EVALUATION OF THE PERFORMANCE OF HUMIC ACID PRODUCTS IN TURFGRASS MANAGEMENT

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Sponsor:**Luscar Ltd.**

OBJECTIVE

The purposes of this project were to 1) determine the effects on turfgrass performance of various humic acid products applied with a regular turfgrass nutrition program and 2) determine differences between granular and liquid formulations of humic acid products with respect to turfgrass performance.

The project tested several humic acid products at sponsor recommended rates on creeping bentgrass fairway turf. Observations included visual estimates of turf performance (color, quality, uniformity, density) and instrumental measurements of turf color, measured weekly during the experiment, shoot growth rates (dry matter accumulation measured by clipping collection) before, at the midpoint and at the end of the experiment, root system growth measured by core collection and root system measurement at the beginning and end of growing season, soil micro and macronutrient analysis and leaf tissue analysis at the beginning, midpoint (leaf), and end of the experiment, and other stress responses as they occurred (weed, disease, etc.)

EXPERIMENTAL DESIGN / METHODS

The treatments consist of four humic acid materials, two liquid and two granular formulations as provided by the sponsor (Table 1). In addition to the humic acid treatments, there were three controls: a blank control (no treatment), a macronutrient control (N-P-K only) and a micronutrient control (NPK + Cu-Zn-Fe at levels present in the humic acid products). Treatments were applied to turf maintained with a normal N-P-K fertilization program (except for controls). Each treatment was replicated 5 times and applied to 1 x 4 m plots in a randomized complete block design. Plots were located on a creeping bentgrass research area at the Guelph Turfgrass Institute. The bentgrass turf was mowed at fairway height (11 mm) but received no herbicide or fungicide treatments. Irrigation was withheld during the second half of the trial in order to introduce drought stress, but natural precipitation prevented this from developing.

Rates and schedules for the humic acid products were as specified by the sponsor (Table 1). Rates and schedules for the micronutrient control were designed to match the micronutrient contrent of the humic acid treatments. Rates and schedule for the N-P-K fertilization were as for a typical fairway turf fertility program.

Liquid humic products were applied in a drench (7 l water m^{-2}). Equivalent amounts of water will be applied to controls and other treatments. Granular humic product #1 was mixed and applied with the granular fertilizer treatment (broadcast application). Granular humic product #2 was applied at the same time as the first fertilizer application.

Table 1. Treatments, rates and schedule for humic acid products trial.

Treatment		Rate (m^{-2})				
		May 1	June 1	July 1	August 1	Sept. 1
Control		-	-	-	-	-
Macronutrient control		5 g N (26-4-12)	5 g N (37-0-0)	2.5 g N (37-0-0)	2.5 g N (37-0-0)	5 g N (26-4-12)
Micronutrient control	N-P-K + Stock solution (0.06% Cu, 0.06% Zn, 0.1% Fe)	2 ml	0.5 ml	0.5 ml	0.5 ml	0.5 ml
Liquid humic product #1 (L155)	N-P-K +	2 ml	0.5 ml	0.5 ml	0.5 ml	0.5 ml
Liquid humic product #2 (L 168)	N-P-K +	2 ml	0.5 ml	0.5 ml	0.5 ml	0.5 ml
Granular humic product #1 (L 154)	N-P-K +	0.056 g	0.014 g	0.014 g	0.014 g	0.014 g
Granular humic product #2 (L 157)	N-P-K +	90 g	-	-	-	-

Turf color, quality, uniformity, and density were assessed visually and turf color by Minolta CR310 colorimeter. Visual assessments of color, quality, uniformity, and density, and instrumental color readings were recorded before treatment application, and then weekly for 18 weeks beginning in late May, 2000.

Clipping collection for yield (growth rate) and tissue content analysis (N, P, K, Ca, Mg, Zn, Cu, Mn, and B), was done prior to treatment application, at the mid point in the exeriment, and after the last treatment application. Mowing was withheld for 3-5 days prior to tissue collection, and tissue was sampled in a 0.85 m^2 subsample from each plot using a walk-behind greens mower. Tissue samples were oven-dried, weighed, and then submitted to Laboratory Services, University of Guelph, for elemental analysis.

