

Field evaluation of wetting agent efficacy against localized dry spot, soil moisture, and root system growth on creeping bentgrass putting green turf - 2010 trial.

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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 (20 psi, Teejet 8001VS flat fan nozzles, 20 ml sec⁻¹) on May 24 (all), June 2 (treatments 3-5), June 21 (treatments 7-9), July 19 (treatments 6-9),

August 16 (treatments 7-9) and September 13, 2010 (treatments 7-9). 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.

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. Water droplet absorption tests were made

Table 1. Treatments.

Treatment	Rate (mL 100 m ⁻²)	Application schedule
1 Control	—	
2 Respond 3 preventative	120	0 and 10 days
3 NCF-091 1/2x preventative	125	0 and 10 days
4 NCF-091 1x preventative	250	0 and 10 days
5 NCF-091 2x preventative	500	0 and 10 days
6 Respond 3 curative	180 / 90	0 and "midseason"
7 NCF-091 1/2x curative	125 / 62.5	monthly
8 NCF-091 1x curative	250 / 125	monthly
9 NCF-091 2x curative	500 / 250	monthly

All treatments were watered in immediately with 20 min of irrigation. All treatments were applied in 8 L water 100 m⁻² except for the day 0 treatment for Respond 3 curative, which was applied in 30 L water 100 m⁻². Treatments 6-9 had an initial high rate, followed by a lower rate at monthly intervals.





Figure 1. Plot area on research green, May 28, 2010 (10 days after first treatment).

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 droplet penetration test (time to penetration of a 35 μ l 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 2 and 3). The season was wetter than average, with ~500 mm of rainfall during the course of the experiment. Temperatures were slightly below normal for summer in Guelph, with only four days above 30°C. To increase the likelihood of localized dry spot development, irrigation was withheld from the plots after the middle of July.

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

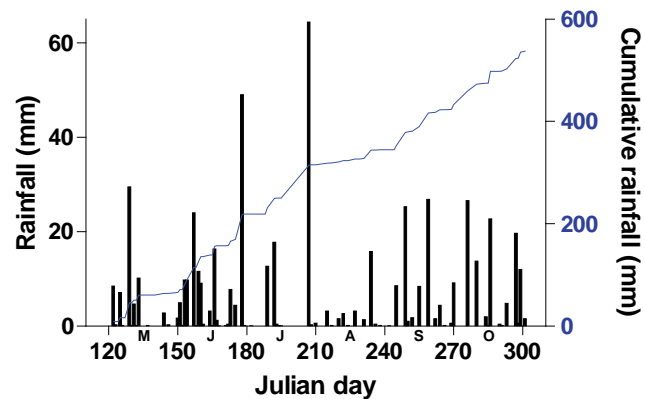


Figure 2. Daily and cumulative precipitation – summer 2010. Data are from the Environment Canada weather station at the GTI.

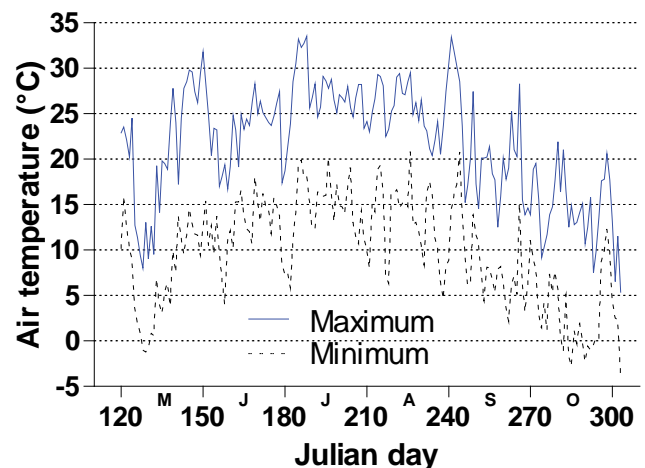


Figure 3. Daily maximum and minimum air temperatures – summer 2010. Data are from the Environment Canada weather station at the GTI.

