

Comparing plant growth regulators: Anuew, Primo Maxx and an experimental on a USGA putting green Project G20-01

Dr. Eric M. Lyons (Principal Investigator)
Corey Flude, M.Sc. (Research Technician)
John R. Watson, M.Sc. (Research Technician)
Emily Howard (Summer Student Research Assistant)

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

SPONSOR: Nufarm

ABSTRACT

Plant growth regulators are applied to economically significant turf on golf courses to control height, reduce frequency of mowing operations, and enhance playing surface consistency. This study compared Anuew (prohexadione-calcium), Primo Maxx (trinexapac-ethyl) and experimental NAI-20026 (trinexapac-ethyl) on turfgrass growth and quality parameters on a mature bentgrass/annual bluegrass greens height stand of turf. On many occasions throughout the experiment, PGR treatments significantly reduced turfgrass growth when compared to the untreated control and improved turfgrass quality and colour ratings. A rate effect was also detected in the experiment and NufTE (experimental NAI-20026) performed similarly to Primo on both the GDD and 4-week application schedule and often were ranked the same for many parameters throughout the experiment. No stress symptoms (yellowing, etiolation) were observed on the putting green turf in response to PGR application during hot/dry weather at any point during the experiment.

KEYWORDS

Putting green, plant growth regulators, plant biomass, NDVI, turf colour, turf quality

OBJECTIVE

This project evaluated the effect of Anuew (prohexadione-calcium) as compared with industry standard, Primo Maxx (trinexapac-ethyl) and experimental NAI-20026 (trinexapac-ethyl) on turfgrass growth and quality parameters on a mature bentgrass/annual bluegrass greens height stand of turf. Performance was assessed by how the treatments impacted turfgrass growth (clipping

biomass), any stress if observed, and associated turfgrass quality measures.

EXPERIMENTAL DESIGN AND METHODS

The experiment was conducted at the Guelph Research Station/Guelph Turfgrass Institute (GTI), Victoria Rd. site, University of Guelph, ON. Canada (43° 32' 50" N latitude, 80° 13' 50" W longitude). The experiment commenced on May 21, 2020 with pre-treatment fertilizer application and concluded on August, 28, 2020 with the final clipping collection and visual ratings. The area utilized for this experiment was a constructed USGA putting green (80% sand : 20% peat), supporting a mixed stand of turf; the putting green was last seeded to 'L-93' and 'T-1' creeping bentgrass, with natural annual bluegrass encroachment, representing an older, established playing surface (Figure 1).

The greens area was maintained at ~3 mm height of cut and mowed five times weekly. Regular mowing was skipped to allow 4-5 days of growth prior to clipping collection events. Plots were also brushed equally using a push-broom prior to clipping collection to remove dew and stand turf up to improve sample acquisition. Irrigation was applied to the plot area as required to prevent drought stress. Prior to the experimental period, nitrogen fertility was applied in the form of Nutrite 30-0-6 90% FMS Extended release fertilizer at the equivalent of 0.65 Kg actual N/100 m² on May 21, 2020, with the goal of providing a consistent release of nitrogen for the duration of the study. This fertilizer was selected to work in conjunction of the GDD component of the study; the mechanism of release of the fertilizer is based on temperature. No visual deficiencies in nitrogen were observed throughout the study. A maintenance record of other turfgrass operations on the USGA greens area is included in Appendix a) of this report.



Figure 1. Photo of experimental layout for the 2020 greens height Nufarm PGR trial

The experiment was set-up as a randomized complete block design (RCBD) with 10 treatments (Table 1) replicated four times, for a total of 40 experimental units. Plot size was 1 m x 2 m. For purposes of the report, short form acronyms for each treatment are also listed in Table 1 for reference.

Table 1. Treatment list for 2020 Nufarm PGR Trial

Treatment	Rate (/100m ²)	Short form	Spray Volume (L/100m ²)	Frequency
1) Untreated control (DI Water)	-	UTC	5	Every spray event
2) Anuew (Prohexadione-Calcium)	1.4 g	Anuew1.4	5	300 GDD
3) Anuew (Prohexadione-Calcium)	2.8 g	Anuew2.8	5	300 GDD
4) Anuew (Prohexadione-Calcium)	5.6 g	Anuew5.6	5	300 GDD
5) NAI-20026 (Trinexapac-ethyl)	8.0 mL	NufTE8G	5	300 GDD
6) NAI-20026 (Trinexapac-ethyl)	8.0 mL	NufTE84W	5	4 week
7) Primo MAXX (Trinexapac-ethyl)	8.0 mL	Primo8G	5	300 GDD
8) Primo MAXX (Trinaxapac-ethyl)	8.0 mL	Primo84W	5	4 week
9) Anuew (Prohexadione-Calcium)+ NAI-20026 (Trinexapac-ethyl)	1.4 g + 4.0 mL	ATECombo	5	300 GDD
10) Anuew (Prohexadione-Calcium)+ Primo MAXX (Trinexapac-ethyl)	1.4 g + 4.0 mL	APrCombo	5	300 GDD

The 4-Week spacing treatments were applied on May 27, June 25, July 27 and August 20, 2020. 300 Growing Degree Day (GDD) treatments were applied approximately every 300GDD although this schedule varied slightly due to weather conditions, available staff and project scheduling. GDD were calculated assuming a T_{BASE} of 0 as requested by the sponsor and calculated as:

$$GDD = (T_{MAX} + T_{MIN}) / 2$$

Please refer to Table 2 for 300GDD application dates and accumulated GDD at day of spray. All

spray applications were completed using a 4-nozzle compressed air sprayer equipped with Teejet 8001VS flat fan nozzles (output was 3.8 mL/sec/nozzle at 20 psi). Deionized (DI) water was used as the carrier for the PGRs as it was noted in the sponsor's protocol that Prohexadione-Calcium requires an acidifying fertilizer to mitigate any effects of calcium over 40 mg/L; the tap water at the GTI tested above this threshold in 2018 – 77 mg/L. As with previous PGR studies, using DI water allowed us to examine the effects of the PGRs without potential influence from an acidifying fertilizer at different application intervals.

