Effects of experimental micronutrient product on nutrient uptake and shoot and root growth of Kentucky bluegrass (*Poa pratensis*) and creeping bentgrass (*Agrostis stolonifera*) grown in sand and soil rootzones

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The objective of this research project was to compare the effects of the sponsor's micronutrient product on nutrient uptake and root and shoot growth of established Kentucky bluegrass and creeping bentgrass.

Data collected included:

1. turf performance (color and quality) estimated visually and by canopy reflectance (chlorophyll index) measurement
2. rate of growth of shoot system
3. total root system growth
4. tissue nutrients in shoot systems.

MATERIALS/METHODS

The experimental design was 2 species x 3 rootzones x 9 nutrient treatments, for a total of 27 treatments (Table 1). The rootzone types were USGA standard non-calcareous sand and a soil/sand mixture (80% non-calcareous USGA sand, 20% native sandy loam soil v:v). Each treatment was replicated 5 times in 10 x 10 cm plastic pots filled to the rim (approx. 0.5 litre) with rootzone. Seeding rates were 17 g m^{-2} for the "America" Kentucky bluegrass and 8.5 g m^{-2} for the "L-93" creeping bentgrass. Pots were seeded Aug 26, 2009 and placed in a randomized complete block layout in the greenhouses at the Bovey Bldg., University of Guelph (Figure 1).

Pots were kept moist until germination began, and thereafter were irrigated to prevent stress. Fertilization was a standard turf maintenance regime (N-P-K 4:1:2 ratio supplied at an annualized rate of 10 or 20 g actual N m^{-2}), except for treatments with no NPK fertility. Germination and establishment (cover development) as well as color were assessed with the Spectrum CM1000 chlorophyll meter (25 dates between Sep 21 and Dec 03). Pots were treated with all treatments on Oct 19 and Nov 30, and with the NPK component of all treatments on Nov 9 and Dec 22.

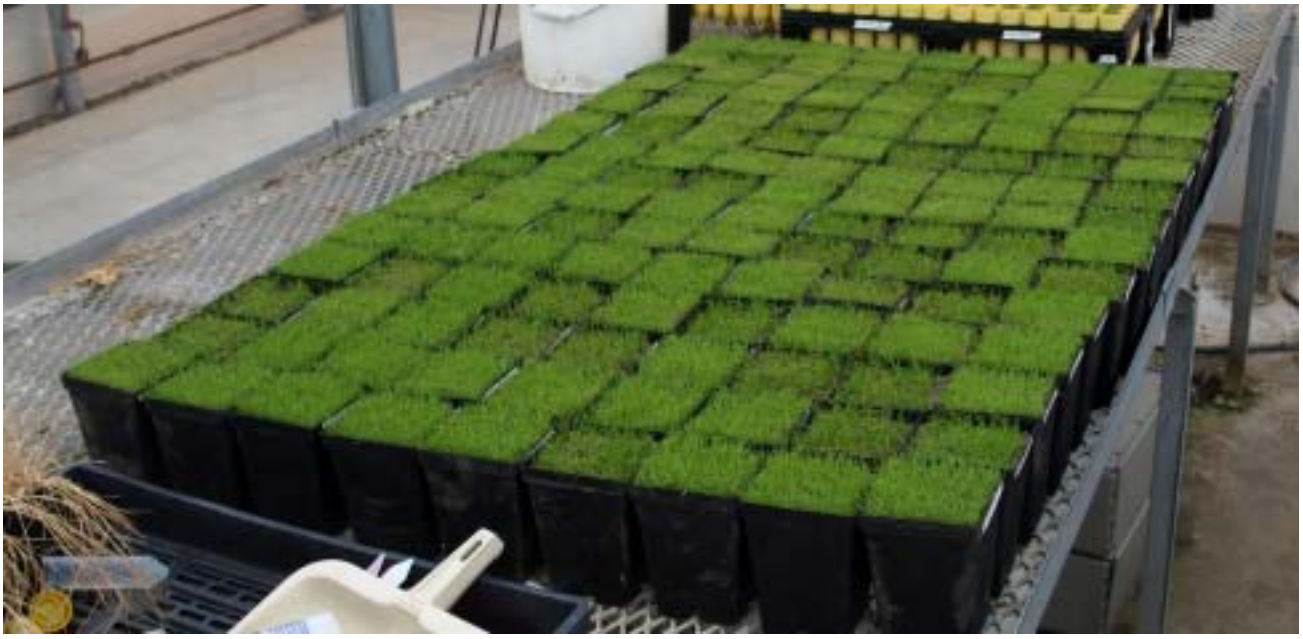

Figure 1. Experimental pots laid out in randomized complete block design: 45 days after seeding and 11 days before first treatment application.