Soil sampling and analysis (root system size, soil pH, Mg, P, K, Zn, Cu, Mn, and Fe) was done prior to treatment application and after the last treatment application. Four cores (2 cm Ø x 20 cm depth) were taken randomly from each plot for soil elemental content analysis and two further cores were sampled for root system measurements. Cores for soil analysis were pooled, air dried, and submitted to Laboratory Services, University of Guelph, for elemental analysis. Cores for root system measurements were washed free of soil and the root systems measured, air-dried, and weighed.

All data were analysed statistically for treatment main effects and interactions. Statistically significant differences between the humic acid treatments and the controls, particularly the micronutrient control, would be indicative of effects of humic acid on turf performance.

RESULTS

Turf performance - visual ratings

There were no significant differences among the treated plots for turf density, uniformity, quality, or color as rated visually (Table 2). By the end of the experiment all of the plots receiving N-P-K had significantly better ratings than the untreated check, but the differences among them were not significant. All of the ratings, including the untreated check, were well within acceptable range for fairway bentgrass turf.

Turf color - instrumental readings

The instrumental color readings indicated a similar pattern of response to the visual ratings (Table 3). All N-P-K treated plots were significantly darker and greener than the untreated check by the 3rd week of the experiment, but the differences among the treated plots were not significant. Lightness and hue angle are the most useful of the three instrumental color parameters, correlating well with visual ratings. The sensitivity of the colorimeter and the variable background of the turf resulted in treatment effects being detectable on fewer than half of the observation dates.

Turf shoot growth - clipping yield

As expected, there was increased shoot growth with N-P-K treatments, compared to the untreated check. There was no significant difference among the treatments (Table 4). No effect was detected of either micronutrients or humic acid treatments.

Tissue analysis

There were some significant patterns in tissue contents attributable to the treatments (Table 5). Macronutrients N and K were significantly higher in all the N-P-K treatments compared to the untreated control. P, Ca, and Mg were uniform across all treatments. Micronutrient content in the tissue was also significantly affected by treatments: Cu and Zn content was increased by all treatments, but particularly by the micronutrient control and the liquid humic treatment #2 (L168). Mn was increased in all treatments, but the differences from the untreated check were not significant. Of the treatments, the granular humic product (L157) and the liquid (L168) showed the largest increase in Mn. Boron content in the treated plots was significantly decreased compared to the untreated check at the midpoint in the experiment, but the absolute difference was small.

Root system

There were no significant treatment effects on the turf root systems, either root length or root mass (Table 6). There was a general decrease in root system length combined with an increase in root mass over the period of the experiment, which is typical of turfgrass root systems during the summer.

Soil analysis

There were changes in the soil analysis of macro- and micronutrients between the beginning and end of the experiment (a drop in P and Mn, an increase in K, Mg, and Fe), but there were no significant treatment effects (Table 7).

Table 2. Visual ratings of creeping bentgrass fairway turfgrass plots. Where lsd values are not given, differences among treatments were not significant.