Table 2. Growing Degree Day (GDD) accumulations between re-applications of 300GDD growth regulator treatments

Application number	Date	Actual Accumulated GDD
1	May 27, 2020	0 – Initial application
2	June 12, 2020	302.6
3	June 30, 2020	314.1
4	July 13, 2020	298.5
5	July 27, 2020	299.6
6	August 10, 2020	283.8

Data collected for this study included visual turfgrass ratings (colour and quality) using a modified National Turfgrass Evaluation Protocol (NTEP) rating system 1-9 scale. Canopy reflectance was also evaluated (normalized difference vegetation index, NDVI) using a Greenseeker optical sensor, model 505 (NTech Industries Inc., Ukiah CA, USA). Clippings were collected approximately 4-6DAT and 8-10DAT from the experimental units to determine both fresh and dry weight to evaluate turfgrass growth response. Clippings were collected using a Toro Greensmaster Flex-18 walk behind greens reel type mower (0.45 m width of cut), bench set to 3 mm. To collect clippings, a half mower swath (0.225 m) was cut at the end of each plot to allow for an accurate start and end point. The total area clipped and collected in each plot was 0.70 m² (0.45m mower width x 1.55 m swath length). Clippings from each plot were emptied from the mower's basket into a large plastic tote, quantitatively transferred into standard paper lunch bags, fresh weights recorded,

and were dried for a minimum of 72 hours at 60°C in an electric drying oven. Samples were subsequently weighed for determination of dry weight.

An anecdotal photographic record of the study was maintained.

Climate data was recorded throughout the experimental period using the Environment Canada weather station at GTI and can be viewed in Appendix b).

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

Table 3. Clipping collection data at 5 and 9 days after initial treatment (DAT). Fresh and dry biomass weights are presented

Treatment	Frequency	Fresh Weight Biomass (g)			Dry Weight Biomass (g)		
		20200601		20200605	20200601		20200605
		5DAT 1	9DAT 1		5DAT 1	9DAT 1	
Control (0 mL/m ²)	0	31.00 ¹	18.89	A	10.96	5.44	A
Anuew (1.4 g/100m ²)	300 GDD	29.03	10.50	B	10.90	3.30	B
Anuew (2.8 g/100m ²)	300 GDD	30.43	10.75	B	11.50	3.33	B
Anuew (5.6 g/100m ²)	300 GDD	23.28	8.38	B	9.28	2.78	B
NufTE8G (8.0 mL/100m ²)	300 GDD	28.10	9.68	B	10.65	3.03	B
NufTE84Wk (8.0 mL/100m ²)	4 Weeks	24.80	7.90	B	9.63	2.53	B
Primo8G (8.0 mL/100m ²)	300 GDD	25.40	8.20	B	9.73	2.70	B
Primo84W (8.0 mL/100m ²)	4 Weeks	28.15	8.55	B	10.62	2.75	B
ATE Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300 GDD	27.15	8.90	B	10.43	2.78	B
APr Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300GDD	24.38	7.80	B	9.30	2.53	B
SE		NS	1.15		NS	0.33	

¹ Plant biomass values within each column are a mean of 4 replications; means within columns followed by the same letter are not significantly different (Tukey-Kramer method, $P > 0.05$). Due to variable timing between samplings the clipping weights were statistically analyzed by collection date and weights cannot be compared between dates/columns. DAT denotes days after treatment. ATE Combo is Anuew + NufTE (1.4 g/100m² + 8mL/100m²). APr combo is Anuew + Primo (1.4 g/100m² + 8mL/100m²). The standard error (SE) for the Tukey-Kramer LS Means values are also presented in the table.

Table 4. Clipping collection data at 5 and 10 days after treatment (DAT) for the second 300GDD application. Fresh and dry biomass weights are presented

Treatment	Frequency	Fresh Weight Biomass (g)			Dry Weight Biomass (g)		
		20200617		20200622	20200617		20200622
		5DAT GDD2	10DAT GDD2		5DAT GDD2	10DAT GDD2	
Control (0 mL/m ²)	0	16.98 ¹	13.50	A	5.73	3.88	A
Anuew (1.4 g/100m ²)	300 GDD	10.57	11.05	B	3.76	3.30	AB
Anuew (2.8 g/100m ²)	300 GDD	7.93	10.93	BC	2.78	3.40	AB
Anuew (5.6 g/100m ²)	300 GDD	5.25	6.00	D	1.98	1.75	C
NufTE8G (8.0 mL/100m ²)	300 GDD	6.35	8.43	CD	2.23	2.60	BC
NufTE84Wk (8.0 mL/100m ²)	4 Weeks	7.45	11.35	CD	2.58	3.26	AB
Primo8G (8.0 mL/100m ²)	300 GDD	7.15	7.85	CD	2.58	2.40	BC
Primo84W (8.0 mL/100m ²)	4 Weeks	8.60	11.63	BC	2.98	3.40	AB
ATE Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300 GDD	6.13	7.70	CD	2.23	2.45	BC
APr Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300GDD	6.60	8.05	CD	2.40	2.50	BC
SE		0.80	1.10		0.25	0.30	

¹ Plant biomass values within each column are a mean of 4 replications; means within columns followed by the same letter are not significantly different (Tukey-Kramer method, $P > 0.05$). Due to variable timing between samplings the clipping weights were statistically analyzed by collection date and weights cannot be compared between dates/columns. DAT denotes days after treatment. ATE Combo is Anuew + NufTE (1.4 g/100m² + 8mL/100m²). APr combo is Anuew + Primo (1.4 g/100m² + 8mL/100m²). The standard error (SE) for the Tukey-Kramer LS Means values are also presented in the table.

