EFFECTS OF HUMIC PRODUCTS ON GROWTH OF CREEPING BENTGRASS

K. Carey

Department of Plant Agriculture and the Guelph Turfgrass Institute,
University of Guelph, Ontario.

Sponsor: Luscar, Ltd.

The objective of this research project was to compare the effects of humic products on root and shoot growth of newly seeded and establishing creeping bentgrass.

Data collected included observation of the rate (timing and percentage) of germination of creeping bentgrass (*Agrostis palustris*) seed, the rate of establishment of seedlings and seedling vigor, nutrient uptake by seedling plants, rate of growth of shoot system, and total root system growth in establishing plants.

EXPERIMENTAL DESIGN / METHODS

The experimental design included six management treatments (two products x two rates and two controls) and two rootzone types, for a total of 12 treatments. The management treatments were two rates each of a liquid and a granular (L-157) humic product supplied by the sponsor, as well as standard fertility control and untreated control (Table 1). The liquid humate treatments were 90 ml 100 m^{-2} (1x) and 180 ml 100 m^{-2} (2x); the granular treatments were 2.5 kg 100 m^{-2} (1x) and 5.0 kg 100 m^{-2} (2x). The two rootzone types were 100% USGA specification sand and 80:20 v/v USGA standard sand:milled sphagnum moss peat. Each treatment was replicated five times in 12.5 cm plastic pots filled to the rim (approx. 1 litre) with rootzone. Seeding rate was 0.85 g m 2 of 'Penncross' creeping bentgrass. Pots were seeded May 15, 2002, and placed in a randomized complete block layout in the greenhouses at the Bovey Bldg., University of Guelph.

Pots were kept moist until germination, and thereafter were irrigated to prevent stress. Fertilization for all treatments except the unfertilized control was a standard turf maintenance regime (4:1:2 N-P-K ratio supplied at an annualized rate of 0.02 g actual N m^{-2}). Germination and establishment were assessed by ranking pots according to a visually estimated scale. Rootzone moisture levels (percent volumetric water) was recorded. Rootzone mixes were analysed at irrigation for pH and electrical conductivity. Colour was assessed with the Spectrum CM1000 chlorophyll meter. Observations were made at irrigation applications until the end of the experiment (6 weeks after germination). Plant leaf tissue was collected regularly as the plants were clipped to 15 mm height.

Leaf tissue was dried and weighed to determine shoot growth rates.

At the end of the experiment (6 weeks after germination), replicates were analysed for rootzone growth. Plants were removed from the pots, root systems washed free of soil, and rootzone length was measured and density rated visually.

Table 1. Treatments applied to creeping bentgrass pots.

Treatment	Rootzone	Humic product / rate	Fertilizer
sand liquid 2x	100% USGA sand	Liquid (L157), 180 ml 100 m^{-2}	0.02 g actual N m^{-2}
sand liquid 1x	100% USGA sand	Liquid (L157), 90 ml 100 m^{-2}	0.02 g actual N m^{-2}
sand granular 2x	100% USGA sand	Granular, 5.0 kg 100 m^{-2}	0.02 g actual N m^{-2}
sand granular 1x	100% USGA sand	Granular, 2.5 kg 100 m^{-2}	0.02 g actual N m^{-2}
sand fertilizer	100% USGA sand	-	0.02 g actual N m^{-2}
sand control	100% USGA sand	-	-
80:20 liquid 2x	80:20 v/v sand/sphagnum peat	Liquid (L157), 180 ml 100 m^{-2}	0.02 g actual N m^{-2}
80:20 liquid 1x	80:20 v/v sand/sphagnum peat	Liquid (L157), 90 ml 100 m^{-2}	0.02 g actual N m^{-2}
80:20 granular 2x	80:20 v/v sand/sphagnum peat	Granular, 5.0 kg 100 m^{-2}	0.02 g actual N m^{-2}
80:20 granular 1x	80:20 v/v sand/sphagnum peat	Granular, 2.5 kg 100 m^{-2}	0.02 g actual N m^{-2}
80:20 fertilizer	80:20 v/v sand/sphagnum peat	-	0.02 g actual N m^{-2}
80:20 control	80:20 v/v sand/sphagnum peat	-	-

Root systems were dried at 95°C for 48 hours and dry weight was recorded. Leaf tissue samples were collected and analysed for nutrient content (P, K, Ca, Mg, Zn, Cu, Mn, B) at three weeks and at the end of the experiment. Rootzone samples were collected and analysed for nutrient content (P, K, Ca, Mg, Zn, Cu, Mn) and CEC at the end of the experiment. An anecdotal photographic record of the experiment was kept.

