

Longevity of Turf Response to Agrium AT Slow and Controlled Release Fertilizers – 2012 trial

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Sponsor: Agrium Advanced Technologies

The objective of this research project was to quantify turf response to a one-time application of coated urea fertilizers on Kentucky bluegrass turf on a soil rootzone.

Data collected included the duration and strength of the color response following application of the tested products, turf quality, uniformity, and density, and resistance of the turf to disease and other stresses.

MATERIALS/METHODS

The treatments consisted of the sponsor's products at specified rate and application program (Table 1). An unfertilized check treatment was also included. Treatments were applied to 1 x 3 m plots of Kentucky bluegrass turf maintained as a home-lawn type turf on the research ranges at the Guelph Turfgrass Institute (mowing at 40 mm, irrigation to prevent stress) (Figure 1). Treatments were replicated four times in a randomized complete block design. Treatments were applied May 17, 2012 according to the recommended programs.

Color response of the turf to treatments was assessed pre-treatment, and then on a weekly

basis, both visually and using instrumental color (canopy reflectance – normalized-difference vegetation index using an Ntech Greenseeker). Uniformity of the color response was assessed visually using a scale of 1 to 9 (1=dead, 9=ideal, 5=acceptable). Plots were rated for turf quality, density and uniformity. Clippings were collected at 2, 4, 6, 8, 10, 12, 14, and 16 weeks after treatment, dried and weighed to determine shoot dry matter accumulation per unit area. Soil temperature at 5 cm depth was monitored with Spectrum WatchDog data loggers, and reported as daily mean. Other stresses were measured as they occurred (disease, weed, drought).

Spring greenup will be assessed in April 2013.

An anecdotal photographic record of the experiment was kept.

All measurements were analyzed by appropriate statistical analyses (general linear models).

RESULTS

Environmental data

Daily air and soil temperatures for May - October 2012 are presented in Figures 2 and 3.

Visual ratings

Color differences between treated and control plots appeared by 12 DAT (Table 2), but the differences between fertilizer treatments were very small, except for Polyon 42-0-0 SGN 250 treatment, which never produced a color response

Table 1. Treatments

Treatment	Rate	
	lb. N / M	g N m ⁻²
1 Untreated control	—	—
2 Urea 46-0-0	1.00	4.88
3 ProTurf Turf N (Polyon) 44-0-0 SGN 250	1.25	6.10
4 ProTurf Turf N (Polyon) 44-0-0 SGN 190	1.25	6.10
5 Polyon 43-0-0 SGN 250	1.75	8.54
6 Polyon 43-0-0 SGN 190	1.75	8.54
7 Polyon 42-0-0 SGN 250	2.00	9.76
8 XCU 43-0-0 SGN 260	1.25	6.10
9 XCU 43-0-0 SGN 190	1.25	6.10
10 ProTurf Turf N (Poly-S) 40-0-0	1.25	6.10





Figure 1. Plot area June 7, 2012 (21 DAT).

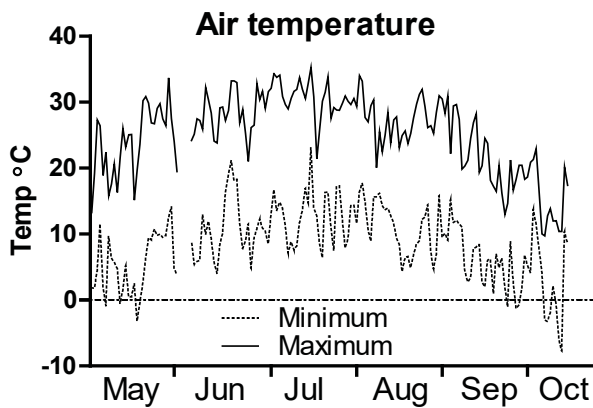


Figure 2. Daily air temperatures at GTI, summer 2012.

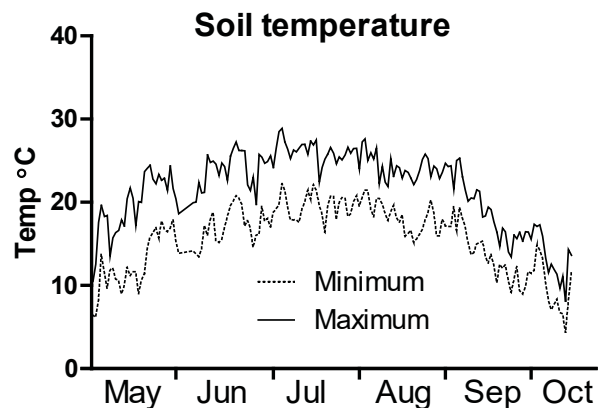


Figure 3. Daily soil temperatures at GTI, summer 2012.

(see also canopy reflectance data below). There were no visible differences among treated plots for quality, uniformity, or density. The NDVI values are a reasonable proxy for visual color (Figure 4), with observed range of differences in NDVI (~ 0.2 units) corresponding to about 3 ranks of visual color differences (6 to 9).