from treatments, drought stress, localized dry spot (development). There was no evidence of phytotoxicity, which would have appeared as a decline in NDVI immediately following applications compared to the control plots, in any of the treatments; this confirmed visual assessments of the plots. Over the course of the trial, the performance of the treated plots as assessed by canopy reflectance was consistently higher than the control (Figure 4). Among the

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

Treatment	04/22	04/30	05/10	05/17	05/20	05/25²	05/27
Control	0.518 abc ¹	0.491 c	0.588 bc	0.576 c	0.500 e	0.518 e	0.554 d
NCF-091 1/2x cur	0.537 a	0.537 a	0.584 c	0.611 a	0.556 a	0.601 a	0.623 ab
NCF-091 1/2x prev	0.507 bc	0.504 bc	0.606 ab	0.599 b	0.522 d	0.584 bc	0.607 c
NCF-091 1x cur	0.517 abc	0.514 b	0.613 a	0.606 ab	0.552 abc	0.597 ab	0.612 bc
NCF-091 1x prev	0.452 d	0.469 d	0.546 d	0.578 c	0.495 e	0.548 d	0.616 bc
NCF-091 2x cur	0.532 ab	0.541 a	0.624 a	0.617 a	0.555 ab	0.605 a	0.607 c
NCF-091 2x prev	0.503 bc	0.513 b	0.571 c	0.616 a	0.542 bc	0.596 ab	0.614 bc
Respond 3 cur	0.507 bc	0.509 bc	0.570 c	0.610 a	0.539 c	0.576 c	0.632 a
Respond 3 prev	0.493 c	0.514 b	0.589 bc	0.613 a	0.548 abc	0.606 a	0.607 c
msd p=0.05	0.030	0.019	0.020	0.011	0.014	0.014	0.013
	05/29	05/31	06/04	06/08	06/14	06/16	06/23
Control	0.542 f	0.583 d	0.620 g	0.618 cd	0.618 d	0.581 d	0.551 c
NCF-091 1/2x cur	0.593 abc	0.645 ab	0.655 f	0.609 de	0.639 bc	0.598 bc	0.584 b
NCF-091 1/2x prev	0.585 cd	0.636 b	0.679 bc	0.634 ab	0.639 bc	0.596 bc	0.612 a
NCF-091 1x cur	0.598 a	0.639 ab	0.665 e	0.644 a	0.650 a	0.599 bc	0.560 c
NCF-091 1x prev	0.573 e	0.618 c	0.689 a	0.599 e	0.634 c	0.609 a	0.612 a
NCF-091 2x cur	0.593 abc	0.638 ab	0.671 de	0.629 bc	0.647 ab	0.600 b	0.587 b
NCF-091 2x prev	0.587 bcd	0.633 b	0.684 ab	0.579 f	0.609 d	0.601 b	0.609 a
Respond 3 cur	0.580 de	0.634 b	0.657 f	0.615 cd	0.614 d	0.582 d	0.601 a
Respond 3 prev	0.596 ab	0.650 a	0.675 cd	0.611 de	0.630 c	0.594 c	0.606 a
msd p=0.05	0.010	0.012	0.006	0.015	0.010	0.006	0.013
	06/28	06/30	07/02	07/06	07/09	07/12	07/15
Control	0.607 e	0.559 ef	0.565 e	0.556 e	0.597 e	0.514 f	0.476 d
