UNIVERSITY OF GEORGIA

ORGANIC MATTER DYNAMICS IN THE SURFACE ZONE OF A USGA GREEN: PRACTICES TO ALLEVIATE PROBLEMS

1997 Research Grant: $20,000
(Second Year of Support)

Dr. Robert N. Carrow
Principal Investigator

It is the hypothesis of the author that two turfgrass grower problems arise by accumulation of organic matter in the surface 0 to 2 inch zone of a USGA green from an initial level of 1.0 to 5.0% (by weight) at establishment to 8 to 12% after 2 years. Organic matter accumulation occurs even under excellent management and regardless of specification (i.e., it is not dependent on specifications). The two proposed problems are:

I. **Summer Bentgrass Decline in Response to Root Deterioration and Plugging of the Macropores that are Important for Soil O_2 and Infiltration of Water**. A project was initiated in late spring 1996 to investigate the influence of treatments (summer cultivation, sand topdressing, sand substitutes, wetting agents) on maintaining infiltration, soil O_2 status, and root viability. This field study will continue until fall 1998. Observations to date are:

   a. Percent organic matter by weight ranged from 10.1 to 10.2% for the untreated control in the surface 0 to 3.0 cm zone. Core aeration with sufficient topdressing to fill the holes in March was the only treatment to reduce percent O.M. content (i.e., to 4.1 and 7.7%).

   b. High surface O.M. content in the surface 0 to 3.0 cm zone resulted in the following soil physical properties relative to USGA recommended specifications (in parenthesis): total porosity of 74.2 to 76.7% (35 to 55%); aeration porosity of 17.3 to 22.5% (15 to 30%); capillary porosity of 54.1 to 56.9% (15 to 25%).

   c. The surface zone resulted in saturated hydraulic conductivities (SHC) of 53 to 304 mm hr^{-1} for the control (minimum recommended is 120 mm hr^{-1}) and oxygen diffusion rates (ODR) of <0.20 μgO_2 cm^{-2} min^{-1} (threshold for O_2 stress) on all readings in 1996 for 2.5 to 26 hours after irrigation. In 1997 ODR readings were occasionally <0.20 for 26 to 50 hours after irrigation.

   d. The major effect of treatments was on SHC at 1 to 7 days and 17 to 26 days after cultivation (DAC). At 17 to 26 DAC the most effective treatments for maintaining SHC were: HJR (Hydro-Ject run in raised position for ¼ inch diameter hole) with sand topdressing (S), wetting agent (WA), or biostimulant (B); (468 to 548 mm hr^{-1} versus control of 139 mm hr^{-1}). The next most effective treatments were HJL (Hydro-Ject

lowered position); HJR; HJR + Sand + WA; and HJR + Sand + WA + B; (385 to 405 mm hr^{-1}).

e. Treatments resulting in the greatest percentage (in parenthesis) of visual ratings greater than the control for all shoot parameters were HJL; HJR; HJR + WA; and HJR + B; (11 to 27% readings > control).

II. **Inhibition of Root Development (in Spring/Fall) from the Zone of High Organic Matter Content**. A second project was initiated in winter 1996 to investigate the influence of selected cultivation procedures, that are non-disruptive, on root development. Wetting agent and sand substitute treatments were also included. The goal is to determine whether better root growth/depth can be achieved by increasing macropores in the surface 0 to 3 cm zone without conducting the traditional spring/fall core aeration operation. This field project will continue through spring 1999. Observations to date are:

a. High O.M. content (18.8%, wt.) in the surface 0 to 3.0 cm zone reduced aeration porosity to 8.6 to 10.5% and caused SHC values of 9 to 125 mm hr^{-1} (control) with lowest SHC occurring in November through May. Apparently as adventitious roots develop in the fall, surface macropores become plugged with live roots and SHC markedly declines.

b. ODR values at 3 cm and 10 cm were frequently <0.20 μgO_2 cm^{-2} min^{-1} at 2 to 31 hrs after irrigation. ODR values at either depth were only occasionally improved by HJR or HJR + WA treatment.

c. The primary treatment influence was on SHC where the most effective treatments for maintaining SHC at 24 to 41 DAC were HJR + WA; HJR; HJR + G + WA (G = using 70% sand + 30% Greenschoice topdressing); AW (Aerway Greens Slicer, Fine Tines); (168 to 239 mm hr^{-1} versus 63 mm hr^{-1} control). Quad tines (solid, ¼ inch diameter) with or without G topdressing resulted in SHC values of 52 to 72 mm hr^{-1} at 24-41 DAC.

d. Treatments resulting in least shoot injury (i.e., ratings similar to control) were: HJR + G; HJR; HJR + WA; HJR + G + WA.

BIOGRAPHICAL INFORMATION

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PRESENT EMPLOYMENT: 1985 to present at the University of Georgia. Currently, Professor with 100% turfgrass research responsibilities.

PAST EMPLOYMENT: 1972-76 at the University of Massachusetts (teaching and research in turfgrass science).
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EDUCATION: 1968 - B.S., Soil Science, Michigan State University
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RESEARCH INTERESTS: Areas of research emphasis are: a) turfgrass environmental stress resistance mechanisms (drought, high temperature, salinity, low light and nutrient deficiencies), and b) turfgrass traffic stress resistance and alleviation (wear, soil compaction). Concentration is on seashore paspalum, bentgrass, and tall fescue species. Dr. Carrow has written 78 refereed scientific publications, 147 popular articles for turf managers, and is co-editor of two turfgrass scientific books. He is co-author of two turfgrass science books to be submitted to the publisher in Sep. 97 and Nov. 97. He has made 325 presentations to scientific and professional turf audiences in 35 states and 7 countries.

RECOGNITION: Dr. Carrow is a Fellow of the American Society of Agronomy and Vice-President of the International Turfgrass Society for turfgrass scientists. He has served in numerous offices and committees in professional societies and turfgrass organizations.

PERSONAL: Married (Rose), two daughters (Tricia and Michele)

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It is the hypothesis of the author that two turfgrass grower problems arise from accumulation of organic matter in the surface 0 to 2 inch zone of a USGA green. Organic matter accumulation occurs even under excellent maintenance. These problems are the focus of the two projects in this report: a) Project 1 deals with summer conditions (see pages 1-1 to 1-26), and b) Project 2 concentrates on root development in spring and fall (see pages 2-1 to 2-23).

