Assessing various wetting agents on golf putting greens comprised of calcareous and siliceous sand-based rootzones

G19-04A – Greens Height Soil Surfactant Study – Calcareous Sand Rootzone
G19-04B – Greens Height Soil Surfactant Study – Siliceous Sand Rootzone

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ABSTRACT

Maximizing the amount of water that reaches the rootzones is important for maintaining healthy golf greens. This study compared various wetting agent treatments on calcareous and siliceous sand putting greens to determine their capabilities of reaching soil root zones and their impacts on turfgrass properties. To document the effect of the wetting agents on the rootzone profiles over time, soil volumetric water content was taken throughout the study using a TDR probe. Visual ratings and NDVI readings were taken on a weekly basis as an indicator of turfgrass colour quality. Water droplet penetration tests (WDPT) were done periodically throughout the study to assess infiltration of wetting agents into the rootzones. There were few significant differences in TDR values between treatments and controls at various days after treatment on the calcareous sand putting green. The siliceous sand putting green had significant differences in TDR values between treatments and controls at certain days after treatment. There were no significant differences in visual ratings and NDVI readings on both calcareous and siliceous sand putting greens. On the calcareous sand putting green, there were significant differences in WDPT at 0 cm between the treatments and controls. On the siliceous sand putting green, there were significant differences in WDPT at 0-5 cm depths between the treatments and controls. Wetting agent applications improved water absorption on both calcareous and siliceous sand-based golf rootzones.

KEY WORDS: Rootzones, Soil surfactants, Profiles, Cores, Volumetric water content

OBJECTIVE

This project compares three products from the Aqua-Aid family of soil surfactants and soil enhancers that Ontario Seed Company currently has in their commercially available turf products line-up. These products were compared with an industry standard wetting agent, Revolution, from Aquatrols as a positive control in the study. There was also an untreated control included in the study. The projects were conducted on two newly established putting greens. Project A) was conducted on a putting green constructed from calcareous USGA sand at the new Guelph Turfgrass Institute site. Project B) was completed on a putting green constructed from siliceous sand conforming to the United States Golf Association (USGA) construction method. 2019 results provide a preliminary look at the function/efficacy of soil surfactants, with the goal of examining their long-term effects on rootzone and turfgrass properties over subsequent seasons. Current and future results may also be used by the sponsor for marketing of these products in the Canadian market.

EXPERIMENTAL DESIGN AND METHODS

Both experiments were conducted at the new Guelph Research Station/Guelph Turfgrass Institute (GTI), College Ave. E., University of Guelph, ON. Canada. The experiments commenced on June 18, 2019 with pre-treatment data collection and initial product application. Due to early onset of late fall/early winter conditions, the 2019 studies concluded on October 18 with the final NDVI and TDR readings.

The greens height area utilized for Project A) was a calcareous sand rootzone propagated with a mixed stand of creeping bentgrass and annual bluegrass

aeration cores from the neighbouring Cutten Fields Golf Club. The rootzone was also overseeded with 'T1' creeping bentgrass at establishment. This putting green area is representative of an older established playing surface (Figure 1).

Figure 1. Photo of experimental layout for the 2019 greens height soil surfactant studies. Left photo is Project A) on the "OSC" calcareous sand green and right photo is Project B) on the USGA siliceous sand rootzone at the new GTI location.

The greens height area utilized for Project B) was a siliceous sand rootzone conforming to USGA construction method. This green was seeded to 'V8' creeping bentgrass and is representative of a newer construction playing surface (Figure 1).

The greens height areas were maintained at ~ 3.2 mm height of cut and three to four times weekly. Irrigation was applied to the plot areas as required to prevent drought stress. A detailed maintenance record of other turfgrass operations on the experimental areas is included in Appendix a) of this report.

Both experiments were set-up as randomized complete block designs (RCBD) with eight treatments (Table 1) replicated four times, for a total of 32 experimental units. Plot size was 1m x 2m. Treatments were re-randomized for each experiment.

Table 1. Treatment list for both 2019 soil surfactant trials on the "OSC" calcareous sand rootzone and USGA siliceous sand rootzone.

Treatment	Short Form	Rate ($mL/100m^2$)	Rate ($oz/1000ft^2$)	Spray Volume ($L/100m^2$)	Frequency (days)	# of Apps
1) OARS HS	OARSHS28	159	5	8	28	5
2) OARS HS	OARSHS56	159	5	8	56	3
3) PBS 150	PBS15014	175	5.5	8	14	2
4) Turf Power (thatch reduction rate)	TPower28	509	16	8	28	5
5) OARS HS + Turf Power	OTPCom28	159 + 509	5 + 16	8	28	5
6) Revolution	Revolu28	191	6	8	28	5
7) Revolution	Revolu56	191	6	8	56	3
8) Untreated Control	UTC	0	0	8*	28	5

* Untreated control had water applied during spray operations on a 28 day frequency to reduce any variability related to spray volume or the water itself

Experimental treatments were applied to the plots using a 4-nozzle compressed air sprayer to simulate application conditions of a field sprayer. Standard application practices included use of XR Tee-Jet 8001VS flat-fan nozzles on a 4-nozzle compressed air sprayer at an application pressure of 20psi. Output was calibrated at 3.3 mL/sec/nozzle at 20 psi and application ground speed was adjusted to achieve a spray volume equivalent to 8L/100m^2. Treatments were mixed in 2L aliquots. Following treatment application, the plot areas were irrigated to deliver 5-6 mm to water-in treatments; amounts applied are noted in Appendix b).

Table 2. Dates of application for both 2019 Soil Surfactant trials

Application number	Date	Description
1	June 18, 2019	Initial application – All treatments
2	July 02, 2019	PBS150 14-day re-application
3	July 16, 2019	Re-application for 28 day scheduled treatments
4	August 13, 2019	Re-application for 28 + 56 day scheduled treatments
5	September 10, 2019	Re-application for 28 day scheduled treatments
6	October 09, 2019	Final 2019 application for 28 + 56 day scheduled treatments

Data collected for both studies study included canopy reflectance (normalized difference vegetation index, NDVI) using a Greenseeker optical sensor, model 505 (NTech Industries Inc., Ukiah CA, USA) and visual turfgrass ratings when differences were observed (colour, quality) using a modified National Turfgrass Evaluation Protocol (NTEP) rating system 1-9 scale.