Treatment																			
	Density																		
	05/25	**06/02**	**06/09**	**06/16**	**06/23**	**06/29**	**07/07**	**07/17**	**07/25**	**08/01**	**08/08**	**08/14**	**08/24**	**09/01**	**09/15**	**10/02**	**10/11**	**10/26**	**Mean**
Control	8.0[1]	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	7.0	7.2	7.4	7.2	7.8	8.0	7.2	7.8	7.2	7.71
Macronutrient Control	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.4	8.0	7.8	8.0	8.0	8.0	8.0	7.8	8.0	8.00
Micronutrient Control	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	7.8	8.0	8.0	8.0	8.0	8.0	8.0	7.99
Liquid #1 (L 155)	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.2	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.01
Liquid #2 (L 168)	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.2	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.01
Granular #1 (L 154)	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.2	8.0	7.8	8.0	8.0	8.0	8.0	8.0	8.0	8.00
Granular #2 (L 157)	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	7.8	8.0	8.0	8.0	8.0	8.0	8.0	7.99
lsd p=0.05										0.58	0.22		0.22			0.22		0.22	0.06
	Uniformity																		
	05/25	**06/02**	**06/09**	**06/16**	**06/23**	**06/29**	**07/07**	**07/17**	**07/25**	**08/01**	**08/08**	**08/14**	**08/24**	**09/01**	**09/15**	**10/02**	**10/11**	**10/26**	**Mean**
Control	6.0[2]	7.0	7.0	8.0	7.0	7.4	7.6	7.0	7.6	6.0	6.0	7.0	7.0	7.2	7.2	6.2	6.8	6.6	6.92
Macronutrient Control	6.0	7.0	7.0	8.0	7.0	7.2	7.2	7.0	7.8	6.0	6.6	7.2	7.8	7.8	7.8	7.6	7.6	7.2	7.21
Micronutrient Control	6.0	7.0	7.0	8.0	7.0	7.0	7.0	7.0	7.6	6.0	6.8	7.4	7.6	7.6	7.6	7.8	7.8	7.6	7.21
Liquid #1 (L 155)	6.0	7.0	7.0	8.0	7.0	7.0	7.6	7.0	7.8	6.0	6.8	7.4	7.8	7.6	7.6	7.6	7.6	7.0	7.21
Liquid #2 (L 168)	6.0	7.0	7.0	8.0	7.0	7.2	7.4	7.0	8.0	6.0	6.4	7.4	7.6	7.8	7.4	7.6	7.6	7.4	7.21
Granular #1 (L 154)	6.0	7.0	7.0	8.0	7.0	7.2	7.2	7.0	7.6	6.0	6.6	7.2	7.4	7.6	7.6	7.8	7.8	7.2	7.18
Granular #2 (L 157)	6.0	7.0	7.0	8.0	7.0	7.2	7.6	7.0	7.6	6.0	7.0	7.4	7.8	7.4	7.6	7.8	8.0	7.2	7.26
lsd p=0.05											0.56					0.64	0.60	0.60	0.19
	Quality																		
	05/25	**06/02**	**06/09**	**06/16**	**06/23**	**06/29**	**07/07**	**07/17**	**07/25**	**08/01**	**08/08**	**08/14**	**08/24**	**09/01**	**09/15**	**10/02**	**10/11**	**10/26**	**Mean**
Control	6.0[3]	7.0	7.0	7.0	7.0	7.0	6.8	7.0	7.0	5.4	6.0	6.8	7.0	7.0	7.0	6.6	6.8	6.8	6.73
Macronutrient Control	6.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	6.0	7.0	7.0	7.0	7.2	7.0	7.2	7.6	7.2	6.96
Micronutrient Control	6.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	6.0	6.8	7.4	7.2	7.0	7.0	7.2	7.6	7.8	7.00
Liquid #1 (L 155)	6.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	6.0	7.0	7.2	7.0	7.2	7.0	7.0	7.6	7.0	6.94
Liquid #2 (L 168)	6.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	6.0	7.0	7.2	7.2	7.2	7.0	7.6	7.6	7.4	7.01
Granular #1 (L 154)	6.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	6.0	6.8	7.0	7.0	7.0	7.2	7.2	7.6	7.4	6.96
Granular #2 (L 157)	6.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	6.0	7.0	7.2	7.0	7.0	7.0	7.2	7.6	7.2	6.96
lsd p=0.05										0.27	0.31							0.58	0.13
	Colour																		
	05/25	**06/02**	**06/09**	**06/16**	**06/23**	**06/29**	**07/07**	**07/17**	**07/25**	**08/01**	**08/08**	**08/14**	**08/24**	**09/01**	**09/15**	**10/02**	**10/11**	**10/26**	**Mean**
Control	7.0[4]	7.0	7.6	7.0	8.0	7.0	7.2	8.0	7.2	7.2	7.0	7.6	7.6	7.4	7.6	8.0	8.0	7.2	7.42
Macronutrient Control	7.0	7.0	7.8	7.0	8.0	7.8	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	7.81
Micronutrient Control	7.0	7.0	7.8	7.0	8.0	7.6	8.0	8.0	8.0	8.0	7.8	8.0	8.0	8.0	8.0	8.0	8.0	8.0	7.79
Liquid #1 (L 155)	7.0	7.0	7.8	7.0	8.0	7.8	7.8	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	7.80
Liquid #2 (L 168)	7.0	7.0	7.8	7.0	8.0	7.6	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	7.80
Granular #1 (L 154)	7.0	7.0	7.8	7.0	8.0	7.4	8.0	8.0	8.0	8.0	7.8	8.0	8.0	8.0	8.0	8.0	8.0	8.0	7.78
Granular #2 (L 157)	7.0	7.0	7.8	7.0	8.0	7.8	7.8	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	7.80
lsd p=0.05							0.38		0.22	0.22	0.31	0.27	0.27	0.27	0.27			0.22	0.12

[1] Visual rating 0 - 10, 0= bare soil, 5= acceptable density, 10 = highest density.
[2] Visual rating 0 - 10, 0= poorest, 5= acceptable uniformity, 10 = uniform turf.
[3] Visual rating 0 - 10, 0= poorest, 5= acceptable quality, 10 = highest quality (integrating color, uniformity and density).
[4] Visual rating 0 - 10, 0= yellow, 5= acceptable color, 10 = darkest green.