Table 1. Treatments.

Treatment	Species	Rootzone	Nutrient treatment	Rate
1	Kentucky bluegrass	Soil	NPK + Solu-Cal S	20 g actual N m^{-2} y^{-1}
2	Kentucky bluegrass	Soil	NPK + Solu-Cal S	10 g actual N m^{-2} y^{-1}
3	Kentucky bluegrass	Soil	NPK + Liq Carboxy	20 g actual N m^{-2} y^{-1}
4	Kentucky bluegrass	Soil	NPK + Liq Carboxy	10 g actual N m^{-2} y^{-1}
5	Kentucky bluegrass	Soil	NPK	20 g actual N m^{-2} y^{-1}
6	Kentucky bluegrass	Soil	NPK	10 g actual N m^{-2} y^{-1}
7	Kentucky bluegrass	Soil	Solu-Cal S	—
8	Kentucky bluegrass	Soil	Liq Carboxy	—
9	Kentucky bluegrass	Soil	No added nutrients	—
10	Creeping bentgrass	Soil	NPK + Solu-Cal S	20 g actual N m^{-2} y^{-1}
11	Creeping bentgrass	Soil	NPK + Solu-Cal S	10 g actual N m^{-2} y^{-1}
12	Creeping bentgrass	Soil	NPK + Liq Carboxy	20 g actual N m^{-2} y^{-1}
13	Creeping bentgrass	Soil	NPK + Liq Carboxy	10 g actual N m^{-2} y^{-1}
14	Creeping bentgrass	Soil	NPK	20 g actual N m^{-2} y^{-1}
15	Creeping bentgrass	Soil	NPK	10 g actual N m^{-2} y^{-1}
16	Creeping bentgrass	Soil	Solu-Cal S	—
17	Creeping bentgrass	Soil	Liq Carboxy	—
18	Creeping bentgrass	Soil	No added nutrients	—
19	Creeping bentgrass	USGA sand	NPK + Solu-Cal S	20 g actual N m^{-2} y^{-1}
20	Creeping bentgrass	USGA sand	NPK + Solu-Cal S	10 g actual N m^{-2} y^{-1}
21	Creeping bentgrass	USGA sand	NPK + Liq Carboxy	20 g actual N m^{-2} y^{-1}
22	Creeping bentgrass	USGA sand	NPK + Liq Carboxy	10 g actual N m^{-2} y^{-1}
23	Creeping bentgrass	USGA sand	NPK	20 g actual N m^{-2} y^{-1}
24	Creeping bentgrass	USGA sand	NPK	10 g actual N m^{-2} y^{-1}
25	Creeping bentgrass	USGA sand	Solu-Cal S	—
26	Creeping bentgrass	USGA sand	Liq Carboxy	—
27	Creeping bentgrass	USGA sand	No added nutrients	—

Plant leaf tissue was collected about every 10 days beginning Oct 30 as the plants were clipped to 20 mm height. Leaf tissue was dried and weighed to determine shoot growth rates.

At the end of the experiment, replicates were analyzed for rootzone growth. Plants were removed from the pots, root systems washed free of soil, and rootzone length and fresh weight were measured. The root systems were then dried at 60°C for 48 hours and dry weight recorded.

An anecdotal photographic record of the experiment was kept.

All measurements were analyzed by appropriate statistical analyses (general linear models).

RESULTS

Canopy reflectance: germination and cover establishment. There were differences between the species x rootzone combinations 4 weeks (Sep 21) and 2 weeks (Oct 5) prior to treatment, which reflected differences in cover development (Kentucky bluegrass had a less dense canopy than creeping bentgrass) and turf growth status (creeping bentgrass on the USGA sand had slightly higher chlorophyll index values than on the soil rootzone) (Table 2, Figure 2).