To document the effect of the soil surfactants/conditioners on the rootzone profiles over time, soil volumetric water content (VWC) was taken throughout the study using a time-domain reflectometer (TDR) probe (Spectrum Technologies, model: TDR 350) equipped with 12 cm long rods. To document hydrophobicity, four soil cores (subsamples) ~15cm depth were removed from each plot on a specified schedule (Table 3), air dried in the lab for ~14 days at ambient room conditions and evaluated for hydrophobicity using the water droplet penetration time (WDPT) test. The WDPT test identifies how long it takes a 35 μL droplet of water applied to the soil cores at 1cm intervals along the depth of the core to be absorbed, beginning at the thatch-air interface to a depth of 6 cm (Letey et al., 2000; Lyons et al., 2009).

Table 3. Soil core sampling schedule for 2019 surfactant trial on the “OSC” calcareous sand rootzone (Project A) and USGA siliceous sand rootzone (Project B). Four sub-samples per plot were taken for evaluation using the WDPT test

Sampling number	Date	Description
1	June 18, 2019	Pre-treatment soil cores
2	June 25,26, 2019	7 days after initial application (Project A); 8 days after initial application (Project B)
3	July 23, 2019	35 days after initial application
4	August 09, 2019	52 days after initial application
5	August 20, 2019	63 days after initial application
6	End of season	Not completed

An anecdotal photographic record of the study was maintained and is available to the sponsor on Dropbox. The plot plans will also be included for reference. Link to the photos and plot plans will accompany the report in e-mail format. Photos will remain available for the remainder of 2019 and

sponsor will be notified prior to any changes in sharing format.

Climate data was recorded throughout the experimental period using the Environment Canada weather station at the original GTI site, located at 328 Victoria Rd. S. in Guelph, ON. (Approx. 1 Km from test site) and can be viewed in Appendix C).

All data were subjected to an analysis of variance (ANOVA) in the Statistical Analysis System (SAS Institute, Ver. 9.4, Cary, NC, USA) using Proc GLIMMIX. Multiple means comparisons that yielded letter groupings for purposes of illustrating statistical significance were generated using the Tukey-Kramer method. The type I error rate (significance level) for statistical comparisons was set at $\alpha=0.05$.

RESULTS AND DISCUSSION – Project A)

Table 4. Water droplet penetration (WDPT) test results for 2019 soil surfactant study conducted on “OSC” calcareous sand rootzone at new GTI location. Turfgrass on this rootzone was originally propagated from aeration cores from Cutten Fields Golf Club and were a mix of annual bluegrass and creeping bentgrass; the green was overseeded with ‘T-1’ bentgrass at planting.

	190618	190625		190723		190809		190820		190618	190626	190723		190809		190820
Treatment	----------0 cm depth (Thatch-air interface)----------									----------1 cm depth----------						
UTC28	85.15[1]	139.25	A	140.02	A	178.77	AB	74.87	AB	2.36	11.36	23.37	AB	47.81	A	9.37
OARSHS28	96.82	15.98	B	8.70	B	65.60	BC	10.99	C	1.86	0.67	2.77	B	6.67	B	0.89
OARSHS56	85.39	21.43	B	103.63	A	131.92	ABC	17.27	BC	4.80	0.99	8.26	AB	10.06	B	0.97
PBS15014	66.67	16.96	B	19.04	B	60.69	C	26.27	ABC	4.38	5.29	4.13	B	9.11	B	2.38
TPower28	113.51	147.57	A	137.77	A	152.85	ABC	82.58	A	7.71	14.90	28.21	A	29.15	AB	6.63
OTPCom28	80.94	28.82	B	12.94	B	50.56	C	13.47	C	8.75	1.63	5.20	B	4.17	B	1.52
Revolu28	97.73	36.89	B	22.47	B	102.69	ABC	27.96	ABC	3.34	3.34	3.44	B	14.19	AB	4.11
Revolu56	111.20	18.54	B	89.67	AB	203.08	A	11.91	C	5.68	4.30	10.01	AB	14.91	AB	1.77
SE	NS	19.37		24.16		34.64		17.35		NS	NS	6.81		10.33		NS

	190618	190625	190723	190809		190820	190618	190626	190723	190809		190820
Treatment	----------2 cm depth----------						----------3 cm depth----------					
UTC28	-	1.64	4.24	11.07	A	2.15	-	0.93	0.42	2.40	A	1.51
OARHS28	-	0.91	0.44	2.12	B	0.78	-	0.26	0.16	0.95	AB	0.41
OARSHS56	-	1.40	2.63	1.65	B	1.16	-	1.71	0.52	1.01	AB	1.62
PBS15014	-	1.07	0.37	1.08	B	0.67	-	0.17	0.28	0.22	B	0.14
TPower28	-	1.91	2.69	5.93	AB	2.30	-	0.48	0.49	0.00	B	1.72
OTPCom28	-	1.19	0.95	1.75	B	0.87	-	1.23	0.18	0.48	B	0.12
Revolu28	-	1.08	0.34	2.29	B	1.13	-	0.11	0.46	0.78	AB	0.30
Revolu56	-	0.35	1.29	2.86	B	1.40	-	0.13	1.66	1.56	AB	0.15
SE	-	NS	NS	2.01		NS	-	NS	NS	0.59		NS

[1] WDPT absorption times are expressed in seconds (time for 35 μL water droplet to penetrate soil cores). Times within each column are a mean of 4 replications; 4 sub-samples (cores) per replication; means within columns followed by the same letter are not significantly different (Tukey-Kramer method, P > 0.05). (-) denotes missing data e.g. cores were not in suitable condition to complete the test. The standard error (SE) for the Tukey-Kramer LS Means values are also presented in the table.