Table 3. Instrumental color readings on creeping bentgrass fairway plots. Where lsd values are not given, differences among treatments were not significant.

Lightness (L): 0 = black, 100 = white																	
	6/01	**6/09**	**6/16**	**6/23**	**7/04**	**7/11**	**7/19**	**7/24**	**8/02**	**8/08**	**8/15**	**8/24**	**8/30**	**9/13**	**9/25**	**10/12**	**Mean**
Control	39.6	37.2	36.8	38.0	37.9	36.2	35.6	34.8	38.8	33.7	34.6	33.1	37.1	34.0	36.6	34.4	36.1
Macronutrient Control	39.2	37.0	34.4	36.9	37.2	34.3	34.7	34.9	38.6	35.9	34.9	32.8	36.4	34.3	36.7	34.1	35.8
Micronutrient Control	38.7	36.3	34.7	37.0	35.6	34.9	33.5	35.5	38.6	33.6	36.0	33.0	37.3	34.8	37.5	34.1	35.7
Liquid #1 (L 155)	39.0	37.0	34.8	36.9	37.1	34.7	35.3	35.4	38.7	34.1	35.8	32.8	36.3	35.1	37.0	34.8	35.9
Liquid #2 (L 168)	38.9	36.8	34.5	37.4	36.7	34.5	34.8	35.7	39.1	35.2	35.4	33.0	36.7	34.2	37.4	34.3	35.9
Granular #1 (L 154)	39.2	36.8	35.3	37.0	36.7	34.5	34.4	36.1	38.7	33.5	35.9	32.8	37.1	34.1	34.6	34.8	35.7
Granular #2 (L 157)	39.0	36.9	35.3	37.1	37.0	35.2	35.0	35.9	38.7	33.7	36.3	33.2	36.9	34.9	37.1	34.5	36.1
Lsd p=0.005	0.44				1.17		1.13			1.22	1.01				1.48		
Chroma (C): 0 = grey, 60 = fully saturated																	
	6/01	**6/09**	**6/16**	**6/23**	**7/04**	**7/11**	**7/19**	**7/24**	**8/02**	**8/08**	**8/15**	**8/24**	**8/30**	**9/13**	**9/25**	**10/12**	**Mean**
Control	15.8	13.8	26.0	14.7	12.1	14.8	9.2	10.8	15.0	12.5	12.2	8.1	11.2	10.7	11.9	15.2	13.4
Macronutrient Control	15.8	12.9	14.9	13.4	11.3	13.8	9.8	10.1	15.4	15.2	12.5	7.9	11.9	12.6	13.9	15.7	12.9
Micronutrient Control	15.2	13.7	16.3	13.5	12.0	14.4	8.2	11.1	15.8	13.5	13.1	8.3	11.0	13.1	13.4	14.9	13.0
Liquid #1 (L 155)	15.3	14.3	15.7	14.2	11.7	14.6	9.3	10.6	15.6	13.9	13.8	8.4	12.2	12.8	13.3	15.5	13.2
Liquid #2 (L 168)	15.2	13.7	14.9	13.4	12.5	14.3	9.2	10.8	15.8	14.8	13.2	8.3	11.9	12.8	13.4	15.6	13.1
Granular #1 (L 154)	15.3	13.6	16.2	13.7	11.3	13.8	9.0	10.9	16.0	13.2	13.4	8.2	10.8	12.4	13.5	15.6	12.9
Granular #2 (L 157)	15.2	13.3	16.7	14.8	11.7	15.4	9.7	10.8	15.3	13.6	13.6	8.8	11.1	13.1	13.2	15.4	13.2
Lsd p=0.005	0.46			1.08						1.08	1.00			1.14			
Hue angle (H): in the observed range lower values are yellower, higher are greener																	
	6/01	**6/09**	**6/16**	**6/23**	**7/04**	**7/11**	**7/19**	**7/24**	**8/02**	**8/08**	**8/15**	**8/24**	**8/30**	**9/13**	**9/25**	**10/12**	**Mean**
Control	116.6	130.1	132.7	123.9	116.3	128.7	116.5	114.7	126.3	129.2	128.3	120.0	112.2	125.0	111.8	129.7	122.6
Macronutrient Control	117.7	129.3	132.4	125.8	119.1	133.0	119.0	115.7	128.8	128.3	132.8	126.7	124.2	131.9	122.1	132.6	126.2
Micronutrient Control	116.9	131.9	132.3	124.2	123.9	133.2	119.2	115.4	127.8	135.7	126.7	126.1	119.1	130.1	117.8	133.7	125.9
Liquid #1 (L 155)	116.9	131.4	130.3	126.4	119.5	133.7	117.6	107.9	129.3	135.6	128.0	128.6	125.3	130.6	120.8	131.6	125.8
Liquid #2 (L 168)	117.3	130.8	132.4	124.6	125.4	132.3	117.3	113.8	127.5	130.8	130.8	128.3	124.5	133.3	119.0	131.5	126.2
Granular #1 (L 154)	117.1	131.5	131.4	125.5	119.9	132.4	118.8	111.7	128.7	135.1	128.2	125.1	120.3	131.1	128.1	131.6	126.0
Granular #2 (L 157)	118.3	130.2	130.8	126.8	120.0	133.2	120.7	111.1	127.9	134.0	127.0	129.9	123.6	131.6	117.5	131.9	125.9
Lsd p=0.005	1.06			1.72		2.11				3.89	3.73			3.43			1.59