PROJECT 1:

CULTIVATION AND AMENDMENTS ON SUMMER BENTGRASS DECLINE AND ROOTING ON A USGA GREEN (T-109)

R. N. Carrow

Proposed Problem. Within the southern zones of creeping bentgrass use, prolonged high temperature stress arises from the long, hot summers and high humidity of the Southeast. Previously "bentgrass summer decline" was reported to be due to root Phythium species. However, the sequence of injuries I believe is causing this problem is:

Bentgrass Summer Decline

Indirect High Temperature Stress
* **depletion of carbohydrates by an imbalance of PS and Res.**

↓

Root Growth and Viability Declines
* **massive root death may occur**

↓

1. **Death of Root Cells Result in Abundant Fresh Organic Matter**
2. **Thatch - Soil Interface Seals (low infiltration)**
3. **Zone of Low Soil O_2 forms and enhances the rate of root dieback and soon causes shoot injury.**
4. **Water and Nutrient Uptake Declines**
5. **Shoot Tissue Succulent and Less Wear Tolerant**
6. **Disease Organisms May Increase With Slow Plant Growth and Abundant O.M.**
7. **Soluble Salts May Increase in Surface**

Carbohydrates are produced in the photosynthesis (PS) process while respiration (Res.) is a major process that uses (depletes) carbohydrates. Essentially, carbohydrate depletion occurs under high temperatures where photosynthesis increases but at a slower rate than does respiration. When carbohydrates become limited the shoot tissues have priority over root cells; thereby, roots start to decline in health and dieback. Once root death starts, these roots lose their "structure", lyse, and become more gel-like; thereby, reducing infiltration and enhancing the potential for O_2 stress (especially under the high O_2 demand of summer). Unless infiltration is improved, soil O_2 stress rapidly causes further root decline. This example of surface organic matter dynamics;

* is primarily an issue of maintaining root viability in the summer months via maintenance of surface infiltration/soil O_2 status.

* occurs primarily in the southern region of bentgrass use, and especially where humidity is high; but may occur with unusually humid/hot weather patterns of northern locations (such as in 1995) and/or humid, low-air drainage greens.

* and, research has focused mainly on secondary aspects (i.e., root Pythiums) and not summer cultivation or topdressing as means of maintaining root viability.

Objectives

To determine the effectiveness of summer cultivation practices and amendments to create macropore channels and/or enhance macroporosity on:

- rooting maintenance and viability in the summer
- shoot performance
- soil O_2 status
- water infiltration

Procedures

This study was initiated in June 1996 on a 11 year old Penncross creeping bentgrass green built to USGA specifications. The green is mowed three times per week at 5/32 inch; topdressed every 3 weeks at 0.75 ft^3 per 1000 ft^2 during the growing season; and received 3.50-2.21-2.42 (1996) and 3.25-3.17-2.80 (1997) of $N\text{-}P_2O_5\text{-}K_2O$ per 1000 ft^2.

Table 1-1. Treatments for study T-109.

Treat No.	Description	Target Dates
1.	No cultivation	None
2.[a]	Core Aerate, H.T., 5/8 dia. Apply 14,000 ml sand per plot after cultivation.	Mar 15 Oct 2
3.[b]	Hydro-Ject, Lowered = HJL	June 1 + every 3 weeks
4.[b]	Hydro-Ject, Raised = HJR	June 1 + every 3 weeks
5.	HJR + sand = HJR+S Sand topdressing at 1700 ml per 80 ft^2 plot. This is a 0.75 ft^3 per 1000 ft^2 rate.	Cultivation - see #3 Topdressing - May 15, Jun 10, Jul 10, Aug 10
6.	HJR + Greenschoice = HJR+G Greenschoice applied as topdressing at 1700 ml per 80 ft^2.	Cultivation - see #3 Topdressing - see #5
7.[c]	HJR + Wetting Agent = HJR+WA Wetting Agent is Naiad.	Cultivation - see #3 WA - May 15, Jun 10, Jul 1 & 22, Aug 15
8.[d]	HJR + Biostimulant = HJR+B Biostimulant is CytoGro.	Cultivation - see #3 B - Jun 10, Jul 5, Aug 5, Sep 5
9.	HJR + Sand + WA = HJR + S + WA	Cultivation - see #3 Sand - see #5 WA - see #7
10.	HJR + Sand + WA + B = HJR + S + WA + B	Cultivation - see #3 Sand - see #5 WA - see #7 B - see #8
11.	LandPride+Greenschoice Injection = LP+GI	Cultivation - see #3

[a] Core aerate at 2 x 2" spacing. Topdressing rate is about 6 ft^3 per 1000 ft^2.

[b] HJR = #2 setting, 3½ inch spacing, ¼" dia. hole.
HJL = #2 setting, 3 inch spacing, ⅛" dia. hole.

[c] Wetting Agent. Use Naiad at 3 oz per 1000 ft^2 with 2-wheel cart sprayer, 2 nozzles, 40" patterns, twice (2X) over plot area. Mix 108 ml Naiad plus 4350 ml water. Water in briefly to get off leaves.

[d] Biostimulant is CytoGro (.005% active ingredient of kinetin) applied at 1 fl. oz per 1000 ft^2. Use 2-wheel cart sprayer, 2 nozzles, 40" pattern, 2X over plot area. Mix 24 ml of CytoGro in 3000 ml water. Do not wash off leaves.

Treatments are applied to 8 x 10 ft plots in a randomized complete block with 4 blocks (reps).

Results.

As reference points for data in Tables 1-2 to 1-5, the USGA guidelines for soil physical properties are presented below:

PHYSICAL PROPERTIES OF THE ROOT ZONE MIX

Physical Property	Recommended Range	
Total Porosity	35% - 55%	
Air-filled Porosity (at 40 cm tension)	15% - 30%	
Capillary Porosity (at 40 cm tension)	15% - 25%	
Saturated Conductivity	Lab	Approx Field SHC (reduced by 60%)
Normal range:	6-12 in./hr (150-300 mm hr^{-1})	60-120 mm hr^{-1}
Accelerated range:	12-24 in./hr (300-600 mm hr^{-1})	120-240 mm hr^{-1}
Organic Matter Content (by weight)	1% - 5% (ideally 2% - 4%)	

Data obtained to date are:

a. Surface (0-3 cm) soil physical conditions are in Table 1-2 and 1-3 for cores run at 40 cm tension.

b. Saturated hydraulic conductivity data obtained in the field to determine water permeability through the surface zone are in Tables 1-4 and 1-5. In the laboratory procedure for SHC where no grass is present, the desirable range in our climate is 300 to 600 mm hr^{-1}. Since field SHC declines to 25% to 40% of lab SHC, these would correspond to minimum field values of 120 to 240 mm hr^{-1} (i.e., 4.8 to 9.6 inches hr^{-1}).

c. Oxygen diffusion and moisture content of the surface 0 to 3 cm zone at various times after irrigation are presented in Tables 1-6 and 1-7. ODR values of <0.20 $\mu gO_2 \cdot cm^{-2}$ min^{-1} indicate conditions of limited soil O_2 for maximum root function and growth.

d. Turfgrass shoot performance (visual quality, shoot density, and color) are in Tables 1-8 to 1-14.

e. Physiological stress indexes (IR/R, NDVI, Reflectance 661 nm) for the turfgrass canopy are in Tables 1-15 to 1-21. Reflectance in the 507 to 706 nm range is considered the photosynthetically active range (PAR) and the ideal is low reflectance (i.e., this equals high absorption). Physiological stress, disease, reduced photosynthetic pigments, or reduced leaf area index (LAI) increase 507 to 706 nm reflectance (i.e., reduce absorption) and tend to decrease 750 to 1100 nm (near infrared region) reflectance. Stress information often improves by looking at combinations of spectral ranges, such as:

- IR/R. Defined in Table 1-15.
- NDVI. Defined in Table 1-17.

