Field evaluation of wetting agent efficacy against localized dry spot and hydrophobicity in creeping bentgrass putting green turf -AquaAid

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The objective was to determine efficacy of wetting agents on creeping bentgrass putting green turf on a high sand rootzone. Efficacy against localized dry spot, effects on soil moisture content, and on root system growth and health were to be determined.

MATERIALS/METHODS

The experiment was located on the alternative construction putting green at the GTI, which is a typical industry standard green of this type, with 30 cm of USGA specification rootzone mixture (80% sand, 20% peat v/v) on a graded subsoil with tile drains but no gravel drainage layer (Figure 1). Permanent turf cover on this green is 'Cobra' creeping bentgrass (*Agrostis stolonifera*) and invasive weedy *Poa annua*. The green has developed hydrophobic layers in previous seasons. Standard cultural practices were maintained (mowing at 5 mm, regular fertility).

Test Design: The test was a complete randomized block design with four replicates per treatment. Each plot measured 2 m x 1 m.

Treatments: Treatments listed in Table 1 were applied via a calibrated compressed air sprayer (Figure 2: 20 psi, Teejet 8001VS flat fan nozzles, 20 ml sec^{-1}) on July 3, July 15, July 30, August 28, and September 23, 2009. All liquid applications were made in 80 ml of water per square meter (8 L 100 m^{-2}). Control plots were treated with water only. Treatments were watered following application.

Data collected included

Environmental Data: Environmental data collected included daily max/min air temperature, irrigation records (turfgrass site manager), rainfall and an initial soil analysis: macro and micronutrients, soil type, particle size, % organic matter.

Evaluation: Turf health and uniformity were assessed with canopy reflectance measurements (normalized-difference vegetation index; Greenseeker). The NDVI values are decreased by phytotoxicity, drought, localized dry spot, and have been shown to be well correlated with visual estimates of turf quality.

Plots were evaluated for visual rating of localized dry spot when it occurred. The extent of the symptoms was recorded as the percentage exhibiting symptoms.

Soil moisture readings (% volumetric water) were recorded using a ThetaProbe soil moisture meter. Monthly water droplet absorption tests were made on 4-6 cm soil cores: 4 soil cores, approximately 15 cm each, were taken from each plot, air dried for two weeks at room temperature, and evaluated for hydrophobicity using the water

Table 1. Treatments

Treatment	Rate per application	Application schedule
1 OARS 6	1.9 mL m^{-2} in 80 mL water	Monthly July- September
2 OARS 5	1.6 mL m^{-2} in 80 mL water	Monthly July- September
3 OARS 4	1.3 mL m^{-2} in 80 mL water	Monthly July- September
4 PBS150 2x	2.5 mL m^{-2} in 80 mL water	Day 0 and Day 14
5 PBS150 1x	2.5 mL m^{-2} in 80 mL water	Day 0
6 PBS150 4x	1.3 mL m^{-2} in 80 mL water	Monthly July- September
7 Respond 3	1.3 mL m^{-2} in 80 mL water	Monthly July- September
8 Control	—	—

Figure 1. Plot area on research green, July 9, 2009.

Figure 2. Application of treatments with compressed air sprayer.

droplet penetration test (time to penetration of a 35 μl droplet of distilled water placed at 1 cm intervals along the core starting at the thatch-air interface and ending at 6 cm).

Data Analysis: Data were analysed and means compared using appropriate statistical methods (ANOVA).

RESULTS

Environmental data. Rainfall and temperature data were recorded at the Environment Canada weather station in the research ranges at the GTI (Figures 3 and 4). The season was slightly wetter than average, with ~300 mm of rainfall during the course of the experiment. Temperatures were below normal for summer in Guelph, with only two days near 30°C. To increase the likelihood of localized dry spot development, irrigation was withheld from the plots after the middle of July. In spite of the cool wet weather, the turf experienced two significant periods of drought and dry spot development, in late July and September.