NCF-091 1/2x cur	0.625 d	0.564 de	0.552 f	0.582 d	0.636 d	0.602 e	0.492 cd
NCF-091 1/2x prev	0.662 a	0.608 a	0.593 bc	0.615 b	0.639 cd	0.614 cd	0.533 b
NCF-091 1x cur	0.611 e	0.552 f	0.555 ef	0.596 c	0.642 cd	0.619 bc	0.558 a
NCF-091 1x prev	0.660 a	0.612 a	0.600 b	0.618 b	0.656 a	0.626 b	0.505 c
NCF-091 2x cur	0.629 cd	0.572 cd	0.580 d	0.599 c	0.653 ab	0.628 b	0.543 ab
NCF-091 2x prev	0.662 a	0.613 a	0.611 a	0.633 a	0.657 a	0.641 a	0.504 c
Respond 3 cur	0.635 bc	0.584 b	0.589 cd	0.603 c	0.659 a	0.605 de	0.495 c
Respond 3 prev	0.643 b	0.581 bc	0.591 bc	0.599 c	0.646 bc	0.613 cde	0.538 b
msd p=0.05	0.010	0.011	0.011	0.011	0.008	0.012	0.016
	07/19	07/23	07/27	08/03	08/19	08/26	08/30
Control	0.578 e	0.571 f	0.659 f	0.620 de	0.572 f	0.589 e	0.620 e
NCF-091 1/2x cur	0.599 d	0.595 de	0.685 de	0.620 de	0.622 de	0.623 d	0.654 d
NCF-091 1/2x prev	0.618 b	0.608 bc	0.682 e	0.614 e	0.617 e	0.623 d	0.665 bc
NCF-091 1x cur	0.611 bc	0.588 e	0.694 b	0.685 a	0.638 b	0.635 b	0.670 ab
NCF-091 1x prev	0.628 a	0.609 bc	0.689 cd	0.635 c	0.625 cde	0.633 b	0.666 bc
NCF-091 2x cur	0.618 b	0.615 b	0.702 a	0.652 b	0.652 a	0.647 a	0.677 a
NCF-091 2x prev	0.631 a	0.627 a	0.690 bc	0.626 d	0.631 bc	0.637 b	0.666 bc
Respond 3 cur	0.609 c	0.606 bc	0.687 cd	0.656 b	0.620 de	0.633 bc	0.671 ab
Respond 3 prev	0.614 bc	0.601 cd	0.690 c	0.628 cd	0.629 cde	0.626 cd	0.659 cd
msd p=0.05	0.008	0.010	0.004	0.008	0.009	0.007	0.009
	09/01	09/07	09/09	09/14	09/20	09/23	
Control	0.585 d	0.512 a	0.525 a	0.516 a	0.583 a	0.623 ab	
NCF-091 1/2x cur	0.605 b	0.481 b	0.484 b	0.464 bc	0.544 abc	0.618 ab	
NCF-091 1/2x prev	0.612 b	0.446 d	0.441 c	0.359 e	0.430 e	0.513 d	
NCF-091 1x cur	0.633 a	0.470 bcd	0.471 bc	0.457 bcd	0.533 bcd	0.604 abc	
NCF-091 1x prev	0.612 b	0.396 e	0.387 d	0.323 e	0.383 f	0.460 e	
NCF-091 2x cur	0.634 a	0.490 ab	0.490 b	0.475 b	0.567 ab	0.633 a	
NCF-091 2x prev	0.601 bc	0.377 e	0.344 e	0.261 f	0.329 g	0.429 e	
Respond 3 cur	0.616 b	0.473 bc	0.461 bc	0.420 d	0.497 d	0.572 c	
Respond 3 prev	0.588 cd	0.450 cd	0.448 c	0.433 cd	0.527 cd	0.593 bc	
msd p=0.05	0.016	0.027	0.034	0.037	0.039	0.036	