Canopy reflectance: treatment effects. Once the fertility treatments began (Oct. 19), treatment effect began to be evident in addition to the species x rootzone effects. The NPK rate effect was apparent by 4 days after the first treatment (Oct. 23), and remained so until the end of the experiment (Table 2). The pattern of effects, which was consistent across the trial, was the

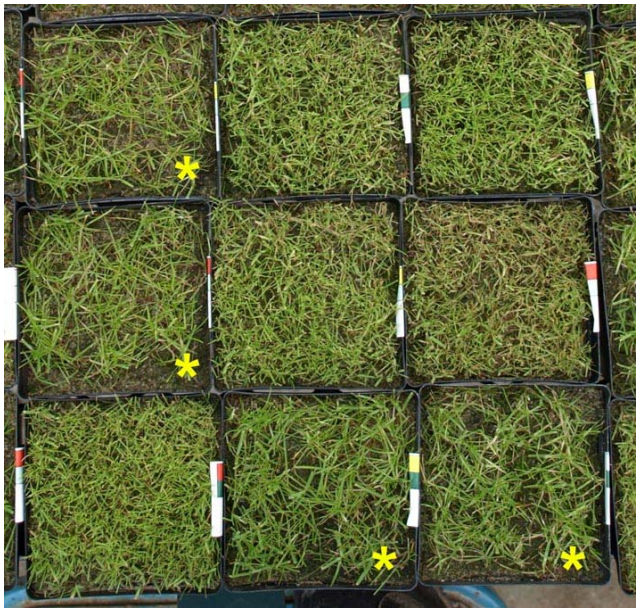

Figure 2. Typical cover development in Kentucky bluegrass pots (asterisks) and creeping bentgrass pots prior to treatment application.

Table 2. Effects of treatments on canopy reflectance measured by chlorophyll index.

Treatment main effect	09/21	10/05	10/19	10/20	10/21	10/23	10/24	10/26
Species*Rootzone								
CB Soil	239.9 b[1]	141.9 b	110.0 a	115.5 a	124.6 a	145.6 a	140.6 a	166.2 a
CB USGA	259.7 a	146.2 a	104.4 b	109.0 b	113.3 b	132.2 c	129.6 c	152.7 b
KB Soil	192.7 c	136.6 c	109.5 a	116.9 a	125.5 a	138.6 b	134.5 b	154.9 b
NPK fertility								
0	233.4	139.7 b	108.1 a	112.2 b	118.3 b	125.7 c	117.1 c	126.5 c
1	231.1	139.7 b	106.7 b	113.7 b	122.2 a	142.2 b	140.1 b	166.0 b
2	227.8	145.4 a	109.1 a	115.5 a	122.9 a	148.5 a	147.4 a	181.3 a
Amendment								
Carboxy	233.8	144.4 a	107.7	113.6	120.6 ab	140.0	138.0 a	165.1 a
None	227.3	139.8 b	108.2	113.7	119.9 b	138.8	132.4 b	153.0 b
Solu-cal S	231.2	140.5 b	108.1	114.1	122.9 a	137.6	134.2 b	155.7 b
msd p=0.05	7.6	3.2	1.4	1.5	2.4	3.6	2.1	2.8

	10/27	10/28	10/30	11/02	11/03	11/04	11/09	11/15
Species*Rootzone								
CB Soil	184.5 a	203.8 a	160.9 a	170.9 a	174.0 a	169.5 a	141.7 a	194.0 a
CB USGA	172.0 b	187.4 b	155.1 b	161.6 b	165.9 b	161.6 b	133.4 c	182.1 b
KB Soil	167.9 c	182.4 c	155.0 b	161.2 b	162.4 b	157.6 c	136.4 b	173.7 c
NPK fertility								
0	130.1 c	137.1 c	129.3 c	128.8 c	128.4 c	123.5 c	115.6 c	126.2 c
1	183.7 b	202.7 b	166.2 b	173.7 b	174.7 b	170.0 b	142.7 b	193.8 b
2	210.7 a	233.7 a	175.5 a	191.3 a	199.3 a	195.2 a	153.1 a	229.8 a
Amendment								
Carboxy	183.7 a	201.7 a	162.5 a	171.7 a	176.4 a	170.5 a	141.1 a	188.2 a
None	168.3 c	183.0 c	154.8 b	158.9 c	161.1 b	157.9 b	134.2 b	179.3 b
Solu-cal S	172.5 b	188.8 b	153.7 b	163.2 b	164.9 b	160.3 b	136.1 b	182.4 b
msd p=0.05	3.6	3.8	2.7	3.2	3.9	2.8	2.4	4.3