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

RESULTS

Germination

There were some differences among the treatments in germination of the bentgrass seed (Table 2), but they were primarily attributable to different rootzones, with seedling germinating and establishing significantly better on the 80:20 mix than on straight sand. Within the sand pots, there was a trend for the humate treatments to establish better than the unfertilized and fertilized controls, but the differences were not statistically significant.

Table 2. Germination / seedling counts

Treatment	19-May	22-May	31-May
sand liquid 2x	0.5[1]	55.4[2] abcd	45.0 abc
sand liquid 1x	0.3	47.6 abcd	39.0 abc
sand granular 2x	0.5	42.0 bcd	33.0 bc
sand granular 1x	0.2	87.4 ab	65.0 ab
sand fertilizer	0.1	38.0 cd	18.0 c
sand control	0.2	29.6 d	17.0 c
80:20 liquid 2x	0.4	94.0 a	76.0 a
80:20 liquid 1x	0.6	73.0 abcd	73.0 ab
80:20 granular 2x	0.4	81.0 abc	56.0 abc
80:20 granular 1x	0.6	82.0 abc	81.0 a
80:20 fertilizer	0.2	81.0 abc	79.0 a
80:20 control	0.1	67.0 abcd	71.0 ab
Pooled treatments			
minus fertilizer	0.1	52.1	46.4
plus fertilizer	0.4	67.7	56.2
80:20	0.4	79.7 a	72.7 a
sand	0.3	50.0 b	36.2 b
Granular 1x	0.4	84.7	73.0
Liquid 1x	0.5	60.3	56.0
Granular 2x	0.5	61.5	44.5
Liquid 2x	0.5	74.7	60.5
minus humate	0.2	53.9	46.3
Block			
1	0.4	90.8 a	63.8
2	0.2	65.8 ab	71.7
3	0.4	42.0 b	39.2
4	0.3	57.3 b	46.7
5	0.5	68.3 ab	50.8

[1]Germination rating, scale 0-10, 10 = complete germination, mean of 5 replicates
[2]Number of seedlings, mean of 5 replicates
Means within columns followed by the same letter are

Chlorophyll index

The humate treatments had a significant effect on measured chlorophyll content, particularly late in the experiment (Table 3), though there were no differences among the humate treatments, either for rate or for formulation. By July 1 the treatments on sand with humate had as high a chlorophyll content as those on 80:20 mix. Fertilization also had a significant effect on chlorophyll content.

Shoot growth rate

The shoot growth rate of plants in humate treated pots was significantly higher than those without humate, as measured by instantaneous growth and total biomass accumulation (Table 4). The granular 1x and liquid 2x treatments tended to have slightly higher growth rates than the granular 2x and liquid 1x, but these differences were small. Fertilizer had a significant effect on shoot growth, as expected, but there were smaller differences between rootzone mixes.

Root growth and shoot/root ratio

There was an increase in root growth in all humate treated pots compared to those without humate, and it was significant in the case of the liquid 2x treatment (Table 5). Rootzone type also had a significant effect on root system growth, with higher values in the 80:20 mix than in the straight sand. There were significant differences among treatments in shoot/root ratio, but these could not be attributed to fertilizer, rootzone mix, or humate effects.

Leaf tissue analyses

Leaf tissue samples were so small as to make some analyses problematic, but there were some effects noted, particularly effects of fertilizer on increasing P and Mn contents and decreasing Mg contents, and of sand rootzones on increased Ca and Zn, and decreased Mg and Mn (Table 6). Humate treatments had a trend toward decreased Zn and Cu, and increased Mn, but the effects was small and not significant.