¹ Normalized- difference 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.

treatments, the general pattern in NDVI was NCF-091 2x cur, NCF-091 2x prev > NCF-091 1x cur, NCF-091 1/2x prev, Respond 3 prev, Respond 3 cur > NCF-091 1x prev > NCF-091 1/2x cur >> Control.

Localized dry spot. The wet summer resulted in very little visible localized dry spot development. This is in spite of irrigation being withheld from the plot areas. Other more seriously affected parts of the green showed a LDS period

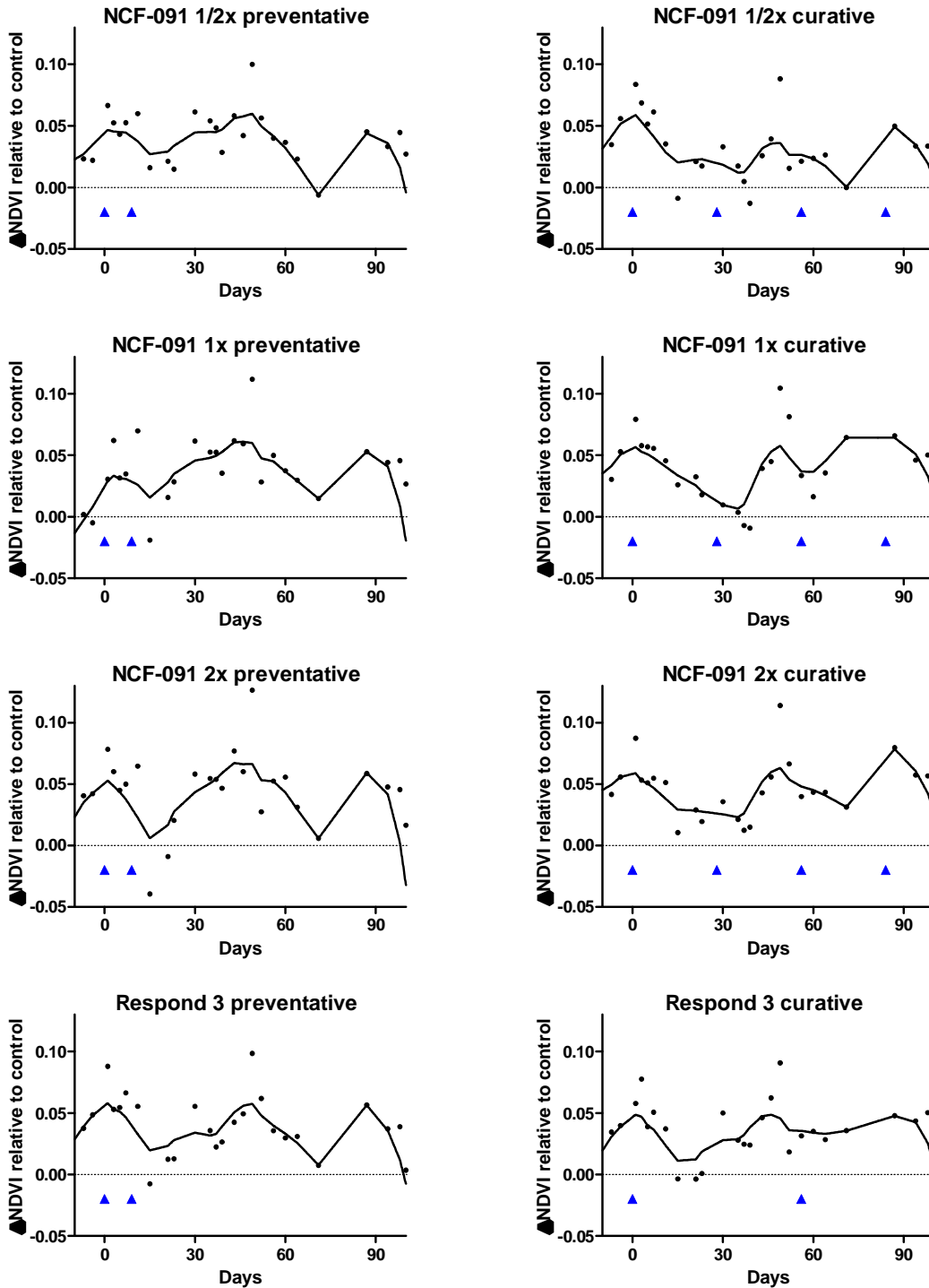


Figure 4. Increase in canopy reflectance in treated plots relative to untreated check. LOWESS spline curves indicate trends of mean values. Principal periods of significant treatment effects are evident in late July (days 90-110) and in September (days 140+). Blue arrows indicate treatment applications.

in late July and September, which was also evident in the NDVI data on these plots, but not in LDS development. Nevertheless, during the periods when visible LDS symptoms did develop, there were significant differences between the treated plots and the untreated control. There were few strong differences among the wetting agent treatments (Table 3).