Also, reflectance at 661 nm is presented based on correlation of turfgrass shoot parameters versus 8 spectral ranges. The 661 nm region is in the PAR region.

f. Root data are in Table 1-22.

Table 1-2. Bulk density, organic matter content, and mineral matter content in the surface 0 to 3 cm zone in June and August 1997 (T-109).

Treatment and Contrast‡	Bulk Density		Percent Organic Matter		Organic Matter Content§		Mineral Matter Content§	
	6 Jun	18 Aug	6 Jun	18 Aug	6 Jun	18 Aug	6 Jun	18 Aug
	----- g cm^{-3} ------		----- % (wt.)-----		-------- g ---------		------- g --------	
Control vs.	.51	.62	10.2	10.1	7.5	9.3	67.5	84.4
CA (Mar)	.70**	.69	4.1**	7.7*	4.4*	8.8	99.1**	105.7*
HJL	.54	.58	9.7	10.2	7.7	9.1	69.8	81.7
HJR	.48	.60	11.5	11.7	8.3	10.0	62.6	75.7
HJR + Sand	.57	.63	9.4	10.6	7.7	9.7	74.9	82.4
HJR + Greenschoice	.56	.54†	7.4	10.2	5.8	9.0	73.5	79.2
HJR + WA	.59	.58	9.1	10.0	7.6	9.3	80.2	85.5
HJR + B	.52	.59	8.4	10.1	6.2	9.7	70.2	88.2
HJR + Sand + WA	.51	.59	10.1	11.1	7.7	9.3	68.4	75.7
HJR + Sand + WA + B	.52	.60	8.5	11.4	6.4	10.2	69.4	79.2
LP + Greenschoice I	.52	.54†	10.0	11.1	6.9	9.4	68.8	76.1
LSD (.05) =	.12	.10	4.3	2.2	3.0	1.3	18.9	16.8
F-test	†	.20	†	†	.39	.56	*	*
CV (%)	15	11	33	14	31	10	18	14

‡ Contrast versus Control based on LSD.

**, *, † Significant difference at P ≤.01, .05, and .10.

§ Weight is grams per 50 cm^2 surface area X 3.0 cm deep.

Table 1-3. Total Porosity, aeration porosity (macroporosity) and moisture retention in the surface 0 to 3 cm zone in 1997 (T-109).

Treatment and Contrast ‡	Total Porosity		Aeration Porosity (-0.004 MPa)		Moisture Retention (-0.004 MPa)	
	6 Jun	18 Aug	6 Jun	18 Aug	6 Jun	18 Aug
	% (Vol.)					
Control vs.	74.2	76.7	17.3	22.5	56.9	54.1
CA (Mar)	68.8†	71.4†	21.9	21.9	46.8*	49.4
HJL	75.0	76.7	21.1	27.1	53.9	49.7
HJR	75.7	72.6	17.2	19.9	58.5	52.7
HJR + Sand	73.1	74.3	21.1	22.2	52.0	52.0
HJR + Greenschoice	75.3	77.1	21.2	21.4	54.1	55.7
HJR + WA	73.2	74.1	19.3	21.9	53.9	52.2
HJR + B	76.2	76.6	22.1	22.3	54.1	54.3
HJR + Sand + WA	76.6	78.7	20.9	27.5	55.6	51.2
HJR + Sand + WA + B	73.5	75.6	22.6†	21.8	50.9	53.8
LP + Greenschoice I	75.5	76.6	18.2	23.1	57.3	53.5
LSD (.05) =	5.6	5.6	6.1	8.5	8.0	9.7
F-test	.29	.30	.59	.78	.23	.96
CV (%)	5	5	21	26	10	13

‡ Contrast versus Control based on LSD.

**, *, † Significant difference at P ≤ .01, .05, and .10.

Table 1-4. Saturated hydraulic conductivity at selected days after the previous HJR cultivation operation (DAC) in summer 1996 and 1997. (T-109)

Treatment and Contrast ‡§	Saturated Hydraulic Conductivity (SHC)									
	1996						1997			
	19 Jul 3 DAC	6 Aug 21 DAC	15 Aug 7 DAC	3 Sep 26 DAC	9 Sep 4 DAC	23 Sep 18 DAC	16 Jul 1 DAC	4 Aug 20 DAC	12 Aug 1 DAC	28 Aug 17 DAC
	mm hr^{-1}									
Control vs.	199	219	67	137	223	53	101	190	304	96
CA (Mar)	299	93	116	116	223	64	277	364	230	148
HJL	190	222	192	764*	538	390*	500	255	674	477
HJR	448	190	470	775*	652*	457*	827**	254	1062†	322
HJR + Sand	838**	217	830**	1136**	622†	599**	503	342	751	447
HJR + Greenschoice	488	160	776*	545†	883**	307†	454	290	506	223
HJR + WA	791**	145	1024**	505	961**	737**	719*	298	578	749*
HJR + B	636*	100	861**	413	868**	379*	548†	595†	685	855**
HJR + Sand + WA	658*	123	830**	821**	705*	385*	488	474	508	210
HJR + Sand + WA + B	930**	108	343	446	608†	500**	496	385	737	484
LP + Greenschoice I	176	80	233	100	323	234	233	134	151	103
LSD (.05) =	322	197	579	506	427	256	557	439	772	575
F-test	**	.78	**	**	**	**	.36	.69	.48	†
CV (%)	43	91	77	67	49	49	83	93	95	106

‡ Contrast versus Control based on LSD.

**, *, † Significant difference at P≤.01, .05, and .10.

§ Treatment Dates:

	1996	1997
CA	29 Mar; 1 Oct	15 Mar
HJL, HJR, LP + GI	6, 24 Jun; 16 Jul; 8 Aug; 5 Sep	3, 25 Jun; 15 Jul; 11 Aug; 4 Sep
Sand Top., Greenschoice Top.	15 May; 11 Jun; 8, 30 Jul	15 May; 10 Jun; 10 Jul; 6, 28 Aug
Wetting Agent	16 May; 11 Jun; 9, 29 Jul; 12 Aug	15 May; 11 Jun; 10 Jul;,7, 28 Aug
Biostimulant	11 Jun; 9 Jul; 9 Aug; 13 Sep	11 Jun; 11 Jul; 7, 28 Aug

Table 1-5. Summary of saturated hydraulic conductivity (SHC) data at selected days after cultivation operation (DAC) in 1996 and 1997 (T-109).