Table 3. Chlorophyll index

Treatment	25-Jun	28-Jun	1-Jul	3-Jul
sand liquid 2x	147.5[1] cde	119.6 bc	222.1 cd	276.7 ab
sand liquid 1x	146.1 cde	131.4 abc	220.3 cd	270.8 ab
sand granular 2x	151.5 bcd	120.9 bc	212.6 de	279.2 ab
sand granular 1x	157.7 ab	134.5 abc	247.2 a	273.5 ab
sand fertilizer	141.7 e	131.0 bc	201.5 e	244.2 c
sand control	141.9 de	133.5 abc	147.3 f	151.0 d
80:20 liquid 2x	163.6 a	129.6 bc	243.5 ab	263.4 abc
80:20 liquid 1x	148.1 bcde	135.0 ab	244.4 ab	287.0 a
80:20 granular 2x	166.6 a	116.7 c	248.1 a	271.4 ab
80:20 granular 1x	153.6 bc	149.2 a	230.6 bc	264.5 abc
80:20 fertilizer	164.3 a	97.3 d	229.8 bc	261.2 bc
80:20 control	122.6 f	124.9 bc	135.8 f	143.6 d
LSD p = 0.05	9.8	18.0	14.8	23.8
Pooled treatments				
minus fertilizer	137.1 b	126.0	150.2 b	149.4 b
plus fertilizer	153.5 a	127.2	229.9 a	271.2 a
80_20	153.2	125.4	222.0	248.5
sand	147.7	128.5	208.5	249.2
Granular 1x	155.6 a	141.9 a	238.9 a	269.0
Liquid 1x	147.1 b	133.2 b a	232.4 a	278.9
Granular 2x	159.1 a	118.8 c	230.4 a	275.3
Liquid 2x	155.6 a	124.6 b c	232.8 a	270.1
minus humate	142.7 b	121.7 b c	178.6 b	200.0

[1]Chlorophyll index measured with Spectrum CM1000 chlorophyll meter: index 0 – 1000 indicates absorption of light at 740 and 800 nm by vegetation, where 1000 = full absorption; mean of 10 readings x 5 replicates. Means within columns followed by the same letter are not significantly different (Duncans NMRT, p = 0.05). Where no letters appear, factor was not a significant source of variation in the ANOVA.

Soil chemistry

There were few significant patterns among the treatment effects on in situ soil electrical conductivity, salinity, or pH (Table 7). The fertilized treatments, as expected, had a higher EC and salt content and a lower pH, and there was a tendency for the humate treatments to follow this pattern, but the trend was not significant.

The analysis of the soil samples at the end of the experiment revealed some significant differences based on fertilizer (which increased K, Mg, P, and CEC) and rootzone (sand had increased Ca, Cu, K, Mg, Mn, and CEC but decreased P) (Table 8). The humate treatments resulted in decreased Ca and increased K, Mg, P and CEC, though the effect was only significant for some treatments in Ca and for K and P.

DISCUSSION AND CONCLUSIONS

The humate treatments all had significant beneficial effects on bentgrass growth in high sand media, particularly on root system growth, which was reflected in overall vigour and growth rate. There were rarely any differences among the different humate formulations or rates, and when differences were detected, the trends were not consistent. The beneficial effects were stronger in the 100% sand pots than in the 80:20 mixture.