Table 4 - Continued. Water droplet penetration (WDPT) test results for 2019 soil surfactant study conducted on “OSC” calcareous sand rootzone at new GTI location. Turfgrass on this rootzone was originally propagated from aeration cores from Cutten Fields Golf Club and were a mix of annual bluegrass and creeping bentgrass; the green was overseeded with ‘T-1’ bentgrass as planting.

Treatment	190618	190625	190723	190809	190820	190618	190626	190723	190809	190820
	4 cm depth					5 cm depth				
UTC28	-	0.40[1]	-	0.33	0.20	-	0.15	0.09	-	0.00
OARSHS28	-	0.00	0.12	0.57	0.18	-	0	0.27	-	0.00
OARSHS56	-	0.43	0.15	0.38	0.45	-	0.02	-	-	0.00
PBS15014	-	0.00	0.00	0.00	0.00	-	0.13	0.18	-	0.00
TPower28	-	0.00	0.59	0.00	1.10	-	0.07	0.09	-	3.35
OTPCom28	-	0.25	0.00	0.00	0.00	-	0.00	0.38	-	0.00
Revolu28	-	0.04	0.00	-	0.00	-	0.01	0.34	-	0.00
Revolu56	-	0.25	0.00	0.00	0.00	-	0.00	-	-	0.00
SE	-	NS	NS	NS	NS	-	NS	NS	-	NS

Treatment	190618	190625	190723	190809	190820
	6 cm depth				
UTC28	-	-	-	-	0.00
OARSHS28	-	-	-	-	0.00
OARSHS56	-	-	-	-	0.00
PBS15014	-	-	-	-	-
TPower28	-	-	-	-	9.00
OTPCom28	-	-	-	-	-
Revolu28	-	-	-	-	0.00
Revolu56	-	-	-	-	0.00
SE	-	-	-	-	NS

[1] WDPT absorption times are expressed in seconds (time for 35 μL water droplet to penetrate soil cores). Times within each column are a mean of 4 replications; 4 sub-samples (cores) per replication; means within columns followed by the same letter are not significantly different (Tukey-Kramer method, P > 0.05). (-) denotes missing data e.g. cores were not in suitable condition to complete the test. The standard error (SE) for the Tukey-Kramer LS Means values are also presented in the table.

Table 5. NDVI readings for 2019 soil surfactant study conducted on “OSC” calcareous sand rootzone at new GTI location. Turfgrass on this rootzone was originally propagated from aeration cores from Cutten Fields Golf Club and were a mix of annual bluegrass and creeping bentgrass; the green was overseeded with ‘T-1’ bentgrass as planting.

Turfgrass NDVI G19-04A	190618	1090703	170712	190722	190802	190815	190822	190905	190913	190920	190927	191011	191018
Treatment	Pre-Treatment	15DAT1	24DAT1	34DAT1	45DAT1	58DAT1	65DAT1	79DAT1	87DAT1	94DAT1	101DAT1	115DAT1	122DAT1
UTC28	0.424[1]	0.244	0.322	0.276	0.193	0.374	0.337	0.427	0.481	0.460	0.461	0.498	0.478
OARSHS28	0.446	0.256	0.319	0.276	0.190	0.363	0.336	0.409	0.455	0.438	0.433	0.467	0.447
OARSHS56	0.456	0.273	0.324	0.286	0.212	0.382	0.351	0.416	0.472	0.451	0.435	0.462	0.442
PBS15014	0.444	0.242	0.321	0.282	0.191	0.367	0.330	0.419	0.474	0.449	0.453	0.490	0.475
TPower28	0.462	0.296	0.359	0.316	0.236	0.395	0.363	0.435	0.493	0.474	0.468	0.492	0.474
OTPCom28	0.456	0.266	0.335	0.297	0.206	0.387	0.365	0.449	0.492	0.476	0.473	0.515	0.493
Revolu28	0.458	0.240	0.331	0.283	0.213	0.373	0.370	0.448	0.489	0.479	0.473	0.501	0.487
Revolu56	0.444	0.254	0.341	0.305	0.235	0.374	0.355	0.403	0.466	0.450	0.433	0.461	0.445
SE	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1] NDVI readings presented are means of 4 replications, and readings within each row followed by the same letter are not significantly different from each other (P > 0.05) using the Tukey-Kramer method. Due to variable timing between treatment application, data were statistically analyzed by collection date and results cannot be compared between dates/columns. DAT denotes days after treatment. The standard error (SE) for the Tukey-Kramer LS Means values are also presented in the table.

Table 6. Visual Colour ratings for 2019 soil surfactant study conducted on “OSC” calcareous sand rootzone at new GTI location. Turfgrass on this rootzone was originally propagated from aeration cores from Cutten Fields Golf Club and were a mix of annual bluegrass and creeping bentgrass; the green was overseeded with ‘T-1’ bentgrass as planting.

G19-04A	----------Colour----------			----------Quality----------		
	190618	190822	190905	190618	190822	190905
Treatment	Pre-treatment	65DAT1	79DAT1	Pre-treatment	65DAT1	79DAT1
UTC28	5[1]	6.8	7.3	6	6.3	6.3
OARSHS28	5	6.5	6.8	6	5.8	5.5
OARSHS56	5	6.5	6.8	6	6.0	5.3
PBS15014	5	7.0	7.5	6	6.3	6.3
TPower28	5	6.3	7.3	6	5.8	6.0
OTPCom28	5	6.5	7.0	6	6.0	6.5
Revolu28	5	7.0	7.8	6	6.5	6.8
Revolu56	5	6.3	6.8	6	5.8	5.0
SE	NS	NS	NS	NS	NS	NS

[1] Visual colour ratings presented are means of 4 replications, and ratings within each column followed by the same letter are not significantly different (NS) from each other (P > 0.05) using the Tukey-Kramer method. Visual colour/quality ratings are based on the NTEP 1-9 rating scale, 9 = Ideal green colour/quality for putting green turf, 1= poorest colour/ or quality yellow and dead putting green turf, 6 = minimum acceptable turf colour or quality for a golf course fairway. Data were statistically analyzed by collection date and results cannot be compared between dates/columns. DAT denotes days after treatment. The standard error (SE) for the Tukey-Kramer LS Means values are also presented in the table.

