrader, and V.L. Youngs. 1974. Analysis by digestion and colorimetric assay of total nitrogen in plant tissues high in nitrate. Crop Sci. 14:854-856.

De Datta, S.K., and F.E. Broadbent. 1988. Methodology for evaluating nitrogen utilization efficiency by rice genotypes. Agron. J. 80:793-798.

Geron, C.A., T.K. Danneberger, S.J. Traina, T.J. Logan, and J.R. Street. 1993. The effects of establishment methods and fertilization practices on nitrate leaching from turfgrass. J. Environ. Qual. 22:119-125.

Howard, H.F., and T.L. Watschke. 1984. Hydroponic culture of grass plants for physiological experiments. Crop Sci. 24:991-992.

Kolek, J., and V. Kozinka. 1991. The root as an integral part of the plant. p. 8. In: Physiology of The Plant Root System. Kluker Academic Publishers. Boston, MA.

Moll, R.H., E.J. Kamprath, and W.A. Jackson. 1982. Analysis and interpretation of factors which contribute to efficiency of nitrogen utilization. Agron. J. 74:562-564.
Pellett, R.M., and E.C. Roberts. 1963. Effects of mineral nutrition on high temperature induced growth retardation of Kentucky bluegrass. Agron. J. 55:474-476.
Sander, D.H., W.H. Allaway, and R.D. Olsen. 1987. Modification of nutritional quality by environment and production practices. pp. 45-82. In: Nutritional Quality of Cereal Grains. Eds: Olsen, R.D., and K.Z. Frey. Amer. Sci. Agron. Monograph. No. 28. Madison, WI.
Swiader, J.M., Y. Chyan, and F.G. Freiji. 1994. Genotypic differences in nitrate uptake and utilization efficiency in pumpkin hybrids. J. Plant Nutri. 17:1687-1699.
Turgeon, A.J. 1998. Turfgrass Management. 5th Edition, Prentice-Hall Inc., Englewood Cliff, NY.