Volumetric water content. There were significant differences among treatments for volumetric water content as measured with the ThetaProbe on all measurement dates (Table 4). Water contents were well into adequately watered range (field capacity on a USGA sand rootzone is typically 25-30%). There were not large absolute differences among any of the treatments, but the overall pattern of soil moisture over the season

was NCF-091 2x cur > NCF-091 1x cur, Respond 3 prev, NCF-091 1/2x cur, Respond 3 cur > NCF-091 1/2x prev > NCF-091 1x prev, Control, NCF-091 2x prev. Generally the curative (monthly application) treatments had better soil moisture values than the preventative.

Correlations among performance characteristics. The efficacy of the treatments as measured by localized dry spot development was correlated with other observed variables on the dates when LDS was significant. There was a clear decline in canopy reflectance with an increase in localized dry spot (Figure 5).

A similar pattern was seen between LDS and the soil moisture (Figure 6) and NDVI and soil moisture (Figure 7) early in the season, but

Table 3. Localized dry spot development.

Treatment	05/25	06/04	07/06	07/28	08/10
Control	5.0 a ¹	4.3 a	3.5 a	2.5 a	3.8 a
NCF-091 1/2x cur	2.3 ab	0.8 b	0.8 bc	0.3 b	1.3 bc
NCF-091 1/2x prev	3.5 ab	1.8 b	2.0 ab	0.5 b	2.0 ab
NCF-091 1x cur	1.8 b	0.0 b	0.5 bc	0.0 b	0.3 bc
NCF-091 1x prev	3.5 ab	0.8 b	1.0 bc	0.5 b	1.0 bc
NCF-091 2x cur	1.3 b	0.0 b	0.0 c	0.0 b	0.0 c
NCF-091 2x prev	1.5 b	0.3 b	0.3 c	0.3 b	0.3 bc
Respond 3 cur	2.8 ab	1.0 b	0.5 bc	0.3 b	0.5 bc
Respond 3 prev	2.5 ab	1.0 b	1.0 bc	0.0 b	1.5 bc
msd p=0.05	3.09	2.16	1.70	1.18	1.96

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	05/25	06/04	06/07	07/07	07/29
Control	13.88 c ¹	23.76 c	26.32 bc	19.88 abc	18.43 b
NCF-091 1/2x cur	19.21 a	28.30 ab	29.06 ab	21.25 ab	20.65 a
NCF-091 1/2x prev	15.96 bc	23.83 c	28.24 abc	18.86 bc	19.06 ab
NCF-091 1x cur	16.24 abc	27.93 ab	29.35 a	21.35 ab	19.64 ab
NCF-091 1x prev	16.65 abc	25.22 bc	25.97 c	20.19 abc	18.87 b
NCF-091 2x cur	19.14 ab	30.22 a	29.84 a	21.86 ab	20.65 a
NCF-091 2x prev	19.35 a	28.14 ab	28.15 abc	23.18 a	19.29 ab
Respond 3 cur	16.56 abc	27.12 ab	29.26 a	16.85 c	19.70 ab
Respond 3 prev	17.04 abc	27.18 ab	27.96 abc	18.71 bc	18.49 b
msd p=0.05	3.24	3.28	2.87	3.87	1.68

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)