Table 5. Clipping collection data at 4 days after treatment (DAT) for the second 4-Week application, 11DAT second 4-Week application / 6DAT for the third 300GDD application and 10 days after the third 300 GDD scheduled application. Fresh and dry biomass weights are presented

Treatment	Frequency	Fresh Weight Biomass (g)			Dry Weight Biomass (g)		
		20200629 4DAT 4Wk2	20200706 6DAT GDD3/ 11DAT 4Wk2	20200710 10DAT GDD3	20200629 4DAT 4Wk2	20200706 6DAT GDD3/ 11DAT 4Wk2	20200710 10DAT GDD3
Control (0 mL/m ²)	0	16.95 ¹	14.85 A	11.88 A	4.60	4.23 A	3.48 A
Anuew (1.4 g/100m ²)	300 GDD	17.68	11.73 ABC	10.55 AB	4.73	3.43 ABC	3.10 AB
Anuew (2.8 g/100m ²)	300 GDD	17.88	12.60 AB	8.20 BCD	4.63	3.63 AB	2.38 BCD
Anuew (5.6 g/100m ²)	300 GDD	14.58	8.65 BCD	6.90 CD	3.98	2.44 CDE	2.15 CD
NufTE8G (8.0 mL/100m ²)	300 GDD	15.68	10.98 BC	6.90 CD	4.15	3.13 BCD	2.08 CD
NufTE84Wk (8.0 mL/100m ²)	4 Weeks	13.48	8.13 CD	9.30 ABC	3.65	2.33 DE	2.65 BC
Primo8G (8.0 mL/100m ²)	300 GDD	16.13	10.03 BCD	7.93 BCD	4.40	2.88 BCDE	2.45 BCD
Primo84W (8.0 mL/100m ²)	4 Weeks	13.65	6.48 D	6.93 CD	3.73	1.95 E	1.98 CD
ATE Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300 GDD	14.10	10.63 BC	6.13 D	3.80	3.05 BCD	1.88 D
APr Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300GDD	15.48	12.53 AB	8.05 BCD	4.20	3.63 AB	2.40 BCD
SE	NS	1.20	0.88	NS	0.30	0.22	

¹ Plant biomass values within each column are a mean of 4 replications; means within columns followed by the same letter are not significantly different (Tukey-Kramer method, P > 0.05). Due to variable timing between samplings the clipping weights were statistically analyzed by collection date and weights cannot be compared between dates/columns. DAT denotes days after treatment. ATE Combo is Anuew + NufTE (1.4 g/100m² + 8mL/100m²). APr combo is Anuew + Primo (1.4 g/100m² + 8mL/100m²). The standard error (SE) for the Tukey-Kramer LS Means values are also presented in the table.

Table 6. Clipping collection data at 4 and 8 days after treatment (DAT) for the fourth 300GDD application. Fresh and dry biomass weights are presented

Treatment	Frequency	Fresh Weight Biomass (g)		Dry Weight Biomass (g)	
		20200717 4DAT GDD4	20200721 8DAT GDD4	20200717 4DAT GDD4	20200721 8DAT GDD4
Control (0 mL/m ²)	0	14.73 ¹ AB	8.60 ABC	3.83 AB	2.13 AB
Anuew (1.4 g/100m ²)	300 GDD	10.60 CDE	7.88 BCD	2.85 CDE	1.95 ABC
Anuew (2.8 g/100m ²)	300 GDD	11.83 BCD	6.30 D	3.13 ABCD	1.58 C
Anuew (5.6 g/100m ²)	300 GDD	7.10 E	6.10 D	1.92 E	1.60 C
NufTE8G (8.0 mL/100m ²)	300 GDD	9.35 DE	6.03 D	2.50 DE	1.58 C
NufTE84Wk (8.0 mL/100m ²)	4 Weeks	15.73 A	9.49 AB	3.98 A	2.28 AB
Primo8G (8.0 mL/100m ²)	300 GDD	10.78 CDE	6.93 CD	2.83 CDE	1.73 BC
Primo84W (8.0 mL/100m ²)	4 Weeks	13.25 ABC	10.03 A	3.55 ABC	2.40 A
ATE Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300 GDD	9.85 CDE	7.58 BCD	2.63 DE	1.93 ABC
APr Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300GDD	11.03 BCDE	7.45 BCD	2.95 BCD	1.88 BC
SE		1.15	0.60	0.26	0.16

¹ Plant biomass values within each column are a mean of 4 replications; means within columns followed by the same letter are not significantly different (Tukey-Kramer method, P > 0.05). Due to variable timing between samplings the clipping weights were statistically analyzed by collection date and weights cannot be compared between dates/columns. DAT denotes days after treatment. ATE Combo is Anuew + NufTE (1.4 g/100m² + 8mL/100m²). APr combo is Anuew + Primo (1.4 g/100m² + 8mL/100m²). The standard error (SE) for the Tukey-Kramer LS Means values are also presented in the table

Table 7. Clipping collection data at 3 and 9 days after treatment (DAT) for the fifth 300GDD application and third 4-Week scheduled application. Fresh and dry biomass weights are presented

Treatment	Frequency	Fresh Weight Biomass (g)				Dry Weight Biomass (g)			
		20200730		20200805		20200730		20200805	
		3DAT GDD 5/ 3DAT 4Wk3	9DAT GDD 5/ 9DAT 4Wk3	3DAT GDD 5/ 3DAT 4Wk3	9DAT GDD 5/ 9DAT 4Wk3				
Control (0 mL/m ²)	0	8.03 ¹ A	12.18 A	2.15 A	3.33 A				
Anuew (1.4 g/100m ²)	300 GDD	6.45 AB	9.00 B	1.73 AB	2.58 B				
Anuew (2.8 g/100m ²)	300 GDD	5.50 BC	7.50 BC	1.50 B	2.18 BC				
Anuew (5.6 g/100m ²)	300 GDD	4.48 C	6.38 C	1.30 B	1.93 C				
NufTE8G (8.0 mL/100m ²)	300 GDD	5.10 BC	6.65 C	1.40 B	2.00 BC				
NufTE84Wk (8.0 mL/100m ²)	4 Weeks	5.25 BC	6.18 C	1.43 B	1.85 C				
Primo8G (8.0 mL/100m ²)	300 GDD	5.70 BC	7.08 BC	1.58 B	2.10 BC				
Primo84W (8.0 mL/100m ²)	4 Weeks	5.53 BC	6.48 C	1.55 B	1.93 C				
ATE Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300 GDD	4.98 BC	5.90 C	1.33 B	1.70 C				
APr Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300GDD	5.45 BC	6.13 C	1.55 B	1.83 C				
SE		0.55	0.62	0.16	0.19				