Table 4. Leaf tissue growth

Treatment	10-Jun	12-Jun	14-Jun	18-Jun	25-Jun	3-Jul
			Dry weight (mg leaf tissue)			
sand liquid 2x	60.5 ab	74.5 abcd	46.3	108.5 bcde	129.6 bcd	298.2 a
sand liquid 1x	56.2 ab	55.9 bcd	35.2	110.5 bcde	120.8 bcd	287.9 a
sand granular 2x	49.8 ab	60.2 abcd	24.3	79.2 de	112.4 cde	262.7 a
sand granular 1x	99.1 a	86.9 abcd	62.7	128.0 abcd	176.5 ab	315.0 a
sand fertilizer	25.0 b	35.5 d	23.2	84.3 de	99.3 de	267.3 a
sand control	24.2 b	37.2 cd	20.3	60.6 e	58.1 ef	97.7 b
80:20 liquid 2x	98.8 a	110.5 ab	66.5	178.8 a	197.4 a	310.5 a
80:20 liquid 1x	77.0 ab	87.4 abcd	56.2	142.2 abc	167.4 abc	306.7 a
80:20 granular 2x	64.7 ab	94.1 abc	35.5	117.1 bcde	138.3 abcd	289.1 a
80:20 granular 1x	114.0 a	115.4 a	56.5	149.1 ab	159.8 abc	295.0 a
80:20 fertilizer	87.0 ab	101.2 ab	67.0	164.1 ab	175.1 ab	283.8 a
80:20 control	91.7 a	90.1 abcd	56.3	86.3 cde	40.9 f	94.8 b
Pooled treatments						
minus fertilizer	54.8	67.0	42.0	82.7 b	66.0 b	108.5 b
plus fertilizer	74.2	81.8	46.7	125.2 a	146.0 a	292.9 a
80_20	88.9 a	99.8 a	56.3	139.6 a	146.5 a	263.3
sand	52.5 b	58.4 b	35.4	95.2 b	116.1 b	254.8
Granular 1x	106.6 a	101.1	59.6	138.6 a	168.2 a	305.0 a
Liquid 1x	66.6 ba	71.6	45.7	126.4 ba	144.1 a	297.3 a
Granular 2x	57.3 b	77.2	29.9	98.2 b	125.3 ba	275.9 a
Liquid 2x	79.7 ba	92.5	56.4	143.7 a	163.5 a	304.4 a
minus humate	57.0 b	66.0	41.7	98.8 b	93.4 b	185.9 b
Treatment			**Growth rate mg / day[1]**			
sand liquid 2x	2.3 ab	37.3 abcd	23.2	27.1 bcde	18.5 bcd	37.3 a
sand liquid 1x	2.2 ab	27.9 bcd	17.6	27.6 bcde	17.3 bcd	36.0 a
sand granular 2x	1.9 ab	30.1 abcd	12.2	19.8 de	16.1 cde	32.8 a
sand granular 1x	3.8 a	43.4 abcd	31.4	32.0 abcd	25.2 ab	39.4 a
sand fertilizer	1.0 b	17.8 d	11.6	21.1 de	14.2 de	33.4 a
sand control	0.9 b	18.6 cd	10.2	15.2 e	8.3 ef	12.2 b
80:20 liquid 2x	3.8 a	55.3 ab	33.2	44.7 a	28.2 a	38.8 a
80:20 liquid 1x	3.0 ab	43.7 abcd	28.1	35.6 abc	23.9 abc	38.3 a
80:20 granular 2x	2.5 ab	47.0 abc	17.8	29.3 bcde	19.8 abcd	36.1 a
80:20 granular 1x	4.4 a	57.7 a	28.3	37.3 ab	22.8 abc	36.9 a