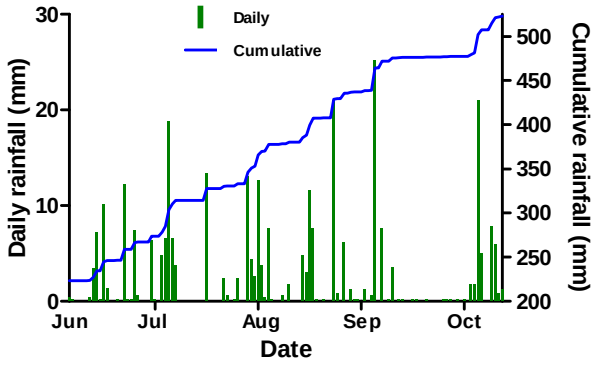

Figure 3. Daily and cumulative precipitation – summer 2009 Data are from the Environment Canada weather station at the GTI.

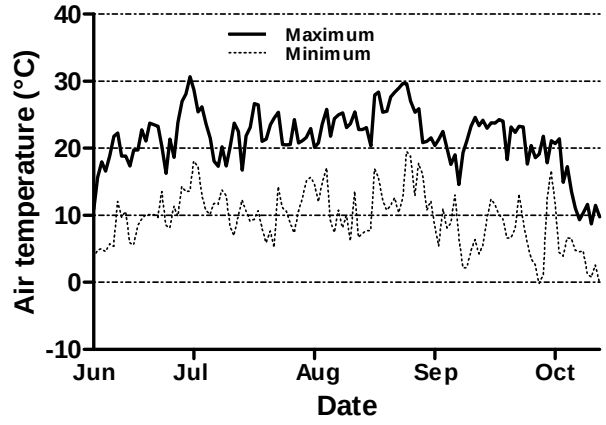

Figure 4. Daily maximum and minimum air temperatures – summer 2009. Data are from the Environment Canada weather station at the GTI.

Turf performance: canopy reflectance. Canopy reflectance readings were significantly different among the treatments on all observation dates (Table 2.) The Greenseeker is very sensitive to NDVI variation, which reflects turf health (chlorophyll content, photosynthetic activity, growth rate), as well as stresses (phytotoxicity from treatments, drought stress, localized dry spot development). There was some evidence of phytotoxicity of two of the treatments, OARS 5 and PBS150 1x, which appeared as a decline in NDVI immediately following applications compared to the control plots; this confirmed visual assessments of slight yellowing in these plots. The same effects were not seen in later applications of the OARS 5. Over the course of the trial, the performance of the treated plots as assessed by canopy reflectance was consistently higher than the control. This is best seen by coding the data to set the control means to 0 (Figure 5). The relative decline in the control plots was due primarily to development of localized dry spot. Among the treatments, the general pattern in NDVI, particularly evident during the stress period in September, was PBS150 monthly, OARS 4 > PBS150 2x, Respond 3 > OARS 6 > OARS 5, PBS150 1x.

It was also possible to assess the uniformity of the plots by examining the coefficients of variation of the canopy reflectance readings. In general, the decrease in canopy reflectance in the control plots was accompanied by an increase in variability. The treated plots remained more uniform (Figure 6).

Localized dry spot. The wet summer resulted in localized dry spot development on only late in the season (September). This is in spite of irrigation being withheld from the plot areas. Other more seriously affected parts of the green showed a LDS period in late July, which was also evident in the NDVI data on these plots, but not in LDS development. On the dates when LDS differences were significant, there were few differences among the treatments, though the PBS 150 single application tended to be more affected (Table 3).

Volumetric water content. There were significant differences among treatments on all dates for volumetric water content as measured with the ThetaProbe (Table 4). The differences in the early part of the trial may not be biologically significant, since water contents are well into adequately watered range (field capacity on a USGA sand rootzone is typically 25-30%), but they may be involved in the detected differences in canopy reflectance. Patterns were stronger in September, when localized dry spots were also detected. There were not large differences among any of the treatments, although, as with LDS, the PBS 150 1x treatment was driest.