¹ Plant biomass values within each column are a mean of 4 replications; means within columns followed by the same letter are not significantly different (Tukey-Kramer method, P > 0.05). Due to variable timing between samplings the clipping weights were statistically analyzed by collection date and weights cannot be compared between dates/columns. DAT denotes days after treatment. ATE Combo is Anuew + NufTE (1.4 g/100m² + 8mL/100m²). APr combo is Anuew + Primo (1.4 g/100m² + 8mL/100m²). The standard error (SE) for the Tukey-Kramer LS Means values are also presented in the table.

Table 8. Clipping collection data at 4 and 9 days after treatment (DAT) for the sixth/final 300GDD application. Fresh and dry biomass weights are presented

Treatment	Frequency	Fresh Weight Biomass (g)				Dry Weight Biomass (g)			
		20200814		20200819		20200814		20200819	
		4DAT GDD 6	9DAT GDD 6	4DAT GDD 6	9DAT GDD 6				
Control (0 mL/m ²)	0	7.18 ¹ A	6.53 A	2.29 A	2.13 A				
Anuew (1.4 g/100m ²)	300 GDD	6.18 A	5.18 ABC	1.95 AB	1.85 AB				
Anuew (2.8 g/100m ²)	300 GDD	5.10 ABCD	3.73 BCD	1.63 BC	1.20 BC				
Anuew (5.6 g/100m ²)	300 GDD	3.18 D	3.03 D	1.03 D	1.05 C				
NufTE8G (8.0 mL/100m ²)	300 GDD	3.93 BCD	3.28 CD	1.35 CD	1.10 C				
NufTE84Wk (8.0 mL/100m ²)	4 Weeks	5.83 AB	5.92 AB	1.88 AB	1.92 AB				
Primo8G (8.0 mL/100m ²)	300 GDD	5.23 ABC	3.83 BCD	1.65 ABC	1.30 BC				
Primo84W (8.0 mL/100m ²)	4 Weeks	6.00 AB	6.83 A	1.95 AB	2.13 A				
ATE Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300 GDD	3.83 CD	2.98 D	1.25 CD	0.95 C				
APr Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300GDD	4.05 BCD	3.55 CD	1.33 CD	1.15 C				
SE		0.60	0.60	0.18	0.20				

¹ Plant biomass values within each column are a mean of 4 replications; means within columns followed by the same letter are not significantly different (Tukey-Kramer method, P > 0.05). Due to variable timing between samplings the clipping weights were statistically analyzed by collection date and weights cannot be compared between dates/columns. DAT denotes days after treatment. ATE Combo is Anuew + NufTE (1.4 g/100m² + 8mL/100m²). APr combo is Anuew + Primo (1.4 g/100m² + 8mL/100m²). The standard error (SE) for the Tukey-Kramer LS Means values are also presented in the table.

Table 9. Clipping collection data at 4 and 8 days after treatment (DAT) for the fourth/final 4-Week application. Fresh and dry biomass weights are presented

Treatment	Frequency	Fresh Weight Biomass (g)				Dry Weight Biomass (g)			
		20200824		20200828		20200824		20200828	
		4DAT 4Wk4	8DAT 4Wk4			4DAT 4Wk4	8DAT 4Wk4		
Control (0 mL/m ²)	0	7.78 ¹ A	9.90 A			2.15 A	2.70 A		
Anuew (1.4 g/100m ²)	300 GDD	4.78 BC	10.05 A			1.58 ABC	2.70 A		
Anuew (2.8 g/100m ²)	300 GDD	4.73 BCD	7.88 AB			1.45 BCD	2.08 B		
Anuew (5.6 g/100m ²)	300 GDD	3.00 CD	6.63 B			1.00 CD	1.85 BC		
NufTE8G (8.0 mL/100m ²)	300 GDD	3.13 CD	7.53 B			1.00 CD	2.00 B		
NufTE84Wk (8.0 mL/100m ²)	4 Weeks	5.18 B	6.29 B			1.63 AB	1.46 C		
Primo8G (8.0 mL/100m ²)	300 GDD	2.80 D	7.75 B			1.03 BCD	2.05 B		
Primo84W (8.0 mL/100m ²)	4 Weeks	3.85 BCD	6.55 B			1.23 BCD	2.00 B		
ATE Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300 GDD	3.23 CD	6.93 B			0.98 CD	1.93 BC		
APr Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300GDD	3.20 CD	7.23 B			0.95 D	1.93 BC		
	SE	0.57	0.60			0.18	0.15		

¹ Plant biomass values within each column are a mean of 4 replications; means within columns followed by the same letter are not significantly different (Tukey-Kramer method, P > 0.05). Due to variable timing between samplings the clipping weights were statistically analyzed by collection date and weights cannot be compared between dates/columns. DAT denotes days after treatment. ATE Combo is Anuew + NufTE (1.4 g/100m² + 8mL/100m²). APr combo is Anuew + Primo (1.4 g/100m² + 8mL/100m²). The standard error (SE) for the Tukey-Kramer LS Means values are also presented in the table.