	11/16	11/20	11/23	11/24	11/25	11/26	11/27	11/30
Species*Rootzone								
CB Soil	193.9 a	161.9 a	174.9 a	194.5 a	206.0 a	205.0 a	198.8 a	201.3 a
CB USGA	189.9 b	156.6 b	168.2 b	187.8 b	195.5 b	193.6 b	187.7 b	191.7 b
KB Soil	173.6 c	153.0 c	162.5 c	180.5 c	185.5 c	186.8 c	179.7 c	187.8 c
NPK fertility								
0	121.3 c	117.0 c	118.5 c	130.6 c	133.6 c	135.0 c	129.8 c	130.4 c
1	196.5 b	172.0 b	182.4 b	203.2 b	211.4 b	207.6 b	202.1 b	208.5 b
2	239.6 a	182.6 a	204.6 a	228.9 a	242.1 a	242.8 a	234.3 a	241.9 a
Amendment								
Carboxy	191.3 a	159.1 a	170.6 a	191.6 a	193.5	199.1 a	191.2 a	195.6 a
None	182.8 b	153.9 b	165.8 b	185.5 b	194.3	189.6 b	184.6 b	189.7 b
Solu-cal S	183.4 b	158.4 a	169.1 ab	185.7 b	199.3	196.7 a	190.4 a	195.5 a
msd p=0.05	3.1	3.4	3.5	5.2	7.0	4.8	3.3	3.4

[1] Means of 225 readings (5 readings per pot x 5 replicates x 6 pots). Means within a column followed by the same letter are not significantly different (Tukey's HSD, p=0.05).

strong NPK rate effect to be combined with a slight increase in canopy reflectance in pots treated with liquid carboxy. The Solu-cal treated pots were not significantly different from the posts without micronutrients on most dates. The effect can be seen best if the canopy reflectance values are corrected against the controls, and plotted as change in cholorophyll index following treatment (Figure 3).

Shoot growth. The pattern of shoot dry matter accumulation as measured by clippings collected was very similar to the canopy reflectance (Table 3). Because the turf in pots with no added NPK was starting to decline (Figure 4), and we were concerned that we would lose root system information, these pots were harvested after the second treatment application date (Nov. 30). Pots receiving NPK treatments were treated a further