Water drop penetration tests / hydrophobicity. Data from the cores collected during the trial indicate that the rootzone in these plots continues to be severely hydrophobic. In fact, comparison of WDPT tests done in connection with various trials over several years show a steady increase in depth and severity of hydrophobic conditions (Figure 7). The water drop penetration tests from this trial showed the most consistent treatment effect patterns in the upper layers of the rootzone (0 and 1 cm deep) (Table 5). By the end of the trial (Oct 14), there were significant reductions in hydrophobicity compared to the control for the 0 and 1 cm depths. The PB150 2x treatment reduced the hydrophobicity at 0 cm 2 weeks after the second application, and the PB150 4x had the best effect at 0 and 1 cm depth at the end of the experiment.

DISCUSSION AND CONCLUSIONS

Wetting agent treatment effects on localized dry spot were limited to late September,

Table 2. Canopy reflectance (normalized-difference vegetation index) in treated plots.

Treatment	06/22	06/25	07/02	**07/04**[2]	07/05	07/07	07/08
PBS150 4x	0.612[1] bc	0.603 cde	0.736 bc	0.685 a	0.686 a	0.687 a	0.670 a
OARS 4	0.616 ab	0.609 bc	0.745 a	0.664 c	0.664 c	0.684 ab	0.664 ab
PBS150 2x	0.611 bc	0.596 e	0.729 d	0.681 a	0.673 b	0.680 bc	0.654 bc
Respond 3	0.608 c	0.597 e	0.736 bc	0.670 bc	0.666 bc	0.671 d	0.653 cd
OARS 6	0.614 bc	0.617 a	0.732 cd	0.655 d	0.653 d	0.673 cd	0.644 d
OARS 5	0.623 a	0.608 bcd	0.731 cd	0.641 e	0.649 d	0.651 e	0.632 e
PBS150 1x	0.611 bc	0.612 ab	0.742 a	0.682 a	0.669 bc	0.675 cd	0.656 bc
Control	0.612 bc	0.602 de	0.740 ab	0.673 b	0.672 b	0.678 bc	0.658 bc
msd p=0.05	0.0076	0.0069	0.0058	0.0064	0.0072	0.0065	0.0098
	07/14	07/15	**07/16**	07/17	07/21	07/27	07/30
PBS150 4	0.654 ab	0.634 c	0.666 a	0.663 b	0.649 ab	0.672 b	0.629 ab
OARS 4	0.659 a	0.643 b	0.675 a	0.659 bc	0.652 a	0.664 cd	0.622 bc
PBS150 2x	0.651 b	0.659 a	0.647 bc	0.673 a	0.645 bc	0.680 a	0.631 a
Respond 3	0.654 ab	0.636 bc	0.656 b	0.656 c	0.651 ab	0.667 bc	0.618 cd
OARS 6	0.657 ab	0.635 bc	0.654 b	0.660 bc	0.650 ab	0.657 d	0.614 d
OARS 5	0.642 c	0.616 d	0.633 d	0.639 d	0.636 d	0.648 e	0.616 cd