80:20 fertilizer	3.4 ab	50.6 ab	33.5	41.0 ab	25.0 ab	35.5 a
80:20 control	3.5 a	45.1 abcd	28.1	21.6 cde	5.8 f	11.8 b
Pooled treatments						
minus fertilizer	2.1	33.5	21.0	20.7 b	9.4 b	13.6 b
plus fertilizer	2.9	40.9	23.4	31.3 a	20.9 a	36.6 a
80_20	3.4 a	49.9 a	28.2	34.9 a	20.9 a	32.9
sand	2.0 b	29.2 b	17.7	23.8 b	16.6 b	31.9
Granular 1x	4.1 a	50.6	29.8	34.6 a	24.0 a	38.1 a
Liquid 1x	2.6 ba	35.8	22.9	31.6 ba	20.6 a	37.2 a
Granular 2x	2.2 b	38.6	15.0	24.5 b	17.9 ba	34.5 a
Liquid 2x	3.1 ba	46.3	28.2	35.9 a	23.4 a	38.0 a
minus humate	2.2 b	33.0	20.9	24.7 b	13.3 b	23.2 b
Treatment			**Total cumulative leaf tissue (mg)**			
sand liquid 2x	60.5 ab	135.0 abc	181.3 ab	289.9 abc	419.5 bcde	717.8 abcd
sand liquid 1x	56.2 ab	112.0 abc	147.3 ab	257.8 abc	378.6 bcde	666.5 bcde
sand granular 2x	49.8 ab	110.0 bc	134.3 ab	213.6 bc	326.0 cde	588.7 cde
sand granular 1x	99.1 a	186.0 ab	248.7 a	376.7 ab	553.3 abc	868.3 ab
sand fertilizer	25.0 b	60.5 c	83.8 b	168.0 c	267.3 de	534.6 def
sand control	24.2 b	61.4 c	81.7 b	142.3 c	200.5 e	298.1 f
80:20 liquid 2x	98.8 a	209.3 ab	275.8 a	454.6 a	652.0 a	962.6 a
80:20 liquid 1x	77.0 ab	164.3 abc	220.6 ab	362.8 ab	530.2 abc	836.9 abc
80:20 granular 2x	64.7 ab	158.8 abc	194.3 ab	311.4 abc	449.7 abcd	738.8 abcd
80:20 granular 1x	114.0 a	229.4 a	285.9 a	435.0 a	594.8 ab	889.8 ab
80:20 fertilizer	87.0 ab	188.3 ab	255.2 a	419.4 a	594.5 ab	878.4 ab
80:20 control	91.7 a	181.8 ab	238.0 a	324.4 abc	365.3 bcde	460.0 ef
Pooled treatments						
minus fertilizer	54.8	121.8	163.8	246.5	312.4 b	420.9 b
plus fertilizer	74.2	156.0	202.7	327.9	473.9 a	766.8 a
80_20	88.9 a	188.7 a	245.0 a	384.6 a	531.1 a	794.4 a
sand	52.5 b	110.8 b	146.2 b	241.4 b	357.5 b	612.3 b
Granular 1x	106.6 a	207.7 a	267.3 a	405.9 a	574.0 a	879.0 a
Liquid 1x	66.6 ba	138.2 ba	183.9 ba	310.3 ba	454.4 ba	751.7 ba
Granular 2x	57.3 b	134.4 ba	164.3 b	262.5 b	387.8 b	663.8 bc
Liquid 2x	79.7 ba	172.2 ba	228.6 ba	372.2 ba	535.8 a	840.2 a
minus humate	57.0 b	123.0 b	164.7 b	263.5 b	356.9 b	542.8 c