Treatment and Contrast‡	Average SHC 96 + 97 §		Range in SHC (96 + 97)		Percent of Readings Greater than Control	
	1-7 DAC	17-26 DAC	1-7 DAC	17-26 DAC	1-7 DAC	17-26 DAC
	---------- mm hr^{-1} ----------		---------- mm hr^{-1} ----------		---------- % ----------	
Control vs.	179	139	67-304	53-219	—	—
CA (Mar)	229	157	116-299	64-364	0	0
HJL	419	405*	190-674	222-764	0	40
HJR	692**	400*	448-1062	190-775	60	40
HJR + Sand	709**	548**	503-838	217-1136	60	40
HJR + Greenschoice	621**	305	454-883	160-545	40	40
HJR + WA	815**	487**	578-1024	145-749	80	40
HJR + B	720**	468**	548-868	100-855	80	60
HJR + Sand + WA	638**	403*	488-830	123-821	60	40
HJR + Sand + WA + B	623**	385*	343-930	108-500	40	20
LP + Greenschoice I	223	130	151-323	80-234	0	0
LSD (.05) =	330	224	—	—	—	—
F-test	**	**	—	—	—	—
CV (%)	43	44	—	—	—	—

‡ Contrast versus Control based on LSD.

**, *, † Significant difference at P ≤.01, .05, and .10.

§ Minimum SHC is 120 to 240 mm hr^{-1}.

Table 1-6. Oxygen diffusion rate (ODR) and moisture content in the surface 3 cm zone in 1996 at different times after irrigation (T-109). DAC = days after cultivation for HJR.

	2 Aug (17 DAC)		13 Aug (5 DAC)			4 Sep (27 DAC)	
Treatment	2.5 hrs	8 hrs	2.5 hrs	8.5 hrs	26 hrs	2.5 hrs	9 hrs
ODR (μg O_2 cm^{-2} min^{-1})							
Control vs.	.14	.26	.06	.11	.18	.18	.19
CA (Mar)	.09	.19	.09	.14	.19	.12	.15
HJR	.10	.24	.10	.11	.15	.18	.19
HJR + WA	.13	.25	.18	.18	.25	.12	.16
LSD (.05)	.13	.18	.16	.16	.16	.15	.14
F-test	.79	.79	.37	.67	.59	.67	.90
CV (%)	69	50	89	75	53	60	51
Moisture Content (% Vol.)							
Control vs.	47.9	49.3	51.0	47.8	48.4	50.3	51.0
CA (Mar)	52.1	50.1	50.6	47.8	47.4	52.3	51.0
HJR	50.3	49.8	49.7	46.5	48.5	51.9	50.1
HJR + WA	50.7	46.7	49.3	46.6	47.4	52.3	49.3
LSD (.05)	5.1	6.9	7.3	7.2	7.2	4.6	5.7
F-test	.38	.67	.94	.95	.96	.72	.88
CV (%)	6	9	9	9	9	6	7

**, *, † Significant difference at P $\leq$.01, .05, and .10.

Table 1-7. Oxygen diffusion rate (ODR) and moisture retention at 3 cm and 10 cm depths in 1997 at different times after irrigation (T-109). DAC = days after the last HJR cultivation.

	28 Jul (13 DAC)				13 Aug (2 DAC)				5 Sep (1 DAC)			
	3 cm		10 cm		3 cm		10 cm		3 cm		10 cm	
Treatment	26 hrs	50 hrs	26 hrs	50 hrs	2.5 hrs	26 hrs	2.5 hrs	26 hrs	2.5 hrs	26 hrs	2.5 hrs	26 hrs
ODR (μg O_2 cm^{-2} min^{-1})												
Control vs.	.36	.35	.19	.19	.30	.23	.23	.21	—	—	—	—
CA (Mar)	.31	.22	.28	.23	.30	.28	.28	.32	.38	.29	.35	.35
HJR	.26	.20†	.18	.14	.27	.25	.26	.36†	.48†	.26	.37	.32
HJR + WA	.34	.31	.18	.16	.34	.29	.22	.24	.54*	.26	.32	.35
LSD (.05)	.29	.16	.15	.11	.13	.10	.14	.17	.11	.07	.19	.10
F-test	.85	.22	.48	.35	.68	.72	.50	.26	*	.32	.80	.76
CV (%)	57	38	48	41	26	34	24	38	14	15	31	19
Moisture Content (% Vol.)												
Control vs.	42.9	33.3	—	—	—	—	—	—	—	—	—	—
CA (Mar)	37.0	30.9	—	—	—	—	—	—	44.7	—	41.0	—
HJR	41.2	37.0	—	—	—	—	—	—	47.1	—	42.3	—
HJR + WA	36.1	29.4	—	—	—	—	—	—	44.6	—	38.1	—
LSD (.05)	10.7	18.6	—	—	—	—	—	—	9.0	—	18.5	—
F-test	.45	.80	—	—	—	—	—	—	.85	—	.75	—
CV (%)	17	37	—	—	—	—	—	—	26	—	11	—

**, *, † Significant difference at P ≤.01, .05, and .10.

Table 1-8. Visual quality in 1996. (T-109)[§]

Treatment and Contrast [‡]	Visual Quality								
	12 Jun	27 Jun	9 Jul	23 Jul	16 Aug	30 Aug	10 Sep	15 Oct	25 Nov
	--------- 9.0 = ideal density, color, uniformity; 1.0 = no live turf ----------								
Control vs.	7.7	8.0	7.5	7.4	7.2	7.3	7.4	7.4	7.5
CA (Mar)	7.8	8.0	7.6	7.5	7.3	7.3	7.2	6.0**	7.1*
HJL	7.9	8.0	7.7	7.5	7.3	7.5	7.5	7.6	7.5
HJR	7.8	7.9	7.7	7.6	7.6†	7.6	7.5	7.6	7.7†
HJR + Sand	7.7	7.9	7.4	7.5	7.2	7.5	7.4	7.6	7.6
HJR + Greenschoice	7.7	7.9	7.6	7.5	7.3	7.5	7.5	7.2†	7.5
HJR + WA	7.8	7.8	7.5	7.6	7.2	7.5	7.5	7.5	7.5
HJR + B	7.7	7.9	7.8	7.6	7.4	7.5	7.5	7.4	7.5
HJR + Sand + WA	7.7	7.9	7.4	7.5	7.3	7.6	7.5	7.5	7.6
HJR + Sand + WA + B	7.8	8.0	7.6	7.4	7.3	7.5	7.5	7.4	7.4
LP + Greenschoice I	7.6	7.6	7.1*	7.2	6.6*	6.7**	6.6**	6.9*	7.5
LSD (.05) =	.31	.29	.40	.26	.47	.40	.40	.33	.21
F-test	.60	.34	†	.20	*	**	**	**	**
CV (%)	3	3	4	2	4	4	4	3	2

[‡] Contrast versus Control based on LSD.