PBS150 1x	0.639 c	0.613 d	0.637 cd	0.645 d	0.639 cd	0.646 e	0.614 d
Control	0.653 ab	0.632 c	0.653 b	0.655 c	0.648 ab	0.661 cd	0.615 cd
msd p=0.05	0.0066	0.0076	0.0099	0.0065	0.0066	0.0081	0.0076
	08/04	08/11	08/14	08/17	08/20	08/24	08/28
PBS150 4	0.673 ab	0.529 d	0.587 a	0.676 b	0.673 ab	0.708 ab	0.671 a
OARS 4	0.671 bc	0.552 bc	0.592 a	0.676 b	0.674 ab	0.707 ab	0.668 ab
PBS150 2x	0.678 a	0.542 cd	0.593 a	0.687 a	0.675 a	0.713 a	0.649 c
Respond 3	0.668 bcd	0.582 a	0.595 a	0.679 b	0.668 b	0.704 bc	0.673 a
OARS 6	0.671 bc	0.578 a	0.570 b	0.662 c	0.659 c	0.698 c	0.664 b
OARS 5	0.665 cde	0.575 a	0.573 b	0.663 c	0.654 c	0.690 d	0.651 c
PBS150 1x	0.659 e	0.570 ab	0.568 b	0.656 cd	0.653 c	0.689 d	0.638 d
Control	0.662 de	0.572 ab	0.576 b	0.653 d	0.659 c	0.692 d	0.637 d
msd p=0.05	0.0065	0.0215	0.0102	0.0071	0.0065	0.0062	0.0054
	08/31	09/02	09/08	09/09	09/10	09/11	09/14
PBS150 4	0.723 a	0.667 a	0.673 a	0.650 a	0.623 ab	0.650 a	0.661 b
OARS 4	0.715 b	0.661 ab	0.669 ab	0.649 ab	0.628 a	0.649 a	0.667 a
PBS150 2x	0.703 c	0.645 c	0.666 b	0.645 ab	0.624 ab	0.647 a	0.659 b
Respond 3	0.707 c	0.656 b	0.669 ab	0.643 b	0.619 bc	0.639 b	0.657 b
OARS 6	0.685 d	0.641 c	0.657 c	0.636 c	0.614 c	0.636 b	0.649 c
OARS 5	0.674 e	0.634 d	0.653 cd	0.627 d	0.602 de	0.622 c	0.649 c
PBS150 1x	0.681 de	0.631 d	0.648 d	0.627 d	0.608 d	0.626 c	0.640 d
Control	0.679 de	0.633 d	0.651 cd	0.625 d	0.602 e	0.626 c	0.628 e
msd p=0.05	0.0076	0.0067	0.0064	0.0058	0.0059	0.0075	0.0058
	09/15	09/17	09/21	09/23	**09/24**	10/06	10/13
PBS150 4	0.661 a	0.655 a	0.693 a	0.684 a	0.665 a	0.649 a	0.617 bc
OARS 4	0.660 a	0.653 ab	0.695 a	0.685 a	0.657 b	0.652 a	0.620 bc
PBS150 2x	0.652 bc	0.650 ab	0.682 b	0.678 b	0.663 ab	0.650 a	0.628 a
Respond 3	0.658 ab	0.653 ab	0.693 a	0.684 a	0.660 ab	0.641 b	0.622 ab
OARS 6	0.648 c	0.650 ab	0.683 b	0.676 b	0.648 c	0.633 c	0.607 de
OARS 5	0.651 c	0.648 b	0.684 b	0.678 b	0.647 c	0.626 c	0.608 de
PBS150 1x	0.635 d	0.630 c	0.666 c	0.662 c	0.643 c	0.627 c	0.614 cd
Control	0.624 e	0.610 d	0.635 d	0.637 d	0.613 d	0.611 d	0.605 e
msd p=0.05	0.0056	0.006	0.0075	0.005	0.0062	0.007	0.0073