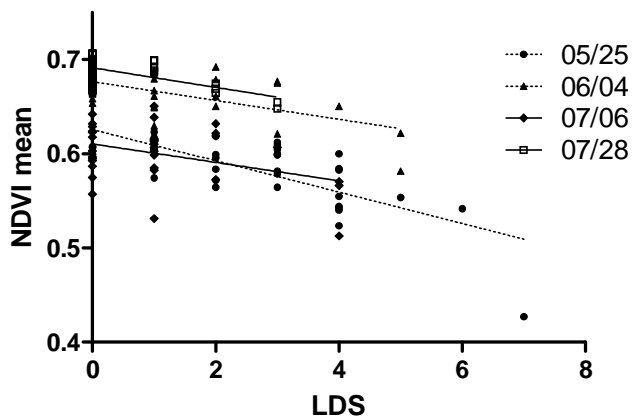


Figure 5. Association between localized dry spot and canopy reflectance. The correlation coefficients on the four dates were 0.73 (05/25), 0.62 (06/04), 0.39 (07/06), and 0.64 (07/28). Charted values are plot means for the 36 plots.

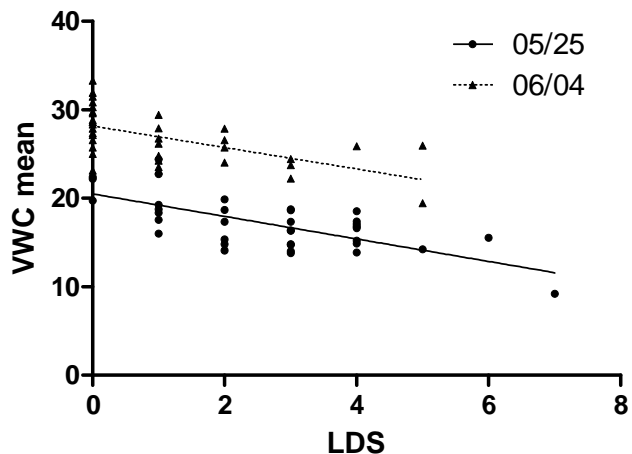


Figure 6. Association between localized dry spot and soil moisture (VWC). The correlation coefficients were 0.69 (05/25) and 0.59 (06/04). Charted values are plot means for the 36 plots.

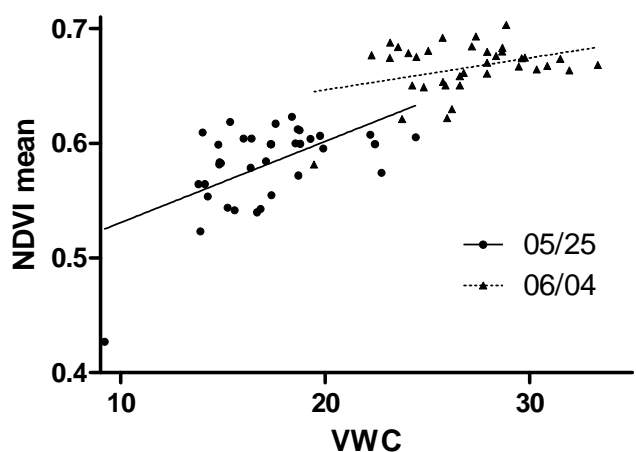


Figure 7. Association between canopy reflectance (NDVI) and soil moisture (VWC). The correlation coefficients were 0.57 (05/25) and 0.35 (06/04). Charted values are plot means for the 36 plots.

the association was not evident later in the season.

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 8). The water drop penetration tests from this trial showed the most consistent treatment effect patterns either pre-treatment or in the upper layers of the rootzone (0 and 1 cm deep) (Table 5). The pre-treatment differences are presumably residual effects from 2009 treatments; this can be seen by the correlation between the 2009 and 2010 values (Figure 9). The levels of hydrophobicity that developed later in the season were only relieved by treatments at or near the surface. There was a trend toward a rate effect in both the curative and preventative treatments with NCF-091, and the most consistent effects were seen at the 1 cm depth. Significant difference pre-treatment (June 11) and in deeper layers indicate a noisy background. When differences among treatments were significant, the best effects were with the 2x rates. Generally the 1x NCF-091 treatments were more effective than the label rate Respond 3 treatments.