Canopy reflectance

The canopy reflectance (normalized-difference vegetation index) data collected with the Greenseeker gave a very precise picture of the response to the treatments. Index values were

calculated both as the raw NDVI values and as values corrected by subtracting the value of the untreated control to remove background variation, since the NDVI value is affected by mowing, moisture status, and other factors in addition to nitrogen status. Figure 5 shows the pattern of change of the raw NDVI values (averaged across all plots) and the Δ NDVI values (averaged across all non-control plots) during the experiment. The fertilizer response pattern in 2012 was much clearer than the response in the 2011 trials, because the application was done earlier and the trial ran for longer. The

Table 2. Visual ratings of treated plots.

Treatment	Color			Uniformity
	12 DAT	28 DAT	40 DAT	28 DAT
Polyon 42-0-0 SGN 250	6.5 b ¹	6.8 cd	6.8 c	7.0
Polyon 43-0-0 SGN 190	8.0 ab	8.5 ab	8.8 a	7.8
Polyon 43-0-0 SGN 250	8.0 ab	8.5 ab	8.5 ab	7.3
ProTurf Turf N (Polyon) 44-0-0 SGN 190	8.0 ab	9.0 a	7.5 abc	7.8
ProTurf Turf N (Polyon) 44-0-0 SGN 250	7.5 ab	8.8 ab	7.5 abc	7.5
ProTurf Turf N (Poly-S) 40-0-0	8.0 ab	7.5 bcd	7.3 abc	7.5
Untreated control	6.5 b	6.3 d	6.5 c	7.0
Urea 46-0-0	7.8 ab	8.0 abc	6.5 c	7.3
XCU 43-0-0 SGN 190	8.8 a	8.5 ab	7.0 bc	7.5
XCU 43-0-0 SGN 260	8.3 a	8.5 ab	7.8 abc	7.8
msd p=0.05	1.7	1.4	1.6	NS

¹ Visual ratings 0-10, 10 = best, 6 = acceptable. Means of 4 replicates; means within columns followed by the same letter are not significantly different (Tukey's HSD test, p=0.05).

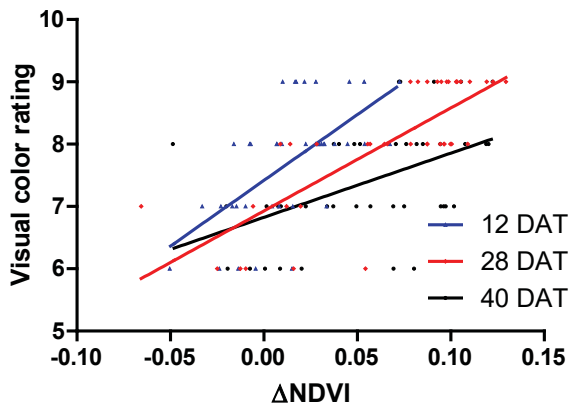


Figure 4. Relationship between visual color ratings and change in canopy reflectance in treated plots. The association is not tight, but the pattern is consistent across observation dates. Points graphed are plot means for Δ NDVI values, and plot values for visual color.

background (raw NDVI values) showed a sharp reduction during the hot dry summer in 2012, which was not seen in 2011.

There were significant differences in canopy reflectance among the treatments beginning 6 DAT and lasting until the last measurement date (146 DAT), with two exceptions (Table 3). As with the 2011 trial, the Polyon 42-0-0 SGN 250 treatment had very little release during the

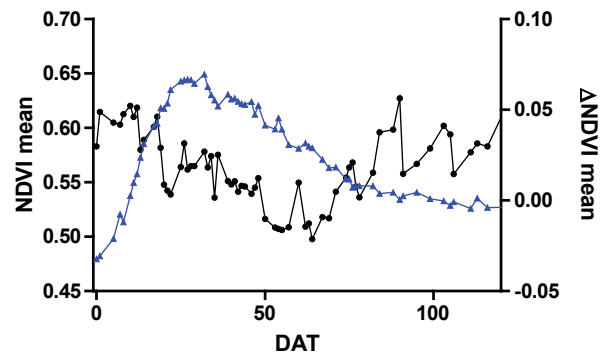


Figure 5. Changes in overall mean NDVI (black •) and Δ NDVI (corrected to remove control value; blue ▲) during the experiment.

experiment as measured by increase in canopy reflectance. Most of the other treatments had significantly larger canopy reflectance values than the untreated control on many dates, although on most dates there were some treatments that were not significantly higher than the control.