Table 10. NDVI readings for 2020 Nufarm PGR experiment from Pre-treatment to end of July, 2020

Turfgrass NDVI		200526	200601	200605	200610	200619	200624	200629	200706	200710	200720	200724	200731							
May - Mid-July									17DAT GDD2/	6DAT GDD3/	10DAT GDD3/	7DAT GDD4/	11DAT GDD4/	4DAT GDD5/						
Treatment	Frequency	-1DAT 1	5DAT1	9DAT1	14DAT1	7DAT GDD2	12DAT GDD2	4DAT 4Wk2	11DAT 4Wk2	15DAT 4Wk2	25DAT 4Wk2	29DAT 4Wk2	4DAT 4Wk3							
Control (0 mL/m ²)	0	0.550	0.542	0.583	A	0.565	0.536	B	0.507	B	0.557	B	0.526	B	0.574	0.555	C	0.534	B	0.584
Anuew (1.4 g/100m ²)	300 GDD	0.549	0.526	0.562	AB	0.557	0.553	AB	0.514	AB	0.577	AB	0.543	AB	0.582	0.577	BC	0.555	AB	0.600
Anuew (2.8 g/100m ²)	300 GDD	0.574	0.537	0.567	AB	0.566	0.554	AB	0.544	AB	0.606	A	0.560	A	0.603	0.588	AB	0.563	A	0.598
Anuew (5.6 g/100m ²)	300 GDD	0.562	0.538	0.559	AB	0.560	0.555	AB	0.545	AB	0.585	AB	0.563	A	0.584	0.592	AB	0.573	A	0.615
NufTE8G (8.0 mL/100m ²)	300 GDD	0.574	0.536	0.556	AB	0.557	0.557	AB	0.542	AB	0.597	AB	0.568	A	0.605	0.598	AB	0.571	A	0.598
NufTE84Wk (8.0 mL/100m ²)	4 Weeks	0.561	0.526	0.550	B	0.546	0.572	A	0.541	AB	0.574	AB	0.547	AB	0.583	0.595	AB	0.551	AB	0.584
Primo8G (8.0 mL/100m ²)	300 GDD	0.555	0.527	0.559	AB	0.555	0.550	AB	0.527	AB	0.598	AB	0.556	AB	0.598	0.593	AB	0.573	A	0.611
Primo84W (8.0 mL/100m ²)	4 Weeks	0.562	0.532	0.570	AB	0.560	0.568	A	0.534	AB	0.584	AB	0.556	AB	0.606	0.593	AB	0.564	A	0.595
ATE Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300 GDD	0.562	0.529	0.557	AB	0.550	0.555	AB	0.530	AB	0.600	AB	0.554	AB	0.600	0.598	AB	0.568	A	0.597
APr Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300GDD	0.566	0.527	0.560	AB	0.555	0.561	A	0.551	A	0.605	A	0.568	A	0.620	0.605	A	0.578	A	0.613
	SE	NS	NS	0.009	NS	0.007	0.012	0.013	0.010	NS	0.007	0.008	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 11. NDVI readings for 2020 Nufarm PGR experiment for August

Turfgrass NDVI		200807	200813	200819	200824	200828				
Mid-July - September		11DAT GDD5/	3DAT GDD6/	9DAT GDD6/	14DAT GDD6/	18DAT GDD6/				
Treatment	Frequency	11DAT 4Wk3	17DAT 4Wk3	23DAT 4Wk3	4DAT 4Wk4	8DAT 4Wk4				
Control (0 mL/m ²)	0	0.528	BC	0.536	B	0.647	0.563	C	0.566	C
Anuew (1.4 g/100m ²)	300 GDD	0.561	A	0.551	AB	0.646	0.575	ABC	0.576	BC
Anuew (2.8 g/100m ²)	300 GDD	0.551	ABC	0.551	AB	0.667	0.579	ABC	0.590	AB
Anuew (5.6 g/100m ²)	300 GDD	0.553	ABC	0.559	AB	0.663	0.581	ABC	0.593	AB
NufTE8G (8.0 mL/100m ²)	300 GDD	0.560	AB	0.561	A	0.678	0.596	A	0.604	A
NufTE84Wk (8.0 mL/100m ²)	4 Weeks	0.523	C	0.539	AB	0.665	0.570	BC	0.575	BC
Primo8G (8.0 mL/100m ²)	300 GDD	0.546	ABC	0.562	A	0.671	0.590	AB	0.600	A
Primo84W (8.0 mL/100m ²)	4 Weeks	0.534	ABC	0.541	AB	0.662	0.573	BC	0.577	BC
ATE Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300 GDD	0.547	ABC	0.558	AB	0.659	0.579	ABC	0.586	ABC
APr Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300GDD	0.539	ABC	0.549	AB	0.665	0.580	ABC	0.591	AB
	SE	0.010	0.007	NS	0.006	0.007				

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 12. Visual colour ratings for 2020 PGR experiment from pre-treatment to end of July, 2020

Turfgrass Colour		20200530	20200605	20200615	20200619	20200702	20200708	20200717	20200721	20200730
Treatment	Frequency	3DAT1	9DAT1	3DAT GDD2	7DAT GDD2	2DAT GDD3/ 7DAT 4Wk2	8DAT GDD3	4DAT GDD4	8DAT GDD4	3DAT GDD5/ 3DAT 4Wk3
Control (0 mL/m ²)	0	7.5 ¹	7.0	7.3	6.3 B	6.5 B	6.0 B	6.5 B	6.3 C	6.8 B
Anuew (1.4 g/100m ²)	300 GDD	7.3	7.5	7.5	7.5 AB	7.8 A	7.3 AB	8.0 A	7.5 AB	7.3 AB
Anuew (2.8 g/100m ²)	300 GDD	7.4	7.5	7.5	7.5 AB	7.8 A	7.8 A	7.5 AB	8.0 AB	8.3 A
Anuew (5.6 g/100m ²)	300 GDD	7.3	7.8	7.5	7.8 A	8.0 A	8.3 A	8.5 A	8.0 AB	8.3 A
NufTE8G (8.0 mL/100m ²)	300 GDD	7.4	7.5	7.5	7.8 A	8.0 A	8.5 A	8.3 A	8.5 A	8.5 A
NufTE84Wk (8.0 mL/100m ²)	4 Weeks	7.0	7.5	8.0	7.8 A	7.5 A	7.8 A	7.8 AB	7.5 AB	7.3 AB
Primo8G (8.0 mL/100m ²)	300 GDD	7.4	7.5	7.3	7.3 B	7.8 A	7.8 A	8.5 A	8.0 AB	7.8 AB
Primo84W (8.0 mL/100m ²)	4 Weeks	7.5	8.0	8.0	8.0 A	8.0 A	7.5 A	8.0 A	7.3 BC	7.5 AB
ATE Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300 GDD	7.1	7.8	7.5	7.5 B	7.8 A	8.3 A	8.5 A	8.0 AB	7.8 AB
APr Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300GDD	7.3	7.5	7.5	7.5 B	8.0 A	8.0 A	8.8 A	8.3 AB	7.8 AB
	SE	NS	NS	NS	0.4	0.3	0.4	0.4	0.4	0.4