Table 4. Clipping dry weights (g m^{-2}) from treated plots at beginning, midpoint, and end of trial. No significant differences were noted among treatments.

Treatment	05/12	07/31	10/20
Control	12.34	4.53	7.82
Macronutrient Control	9.39	6.38	12.06
Micronutrient Control	8.71	4.60	10.21
Liquid #1 (L 155)	8.95	4.93	10.46
Liquid #2 (L 168)	7.66	6.99	11.68
Granular #1 (L 154)	9.23	5.42	10.91
Granular #2 (L 157)	7.48	5.84	11.34

Table 5. Tissue analysis: elemental content at beginning, middle and end of experiment. Where lsd values are not given, differences among treatments were not significant.

Treatment	N			P			K			Ca			Mg		
	0512	0731	1020	0512	0731	1020	0512	0731	1020	0512	0731	1020	0512	0731	1020
	%														
Control	4.29	4.20	4.38	0.42	0.55	0.45	2.52	2.84	2.25	0.92	0.84	0.65	0.29	0.35	0.29
Macronutrient Control	4.20	5.01	5.30	0.40	0.56	0.49	2.44	3.30	2.74	0.91	0.98	0.63	0.28	0.37	0.29
Micronutrient Control	4.05	5.03	5.34	0.38	0.56	0.48	2.39	3.22	2.78	0.90	0.76	0.60	0.28	0.37	0.28
Liquid #1 (L 155)	4.15	5.18	5.13	0.40	0.54	0.46	2.43	3.24	2.63	0.90	0.72	0.62	0.28	0.35	0.28
Liquid #2 (L 168)	4.09	5.17	5.28	0.38	0.55	0.48	2.36	3.35	2.70	0.93	0.71	0.65	0.28	0.35	0.30
Granular #1 (L 154)	4.11	5.23	5.31	0.40	0.55	0.47	2.37	3.27	2.85	0.86	0.73	0.63	0.27	0.35	0.30
Granular #2 (L 157)	4.06	4.81	5.28	0.37	0.56	0.48	2.36	3.31	2.87	0.89	0.75	0.62	0.28	0.36	0.30
lsd p=0.05		0.61	0.31						0.30						

	Cu			Zn			Mn			B		
	0512	0731	1020	0512	0731	1020	0512	0731	1020	0512	0731	1020
	mg kg^{-1}											
Control	11.6	11.2	11.0	38.2	36.8	43.0	91.8	110.6	131.0	26.8	14.6	21.0
Macronutrient Control	11.8	14.2	12.6	40.0	43.6	50.2	87.8	117.8	162.4	23.0	13.0	19.4
Micronutrient Control	11.2	14.6	15.2	38.8	52.2	55.0	92.0	110.2	159.0	25.2	13.0	19.6
Liquid #1 (L 155)	11.8	12.2	13.3	38.0	44.2	47.8	92.0	111.2	154.8	26.2	13.4	19.2
Liquid #2 (L 168)	11.0	14.0	14.0	37.8	50.0	58.0	90.2	105.4	172.2	26.2	12.2	20.8
Granular #1 (L 154)	11.6	12.8	12.4	37.4	46.8	49.8	91.4	107.5	159.0	23.6	12.4	20.2
Granular #2 (L 157)	10.8	12.2	13.2	36.6	44.4	50.6	95.6	120.6	178.4	25.6	13.0	19.6
lsd p=0.05			1.3		6.5	4.1					1.39	

Table 6. Root system size at beginning and end of experiment. No significant differences were noted among treatments.