The Δ NDVI values, when plotted over time, allowed some differentiation among the fertilizer treatments in terms of release characteristics as detected by canopy reflectance. Replicate mean values of Δ NDVI were tested against vari-

Table 3. Change in canopy reflectance (relative to untreated control) in treated plots

Treatment	DAT							
	-13	-9	0	1	5	7	8	10
Polygon 42-0-0 SGN 250	-0.007	-0.010	-0.008	-0.019	-0.021	-0.022	-0.034	-0.035 b
Polygon 43-0-0 SGN 190	-0.029	-0.026	-0.029	-0.025	-0.030	-0.006	-0.018	-0.001 ab
Polygon 43-0-0 SGN 250	0.030	0.024	-0.004	-0.004	-0.012	-0.014	-0.020	-0.006 ab
ProTurf Turf N 40-0-0	-0.135	-0.126	-0.101	-0.103	-0.072	-0.045	-0.037	-0.008 ab
ProTurf Turf N 44-0-0 SGN 190	-0.103	-0.102	-0.084	-0.072	-0.041	-0.007	-0.016	0.007 ab
ProTurf Turf N 44-0-0 SGN 250	-0.020	-0.020	-0.034	-0.025	-0.021	-0.004	-0.010	0.002 ab
Untreated control	0.008	0.004	0.001	0.000	-0.001	0.000	0.001	0.000 ab
Urea 46-0-0	-0.005	-0.001	-0.019	-0.019	-0.005	0.008	0.001	0.013 ab
XCU 43-0-0 SGN 190	-0.053	-0.049	-0.045	-0.045	-0.022	-0.006	-0.003	0.014 ab
XCU 43-0-0 SGN 260	0.008	0.002	0.001	0.004	0.014	0.019	0.019	0.041 a
msd p=0.05	NS	NS	NS	NS	NS	NS	NS	0.061
	11	12	13	14	17	18	19	20
Polygon 42-0-0 SGN 250	-0.032 b	-0.027 c	-0.022 c	-0.016 d	-0.020 d	-0.018 c	-0.002 c	-0.007 b
Polygon 43-0-0 SGN 190	0.005 ab	0.014 abc	0.026 abc	0.030 abc	0.047 ab	0.052 a	0.062 a	0.068 a
Polygon 43-0-0 SGN 250	-0.003 ab	0.000 bc	0.006 bc	0.016 bcd	0.029 bc	0.035 ab	0.061 a	0.042 ab
ProTurf Turf N 40-0-0	0.009 ab	0.016 abc	0.038 ab	0.041 abc	0.055 ab	0.056 a	0.051 abc	0.085 a
ProTurf Turf N 44-0-0 SGN 190	0.020 a	0.022 ab	0.039 ab	0.042 ab	0.049 ab	0.052 a	0.058 ab	0.080 a
ProTurf Turf N 44-0-0 SGN 250	0.010 ab	0.017 abc	0.021 abc	0.037 abc	0.050 ab	0.049 a	0.057 abc	0.044 ab
Untreated control	0.000 ab	0.000 bc	0.000 bc	0.000 cd	0.000 cd	0.000 bc	0.000 bc	0.000 b
Urea 46-0-0	0.020 a	0.024 ab	0.019 abc	0.040 abc	0.047 ab	0.047 ab	0.058 ab	0.042 ab
XCU 43-0-0 SGN 190	0.024 a	0.031 ab	0.051 ab	0.058 a	0.075 a	0.076 a	0.096 a	0.087 a
XCU 43-0-0 SGN 260	0.043 a	0.049 a	0.059 a	0.065 a	0.077 a	0.076 a	0.085 a	0.067 a
msd p=0.05	0.047	0.048	0.053	0.042	0.043	0.048	0.059	0.064
	21	22	25	26	27	28	29	32
Polygon 42-0-0 SGN 250	-0.032 b	-0.027 c	-0.022 c	-0.016 d	-0.020 d	-0.018 c	-0.010 c	-0.002 c
Polygon 43-0-0 SGN 190	0.005 ab	0.014 abc	0.026 abc	0.030 abc	0.047 ab	0.052 a	0.059 a	0.062 a
Polygon 43-0-0 SGN 250	-0.003 ab	0.000 bc	0.006 bc	0.016 bcd	0.029 bc	0.035 ab	0.040 abc	0.061 a
ProTurf Turf N 40-0-0	0.009 ab	0.016 abc	0.038 ab	0.041 abc	0.055 ab	0.056 a	0.070 a	0.051 abc