Table 7. TDR readings for 2019 soil surfactant study conducted on “OSC” calcareous sand rootzone at new GTI location. Turfgrass on this rootzone was originally propagated from aeration cores from Cutten Fields Golf Club and were a mix of annual bluegrass and creeping bentgrass; the green was overseeded with ‘T-1’ bentgrass as planting.

TDR Readings																	
G19-04A	190618		190621	190702	190712	190722	190802	190815		190822	190828	190905	190913	190920	190927		191011	191018	
Treatment	Pre-treatment		3DAT1	14DAT1	24DAT1	34DAT1	45DAT1	58DAT1		65DAT1	71DAT1	78DAT1	86DAT1	96DAT1	103DAT1		116DAT1	125DAT1	
UTC28	23.3[1]	AB	21.4	17.6	13.1	18.0	15.9	21.2	AB	17.8	18.2	15.1	19.7	18.0	15.2	AB	19.5	19.9	AB
OARSHS28	23.5	AB	21.8	17.2	12.1	17.1	16.1	20.6	AB	15.4	15.9	15.1	19.6	16.0	14.6	AB	17.9	18.7	B
OARSHS56	22.2	B	23.3	18.1	13.7	17.5	14.8	20.1	AB	15.8	16.3	15.1	18.4	16.3	14.1	B	18.0	18.5	B
PBS15014	21.7	B	22.0	18.1	14.0	16.4	14.6	19.6	B	15.7	15.6	13.7	18.8	16.4	15.0	AB	17.9	19.3	B
TPower28	25.5	A	20.6	18.8	13.0	19.4	18.4	22.9	A	18.9	18.2	15.2	21.2	18.1	16.6	A	20.2	22.4	A
OTPCom28	22.4	AB	22.4	17.4	14.4	16.5	15.7	19.2	B	16.2	15.9	14.3	18.3	16.4	14.5	B	17.7	18.0	B
Revolu28	22.5	AB	21.1	17.2	12.1	18.4	15.6	20.2	AB	17.5	16.5	13.4	20.6	16.9	14.3	B	18.3	18.2	B
Revolu56	23.9	AB	21.8	18.4	14.8	18.1	16.2	20.3	AB	17.4	18.0	14.4	20.0	17.0	15.1	AB	18.4	19.4	B
SE	0.9		NS	NS	NS	NS	NS	0.9		NS	NS	NS	NS	NS	0.6		NS	0.9	

[1] TDR readings presented are means of 4 replications. Readings were taken with a Spectrum Technologies TDR probe (Model 350) equipped with 12cm rods; readings within each row followed by the same letter are not significantly different from each other (P > 0.05) using the Tukey-Kramer method. Data were statistically analyzed by collection date and results cannot be compared between dates/columns. DAT denotes days after treatment. The standard error (SE) for the Tukey-Kramer LS Means values are also presented in the table.

The WDPT test (Table 4) showed that:

- The most significant differences occurred at the thatch-air interface and 1cm depths over the 2019 field season
- Due to the young age of the putting green, cores were very shallow and fell apart at the first pre-treatment sampling; no significant differences were present pre-treatment
- At the June 25 sampling date, all surfactant treatments performed similarly and had significantly quicker absorption at the thatch-air interface than the UTC and TPower28 treatments
- At the August 09 sampling date
    - OTPCom28 and PBS15014 treatments had significantly quicker absorption at the thatch-air interface than the UTC treatment
    - At 2cm depth all surfactant treatments had significantly improved absorption when compared to the UTC treatment
    - At 3cm depth all surfactant treatments performed similarly, but only PBS15014, TPower28 and OTPCom28 had significantly quicker absorption than the UTC treatment
    - No significant differences were observed below 3cm depth
- At the August 20 sampling date significant differences were only detected at the thatch-air interface depth

Although NDVI, turfgrass colour and quality ratings varied throughout the experiment, no significant differences were detected (Tables 5,6).

TDR readings for volumetric soil water content (VWC) varied throughout the season (Table7). Results showed that:

- During warmer periods with reduced natural rainfall, surfactant treatments generally had numerically lower, sometimes statistically lower VWC values than the UTC and TPower28 treatments
- While some statistical differences were detected, numerically the differences were very small

RESULTS AND DISCUSSION – Project B)

Table 8. Water droplet penetration (WDPT) test results for 2019 soil surfactant study conducted on the USGA siliceous sand rootzone at new GTI location. This rootzone was seeded to 'V8' creeping bentgrass.

	190618	190626		190723		190809		190820		190618	190626		190723		190809		190820	
Treatment	----------0 cm depth (Thatch-air interface)----------									----------1 cm depth----------								
UTC28	28.04[1]	44.48	A	55.36	AB	81.35	A	27.65	A	57.41	4.86	A	8.60	AB	21.92	A	13.41	A
OARSHS28	11.17	6.97	B	6.16	BC	15.44	B	2.53	C	1.56	0.43	B	0.03	B	0.67	B	0.07	B
OARSHS56	18.32	7.19	B	40.35	ABC	39.83	AB	2.39	C	1.28	0.12	B	1.53	B	1.78	B	0.28	B
PBS15014	13.76	7.79	B	11.04	BC	18.37	B	6.41	BC	2.12	0.56	B	0.33	B	1.33	B	0.75	B
TPower28	9.93	32.58	A	83.50	A	68.47	A	16.93	AB	1.41	3.38	A	19.75	A	15.24	A	7.97	A
OTPCom28	37.22	8.84	B	4.81	C	18.02	B	2.02	C	2.62	0.27	B	0.07	B	0.41	B	0.16	B
Revolu28	15.37	5.89	B	8.82	BC	15.15	B	1.46	C	2.35	0.36	B	0.14	B	0.63	B	0.09	B
Revolu56	28.22	4.45	B	40.21	ABC	47.39	AB	3.17	C	1.67	0.13	B	0.46	B	2.42	B	0.70	B
SE	NS	6.83		15.07		14.88		3.55		NS	0.60		3.49		2.94		2.03	