[1] Normalized-vegetation index: mean of ~50 readings x 4 replicates; means within columns followed by the same letter are not significantly different (Tukey's HSD test, p=0.05)

[2] Observation dates most closely following application dates are bolded.

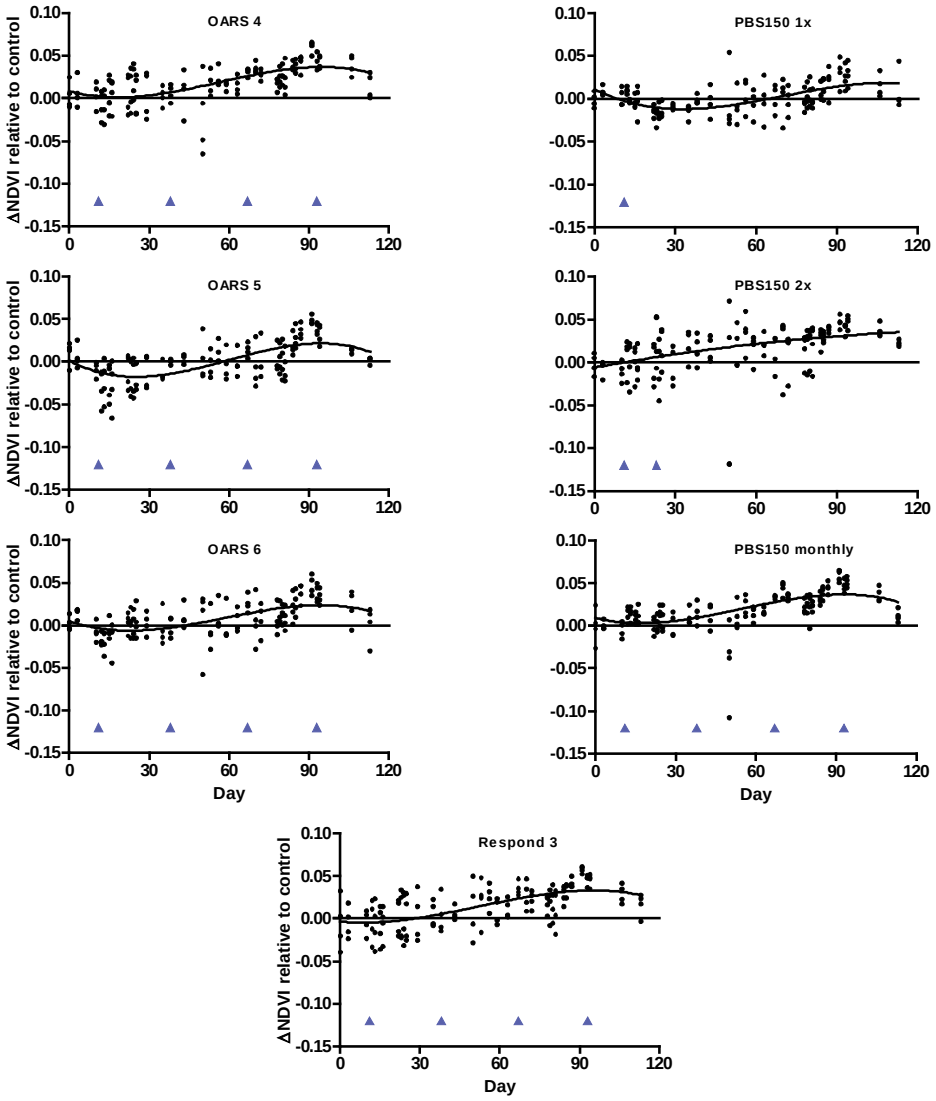

Figure 5. Change in canopy reflectance relative to control plots. Application dates are marked with blue arrows. Points are plot means (~50 readings). Curves are fitted 3rd order polynomials.

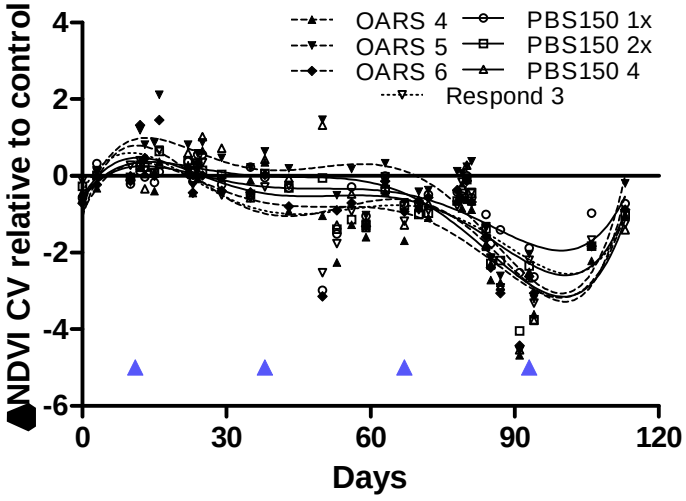

Figure 6. Uniformity of treated plots as estimated by coefficients of variation of NDVI relative to untreated control. Blue arrows indicate treatment applications.

Table 3. Localized dry spot development.