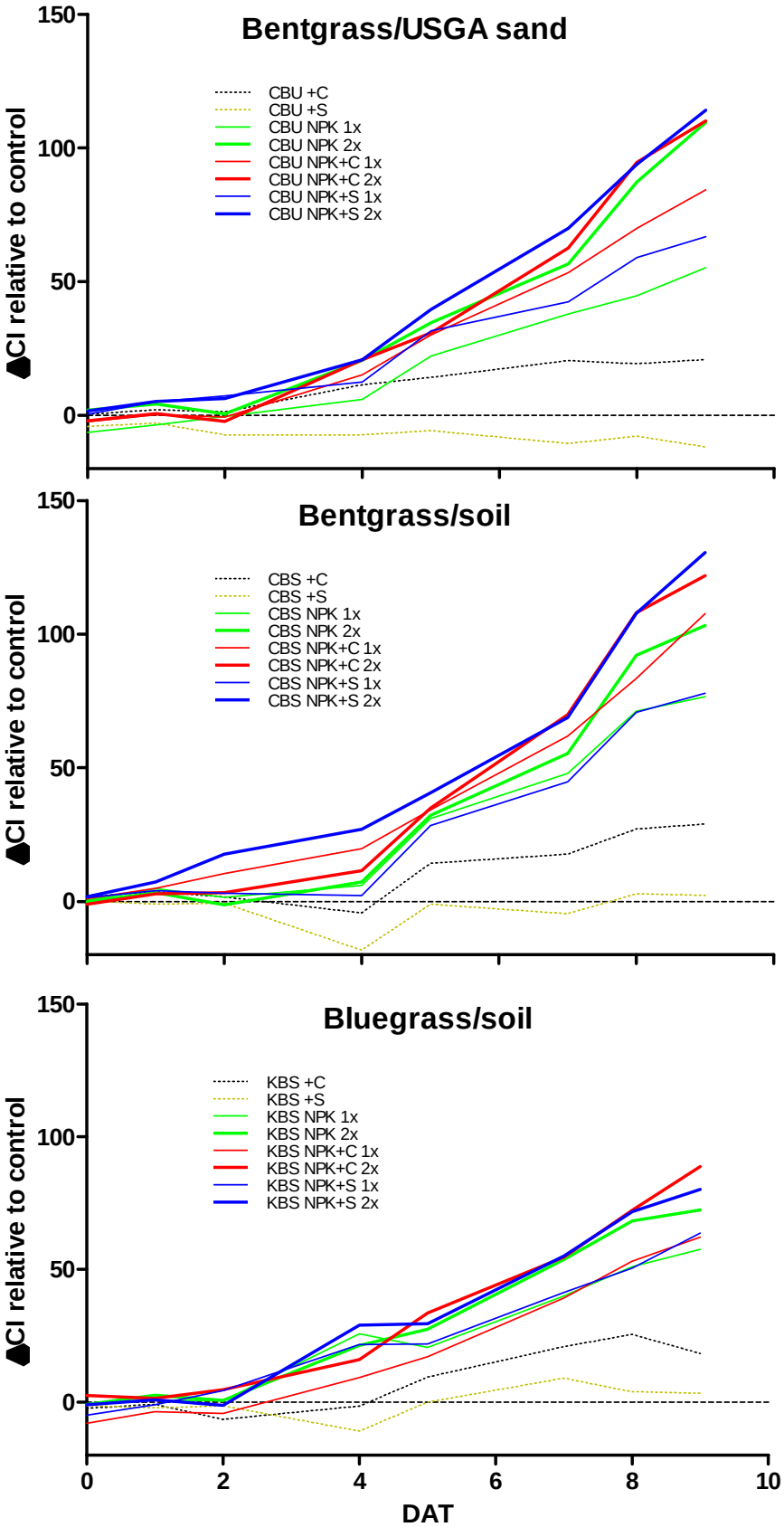

Figure 3. Change in canopy reflectance over time in treated pots. Means are corrected to zero values of the untreated control pots. C=liquid carboxy, S=Solu-cal. Four post-treatment periods are combined in this figure.