ProTurf Turf N 44-0-0 SGN 190	0.020 a	0.022 ab	0.039 ab	0.042 ab	0.049 ab	0.052 a	0.071 a	0.058 ab
ProTurf Turf N 44-0-0 SGN 250	0.010 ab	0.017 abc	0.021 abc	0.037 abc	0.050 ab	0.049 a	0.054 ab	0.057 abc
Untreated control	0.000 ab	0.000 bc	0.000 bc	0.000 cd	0.000 cd	0.000 bc	0.000 bc	0.000 bc
Urea 46-0-0	0.020 a	0.024 ab	0.019 abc	0.040 abc	0.047 ab	0.047 ab	0.050 ab	0.058 ab
XCU 43-0-0 SGN 190	0.024 a	0.031 ab	0.051 ab	0.058 a	0.075 a	0.076 a	0.071 a	0.096 a
XCU 43-0-0 SGN 260	0.043 a	0.049 a	0.059 a	0.065 a	0.077 a	0.076 a	0.085 a	0.085 a
msd p=0.05	0.047	0.048	0.053	0.042	0.043	0.048	0.057	0.059
	33	34	35	36	39	40	41	42
Polygon 42-0-0 SGN 250	-0.007 b	-0.017 d	-0.018 d	-0.007 c	-0.004 c	-0.007 c	-0.003 e	-0.002 d
Polygon 43-0-0 SGN 190	0.068 a	0.102 a	0.098 ab	0.093 a	0.107 a	0.100 a	0.104 a	0.103 a
Polygon 43-0-0 SGN 250	0.042 ab	0.085 ab	0.066 abc	0.064 ab	0.079 ab	0.078 ab	0.074 abc	0.074 abc
ProTurf Turf N 40-0-0	0.085 a	0.087 ab	0.104 a	0.089 ab	0.095 ab	0.092 ab	0.097 ab	0.093 ab
ProTurf Turf N 44-0-0 SGN 190	0.080 a	0.090 ab	0.103 a	0.090 ab	0.104 a	0.096 ab	0.101 a	0.099 a
ProTurf Turf N 44-0-0 SGN 250	0.044 ab	0.035 bcd	0.033 bcd	0.035 bc	0.038 bc	0.035 bc	0.036 bcde	0.032 bcd
Untreated control	0.000 b	0.001 cd	-0.001 cd	0.000 c	0.000 c	0.001 c	0.001 de	0.000 d
Urea 46-0-0	0.042 ab	0.037 bcd	0.038 abcd	0.036 bc	0.033 bc	0.034 bc	0.029 cde	0.027 cd
XCU 43-0-0 SGN 190	0.087 a	0.074 ab	0.064 abc	0.058 ab	0.065 ab	0.065 ab	0.062 abcd	0.057 abc
XCU 43-0-0 SGN 260	0.067 a	0.059 abc	0.066 abc	0.061 ab	0.069 ab	0.064 ab	0.064 abc	0.064 abc
msd p=0.05	0.064	0.061	0.068	0.057	0.064	0.062	0.063	0.062
	43	44	46	47	48	50	53	54
Polygon 42-0-0 SGN 250	0.002 d	0.005 c	0.008 d	0.001 d	-0.004 c	-0.004 c	0.007 bc	0.013 bc
Polygon 43-0-0 SGN 190	0.104 a	0.100 a	0.103 a	0.099 a	0.110 a	0.091 ab	0.090 ab	0.094 ab
Polygon 43-0-0 SGN 250	0.074 abc	0.081 ab	0.083 abc	0.071 abc	0.068 abc	0.057 abc	0.058 abc	0.058 abc
ProTurf Turf N 40-0-0	0.088 ab	0.081 ab	0.091 ab	0.081 ab	0.088 abc	0.087 abc	0.077 abc	0.084 abc
ProTurf Turf N 44-0-0 SGN 190	0.094 a	0.096 a	0.098 a	0.093 a	0.099 ab	0.096 a	0.093 a	0.100 a
ProTurf Turf N 44-0-0 SGN 250	0.030 bcd	0.030 bc	0.029 bcd	0.023 bcd	0.005 bc	0.013 abc	0.010 abc	0.023 abc
Untreated control	0.001 d	0.001 c	0.000 d	0.000 d	0.000 c	0.000 bc	0.000 c	0.000 c
Urea 46-0-0	0.026 cd	0.021 bc	0.020 cd	0.013 cd	-0.006 c	0.001 bc	-0.003 c	0.002 c
XCU 43-0-0 SGN 190	0.052 abcd	0.054 abc	0.051 abcd	0.039 abcd	0.044 abc	0.031 abc	0.026 abc	0.033 abc
XCU 43-0-0 SGN 260	0.063 abc	0.059 abc	0.061 abcd	0.055 abcd	0.035 abc	0.042 abc	0.036 abc	0.048 abc
msd p=0.05	0.059	0.060	0.066	0.064	0.096	0.093	0.085	0.084