Treatment	07/07	07/09	07/14	08/18	08/31	09/10	09/16	09/23
Control	0.0[1]	0.0	0.0	0.0	0.0	0.5	3.3 a	1.8 a
OARS 4	0.0	0.0	0.0	0.0	0.0	0.0	0.3 b	0.0 b
OARS 5	0.0	0.5	0.0	0.5	0.0	0.0	0.3 b	0.0 b
OARS 6	0.3	0.5	0.0	0.5	0.3	0.0	0.3 b	0.3 ab
PBS150 1x	0.0	0.3	0.0	0.0	0.0	0.5	1.3 ab	0.3 ab
PBS150 2x	0.3	0.5	0.0	0.3	0.0	0.3	1.0 b	0.5 ab
PBS150 4	0.3	0.5	0.0	0.5	0.0	0.3	0.5 b	0.0 b
Respond 3	0.0	0.0	0.0	0.3	0.0	0.0	0.5 b	0.0 b
msd p=0.05	NS	NS	NS	NS	NS	NS	2.1	1.6

[1] Visual rating of dry spot development (0-10, 10=full plot area affected). Means of 4 replicates; means within columns followed by the same letter are not significantly different (Tukey's HSD test, p=0.05)

Table 4. Volumetric water content in treated plots

Treatment	06/25	07/09	08/20	09/01	09/04	09/10	09/23
Control	31.3[1] ab	30.5 ab	32.3 ab	25.8 ab	20.7 ab	21.6 b	16.7 c
OARS 4	29.9 b	29.7 b	30.7 b	25.0 b	20.3 b	27.4 a	26.6 ab
OARS 5	32.8 a	33.3 a	33.0 ab	27.5 ab	22.3 ab	29.5 a	28.3 a
OARS 6	31.5 ab	33.8 a	33.2 a	26.8 ab	21.8 ab	29.4 a	27.9 a
PBS150 1x	31.8 ab	31.4 ab	33.1 a	27.9 a	22.6 a	28.4 a	24.3 b
PBS150 2x	31.1 ab	30.7 ab	32.5 ab	24.8 b	21.0 ab	27.4 a	26.3 ab
PBS150 4	32.1 ab	29.5 b	31.9 ab	26.7 ab	22.0 ab	28.3 a	28.1 a
Respond 3	30.4 ab	29.7 b	31.8 ab	25.2 ab	21.2 ab	28.0 a	26.8 ab
msd p=0.05	2.5	3.3	2.3	2.7	2.0	2.5	2.9

[1] Percent volumetric water content measured with ThetaProbe. Means of 9 readings x 4 replicates; means within columns followed by the same letter are not significantly different (Tukey's HSD test, p=0.05)

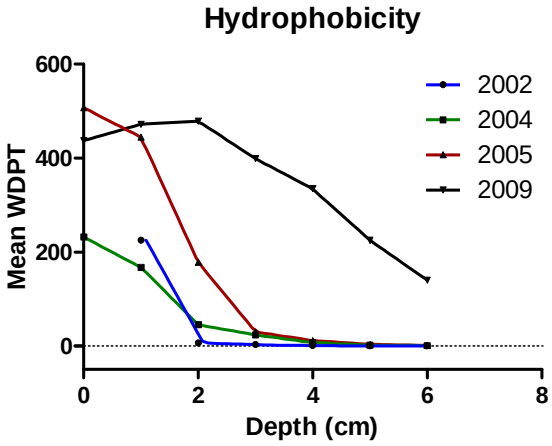

Figure 7. Historical pattern of increase in hydrophobicity and depth of affected rootzone on the California green. Data for 2009 are from the present trial. Data for different years are from trials on different areas of the green, so are not strictly comparable to each other, but indicate the trend.

in large part because the wet summer did not allow LDS to develop to any significant extent. There were some significant treatment effects on volumetric water content in the plots, and on canopy reflectance, which is indicative of photosynthetic activity and plant health. In these cases there was no strong pattern among the wetting agent treatments, although the PBS 150 1x and OARS 5 treatments performed slightly less well based on NDVI. Treatment effects on hydrophobicity of the soil as measured by the water drop penetration tests were very slight and only appeared at the 0 and 1 cm depths in the rootzone.