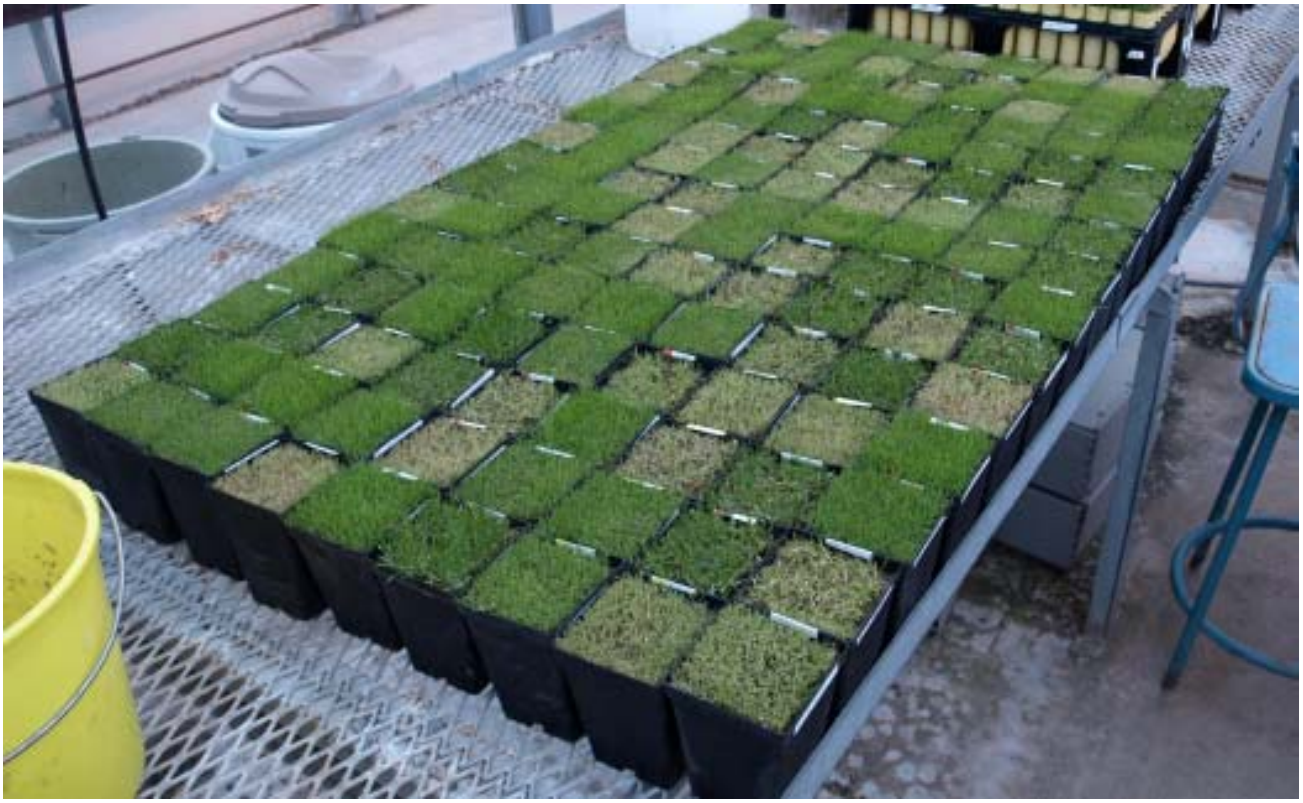

Figure 4. Experimental pots on Nov. 23: pots with no NPK added are clearly declining. These treatments were harvested on Nov. 30.

Table 3. Treatment effects on shoot and root dry matter accumulation.

Treatment main effect	10/30	11/09	11/19	11/30	12/15		01/07	
Species*Rootzone	Shoot growth (g)						Roots (g)	Root:shoot ratio
CB Soil	0.124 a[1]	0.115 ab	0.146 a	0.151 ab	0.270 b	1.093 a	0.998 b	0.941 b
CB USGA	0.111 b	0.125 a	0.146 a	0.161 a	0.328 a	1.149 a	1.393 a	1.177 a
KB Soil	0.099 c	0.113 b	0.122 b	0.145 b	0.231 c	0.679 b	0.672 c	0.874 b
NPK fertility								
0	0.041 c	0.046 c	0.030 c	—	—	—	0.932 b	1.832 a
1	0.122 b	0.123 b	0.141 b	0.116 b	0.216 b	0.852 b	1.172 a	0.737 b
2	0.171 a	0.184 a	0.244 a	0.188 a	0.336 a	1.096 a	0.959 b	0.422 c
msd p=0.05				0.009	0.011	0.042		
Amendment								
Carboxy	0.121 a	0.131 a	0.144	0.155	0.289 a	0.938 b	1.076 a	0.997 ab
None	0.103 b	0.114 b	0.133	0.152	0.265 b	0.956 b	1.028 ab	1.066 a
Solu-cal S	0.110 b	0.109 b	0.137	0.149	0.274 ab	1.027 a	0.959 b	0.928 b
msd p=0.05	0.008	0.011	0.015	0.014	0.016	0.061	0.096	0.131

[1] Means of 5 pots. Means within a column followed by the same letter are not significantly different (Tukey's HSD, p=0.05).

two times, and clippings collected until harvest. The shoot growth was also strongly positively correlated with canopy reflectance (Figure 5).

Root growth. Treatment effects on root growth were less pronounced than on shoot growth, though there were significant effects (Table 3). The high and low NPK levels had reduced root systems compared to the medium level, but root:shoot ratios were mostly influenced by differences in shoot growth.