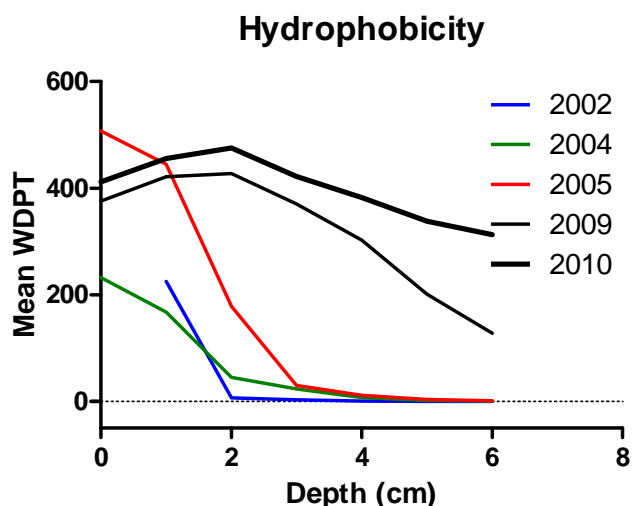


Figure 8. Historical pattern of increase in hydrophobicity and depth of affected rootzone on the California green. Data for 2009 and 2010 are grand means from the plots of the present trial. Data for previous years are from trials on different areas of the green, so are not strictly comparable to each other, but indicate the trend.



DISCUSSION AND CONCLUSIONS

Wetting agent treatment effects on localized dry spot were limited by wet summer which did not allow visual LDS to develop to any significant extent. When LDS symptoms did develop, there

was significantly less in all the wetting agent treatments than in the untreated control, but no strong pattern of differences among the wetting agent treatments. Significant treatment effects on volumetric water content in the plots showed higher soil moistures in the wetting agent treated

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

Treatment	05/05	08/24	10/12	05/05	08/24	10/12
	0 cm depth			4 cm depth		
Control	374.3 ¹	503.5 a	429.6	342.9 a	414.0	462.6
NCF-091 1/2x cur	331.7	550.9 a	305.6	317.8 a	598.2	516.7
NCF-091 1/2x prev	364.0	527.1 a	372.7	184.5 ab	452.7	446.9
NCF-091 1x cur	402.2	282.2 b	424.1	327.1 a	424.4	477.0
NCF-091 1x prev	258.5	566.6 a	460.4	79.5 b	413.2	418.7
NCF-091 2x cur	283.5	292.4 b	454.9	177.5 ab	428.6	392.2
NCF-091 2x prev	232.5	600.0 a	400.1	132.4 ab	600.0	488.3
Respond 3 cur	319.4	600.0 a	496.2	82.5 b	582.3	382.6
Respond 3 prev	344.0	499.0 a	428.7	184.4 ab	451.8	492.6
msd p=0.05	NS	153.46	NS	224.33	NS	NS
	1 cm depth			5 cm depth		
Control	555.2 a	515.0 ab	577.6 a	249.4 a	413.2	453.3
NCF-091 1/2x cur	401.1 abc	600.0 a	513.5 ab	197.1 ab	576.0	412.1
NCF-091 1/2x prev	375.7 abc	499.5 abc	554.7 a	90.4 ab	442.7	439.7
NCF-091 1x cur	517.4 ab	373.8 bc	398.2 bc	193.3 ab	388.4	449.8
NCF-091 1x prev	337.0 abc	476.6 abc	489.2 ab	47.8 b	398.5	439.7
NCF-091 2x cur	256.7 c	315.4 c	464.6 ab	127.1 ab	334.8	402.5
NCF-091 2x prev	271.2 bc	569.6 a	309.8 c	71.3 ab	499.9	484.5
Respond 3 cur	363.8 abc	600.0 a	543.6 ab	42.2 b	537.4	396.8
Respond 3 prev	359.9 abc	477.9 abc	578.9 a	102.4 ab	418.8	472.2
msd p=0.05	253.36	192.09	151.73	187.22	NS	NS
	2 cm depth			6 cm depth		
Control	572.1 a	471.2	563.5 a	135.9	450.1	363.7
NCF-091 1/2x cur	389.7 ab	600.0	568.2 a	152.9	465.8	429.0
NCF-091 1/2x prev	400.2 ab	479.2	578.9 a	57.5	431.8	500.6
NCF-091 1x cur	572.8 a	456.9	537.9 a	94.7	378.4	397.2
NCF-091 1x prev	301.5 b	471.7	505.5 ab	14.8	342.5	506.0
NCF-091 2x cur	356.8 ab	455.3	498.1 ab	91.8	274.1	492.8
NCF-091 2x prev	291.9 b	600.0	371.3 b	45.3	459.8	536.0
Respond 3 cur	295.7 b	600.0	556.7 a	13.8	428.8	401.7
Respond 3 prev	364.3 ab	444.7	518.4 ab	27.0	426.8	466.9
msd p=0.05	246.6	NS	164.52	NS	NS	NS
	3 cm depth					
Control	424.1 a	453.0	500.49			
NCF-091 1/2x cur	314.6 ab	571.5	528.51			
NCF-091 1/2x prev	265.4 ab	456.3	560.45			
NCF-091 1x cur	476.6 a	447.5	544.66			
NCF-091 1x prev	140.2 b	455.3	489.63			
NCF-091 2x cur	270.2 ab	452.7	472.56			
NCF-091 2x prev	137.1 b	600.0	415.91			
Respond 3 cur	134.4 b	600.0	444.52			
Respond 3 prev	298.2 ab	433.8	493.69			
msd p=0.05	242.46	NS	NS			