Sponsor: Aqua-Aid, Inc

Table 5. Water drop penetration test timings for cores removed from treated plots.

Treatment	06/25	07/28	09/22	10/14	06/25	07/28	09/22	10/14	06/25	07/28	09/22	10/14	06/25	07/28	09/22	10/14
	0 cm depth				1 cm depth				2 cm depth				3 cm depth			
Control	600.0[1]	**580.6 a**	**402.5 abc**	**402.8 a**	562.2	**499.0 a**	447.4	**401.8 a**	494.5	383.1	423.0	367.9	386.3	**305.2 b**	347.9	310.1
OARS 4	600.0	**570.4 a**	**317.9 abc**	**287.0 a**	600.0	**594.9 a**	403.5	**369.8 ab**	600.0	529.3	436.8	410.5	528.0	**483.7 ab**	380.0	310.2
OARS 5	577.7	**600.0 a**	**458.6 ab**	**363.6 a**	600.0	**575.7 a**	523.2	**388.0 ab**	559.6	550.3	461.5	497.7	468.1	**477.8 ab**	344.2	341.4
OARS 6	529.4	**590.8 a**	**519.0 a**	**361.7 a**	534.0	**600.0 a**	516.3	**435.3 a**	554.3	569.3	510.4	501.8	516.0	**542.0 a**	367.3	340.5
PBS150 1x	582.5	**567.2 a**	**466.5 ab**	**335.7 a**	600.0	**600.0 a**	449.8	**342.6 ab**	589.9	567.0	469.3	351.0	550.0	**453.3 ab**	452.7	287.1
PBS150 2x	552.3	**62.2 b**	**363.5 abc**	**328.6 a**	519.7	**352.7 b**	417.0	**385.8 ab**	487.9	399.0	447.5	422.9	454.4	**305.2 b**	367.3	330.3
PBS150 4	571.6	**588.4 a**	**202.6 c**	**61.7 b**	570.4	**600.0 a**	291.4	**163.2 b**	571.1	537.6	438.5	344.3	511.0	**520.2 ab**	257.7	296.6
Respond 3	527.4	**529.5 a**	**280.6 bc**	**212.8 ab**	530.8	**560.6 a**	349.5	**323.2 ab**	538.7	461.4	402.5	446.1	466.8	**384.5 ab**	325.5	345.1
msd p=0.05	NS	**84.5**	**212.7**	**208.2**	NS	**118.4**	NS	**236.9**	NS	NS	NS	NS	NS	**232.3**	NS	NS

Treatment	06/25	07/28	09/22	10/14	06/25	07/28	09/22	10/14	06/25	07/28	09/22	10/14
	4 cm depth				5 cm depth				6 cm depth			
Control	312.9	230.1	320.5	215.8	267.0	96.9	261.7	181.8	184.2	50.8	163.6	104.9
OARS 4	435.5	444.3	374.7	295.6	239.0	273.9	281.9	180.1	198.9	193.9	148.3	87.0
OARS 5	397.5	401.1	287.6	238.8	299.4	239.6	186.9	153.9	211.0	153.3	104.9	95.0
OARS 6	478.6	403.3	330.7	289.2	332.0	199.7	244.2	183.1	193.1	109.1	156.5	122.7
PBS150 1x	417.4	296.1	371.1	254.7	309.2	148.5	213.6	132.3	215.2	88.6	89.5	85.1
PBS150 2x	370.7	297.3	338.5	245.5	275.9	182.3	233.3	215.9	169.5	101.4	117.6	126.9
PBS150 4	412.5	424.7	249.6	237.5	314.3	283.0	181.1	192.5	230.3	188.3	110.4	122.6
Respond 3	442.1	345.7	253.5	295.0	319.5	233.7	177.9	168.2	179.2	141.4	115.4	127.2
msd p=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1]Time (sec) for a 35 μL droplet of distilled water to penetrate core (max 600 sec). Mean of 4 cores x 4 replicates. Means within columns followed by the same letter are not significantly different (Tukey's HSD, p=0.05).