[1]Growth rate calculated from tissue rate / days since previous clipping (or seeding for 10-Jun data)
All figures are means of 5 replicates. Means within columns followed by the same letter are not significantly different (Duncans NMRT, p = 0.05). Where no letters appear, factor was not a significant source of variation in the ANOVA.

Table 5. Root growth and shoot/root ratios

Treatment	At harvest			Clippings (total dry weight mg)	Total shoot biomass (mg; clippings + harvested shoot)	Total shoot/ root ratio
	Root dry weight (mg)	Shoot dry weight (mg)	Shoot /root ratio			
sand liquid 2x	0.459[1] b	0.519 bc	1.352 ab	0.718 abcd	1.237 bcd	3.203 ab
sand liquid 1x	0.337 b	0.479 cd	1.538 a	0.667 bcde	1.145 bcde	3.719 a
sand granular 2x	0.380 b	0.498 bcd	1.504 a	0.589 cde	1.087 cde	3.310 ab
sand granular 1x	0.355 b	0.458 cd	1.339 ab	0.868 ab	1.326 abcd	3.871 a
sand fertilizer	0.307 b	0.449 cd	1.479 a	0.535 def	0.984 de	3.228 ab
sand control	0.314 b	0.206 e	0.710 c	0.298 f	0.504 f	1.732 c
80:20 liquid 2x	1.015 a	0.727 a	0.873 bc	0.963 a	1.690 a	2.027 bc
80:20 liquid 1x	0.524 b	0.584 abc	1.168 abc	0.837 abc	1.421 abc	2.867 abc
80:20 granular 2x	0.495 b	0.550 bc	1.204 abc	0.739 abcd	1.288 bcd	2.826 abc
80:20 granular 1x	0.465 b	0.641 ab	1.482 a	0.890 ab	1.531 ab	3.477 a
80:20 fertilizer	0.400 b	0.588 abc	1.619 a	0.878 ab	1.467 abc	3.984 a
80:20 control	0.486 b	0.355 d	0.726 c	0.460 ef	0.815 ef	1.704 c
Pooled treatments						
minus fertilizer	0.386	0.316 b	0.899 b	0.421 b	0.737 b	2.116
plus fertilizer	0.478	0.547 a	1.328 a	0.767 a	1.314 a	3.193
80_20	0.564 a	0.574 a	1.179	0.794	1.369 a	2.814
sand	0.359 b	0.435 b	1.320	0.612	1.047 b	3.177
Granular 1x	0.410 b	0.549	1.411	0.879	1.428	3.674
Liquid 1x	0.431 b	0.532	1.353	0.752	1.283	3.293
Granular 2x	0.437 b	0.524	1.354	0.664	1.188	3.068
Liquid 2x	0.737 a	0.623	1.113	0.840	1.463	2.615
minus humate	0.377 b	0.399	1.133	0.543	0.942	2.662

[1]All figures are means of 5 replicates. Means within columns followed by the same letter are not significantly different (Duncans NMRT, p = 0.05). Where no letters appear, factor was not a significant source of variation in the ANOVA.

Table 6. Leaf tissue content analyses

Treatment	Ca	P	K	Mg	Mn	Zn	B	Cu
	% dry weight				mg kg^{-1}			
	Pooled sample from first two clipping harvest							
sand liquid 2x	0.49	0.93	3.55	0.29	139.33	69.00 bc	27.33	
sand liquid 1x	0.53	0.89	3.38	0.34	140.67	76.00 bc	26.50	
sand granular 2x	0.69	0.85	3.10	0.38	154.00	68.50 bc	30.00	
sand granular 1x	0.59	0.98	3.73	0.37	151.75	63.50 bc	21.00	
sand fertilizer		0.85	3.76		169.50			
sand control	0.51	0.80	3.03		153.00	139.00 a	35.00	
80:20 liquid 2x	0.45	1.01	3.75	0.40	158.40	59.40 bc	25.00	
80:20 liquid 1x	0.44	1.00	3.52	0.41	173.20	60.00 bc	31.00	
80:20 granular 2x	0.49	0.92	3.64	0.46	160.00	62.00 bc	25.40	
80:20 granular 1x	0.52	1.02	3.70	0.37	177.40	53.80 c	21.60	
80:20 fertilizer	0.50	1.05	3.77	0.40	189.60	78.00 b	24.00	
80:20 control	0.49	1.03	3.67	0.39	167.20	59.25 bc	26.80	
Pooled treatments								
minus fertilizer	0.49	1.00	3.55	0.38	176.43	74.83	27.14	
plus fertilizer	0.51	0.97	3.63	0.38	161.61	64.26	25.35	
80_20	0.48	1.00	3.68	0.40	170.97	62.35 b	25.45	
sand	0.55	0.91	3.48	0.34	149.80	74.55 a	26.17	
Granular 1x	0.56	1.00	3.71	0.37	166.00	58.11 b	21.33	
Liquid 1x	0.47	0.95	3.47	0.38	161.00	66.40 ab	29.50	
Granular 2x	0.54	0.90	3.48	0.43	158.29	64.17 ab	26.71	
Liquid 2x	0.47	0.98	3.68	0.36	151.25	62.14 ab	25.88	
minus humate	0.50	1.00	3.67	0.40	175.08	76.60 a	26.27	
Treatment	**Tissue sample from final harvest**							
sand liquid 2x	0.62	0.72	3.40	0.40 d	220.00 abc	95.20 abc	39.00	49.50
sand liquid 1x	0.64	0.68	3.32	0.40 d	180.60 cd	92.20 abcd	35.40	43.00
sand granular 2x	0.67	0.76	3.65	0.47 bcd	275.60 a	98.60 ab	38.80	42.50
sand granular 1x	0.62	0.72	3.00	0.43 cd	206.40 bc	88.00 abcd	30.60	47.00
sand fertilizer	0.61	0.72	3.66	0.44 cd	234.80 abc	103.20 a	33.20	47.50
sand control	0.59							
80:20 liquid 2x	0.58	0.76	3.22	0.58 a	247.40 ab	76.20 cd	34.80	49.75
80:20 liquid 1x	0.59	0.77	3.49	0.55 ab	254.40 ab	82.40 bcd	33.80	50.40
80:20 granular 2x	0.60	0.74	3.59	0.52 abc	261.20 ab	78.00 bcd	36.00	49.75
80:20 granular 1x	0.60	0.71	3.45	0.56 a	273.40 a	72.60 d	31.20	47.67