**, *, † Significant difference at P≤.01, .05, and .10.

[§] Treatment Dates:

CA	29 Mar; 1 Oct
HJL, HJR, LP + GI	6, 24 Jun; 16 Jul; 8 Aug; 5 Sep
Sand Top., Greenschoice Top.	15 May; 11 Jun; 8, 30 Jul
Wetting Agent	16 May; 11 Jun; 9, 29 Jul; 12 Aug
Biostimulant	11 Jun; 9 Jul; 9 Aug; 13 Sep

Table 1-9. Visual quality in 1997. (T-109)[§]

Treatment and Contrast [‡]	Visual Quality 8 Apr	16 May	12 Jun	15 Jul	7 Aug	22 Aug	15 Oct
	--------- 9.0 = ideal density, color, uniformity; 1.0 = no live turf ----------						
Control vs.	7.6	7.5	7.7	7.5	7.4	7.5	7.3
CA (Mar)	6.7**	7.4	7.7	7.7	7.4	7.3	7.2
HJL	7.6	7.5	7.8	7.5	7.7*	8.0**	7.6*
HJR	7.5	7.7	7.7	7.6	7.6	7.7	7.3
HJR + Sand	7.5	7.5	7.8	7.6	7.6	7.6	7.3
HJR + Greenschoice	7.5	7.6	7.7	7.6	7.5	7.6	7.3
HJR + WA	7.6	7.6	7.7	7.5	7.6	7.8[†]	7.5
HJR + B	7.6	7.4	7.7	7.5	7.5	7.4	7.6*
HJR + Sand + WA	7.4[†]	7.5	7.7	7.5	7.4	7.7	7.3
HJR + Sand + WA + B	7.5	7.6	7.8	7.6	7.5	7.6	7.4
LP + Greenschoice I	7.5	7.5	7.4*	7.5	7.1*	6.8**	7.1
LSD (.05) =	.25	.28	.30	.23	.26	.33	.30
F-test	**	.30	.27	.88	**	**	*
CV (%)	2	3	3	2	2	3	3

[‡] Contrast versus Control based on LSD.

**, *, [†] Significant difference at P≤.01, .05, and .10.

[§] Treatment Dates:

CA	15 Mar
HJL, HJR, LP + GI	3, 25 Jun; 15 Jul; 11 Aug; 4 Sep
Sand Top., Greenschoice Top.	15 May; 10 Jun; 10 Jul; 6, 28 Aug
Wetting Agent	15 May; 11 Jun; 10 Jul; 7, 28 Aug
Biostimulant	11 Jun; 11 Jul; 7, 28 Aug

Table 1-10. Shoot density in 1996. (T-109)[§]

Treatment and Contrast [‡]	Shoot Density 12 Jun	27 Jun	9 Jul	23 Jul	16 Aug	30 Aug	10 Sep	15 Oct	25 Nov
	9.0 = ideal shoot density; 1.0 = no live turf								
Control vs.	7.7	8.1	7.5	7.5	7.5	7.4	7.4	7.5	7.5
CA	7.8	8.1	7.7	7.5	7.4	7.4	7.3	7.2*	7.3*
HJL	8.0	8.1	7.9*	7.6	7.4	7.6	7.6†	7.7†	7.6
HJR	7.8	8.0	7.7	7.7	7.7	7.6	7.6†	7.7†	7.8
HJR + Sand	7.7	7.9	7.5	7.5	7.5	7.5	7.5	7.6	7.6
HJR + Greenschoice	7.7	7.9	7.7	7.6	7.5	7.6	7.6†	7.4	7.6
HJR + WA	7.8	7.9	7.7	7.6	7.5	7.6	7.6†	7.6	7.5
HJR + B	7.8	8.0	8.0*	7.6	7.6	7.6	7.5	7.6	7.6
HJR + Sand + WA	7.7	8.0	7.6	7.6	7.6	7.6	7.6†	7.6	7.7*
HJR + Sand + WA + B	7.8	8.1	7.7	7.5	7.6	7.6	7.5	7.5	7.5
LP + Greenschoice I	7.6	7.8	7.4	7.4	7.1*	7.0*	7.1*	7.4	7.5
LSD (.05) =	.29	.31	.35	.21	.33	.31	.28	.22	.19
F-test	.54	.73	*	.54	*	**	**	**	**
CV (%)	3	3	3	2	3	3	3	2	2

[‡] Contrast versus Control based on LSD.

**, *, † Significant difference at P≤.01, .05, and .10.

[§] Treatment Dates:

CA	29 Mar; 1 Oct
HJL, HJR, LP + GI	6, 24 Jun; 16 Jul; 8 Aug; 5 Sep
Sand Top., Greenschoice Top.	15 May; 11 Jun; 8 Jul; 30 Jul
Wetting Agent	16 May; 11 Jun; 9, 29 Jul; 12 Aug
Biostimulant	11 Jun; 9 Jul; 9, 13 Sep

Table 1-11. Shoot density in 1997. (T-109)[§]

Treatment and Contrast [‡]	Shoot Density 8 Apr	16 May	13 Jun	15 Jul	7 Aug	22 Aug	15 Oct
	9.0 = ideal shoot density; 1.0 = no live turf						
Control vs.	7.6	7.5	7.7	7.6	7.5	7.5	7.5
CA (Mar)	7.1**	7.5	7.7	7.7	7.4	7.4	7.3
HJL	7.7	7.5	7.8	7.7	7.7†	8.0**	7.7*
HJR	7.5	7.7†	7.7	7.7	7.6	7.7	7.4
HJR + Sand	7.6	7.6	7.8	7.7	7.6	7.6	7.4
HJR + Greenschoice	7.6	7.6	7.7	7.7	7.6	7.6	7.4
HJR + WA	7.6	7.7†	7.7	7.7	7.7†	7.8†	7.5
HJR + B	7.6	7.4	7.7	7.7	7.6	7.5	7.7*
HJR + Sand + WA	7.5	7.5	7.7	7.6	7.5	7.7	7.4
HJR + Sand + WA + B	7.5	7.6	7.9	7.7	7.5	7.6	7.6†
LP + Greenschoice I	7.5	7.5	7.5	7.6	7.3†	7.1*	7.2
LSD (.05) =	.26	.21	.26	.20	.22	.32	.31
F-test	**	.19	.44	.99	*	**	*
CV (%)	2	2	2	2	2	3	3

[‡] Contrast versus Control based on LSD.

**, *, † Significant difference at P≤.01, .05, and .10.

[§] Treatment Dates:

CA	15 Mar
HJL, HJR, LP + GI	3, 25 Jun; 15 Jul; 11 Aug; 4 Sep
Sand Top., Greenschoice Top.	15 May; 10 Jun; 10 Jul; 6, 28 Aug
Wetting Agent	15 May; 11 Jun; 10 Jul; 7, 28 Aug
Biostimulant	11 Jun; 11 Jul; 7, 28 Aug

Table 1-12. Turfgrass color in 1996. (T-109)[§]