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 ratings are based on the NTEP 1-9 rating scale, 9 = Ideal green colour for greens height turf, 1= poorest colour/yellow and dead greens turf, 6 = minimum acceptable turf colour for a golf course putting green. 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 13. Visual colour ratings for 2020 PGR experiment for August, 2020

Turfgrass Colour		20200805	20200813	20200818	20200824	20200828
Treatment	Frequency	8DAT GDD5/ 8DAT 4Wk3	3DAT GDD6	8DAT GDD6	4DAT 4Wk4	8DAT 4Wk4
Control (0 mL/m ²)	0	6.8 ¹	6.8	7.0 B	6.5 B	6.5 B
Anuew (1.4 g/100m ²)	300 GDD	7.3	7.3	7.5 AB	7.3 AB	7.8 AB
Anuew (2.8 g/100m ²)	300 GDD	7.5	7.5	7.8 AB	8.0 AB	7.8 AB
Anuew (5.6 g/100m ²)	300 GDD	7.8	7.8	7.8 AB	8.5 A	9.0 A
NufTE8G (8.0 mL/100m ²)	300 GDD	8.3	8.3	8.3 AB	8.3 A	8.8 A
NufTE84Wk (8.0 mL/100m ²)	4 Weeks	7.3	8.0	8.3 AB	7.5 AB	7.8 AB
Primo8G (8.0 mL/100m ²)	300 GDD	8.0	7.8	8.0 AB	7.8 AB	8.5 A
Primo84W (8.0 mL/100m ²)	4 Weeks	8.0	8.0	8.0 AB	7.3 AB	7.8 B
ATE Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300 GDD	8.3	7.5	8.0 AB	8.0 AB	8.3 A
APr Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300GDD	8.5	8.3	8.5 A	8.3 A	8.8 A
		NS	NS	0.4	0.5	0.4

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 ratings are based on the NTEP 1-9 rating scale, 9 = Ideal green colour for greens height turf, 1= poorest colour/yellow and dead greens turf, 6 = minimum acceptable turf colour for a golf course putting green. 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 14. Visual turfgrass quality ratings for 2020 PGR experiment from pre-treatment to end of July, 2020

Turfgrass Colour		20200530	20200605	20200615	20200619	20200702	20200708	20200717	20200721	20200730
Treatment	Frequency	3DAT1	9DAT1	3DAT GDD2	7DAT GDD2	2DAT GDD3/ 7DAT 4Wk2	8DAT GDD3	4DAT GDD4	8DAT GDD4	3DAT GDD5/ 3DAT 4Wk3
Control (0 mL/m ²)	0	7.3 ¹	6.8	7.5 AB	7.3 AB	6.5 C	6.8 B	5.8 B	6.3 B	6.5
Anuew (1.4 g/100m ²)	300 GDD	7.3	7.3	7.0 B	7.0 B	7.5 AB	7.3 AB	7.5 A	7.8 A	6.8
Anuew (2.8 g/100m ²)	300 GDD	7.5	7.5	7.3 AB	7.3 AB	7.3 ABC	7.8 AB	7.5 A	8.0 A	7.5
Anuew (5.6 g/100m ²)	300 GDD	7.3	7.8	7.5 AB	7.5 AB	8.0 A	8.0 AB	8.3 A	7.8 A	7.8
NufTE8G (8.0 mL/100m ²)	300 GDD	7.3	7.5	7.5 AB	7.5 AB	7.8 AB	8.3 A	8.0 A	8.0 A	7.3
NufTE84Wk (8.0 mL/100m ²)	4 Weeks	7.0	7.3	7.3 AB	7.3 AB	7.0 BC	7.8 AB	7.8 A	7.8 A	7.0
Primo8G (8.0 mL/100m ²)	300 GDD	6.8	7.0	7.3 AB	7.3 AB	7.5 AB	7.8 AB	8.0 A	7.8 A	7.5
Primo84W (8.0 mL/100m ²)	4 Weeks	7.3	7.8	8.0 A	8.0 A	7.5 AB	7.5 AB	7.8 A	7.3 AB	7.5
ATE Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300 GDD	6.8	7.5	7.5 AB	7.5 AB	8.0 A	8.0 AB	8.0 A	7.5 AB	7.5
APr Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300GDD	7.0	7.0	7.3 AB	7.3 AB	8.0 A	7.8 AB	8.0 A	8.0 A	8.0
	SE	NS	NS	0.3	0.2	0.3	0.4	0.4	0.4	NS

¹ Visual quality 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 quality ratings are based on the NTEP 1-9 rating scale, 9 = Ideal quality greens height turf, 1 = poorest quality/dead greens turf, 6 = minimum acceptable turf quality for a golf course putting green. 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 15. Visual turfgrass quality ratings for 2020 PGR experiment for August, 2020