Table 7. Soil content analyses

Treatment	Ca	P	K	Mg	Mn	Zn	Cu	CEC
	% dry weight				mg kg^{-1}			cmol kg^{-1}
sand liquid 2x	323.00 b	28.00 b	46.80 ab	40.20 a	3.46 a	0.40	1.11 b	1.98 a
sand liquid 1x	298.80 b	24.00 b	48.60 ab	39.20 a	3.62 a	0.40	2.02 a	2.04 a
sand granular 2x	312.60 b	24.00 b	50.40 a	43.00 a	3.34 a	0.39	1.06 b	1.98 a
sand granular 1x	300.20 b	25.60 b	44.40 ab	41.60 a	3.40 a	0.46	1.37 ab	2.00 a
sand fertilizer	329.60 b	25.80 b	48.60 ab	40.60 a	3.24 a	0.40	1.18 ab	2.00 a
sand control	369.60 a	9.40 c	23.80 c	40.80 a	3.68 a	0.45	0.86 b	2.02 a
80:20 liquid 2x	181.40 c	36.80 a	42.60 ab	32.60 b	1.98 b	0.45	0.73 b	1.20 b
80:20 liquid 1x	167.00 c	36.40 a	43.40 ab	31.80 b	1.74 b	0.45	0.66 b	1.16 b
80:20 granular 2x	186.00 c	36.60 a	41.80 ab	32.20 b	1.80 b	0.44	0.62 b	1.24 b
80:20 granular 1x	182.80 c	35.40 a	39.40 b	30.20 b	1.80 b	0.41	0.63 b	1.18 b
80:20 fertilizer	176.40 c	35.40 a	40.80 ab	31.60 b	1.84 b	0.43	0.60 b	1.14 bc
80:20 control	169.20 c	9.20 c	16.40 c	23.40 c	1.82 b	0.35	0.40 b	0.96 c
Pooled treatments								
minus fertilizer	261.00	11.00 b	21.91 b	32.18	2.66	0.40	0.62	1.44
plus fertilizer	247.18	30.86 a	44.78 a	36.37	2.64	0.43	1.01	1.61
80_20	177.13 b	31.63 a	37.40	30.30 b	1.83 b	0.42	0.61 b	1.15 b
sand	322.30 a	22.80 b	43.77	40.90 a	3.46 a	0.42	1.27 a	2.00 a
Granular 1x	241.50	30.50	41.90	35.90	2.60	0.44	1.00	1.59
Liquid 1x	232.90	30.20	46.00	35.50	2.68	0.43	1.34	1.60
Granular 2x	249.30	30.30	46.10	37.60	2.57	0.42	0.84	1.61
Liquid 2x	252.20	32.40	44.70	36.40	2.72	0.42	0.92	1.59
minus humate	261.20	19.95	32.40	34.10	2.65	0.41	0.76	1.53

Means of 5 replicates; means within columns followed by the same letter are not significantly different (Duncans NMRT, p = 0.05). Where no letters appear, factor was not a significant source of variation in the ANOVA.