Treatment and Contrast [‡]	Color								
	12 Jun	27 Jun	9 Jul	23 Jul	16 Aug	30 Aug	10 Sep	15 Oct	25 Nov
	9.0 = dark green; 1.0 = no green, all brown								
Control vs.	7.8	8.0	7.6	7.5	7.5	7.3	7.4	7.4	7.5
CA	7.8	8.1	7.9*	7.5	7.5	7.3	7.3	7.7	7.3
HJL	7.9	8.0	7.8†	7.5	7.4	7.6†	7.6	7.6	7.6
HJR	7.8	8.0	7.8†	7.6	7.7	7.6†	7.6	7.6	7.6
HJR + Sand	7.8	7.9	7.8†	7.6	7.4	7.5	7.6	7.6	7.5
HJR + Greenschoice	7.8	7.9	7.7	7.5	7.4	7.6†	7.6	7.5	7.6
HJR + WA	7.9	7.9	7.7	7.5	7.3	7.5	7.5	7.5	7.5
HJR + B	7.8	8.0	7.9*	7.6	7.5	7.6†	7.5	7.5	7.6
HJR + Sand + WA	7.7	7.9	7.7	7.6	7.4	7.6†	7.6	7.5	7.6
HJR + Sand + WA + B	7.9	8.1	7.8†	7.5	7.6	7.5	7.6	7.5	7.5
LP + Greenschoice I	7.8	7.9	7.5	7.5	7.0	6.9*	7.1†	7.3	7.6
LSD (.05) =	.19	.22	.26	.19	.37	.37	.34	.29	.27
F-test	.62	.43	†	.53	.20	*	†	.20	.70
CV (%)	2	2	2	2	4	3	3	3	2

[‡] Contrast versus Control based on LSD.

**, *, † Significant difference at P≤.01, .05, and .10.

[§] Treatment Dates:

CA	29 Mar; 1 Oct
HJL, HJR, LP + GI	6, 24 Jun; 16 Jul; 8 Aug; 5 Sep
Sand Top., Greenschoice Top.	15 May; 11 Jun; 8, 30 Jul
Wetting Agent	16 May; 11 Jun; 9, 29 Jul; 12 Aug
Biostimulant	11 Jun; 9 Jul; 9 Aug; 13 Sep

Table 1-13. Turfgrass color in 1997. (T-109)[§]

Treatment and Contrast [‡]	Turf Color 8 Apr	16 May	12 Jun	15 Jul	7 Aug	22 Aug	15 Oct
	9.0 = dark green; 1.0 = no green, all brown						
Control vs.	7.7	7.6	7.8	7.5	7.4	7.6	7.5
CA (Mar)	7.2**	7.5	7.8	7.5	7.6	7.6	7.5
HJL	7.7	7.5	7.8	7.5	7.7*	8.0*	7.7
HJR	7.6	7.7	7.7	7.6	7.5	7.7	7.6
HJR + Sand	7.6	7.7	7.9	7.6	7.6	7.7	7.6
HJR + Greenschoice	7.6	7.6	7.7	7.6	7.6	7.7	7.6
HJR + WA	7.7	7.7	7.8	7.5	7.7*	7.8	7.7
HJR + B	7.6	7.4	7.7	7.5	7.6	7.5	7.7
HJR + Sand + WA	7.5	7.5	7.7	7.6	7.5	7.7	7.6
HJR + Sand + WA + B	7.6	7.7	7.9	7.6	7.6	7.7	7.7
LP + Greenschoice I	7.5	7.7	7.6*	7.5	7.3	7.3[†]	7.6
LSD (.05) =	.26	.30	.18	.22	.25	.30	.24
F-test	*	.52	.16	.93	[†]	**	.39
CV (%)	2	3	2	2	2	3	2

[‡] Contrast versus Control based on LSD.

**, *, [†] Significant difference at P≤.01, .05, and .10.

[§] Treatment Dates:

CA	15 Mar
HJL, HJR, LP + GI	3, 25 Jun; 15 Jul; 11 Aug; 4 Sep
Sand Top., Greenschoice Top.	15 May; 10 Jun; 10 Jul; 6, 28 Aug
Wetting Agent	15 May; 11 Jun; 10 Jul; 7, 28 Aug
Biostimulant	11 Jun; 11 Jul; 7, 28 Aug

Table 1-14. Summary of turfgrass shoot performance (visual quality, shoot density, color) for 1996 (9) and 1997 (7) based on percent of readings less than (<) or greater than (>) the Control (T-109).

Treatment and Contrast‡	Turf Quality		Shoot Density		Turf Color		All Shoot Parameters	
	<	>	<	>	<	>	<	>
	%							
Control	—	—	—	—	—	—	—	—
CA	19	0	19	0	6	6	15	2
HJL	0	19	0	38	0	25	0	27
HJR	0	13	0	19	0	13	0	15
HJR + Sand	0	0	0	0	0	6	0	2
HJR + Greenschoice	6	0	0	6	0	6	2	4
HJR + WA	0	6	0	25	0	6	0	12
HJR + B	0	6	0	13	0	13	0	11
HJR + Sand + WA	6	0	0	13	0	6	2	6
HJR + Sand + WA + B	0	0	0	6	0	6	0	4
LP + Greenschoice I	50	0	31	0	25	0	35	0

Table 1-15. Canopy reflectance data presented as the IR/R index in 1996. IR/R = R_{935} / R_{661}; often correlated with LAI. (T-109)[§]

Treatment and Contrast [‡]	IR/R 13 Jun	25 Jun	12 Jul	7 Aug	30 Aug	11 Sep	18 Sep	8 Oct
	---------- Higher Value = Best ----------							
Control vs.	13.9	12.2	15.9	9.7	10.9	10.8	11.3	12.8
CA	14.4	12.6	16.4	10.3	11.4	11.0	11.2	4.4**
HJL	15.4[†]	11.9	16.3	10.2	12.0[†]	12.3*	12.3	13.9
HJR	14.0	11.7	15.6	10.6	11.5	11.0	12.1	12.7
HJR + Sand	13.6	12.8	14.5[†]	10.1	11.3	11.5	11.4	13.2
HJR + Greenschoice	11.7*	12.7	13.9*	10.4	12.4*	12.1*	12.0	13.2
HJR + WA	14.9	12.2	15.9	11.0[†]	11.5	11.7[†]	11.8	12.2
HJR + B	14.5	11.8	15.5	10.6	12.0[†]	12.2*	11.7	13.9
HJR + Sand + WA	13.4	12.4	14.5[†]	10.2	11.7	11.4	11.7	13.2
HJR + Sand + WA + B	14.1	12.0	14.3[†]	10.4	12.2[†]	12.1*	11.9	12.9
LP + Greenschoice I	13.5	12.1	15.0	9.8	10.9	9.4*	11.3	12.8
LSD (.05) =	1.6	1.3	1.6	1.3	1.3	1.1	1.4	1.9
F-test	**	.68	*	.80	.38	**	.74	**
CV (%)	8	7	7	9	8	6	8	11

[‡] Contrast versus Control based on LSD.