Shoot tissue analyses. The addition of the amendments had the greatest effect on the creeping bentgrass that was grown on the sand (Table 4, 5). Solu-Cal S increased the amount of calcium present in the tissue, although this effect was not observed in the Kentucky bluegrass that was grown on soil most probably because the soil contained a significant amount of calcium (Table

Table 4. Macro-nutrient tissue concentration of bentgrass grown in sand and bluegrass grown on soil

Species	Amendment	Total N	P	K
Bentgrass	Carboxy	4.373	0.6739 A	3.252
	None	4.113	0.6143 B	3.096
	Solu-Cal S	4.036	0.5756 B	3.142
Significance		NS	*	NS
Bluegrass	Carboxy	4.412	0.5874 A	3.472
	None	4.107	0.5801 AB	3.432
	Solu-Cal S	4.199	0.5611 B	3.507
Significance		NS	**	NS

* Significance at 0.05
** Significance at 0.01

Table 5. Micro-nutrient tissue concentration of bentgrass grown in sand and bluegrass grown on soil

Species	Amendment	Mg	Ca	Cu	Zn	Mn	B	Fe
Bentgrass	Carboxy	0.3639	0.6252 B	22.7 A	57.1	244.0	19.9	92.5 A
	None	0.3738	0.5981 B	19.8 B	50.0	201.0	20.9	85.3 B
	Solu-Cal S	0.3507	0.6983 A	19.3 B	48.7	263.0	21.0	83.1 B
Significance		NS	*	*	NS	NS	NS	*
Bluegrass	Carboxy	0.3275	0.5087	23.3	54.2	52.7	14.9	74.8
	None	0.3211	0.521	23.7	52.5	52.7	15.2	97.5
	Solu-Cal S	0.3121	0.5311	23.2	52.4	51.2	14.6	78.8
Significance		NS	NS	NS	NS	NS	NS	NS

* Significance at 0.05

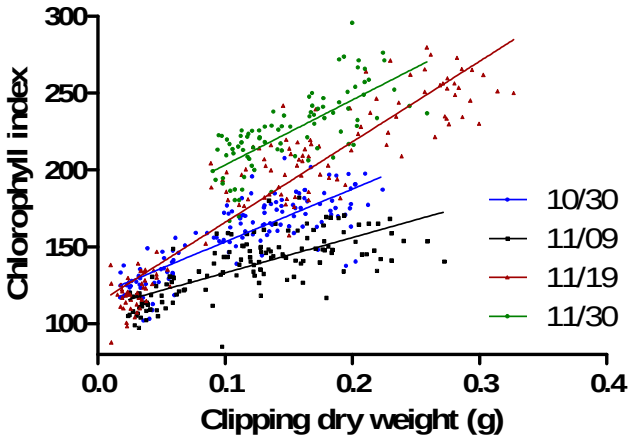

Figure 5. Association between canopy reflectance (chlorophyll index) and shoot dry matter accumulation on clipping dates. Pearson correlation coefficients are: 0.83 (10/30; 0.73 (11/09); 0.93 (11/19); 0.73 (11/30).

5). While calcium can be limiting in some turfgrass systems calcium defidiency and therefore growth responses due to calcium are rare in the field.

Carboxy on the other had an effect the tissue concentration of a number of nutrients in the creeping bentgrass grown on sand, including the macro-nutrient phosphorus and an important nutrient for turfgrass color, iron (Table 4, 5). The Carboxy treatment had increased the uptake of nutrients that are often limiting when grown on non-soil media such as sand. In Kentucky bluegrass grown in soil Carboxy appeared to have an effect on phosphorus uptake (P = O.0506) (Table 4). The lack of differences in the soil grown plots is most likely due to the presence of these nutrients in soil making the effects of the Carboxy.

DISCUSSION AND CONCLUSIONS

Both species x rootzone combination and NPK fertility rates had a significant effect on shoot growth, and a slightly smaller effect on root growth. The two creeping bentgrass treatments had more shoot and root growth than the Kentucky bluegrass, and higher chlorophyll index readings. The NPK fertility treatments showed a typical rate effect, with more shoot growth and higher chlorophyll index values at higher rates.

Generally, the liquid Carboxy treatments showed a slight increase in chlorophyll index and both shoot and root growth compared to the other two treatments. Solu-Cal S treatments were not different from the untreated control.

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