Table 3. Change in canopy reflectance, continued

Treatment	DAT							
	55	57	60	62	63	64	67	69
Polyon 42-0-0 SGN 250	0.008 bcd	0.005 ab	0.016 abc	0.028 ab	0.025 ab	0.028 ab	0.039 ab	0.029 ab
Polyon 43-0-0 SGN 190	0.090 ab	0.081 a	0.079	0.077 a	0.074 ab	0.077 a	0.068 a	0.059 a
Polyon 43-0-0 SGN 250	0.056 abcd	0.048 ab	0.048 abc	0.043 ab	0.043 ab	0.036 ab	0.033 ab	0.034 ab
ProTurf Turf N 40-0-0	0.077 abc	0.063 ab	0.052 abc	0.064 ab	0.064 ab	0.062 ab	0.044 ab	0.038 ab
ProTurf Turf N 44-0-0 SGN 190	0.091 a	0.081 a	0.067 ab	0.081 a	0.081 a	0.082 a	0.069 a	0.060 a
ProTurf Turf N 44-0-0 SGN 250	0.010 abcd	0.000 ab	0.004 bc	-0.003 ab	-0.002 ab	-0.002 ab	-0.012 ab	-0.016 ab
Untreated control	0.000 cd	0.000 ab	0.000 bc	0.000 ab	0.000 ab	0.000 ab	-0.001 ab	0.000 ab
Urea 46-0-0	-0.009 d	-0.012 b	-0.014 c	-0.017 b	-0.016 b	-0.023 b	-0.030 b	-0.029 b
XCU 43-0-0 SGN 190	0.026 abcd	0.011 ab	0.009 abc	0.017 ab	0.007 ab	0.009 ab	0.004 ab	-0.001 ab
XCU 43-0-0 SGN 260	0.042 abcd	0.029 ab	0.027 abc	0.025 ab	0.021 ab	0.020 ab	0.011 ab	0.005 ab
msd p=0.05	0.082	0.084	0.070	0.093	0.093	0.094	0.090	0.085
	71	74	75	76	77	78	82	84
Polyon 42-0-0 SGN 250	0.036 ab	0.038 a	0.044 ab	0.028 a	0.030	0.031	0.043 a	0.030 a
Polyon 43-0-0 SGN 190	0.059 a	0.046 a	0.048 a	0.029 a	0.035	0.037	0.036 ab	0.026 a
Polyon 43-0-0 SGN 250	0.033 ab	0.022 ab	0.025 abc	0.013 ab	0.014	0.015	0.014 abc	0.014 ab
ProTurf Turf N 40-0-0	0.036 ab	0.027 ab	0.021 abc	0.010 ab	0.027	0.026	0.020 abc	0.009 ab
ProTurf Turf N 44-0-0 SGN 190	0.052 a	0.040 a	0.042 ab	0.017 ab	0.042	0.044	0.035 ab	0.028 a
ProTurf Turf N 44-0-0 SGN 250	-0.012 ab	-0.015 ab	-0.018 bc	-0.037 ab	-0.022	-0.025	-0.020 bc	-0.018 ab
Untreated control	0.000 ab	0.000 ab	0.000 abc	0.000 ab	0.000	0.000	-0.001 abc	-0.001 ab
Urea 46-0-0	-0.029 b	-0.032 b	-0.035 c	-0.047 b	-0.032	-0.031	-0.033 c	-0.032 b
XCU 43-0-0 SGN 190	0.000 ab	-0.009 ab	-0.012 abc	-0.015 ab	-0.009	-0.008	-0.009 abc	-0.014 ab
XCU 43-0-0 SGN 260	0.007 ab	0.001 ab	0.003 abc	-0.024 ab	-0.005	-0.006	-0.005 abc	-0.003 ab
msd p=0.05	0.075	0.068	0.064	0.073	NS	NS	0.063	0.050
	88	90	91	95	99	103	105	106
Polyon 42-0-0 SGN 250	0.041 a	0.019 a	0.037 a	0.047 a	0.036 a	0.035 a	0.028 a	0.037 a
Polyon 43-0-0 SGN 190	0.023 ab	0.014 ab	0.011 ab	0.013 ab	0.008 ab	0.004 bc	-0.004 ab	-0.003 ab
Polyon 43-0-0 SGN 250	0.013 abc	0.007 abc	0.009 ab	0.012 ab	0.015 ab	0.009 ab	0.006 ab	0.003 ab
ProTurf Turf N 40-0-0	0.005 abc	0.000 abcd	0.010 ab	0.006 b	0.000 ab	-0.004 bc	-0.005 ab	0.000 ab
ProTurf Turf N 44-0-0 SGN 190	0.021 ab	0.007 abc	0.027 ab	0.014 ab	0.013 ab	0.008 ab	-0.004 ab	0.010 ab
ProTurf Turf N 44-0-0 SGN 250	-0.016 bc	-0.031 cd	-0.020 ab	-0.013 b	-0.022 b	-0.019 bc	-0.027 b	-0.016 b
Untreated control	0.000 abc	-0.001 abcd	-0.001 ab	0.000 b	-0.001 ab	0.000 bc	-0.001 ab	-0.001 ab
Urea 46-0-0	-0.027 c	-0.034 d	-0.029 b	-0.023 b	-0.020 b	-0.022 c	-0.029 b	-0.021 b
XCU 43-0-0 SGN 190	-0.014 bc	-0.021 bcd	-0.010 ab	-0.010 b	-0.014 b	-0.010 bc	-0.023 b	-0.006 b
XCU 43-0-0 SGN 260	-0.001 abc	-0.018 abcd	-0.010 ab	-0.003 b	-0.007 b	-0.004 bc	-0.022 b	-0.011 b
msd p=0.05	0.043	0.040	0.059	0.038	0.042	0.030	0.042	0.041
	111	113	116	123	130	134	138	146
Polyon 42-0-0 SGN 250	0.028 a	0.040 a	0.031 a	0.037 a	0.032 a	0.025 a	0.032 a	0.038 a
Polyon 43-0-0 SGN 190	-0.008 b	0.000 b	-0.007 b	-0.011 b	-0.021 b	-0.020 ab	-0.013 b	-0.008 ab
Polyon 43-0-0 SGN 250	0.005 ab	0.006 ab	0.007 ab	0.004 b	0.001 ab	0.005 ab	0.013 ab	0.010 ab
ProTurf Turf N 40-0-0	-0.009 b	-0.003 b	-0.014 b	-0.013 b	-0.022 b	-0.026 b	-0.023 b	-0.022 b
ProTurf Turf N 44-0-0 SGN 190	0.002 ab	0.008 ab	-0.003 b	-0.008 b	-0.022 b	-0.028 b	-0.029 b	-0.026 b
ProTurf Turf N 44-0-0 SGN 250	-0.016 b	-0.012 b	-0.015 b	-0.014 b	-0.013 b	-0.012 ab	-0.007 ab	-0.001 ab
Untreated control	0.000 ab	0.000 b	0.000 ab	0.000 b	0.000 ab	0.000 ab	0.000 ab	0.000 ab
Urea 46-0-0	-0.020 b	-0.012 b	-0.012 b	-0.011 b	-0.007 b	-0.002 ab	0.004 ab	0.010 ab
XCU 43-0-0 SGN 190	-0.012 b	-0.007 b	-0.016 b	-0.016 b	-0.025 b	-0.025 b	-0.018 b	-0.018 b
XCU 43-0-0 SGN 260	-0.014 b	-0.008 b	-0.011 b	-0.006 b	-0.006 b	-0.002 ab	0.003 ab	0.001 ab
msd p=0.05	0.035	0.036	0.031	0.033	0.038	0.045	0.045	0.054