¹Time (sec) for a 35 μ L 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, $p=0.05$).

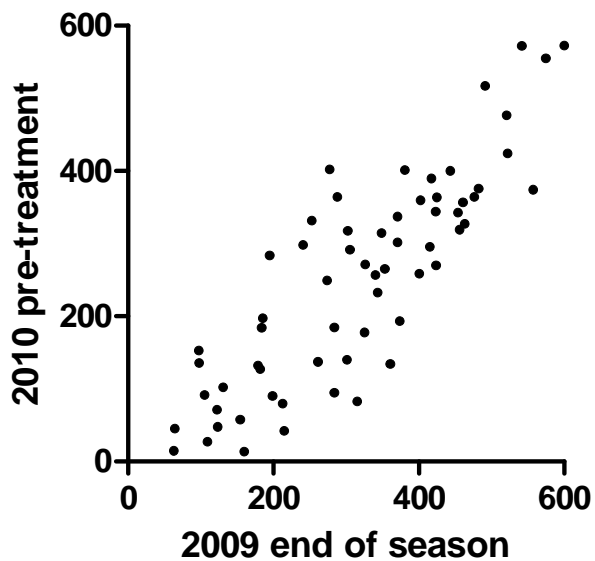


Figure 9. Association between wdpt data for end of season 2009 and pre-treatment 2010. Treatment means by depth are plotted (7 depths per treatment). The association is statistically significant (Pearson $r=0.85$).

plots, and particularly in the curative (monthly application) treatments. The canopy reflectance data, which is indicative of photosynthetic activity and plant health, showed a similar pattern to the soil moisture data. Over the course of the trial, the general order of NDVI values was: NCF-091 2x cur, NCF-091 2x prev > NCF-091 1x cur, NCF-091 1/2x prev, Respond 3 prev, Respond 3 cur > NCF-091 1x prev > NCF-091 1/2x cur >> Control.

During the season, the wetting agent treatments had limited effect on soil hydrophobicity, and then only at the upper levels (0, 1, and 2cm). The background levels of hydrophobicity developing in this green are very high, even at the 6 cm depth. When significant treatment effects were visible from the water drop penetration tests, the pattern was similar to the pattern in the canopy reflectance data, with the two 2x NCF-091 treatments performing best.

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