	190618	190626		190723		190809		190820		190618	190626		190723		190809		190820	
Treatment	----------2 cm depth----------									----------3 cm depth----------								
UTC28	1.06	2.20	A	3.64	B	14.46	A	5.92	A	0.36	0.72		1.92	B	4.52	A	2.58	A
OARSHS28	0.47	0.67	AB	0.05	C	0.23	B	0.03	B	0.00	0.65		0.05	C	0.03	B	0.00	C
OARSHS56	0.77	0.22	B	0.38	C	0.79	B	0.21	B	0.00	0.24		0.54	C	0.64	B	0.17	C
PBS15014	1.26	0.69	AB	0.07	C	0.58	B	0.34	B	1.12	0.20		0.12	C	0.49	B	0.10	C
TPower28	0.53	2.10	A	7.12	A	8.92	A	3.55	AB	0.00	0.84		3.53	A	4.29	A	1.84	AB
OTPCom28	1.53	0.55	AB	0.13	C	0.09	B	0.08	B	0.89	0.49		0.07	C	0.05	B	0.02	C
Revolu28	1.16	0.15	B	0.00	C	0.17	B	0.08	B	0.91	0.08		0.00	C	0.22	B	0.04	C
Revolu56	0.31	0.08	B	0.26	C	0.46	B	0.68	B	0.14	0.02		0.30	C	0.31	B	0.46	BC
SE	NS	0.53		0.60		2.05		1.07		NS	NS		0.34		0.64		0.49	

[1] WDPT absorption times are expressed in seconds (time for 35 μL water droplet to penetrate soil cores). Times within each column are a mean of 4 replications; 4 sub-samples (cores) per replication; means within columns followed by the same letter are not significantly different (Tukey-Kramer method, P > 0.05). (-) denotes missing data e.g. cores were not in suitable condition to complete the test. The standard error (SE) for the Tukey-Kramer LS Means values are also presented in the table.

Table 8 - Continued. Water droplet penetration (WDPT) test results for 2019 soil surfactant study conducted on the USGA siliceous sand rootzone at new GTI location. This rootzone was seeded to 'V8' creeping bentgrass.

	190618	190626	190723	190809	190820	190618	190626	190723	190809	190820
Treatment	----------4 cm depth----------					----------5 cm depth----------				
UTC28	0.02[1]	0.37	1.14 AB	2.17 A	1.82 A	0.00	1.03	0.91 AB	1.77 AB	2.27
OARSHS28	0.01	0.07	0.05 B	0.00 B	0.02 B	0.15	0.29	0.03 B	0.00 B	0.00
OARSHS56	0.00	0.00	0.20 B	0.30 B	0.10 B	0.00	0.17	0.21 B	0.27 AB	0.03
PBS15014	0.17	0.12	0.11 B	0.38 B	0.02 B	0.64	0.55	0.17 B	0.00 B	0.06
TPower28	0.01	0.41	3.33 A	2.58 A	0.93 AB	0.00	0.14	1.59 A	2.73 A	0.58
OTPCom28	0.56	0.30	0.05 B	0.05 B	0.00 B	0.00	0.55	0.03 B	0.00 B	0.00
Revolu28	0.00	0.09	0.00 B	0.07 B	0.03 B	0.00	0.09	0.00 B	0.05 B	0.00
Revolu56	0.00	0.28	0.10 B	0.34 B	0.29 B	0.00	0.00	0.16 B	0.39 AB	0.14
SE	NS	NS	0.86	0.42	0.36	NS	NS	0.39	0.74	NS

	190618	190626	190723	190809	190820
Treatment	----------6 cm depth----------				
UTC28	-	0.20	0.61	1.05	0.75 A
OARSHS28	-	0.48	0.00	-	0.00 B
OARSHS56	-	0.16	0.01	0.36	0.04 B
PBS15014	-	0.22	0.17	0.00	0.03 B
TPower28	-	0.35	0.80	0.81	0.49 AB
OTPCom28	-	0.05	0.23	0.00	0.00 B
Revolu28	-	0.11	0.00	0.10	0.00 B
Revolu56	-	0.00	0.04	0.06	0.06 B
SE	-	NS	NS	NS	0.16

[1] WDPT absorption times are expressed in seconds (time for 35 μL water droplet to penetrate soil cores). Times within each column are a mean of 4 replications; 4 sub-samples (cores) per replication; means within columns followed by the same letter are not significantly different (Tukey-Kramer method, P > 0.05). (-) denotes missing data e.g. cores were not in suitable condition to complete the test. The standard error (SE) for the Tukey-Kramer LS Means values are also presented in the table. μ

Table 9. NDVI readings for 2019 soil surfactant study conducted on the USGA siliceous sand rootzone at new GTI location. This rootzone was seeded to 'V8' creeping bentgrass

Turfgrass NDVI G19-04B	190618	190703	170712	190722	190802	190815	190822	190905	190913	190920	190927	191011	191018	
Treatment	Pre-Treatment	15DAT1	24DAT1	34DAT1	45DAT1	58DAT1	65DAT1	79DAT1	87DAT1	94DAT1	101DAT1	115DAT1	122DAT1	
UTC28	0.418[1]	0.360	0.365	0.477	0.516	0.586	0.549	0.559	0.581	0.589	0.553	0.546	0.540	AB
OARSHS28	0.401	0.354	0.337	0.474	0.521	0.581	0.564	0.569	0.583	0.587	0.553	0.546	0.532	B
OARSHS56	0.377	0.362	0.326	0.491	0.530	0.584	0.563	0.558	0.584	0.579	0.550	0.545	0.539	AB
PBS15014	0.404	0.371	0.342	0.484	0.527	0.580	0.564	0.569	0.585	0.590	0.556	0.553	0.547	AB
TPower28	0.411	0.372	0.362	0.486	0.528	0.589	0.563	0.561	0.583	0.593	0.556	0.554	0.556	AB
OTPCom28	0.435	0.348	0.357	0.473	0.514	0.587	0.561	0.566	0.587	0.589	0.551	0.551	0.560	A
Revolu28	0.435	0.363	0.374	0.481	0.530	0.583	0.571	0.561	0.584	0.587	0.551	0.545	0.535	AB
Revolu56	0.392	0.326	0.323	0.466	0.505	0.583	0.559	0.561	0.585	0.590	0.559	0.551	0.539	AB
SE	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.008	

[1] NDVI readings presented are means of 4 replications, and readings within each row followed by the same letter are not significantly different from each other (P > 0.05) using the Tukey-Kramer method. Due to variable timing between treatment application, data were statistically analyzed by collection date and results cannot be compared between dates/columns. DAT denotes days after treatment. The standard error (SE) for the Tukey-Kramer LS Means values are also presented in the table.