¹Change in normalized-difference vegetation index (compared to untreated control set to 0): mean of 4 replicates; means within columns followed by the same letter are not significantly different (Tukey's HSD test, p=0.05).

ous curves to determine which functions had potential to adequately describe the responses. The online curve fitting and surface fitting web site at www.zunzun.com was used to investigate families of curves. One of the best functions to fit the data was a compound exponential function $\Delta\text{NDVI} = 4 * A * e^{(-0.7 * \text{DAT}/C)} * (1 - e^{(-0.7 * \text{DAT}/C)})$, in which there are two fitted parameters: A, which varies with maximum ΔNDVI , and C, which varies with days to maximum ΔNDVI (Figure 6 and 7). The suitability was judged based on

the combination of goodness of fit, minimum number of parameters, and interpretability of the parameters.

The ΔNDVI values for each treatment were fitted to these curves using GraphPad Prism, and the estimates of A and C for each treatment were compared using ANOVAs. The parameter estimates of the fitted curves are shown in Table 4 and Figure 8, and the fitted curves are shown in Figure 9.

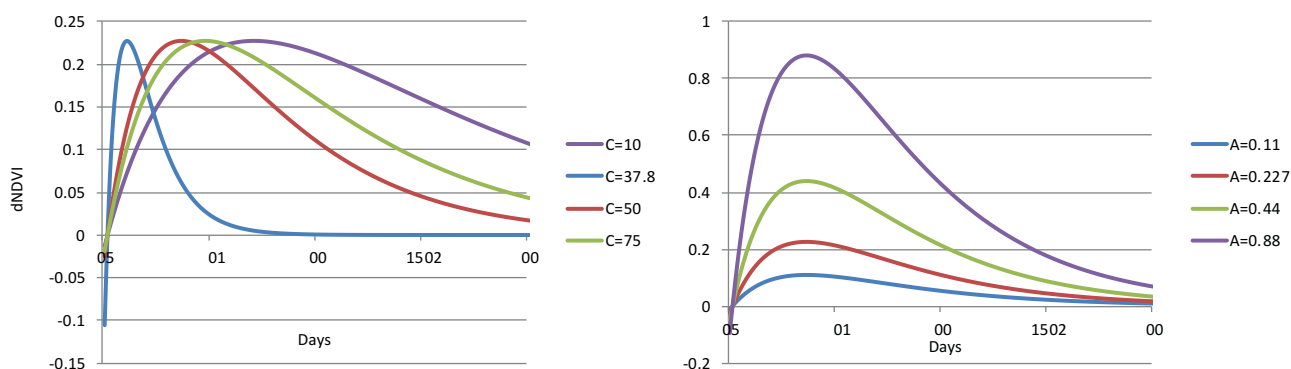


Figure 6. Families of curves of the function $\Delta NDVI = 4 * A * e^{(-0.7 * DAT / C)} * (1 - e^{(-0.7 * DAT / C)})$ illustrating the effects of varying the parameters A and C.