**, *, [†] Significant difference at P≤.01, .05, and .10.

[§] Treatment Dates:

CA	29 Mar; 1 Oct
HJL, HJR, LP + GI	6, 24 Jun; 16 Jul; 8 Aug; 5 Sep
Sand Top., Greenschoice Top.	15 May; 11 Jun; 8, 30 Jul
Wetting Agent	16 May; 11 Jun; 9, 29 Jul; 12 Aug
Biostimulant	11 Jun; 9 Jul; 9 Aug; 13 Sep

Table 1-16. Canopy reflectance data presented as the IR/R index in 1997. IR/R = R_{935} / R_{661}; often correlated with LAI. (T-109)[§]

Treatment and Contrast [‡]	IR/R 30 Apr	23 May	20 Jun	25 Jul	19 Aug	30 Sep	5 Nov
	---------- Higher Value = Best ----------						
Control vs.	10.1	16.5	12.5	11.8	16.7	15.8	13.1
CA	8.7*	15.7	12.8	12.4	16.1	16.3	12.3
HJL	9.8	15.8	12.4	12.2	16.1	18.1*	14.0
HJR	9.8	16.2	11.9	12.1	16.2	15.8	13.4
HJR + Sand	10.5	16.1	13.2	11.7	15.3†	16.3	13.1
HJR + Greenschoice	10.0	16.3	13.4†	12.4	16.6	16.0	12.4
HJR + WA	10.2	16.6	13.1	12.1	16.2	16.4	13.2
HJR + B	9.8	15.3	12.3	10.9	15.4	17.2	13.9
HJR + Sand + WA	9.7	15.5	12.4	12.4	15.8	15.7	12.8
HJR + Sand + WA + B	9.8	15.9	12.6	12.1	15.6	17.7†	13.9
LP + Greenschoice I	9.6	15.0	11.9	11.3	15.3†	15.5	12.5
LSD (.05) =	.89	1.98	1.16	1.52	1.65	2.17	1.26
F-test	†	.89	.19	.61	.73	.29	†
CV (%)	6	9	6	9	7	9	7

‡ Contrast versus Control based on LSD.

**, *, † Significant difference at P≤.01, .05, and .10.

§ Treatment Dates:

CA	15 Mar
HJL, HJR, LP + GI	3, 25 Jun; 15 Jul; 11 Aug; 4 Sep
Sand Top., Greenschoice Top.	15 May; 10 Jun; 10 Jul; 6, 28 Aug
Wetting Agent	15 May; 11 Jun; 10 Jul; 7, 28 Aug
Biostimulant	11 Jun; 11 Jul; 7, 28 Aug

Table 1-17. Canopy reflectance presented as normalized difference vegetation index (NDVI) in 1996. NDVI = $R_{935} - R_{661} / R_{935} + R_{661}$, where R_{935} = reflectance at 790 - 1080 nm and R_{661} = reflectance at 648 to 674 nm. NDVI is often correlated to green biomass, PAR absorption, and LAI. (T-109)[§]

Treatment and Contrast [‡]	NDVI							
	13 Jun	25 Jun	12 Jul	7 Aug	30 Aug	11 Sep	18 Sep	8 Oct
	1.00 = ideal; 0 = no PAR absorption							
Control vs.	.87	.85	.88	.81	.83	.83	.84	.85
CA	.87	.85	.89[†]	.82	.84	.83	.84	.63**
HJL	.88	.85	.88	.82	.85	.85*	.85	.86
HJR	.87	.84[†]	.88	.83	.84	.83	.85	.85
HJR + Sand	.86	.85	.87	.82	.84	.84[†]	.84	.86
HJR + Greenschoice	.84*	.85	.87	.83	.85	.85*	.85	.86
HJR + WA	.87	.85	.88	.83	.84	.84[†]	.84	.84
HJR + B	.87	.84[†]	.88	.83	.85	.85*	.84	.86
HJR + Sand + WA	.86	.85	.87[†]	.82	.84	.84[†]	.84	.86
HJR + Sand + WA + B	.87	.85	.87[†]	.82	.85	.85*	.84	.85
LP + Greenschoice I	.86	.85	.87[†]	.81	.83	.81*	.84	.85
LSD (.05) =	.02	.01	.01	.02	.02	.01	.02	.03
F-test	**	.70	*	.80	.44	**	.77	**
CV (%)	1	1	7	2	2	1	1	2

[‡] Contrast versus Control based on LSD.

**, *, [†] Significant difference at P≤.01, .05, and .10.

[§] Treatment Dates:

CA	29 Mar; 1 Oct
HJL, HJR, LP + GI	6, 24 Jun; 16 Jul; 8 Aug; 5 Sep
Sand Top., Greenschoice Top.	15 May; 11 Jun; 8, 30 Jul
Wetting Agent	16 May; 11 Jun; 9, 29 Jul; 12 Aug
Biostimulant	11 Jun; 9 Jul; 9 Aug; 13 Sep

Table 1-18. Canopy reflectance presented as normalized difference vegetation index (NDVI) in 1997. NDVI = $R_{935} - R_{661} / R_{935} + R_{661}$, where R_{935} = reflectance at 790 - 1080 nm and R_{661} = reflectance at 648 to 674 nm. NDVI is often correlated to green biomass, PAR absorption, and LAI. (T-109)[§]

Treatment and Contrast [‡]	NDVI						
	30 Apr	23 May	20 Jun	25 Jul	19 Aug	30 Sep	5 Nov
	1.00 = ideal; 0 = no PAR absorption						
Control vs.	.82	.88	.85	.84	.89	.88	.86
CA	.79*	.88	.85	.85	.88	.88	.85
HJL	.82	.88	.85	.85	.88	.90	.87
HJR	.81	.88	.84	.85	.88	.88	.86
HJR + Sand	.83	.88	.86	.83	.88	.88	.86
HJR + Greenschoice	.82	.88	.86	.85	.88	.88	.85
HJR + WA	.82	.89	.86	.85	.88	.88	.86
HJR + B	.81	.88	.85	.83	.88	.89	.87
HJR + Sand + WA	.81	.88	.85	.85	.88	.88	.85
HJR + Sand + WA + B	.82	.88	.85	.85	.88	.89	.86
LP + Greenschoice I	.81	.87	.84	.83	.88	.88	.85
LSD (.05) =	.016	.014	.013	.024	.011	.015	.013
F-test	†	.90	.20	.71	.80	.40	†
CV (%)	1	1	1	2	1	1	1

[‡] Contrast versus Control based on LSD.