Table 10. Visual Colour ratings for 2019 soil surfactant study conducted on the USGA siliceous sand rootzone at new GTI location. This rootzone was seeded to 'V8' creeping bentgrass

G19-04B	----------Colour----------			----------Quality----------		
	190618	190822	190905	190618	190822	190905
Treatment	Pre-treatment	65DAT1	79DAT1	Pre-treatment	65DAT1	79DAT1
UTC28	6.3[1]	7	8	5.8	8	6
OARSHS28	5.8	7	8	5.5	8	6
OARSHS56	6.0	7	8	4.5	8	6
PBS15014	6.3	7	8	5.3	8	6
TPower28	6.5	7	8	5.5	8	6
OTPCom28	6.3	7	8	5.8	8	6
Revolu28	6.5	7	8	6.3	8	6
Revolu56	6.0	7	8	4.8	8	6
SE	NS	NS	NS	NS	NS	NS

[1] Visual colour ratings presented are means of 4 replications, and ratings within each column followed by the same letter are not significantly different (NS) from each other (P > 0.05) using the Tukey-Kramer method. Visual colour/quality ratings are based on the NTEP 1-9 rating scale, 9 = Ideal green colour/quality for putting green turf, 1= poorest colour/ or qualityyellow and dead putting green turf, 6 = minimum acceptable turf colour or quality for a golf course fairway. Data were statistically analyzed by collection date and results cannot be compared between dates/columns. DAT denotes days after treatment. The standard error (SE) for the Tukey-Kramer LS Means values are also presented in the table.

Table 11. TDR readings for 2019 soil surfactant study conducted on the USGA siliceous sand rootzone at new GTI location. This rootzone was seeded to 'V8' creeping bentgrass

TDR Readings G19-04B	190618	190621	190702	190712	190722	190802	190815	190822	190828	190905	190913	190920	190927	191011	191018
Treatment	Pre-treatment	3DAT1	14DAT1	24DAT1	34DAT1	45DAT1	58DAT1	65DAT1	71DAT1	78DAT1	86DAT1	96DAT1	103DAT1	116DAT1	125DAT1
UTC28	19.1[1]	16.2	22.6	18.8	17.4 A	15.4	21.6	18.6 A	18.0 A	16.0 A	21.3 A	18.9 A	15.7 A	20.0 A	21.6 A
OARSHS28	18.1	16.8	21.7	18.7	10.9 B	11.4	18.4	13.9 C	13.8 C	12.5 BC	18.5 B	12.1 C	10.2 C	14.6 BC	16.2 C
OARSHS56	17.3	16.4	20.6	17.4	12.5 B	13.0	18.9	15.3 BC	14.3 C	12.5 BC	18.9 AB	14.3 BC	11.5 C	15.0 BC	16.5 C
PBS15014	18.2	16.1	22.2	17.8	12.5 B	12.0	18.5	15.7 ABC	15.4 ABC	13.5 ABC	19.3 AB	15.6 ABC	12.5 BC	17.4 ABC	18.2 BC
TPower28	17.9	15.8	22.0	17.9	16.1 A	15.3	20.4	17.7 AB	17.6 AB	15.5 AB	20.9 AB	17.5 AB	14.5 AB	18.2 AB	20.3 AB
OTPCom28	18.5	15.5	23.5	18.6	11.6 B	12.7	18.7	14.9 BC	15.0 ABC	12.1 C	19.5 AB	12.9 C	11.0 C	15.4 BC	16.8 C
Revolu28	18.4	17.0	21.5	17.8	11.1 B	12.5	19.2	14.9 BC	14.6 BC	13.3 ABC	18.4 B	13.3 C	11.0 C	16.5 ABC	17.6 BC
Revolu56	18.3	16.9	21.6	18.5	12.0 B	11.4	18.6	14.7 BC	14.0 C	12.6 ABC	18.4 B	13.8 C	10.6 C	14.6 C	16.6 C
SE	NS	NS	NS	NS	1.0	NS	NS	0.9	0.9	1.0	0.8	1.1	0.9	1.1	0.8

[1] TDR readings presented are means of 4 replications. Readings were taken with a Spectrum Technologies TDR probe (Model 350) equipped with 12cm rods; readings within each row followed by the same letter are not significantly different from each other (P > 0.05) using the Tukey-Kramer method. Data were statistically analyzed by collection date and results cannot be compared between dates/columns. DAT denotes days after treatment. The standard error (SE) for the Tukey-Kramer LS Means values are also presented in the table.

The WDPT test (Table 8) showed that:

- Cores on the USGA rootzone held together much better than those from project a) at the early stages of the experiment; no significant differences were present pre-treatment
- At the June 26 sampling date, all surfactant treatments performed similarly and had significantly quicker absorption at the thatch-air interface and 1cm depth than the UTC and TPower28 treatments
- At the July 23 sampling date
    - There were variable absorption results at the thatch-air interface; the OTPCom28 treatment ranked quickest for absorption and also had significantly quicker absorption than the UTC and TPower28 treatments
    - At the all depths excluding 6cm, all surfactant treatments had significantly quicker absorption than the TPower28 treatment
- At the August 09 sampling date it was evident that the 56D surfactant treatments were in need of re-application as absorption times were elevated when compared to the 28D surfactant treatments; it should be noted that due to the variability in the dataset that the 56D treatments were not statistically different than the 28D treatments at this sampling date
- At the August 20 sampling date all surfactant treatments performed similarly and were had significantly quicker absorption than the UTC treatment (except for the 5cm depth where no significant differences were detected).