Turfgrass Colour		20200805	20200813	20200818	20200824	20200828
Treatment	Frequency	8DAT GDD5/ 8DAT 4Wk3	3DAT GDD6	8DAT GDD6	4DAT 4Wk4	8DAT 4Wk4
Control (0 mL/m ²)	0	6.5 ¹	6.3	6.8	5.8 B	5.8 B
Anuew (1.4 g/100m ²)	300 GDD	7.3	7.0	6.8	6.8 AB	7.0 AB
Anuew (2.8 g/100m ²)	300 GDD	7.8	7.3	7.5	7.5 A	7.5 A
Anuew (5.6 g/100m ²)	300 GDD	7.8	7.0	7.3	7.8 A	8.0 A
NufTE8G (8.0 mL/100m ²)	300 GDD	7.3	7.8	7.5	8.0 A	8.0 A
NufTE84Wk (8.0 mL/100m ²)	4 Weeks	7.5	7.3	7.3	7.0 AB	7.3 AB
Primo8G (8.0 mL/100m ²)	300 GDD	7.8	7.8	7.3	7.8 A	8.0 A
Primo84W (8.0 mL/100m ²)	4 Weeks	7.5	7.3	7.5	7.3 A	7.5 A
ATE Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300 GDD	7.5	7.0	7.5	7.8 A	7.8 A
APr Combo (1.4 g/100m ² + 4.0 mL/100m ²)	300GDD	7.8	7.5	7.5	7.8 A	8.0 A
		NS	NS	NS	0.4	0.5

¹ Visual quality 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 quality ratings are based on the NTEP 1-9 rating scale, 9 = Ideal quality greens height turf, 1 = poorest quality/dead greens turf, 6 = minimum acceptable turf quality for a golf course putting green. 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.

CONCLUSIONS

The results of experiment show that:

- On many occasions throughout the experiment, all PGR treatments:
 - Significantly reduced turfgrass growth when compared to the untreated control
 - Improved turfgrass quality ratings when compared to the untreated control
 - Had enhanced colour or 'greenness' in response to application
- A rate effect was detected in the experiment:
 - The 2.8 and 5.6 g/100 m² rates of Anuew on the 300 GDD schedule often ranked as the treatments that produced the least amount of clippings
 - The 2.8 and 5.6 g/100 m² rates of Anuew often performed similarly to both combination treatments
- NufTE (experimental NAI-20026) performed similarly to Primo on both the GDD and 4-week application schedule and often were ranked the same for many parameters throughout the experiment
- No stress symptoms (yellowing, etiolation) were observed on the putting green turf in response to PGR application during hot/dry weather at any point during the experiment

Appendix a) Maintenance records for USGA green at the Guelph Turfgrass Institute for the 2020 field season; information submitted by Peter Purvis, Guelph Research Station Superintendent

Height of cut = 3mm
Irrigated to prevent dormancy

Date	Managment	Product Used	Note
April 3, 2020	Foliar fertilized	Urea, 281g/100m2	
June 25, 2020	Dollarspot control	Banner Max -26ml/100m2 and Daconil 2787 - 190ml/100m2	
July 14, 2020	Dollarspot control	Trilogy, 65ml/100m2	PGR trial only
July 17, 2020	Aeration	Spiked with Procore	

Appendix b) Weather records for the Guelph Research Station/Guelph Turfgrass Institute for the 2020 Nufarm PGR Trial

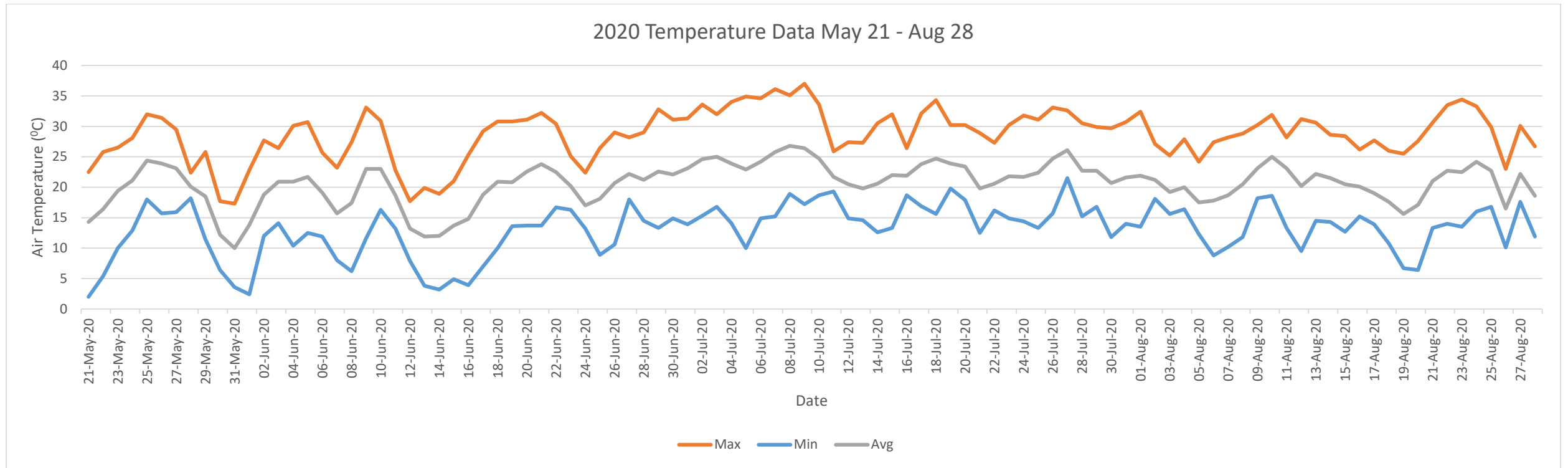


Figure 3. Daily maximum, minimum and average air temperatures recorded at the Guelph research station/Guelph Turfgrass Institute for the 2019 trial period