**, *, † Significant difference at P≤.01, .05, and .10.

[§] Treatment Dates:

CA	15 Mar
HJL, HJR, LP + GI	3, 25 Jun; 15 Jul; 11 Aug; 4 Sep
Sand Top., Greenschoice Top.	15 May; 10 Jun; 10 Jul; 6, 28 Aug
Wetting Agent	15 May; 11 Jun; 10 Jul; 7, 28 Aug
Biostimulant	11 Jun; 11 Jul; 7, 28 Aug

Table 1-19. Canopy reflectance at 661 nm in 1996 (T-109). Range 648-674 nm (Red, PAR). Low percent reflectance = higher PAR absorption.[§]

Treatment and Contrast [‡]	Reflectance (661 nm)							
	13 Jun	25 Jun	12 Jul	7 Aug	30 Aug	11 Sep	18 Sep	8 Oct
	%							
Control vs.	4.4	5.1	4.1	5.7	5.2	7.1	6.5	5.5
CA	4.3	4.9	4.1	5.5	5.1	7.2	6.6	7.9**
HJL	4.0*	5.4	4.1	5.5	4.9	6.7[†]	6.2	5.4
HJR	4.3	5.3	4.2	5.3[†]	5.0	7.1	6.2	5.8
HJR + Sand	4.1[†]	4.9	4.2	5.3[†]	5.1	6.9	6.6	5.3
HJR + Greenschoice	4.3	4.8	4.1	5.1*	4.7	6.7[†]	6.3	5.5
HJR + WA	4.2	5.2	4.2	5.2*	5.1	6.9	6.3	5.8
HJR + B	4.2	5.4	4.2	5.2*	4.9	6.6*	6.4	5.3
HJR + Sand + WA	4.1[†]	4.9	4.2	5.3[†]	5.0	7.0	6.3	5.5
HJR + Sand + WA + B	3.9*	5.2	4.2	5.2*	4.8	6.7[†]	6.3	5.7
LP + Greenschoice I	4.3	4.9	4.3	5.5	5.3	7.6*	6.4	5.6
LSD (.05) =	.36	.52	.45	.48	.46	.45	.64	.67
F-test	.21	.20	.99	.39	.36	**	.95	**
CV (%)	6	7	7	6	6	4	7	8

[‡] Contrast versus Control based on LSD.

**, *, [†] Significant difference at P≤.01, .05, and .10.

[§] Treatment Dates:

CA	29 Mar; 1 Oct
HJL, HJR, LP + GI	6, 24 Jun; 16 Jul; 8 Aug; 5 Sep
Sand Top., Greenschoice Top.	15 May; 11 Jun; 8, 30 Jul
Wetting Agent	16 May; 11 Jun; 9, 29 Jul; 12 Aug
Biostimulant	11 Jun; 9 Jul; 9 Aug; 13 Sep

Table 1-20. Canopy reflectance at 661 nm in 1997 (T-109). Range 648-674 nm (Red, PAR). Low percent reflectance = higher PAR absorption.[§]

Treatment and Contrast [‡]	Reflectance (661 nm)						
	30 Apr	23 May	20 Jun	25 Jul	19 Aug	30 Sep	5 Nov
	%						
Control vs.	4.8	3.8	4.8	5.0	4.0	4.1	4.7
CA	5.3*	4.0	4.7	5.0	4.2	4.1	5.1†
HJL	4.9	4.0	4.8	5.1	4.2	3.7*	4.6
HJR	5.0	3.8	4.9	5.0	4.1	4.1	4.7
HJR + Sand	4.7	3.9	4.6	5.4	4.3	4.0	4.8
HJR + Greenschoice	4.8	3.8	4.5†	5.0	4.0	4.1	5.1†
HJR + WA	4.9	3.8	4.6	5.1	4.2	4.0	4.8
HJR + B	4.9	4.1	4.8	5.6†	4.3	3.8†	4.5
HJR + Sand + WA	4.9	3.9	4.7	4.9	4.2	4.1	4.8
HJR + Sand + WA + B	4.8	3.9	4.8	5.1	4.3	3.7*	4.6
LP + Greenschoice I	5.0	4.1	4.9	5.2	4.2	4.2	4.9
LSD (.05) =	.37	.39	.30	.72	.38	.39	.42
F-test	.16	.84	†	.80	.79	.18	.17
CV (%)	5	7	4	10	6	7	6

‡ Contrast versus Control based on LSD.

**, *, † Significant difference at P≤.01, .05, and .10.

§ Treatment Dates:

CA	15 Mar
HJL, HJR, LP + GI	3, 25 Jun; 15 Jul; 11 Aug; 4 Sep
Sand Top., Greenschoice Top.	15 May; 10 Jun; 10 Jul; 6, 28 Aug
Wetting Agent	15 May; 11 Jun; 10 Jul; 7, 28 Aug
Biostimulant	11 Jun; 11 Jul; 7, 28 Aug

Table 1-21. Summary of physiological stress indexes (IR/R, NDVI, Reflectance 661 nm) across 1996 (8) and 1997 (7) based on percent of readings less than (<) or greater than (>) the control (T-109).

Treatment and Contrast‡	IR/R		NDVI		Reflect. 661 nm		All Indexes	
	<	>	<	>	<	>	<	>
	%							
Control vs.	—	—	—	—	—	—	—	—
CA	13	0	13	7	20	0	15	2
HJL	0	27	0	7	0	20	0	18
HJR	0	0	7	0	0	7	0	5
HJR + Sand	13	0	0	7	0	13	4	7
HJR + Greenschoice	13	20	7	7	7	20	9	16
HJR + WA	0	20	0	7	0	7	0	11
HJR + B	0	0	7	7	7	20	5	9
HJR + Sand + WA	7	0	7	7	0	13	5	7
HJR + Sand + WA + B	7	20	7	7	0	27	5	18
LP + Greenschoice I	13	0	13	0	7	0	11	0

Table 1-22. Root length density (RLD) by depth, change in RLD by depth, total root length (TRL), and change in TRL in 1996. Sample dates were 25 June and 11 September 1996 (T-109).

Treatment and Contrast[§]	Root Length Density (RLD) 25 Jun 96 3 to 10 cm	25 Jun 96 10 to 20 cm	11 Sep 96 3 to 10 cm	11 Sep 96 10 to 20 cm	Percent Roots (RLD) Retained Jun to Sep 3 to 10 cm	Percent Roots (RLD) Retained Jun to Sep 10 to 20 cm	Total Root Length (TRL) 25 Jun	Total Root Length (TRL) 11 Sep	Percent Roots (TRL) Retained Jun to Sep
	cm cm^{-3}				%		cm cm^{-2}		%
Control vs.	19.66	2.13	4.85	0.96	25	45	169	47	27
CA	15.99	2.56	5.14	0.47*	32	18	145	43	30
HJL	18.08	1.77	5.12	0.49*	28	28	153	43	28
HJR	14.70	1.46	6.87	0.61†	47	42	125	58	46
HJR + Sand	17.39	2.22	6.06	0.79	35	36	153	53	35
HJR + Greenschoice	23.12	1.69	9.66†	0.52*	42	31	190	78†	41
HJR + WA	14.91	2.52	4.67	0.63†	31	25	137	41	30
HJR + B	22.01	3.10	4.88	0.88	22	28	196	45	23
HJR + Sand + WA	21.53	2.28	6.60	0.80	31	35	184	58	32
HJR + Sand + WA + B	19.68	2.01	6.16	0.53*	31	26	168	52	31
LP + Greenschoice I	17.56	3.37	7.18	0.73	41	22	165	61	37
LSD (.05) =	9.60	1.87	4.90	0.38	31	61	80	37	26
F-test	.69	.62	.67	.15	.92	.34	.76	.93	.84
CV (%)	36	56	56	39	60	101	34	47	53

‡ Contrast versus Control based on LSD.

**, *, † Significant difference at P≤.01, .05, and .10.