Although NDVI varied throughout the experiment, the only significant differences detected were at the October 18 reading date (Table 9) where the OTPCom28 treatment had significantly higher NDVI than the OARSHS28 treatment.

Turfgrass colour and quality ratings varied throughout the experiment but no significant differences were detected (Table 10).

TDR readings for volumetric soil water content (VWC) varied throughout the season (Table11). Results showed that:

- During warmer periods with reduced natural rainfall, surfactant treatments generally had numerically lower, and sometimes statistically lower VWC values than the UTC and TPower28 treatments
- While not statistically compared, anecdotally, the numerical differences between treatments observed on the USGA siliceous rootzone were much greater than those observed on the calcareous rootzone

CONCLUSIONS AND FUTURE STUDY – Projects A) + B)

The results of experiments show that:

- Surfactant application improves water absorption on both calcareous and siliceous sand-based golf rootzones
    - Absorption on 56D treatments was slowed leading up to re-application suggesting that 28D applications may offer more consistent and quicker water absorption
    - PBS15014 treatment (applied twice, 14 days apart) performed similarly to the 28D surfactant treatments throughout the study suggesting it may have prolonged activity in the rootzone profile
    - Subsequent research is required to confirm if these trends are repeatable
- While not statistically compared, anecdotal differences between the two rootzones utilized in year one of this study were observed
- A dry-down period was not included in the study for 2019 due to generally thin plot areas at the start of the study (completion of grow-in from 2018) and regular timely rainfall throughout the growing season
    - TDR results suggest that differences may be observed due to decreased VWC numbers during times of heat and reduced natural rainfall
    - Colour and quality ratings, as well as NDVI could be good indicators of these differences if present
    - Different lengths of TDR rods may also detect differences at different depths of the rootzone profiles
- Future study will include dry-down phases throughout the field season and data associated with re-watering will also be documented
- Season-end soil cores may also be taken in subsequent years to document the effect of the surfactant and soil conditioner treatments in late-fall
    - Application schedule may begin earlier in the season and extend later to detect these effects
- Spring green-up and other related winter recovery are planned to be documented in the spring prior to the 2020 field season

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Appendix a) Maintenance records for "OSC calcareous rootzone and USGA silecious rootzone at the new Guelph Turfgrass Institute for the duration of the 2019 research project; information submitted by Dustyn Doerr, Cutten Fields Golf Club Maintenance Technician, and compiled by John Watson.

Date	Activity	Location	Amount
Throughout project	Irrigate as required when natural rainfall not sufficient	"OSC" calcareous rootzone, USGA siliceous rootzone	As required and following treatment application
Throughout project	Mowing and sand topdressing	"OSC" calcareous rootzone, USGA siliceous rootzone	Mow three to four times weekly as required and sand topdress as required to hasten fill-in and maintain quality putting green surface
July 12	Fertility: Nutrite N-Fusion 16-2-12	"OSC" calcareous rootzone, USGA siliceous rootzone	0.4 Kg actual N/100m^2
July 26	Ammonium sulphate 21-0-0 Monopotassium phosphate 12-61-0 Urea 46-0-0 Magnesium Sulphate/Manganese sulphate	"OSC" calcareous rootzone, USGA siliceous rootzone	0.06 Kg actual N/100m^2 0.02 Kg actual N/100m^2 0.14 Kg actual N/100m^2
August 07	UMaxx Nutrite 25-0-10 with Fe	"OSC" calcareous rootzone only	0.5 Kg actual N/100m^2
August 09	Ammonium sulphate 21-0-0 Monopotassium phosphate 12-61-0 Urea 46-0-0 Magnesium Sulphate/Manganese sulphate	USGA siliceous rootzone only	0.06 Kg actual N/100m^2 0.02 Kg actual N/100m^2 0.12 Kg actual N/100m^2
August 26	Ammonium sulphate 21-0-0 Monopotassium phosphate 12-61-0 Urea 46-0-0 Magnesium Sulphate/Manganese sulphate	"OSC" calcareous rootzone, USGA siliceous rootzone	0.06 Kg actual N/100m^2 0.02 Kg actual N/100m^2 0.12 Kg actual N/100m^2
September 06	Apply Trilogy SC fungicide for control of dollar spot	"OSC" calcareous rootzone, USGA siliceous rootzone	65mL/100m^2
November TBD	Apply fungicide for snow mould control	"OSC" calcareous rootzone, USGA siliceous rootzone	TBD

Appendix b) - Supplemental irrigation applied to research plots following treatment application. Amounts presented are means of four catch containers placed in the plot area for the duration of the irrigation cycles. Target irrigation amount to water-in treatments was 5-6mm.

G19-04A – "OSC" calcareous rootzone

Irrigation Application Date	Actual Amount applied (mm)
June-18-2019	5.9
July-02-2019	5.9
July-16-2019	6.0
August-13-2019	4.9
September-10-2019	5.8
October-09-2019	5.8

G19-04B – USGA siliceous rootzone

Irrigation Application Date	Actual Amount applied (mm)
June-18-2019	5.0
July-02-2019	7.2
July-16-2019	6.4
August-13-2019	4.7
September-10-2019	6.6
October-09-2019	6.6

Appendix c) Weather records for the Guelph Research Station/Guelph Turfgrass Institute 328 Victoria Rd. S location for the 2019 field season