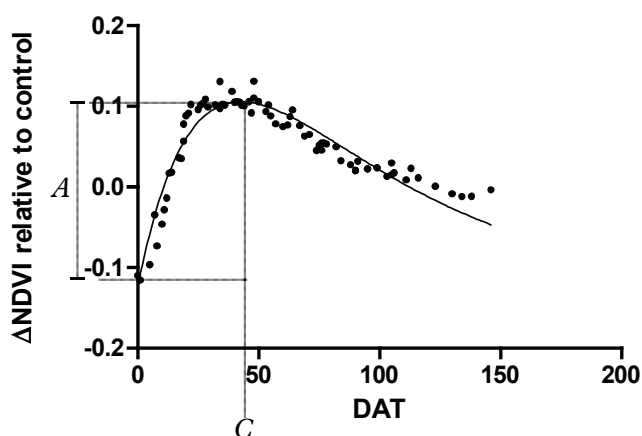


Figure 7. Typical curve fitted to data from one replicate of the Polyon 43-0-0 SGN 190 treatment; A = 0.23, C = 43.1 days, $R^2 = 0.90$.

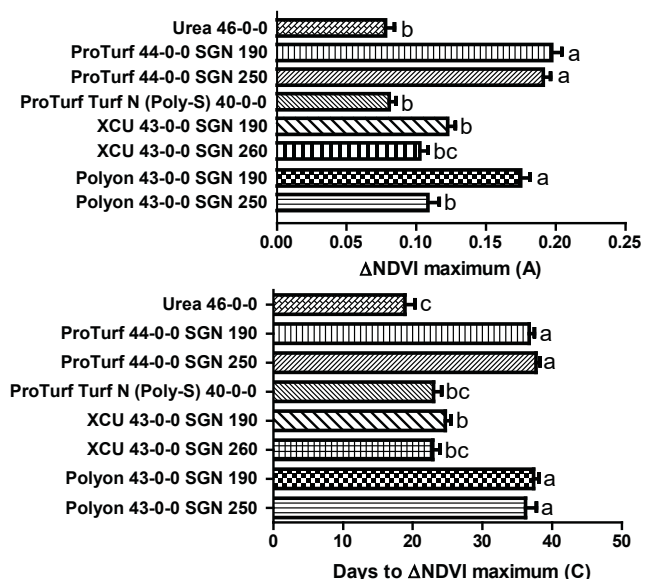


Figure 8. Parameters A and C for curves fitted to fertilizer response as estimated by $\Delta NDVI$. Parameter estimates are all significantly different except where a common letter is present on the bars (Tukey's multiple comparison test, $p=0.05$).

Table 4. Multiple comparisons of estimated parameters for fitted curves of $\Delta NDVI$.

Treatment	A	C
Polyon 43-0-0 SGN 190	0.175 a	37.3 a
Polyon 43-0-0 SGN 250	0.108 b	36.2 a
ProTurf 44-0-0 SGN 190	0.197 a	36.7 a
ProTurf 44-0-0 SGN 250	0.191 a	37.7 a
ProTurf Turf N (Poly-S) 40-0-0	0.081 c	23.0 bc
Urea 46-0-0	0.078 c	18.9 c
XCU 43-0-0 SGN 190	0.123 b	24.6 b
XCU 43-0-0 SGN 260	0.103 bc	22.9 bc

¹ Parameters followed by the same letter are not significantly different (Tukey's Multiple Comparison Test, $p=0.05$)