Appendix b) Continued

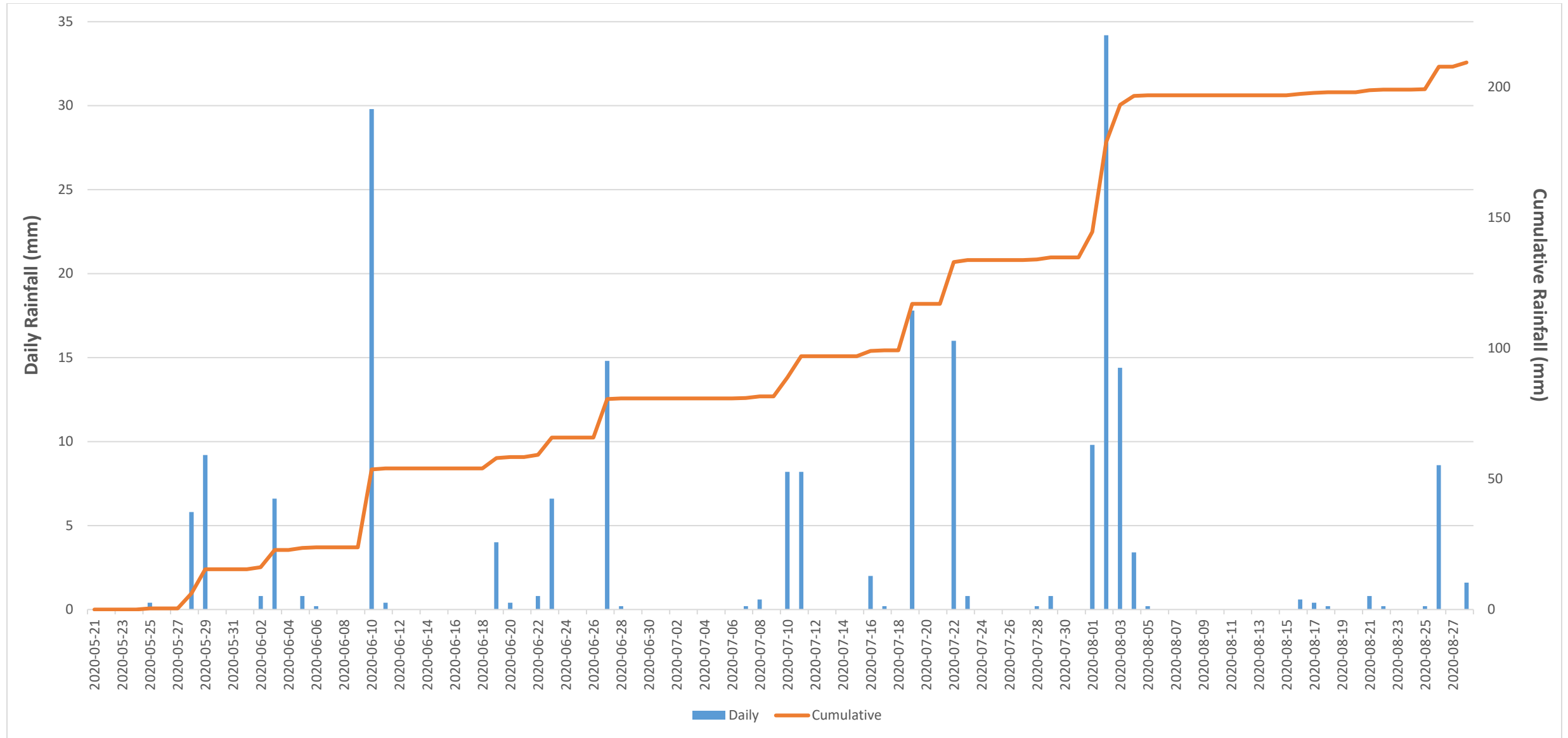


Figure 4. Daily and cumulative rainfall recorded at the Guelph research station/Guelph Turfgrass Institute for the 2020 trial period.

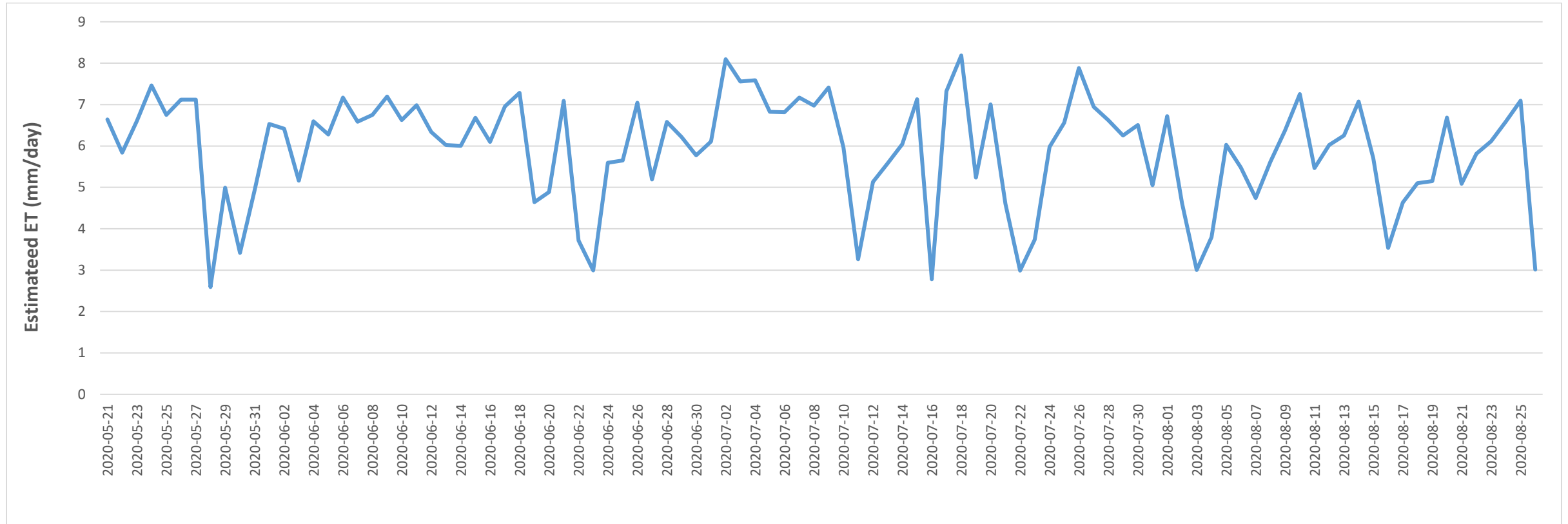


Figure 5. Daily estimated evapotranspiration rate (ET) recorded at the Guelph research station/Guelph Turfgrass Institute for the 2020 trial period.