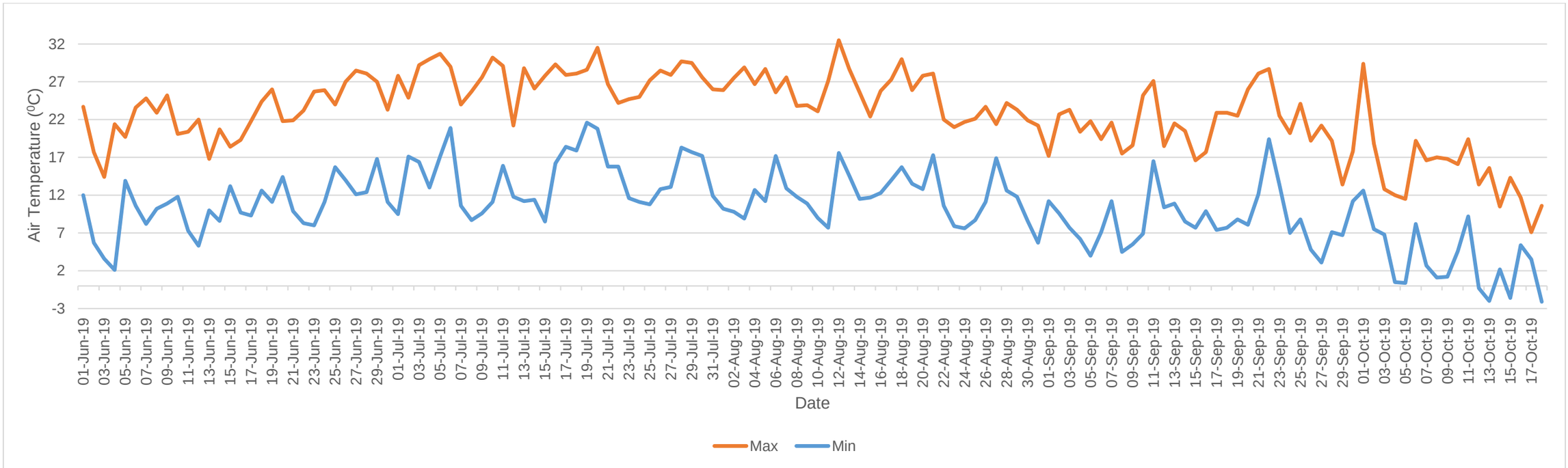

Figure 2. Daily minimum and maximum air temperatures recorded at the Guelph research station/Guelph Turfgrass Institute for the 2019 field season

Appendix c) Continued

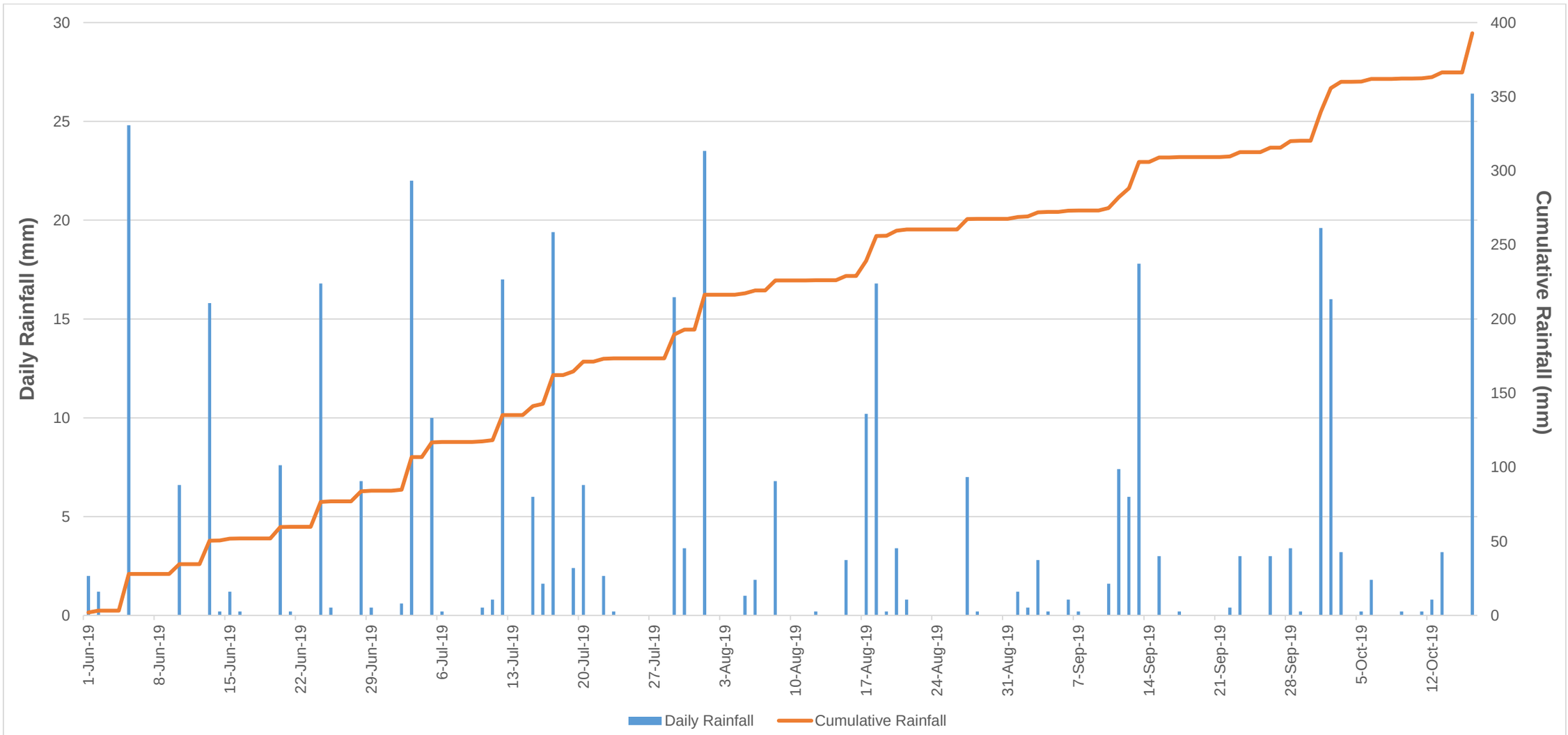

Figure 3. Daily and cumulative rainfall recorded at the Guelph research station/Guelph Turfgrass Institute for the 2019 field season. Rainfall amounts do not include supplemental irrigation or irrigation following treatment applications; see Appendix b) for irrigation amounts following treatment application