Treatment	Length		Rating		Mass	
	05/15	10/20	05/15	10/20	05/15	10/20
Control	19.55[1]	17.00	5.20[2]	6.30	0.20[3]	0.40
Macronutrient Control	20.75	18.05	4.50	6.50	0.19	0.40
Micronutrient Control	21.05	17.20	5.50	5.40	0.21	0.28
Liquid #1 (L 155)	22.45	17.70	5.30	6.40	0.23	0.46
Liquid #2 (L 168)	20.95	16.80	5.10	5.70	0.29	0.35
Granular #1 (L 154)	20.85	19.65	4.80	5.70	0.22	0.38
Granular #2 (L 157)	20.60	17.40	4.60	5.60	0.21	0.32
lsd p=0.05	NS	NS	NS	NS	NS	NS

[1] Length (cm) of root system from bottom of thatch to end of the longest root.
[2] Root system size ranking (visual estimate) 0 - 10, 10 = largest root system.
[3] Mass (g) of dried root system

Table 7. Soil analysis: elemental content at beginning and end of experiment. No significant differences were noted among treatments.

Treatment	P		K		Mg		Zn		Mn	
	05/15	10/20	05/15	10/20	05/15	10/20	05/15	10/20	05/15	10/20
	mg L^{-1}									
Control	12.2	10.4	52.2	42.0	225.3	360.0	2.84	2.95	19.12	17.04
Macronutrient Control	12.6	11.4	59.2	43.8	290.8	359.2	2.95	2.93	19.90	15.92
Micronutrient Control	12.8	10.0	52.2	44.8	279.6	383.2	2.91	2.90	18.56	16.84
Liquid #1 (L 155)	12.2	10.6	55.6	43.0	283.6	352.8	2.76	2.94	18.28	17.46
Liquid #2 (L 168)	12.2	10.6	61.0	46.6	290.2	361.6	2.85	3.09	19.28	16.28
Granular #1 (L 154)	11.6	10.0	53.8	42.0	289.0	355.2	2.85	2.88	20.12	16.88
Granular #2 (L 157)	11.0	10.6	54.4	48.2	284.0	376.0	2.82	2.88	18.06	16.38
	Fe		Cu		S		pH			
	05/15	10/20	05/15	10/20	05/15	10/20	05/15	10/20		
	mg L^{-1}				%					
Control	26.98	32.22	3.30	3.46	0.03	0.03	7.68	7.70		
Macronutrient Control	27.36	32.44	3.40	3.72	0.04	0.04	7.66	7.66		
Micronutrient Control	27.86	32.65	3.39	3.20	0.04	0.04	7.70	7.66		
Liquid #1 (L 155)	26.39	33.66	3.05	3.64	0.04	0.03	7.70	7.72		
Liquid #2 (L 168)	26.98	32.32	2.98	3.48	0.03	0.03	7.64	7.68		
Granular #1 (L 154)	28.57	32.75	3.26	3.60	0.03	0.03	7.74	7.68		
Granular #2 (L 157)	26.51	32.40	3.14	3.42	0.04	0.03	7.72	7.68		

Other stresses

Because of the weather, there were no significant drought stress periods during the experiment, so no treatment effects could be observed on drought tolerance. Similarly, no disease development or insect damage occurred, though in many years this turf would have been prone to dollar spot disease.

CONCLUSIONS

The humic acid products had little significant effect to separate them from the effects of either the normal fertility control or the N-P-K plus micronutrient control, under the conditions of this trial. There were some slight effects of some humic acid treatments on micronutrient content in leaf tissue, but this was not reflected in effects on either root or shoot growth.

Since humic acid products have shown their best potential in management programs on stressed turf, it is likely that the benign conditions during the summer of 2000 may have masked any treatment effects. It might be productive to examine the effects of the material on a more stressed system, either with a poor fertility rootzone, or where drought, heat, or disease stress might increase the chances of treatment effects being detected.Table 2. Visual ratings of creeping bentgrass fairway turfgrass plots. Where lsd values are not given, differences among treatments were not significant.