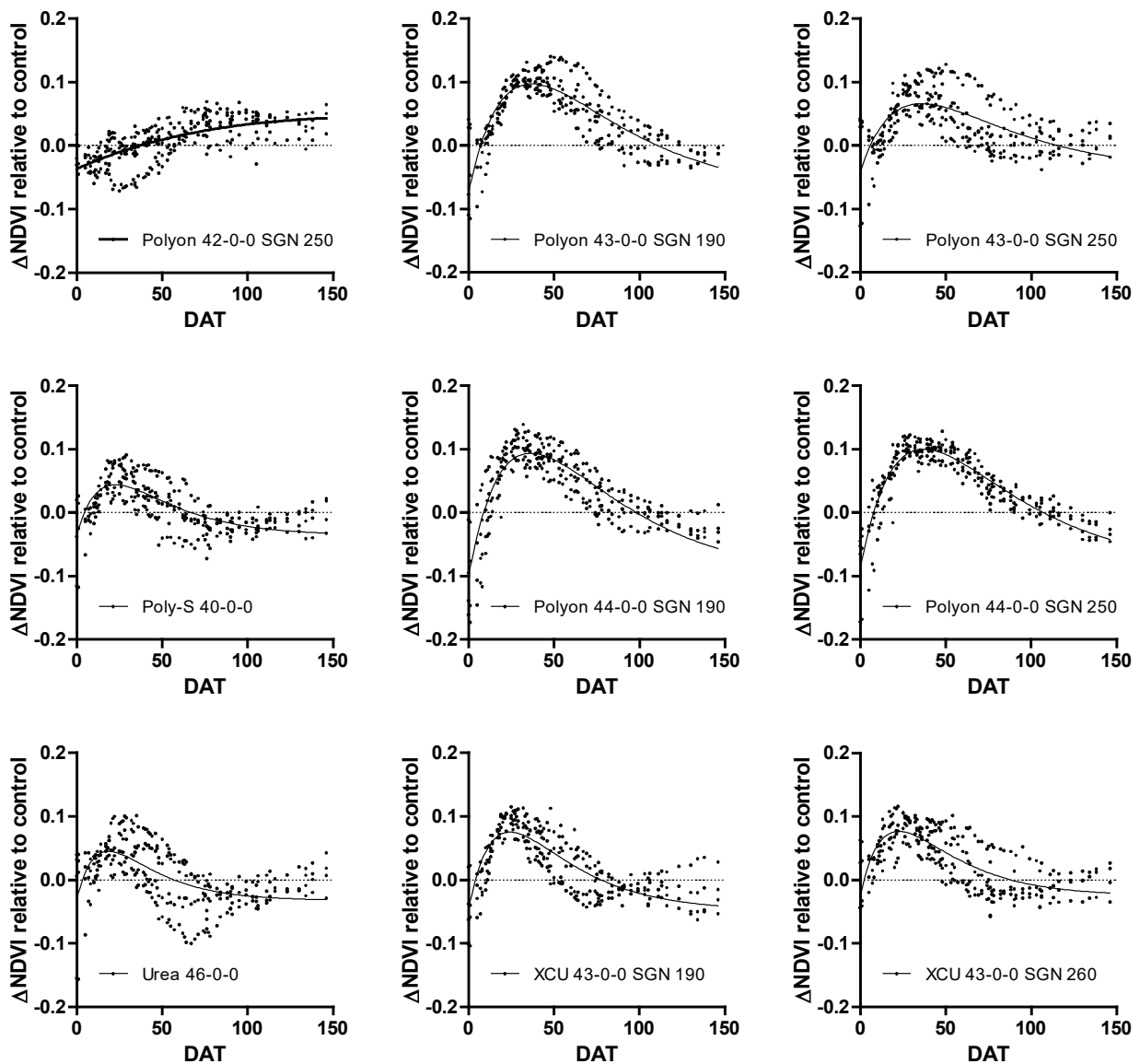


Figure 9. Curves fitted to fertilizer response as estimated by Δ NDVI. See Table 4 for estimates of A (max Δ NDVI) and C (days to max Δ NDVI). Points are replicate meant; curves were fitted to replicates.



Figure 10. Clipping collection: border strips were mowed short (<40 mm) and clippings were then collected from a 0.94 m strip lengthwise in each plot using a Gardena electric reel mower set at 42 mm height of cut.

Table 5. Dry matter accumulation.

Treatment	19	34	48	62	76	93	105
	DAT						
	g m ⁻²						
Polygon 42-0-0 SGN 250	5.72 ¹	5.06	2.60	2.88	5.26	10.14	5.65
Polygon 43-0-0 SGN 190	7.25	9.49	4.28	3.38	5.71	9.38	4.55
Polygon 43-0-0 SGN 250	9.18	10.53	3.68	2.82	4.01	8.03	4.98
ProTurf 40-0-0	9.54	7.32	2.98	2.12	4.40	8.03	3.93
ProTurf 44-0-0 SGN 190	5.39	6.02	2.55	2.45	3.27	7.06	3.60
ProTurf 44-0-0 SGN 250	4.87	5.15	3.00	2.10	3.29	6.30	3.55
Urea	12.08	7.50	2.60	1.72	2.86	6.48	3.53
XCU 43-0-0 SGN 190	8.73	7.53	3.35	1.90	3.32	7.63	4.10
XCU 43-0-0 SGN 260	13.48	10.54	4.13	2.20	4.70	8.93	4.58
Untreated control	9.13	5.65	2.60	2.15	4.18	8.45	4.58
msd p=0.05	NS	NS	NS	NS	NS	NS	NS

¹ Clippings collected from 0.38 x 0.94 m strip of each plot, mowed at 42 mm after 5-7 days of growth.

Shoot growth

Clippings were collected periodically to estimate shoot dry matter accumulation. Plots were mowed to 40 mm and then 5 – 7 days later clippings were collected from a 0.35 m² strip (Figure 10). There were some trends to increased growth in the first 4-6 weeks after treatment, but the differences were not statistically significant, and generally disappeared later in the season (Table 5). The general pattern of increase and decline in growth rates was similar to the response curves as estimated by Δ NDVI. Comparing the plot means for growth with Δ NDVI shows this relationship (Figure 11), which is significant, but weak.

DISCUSSION AND CONCLUSIONS

All treatments except for the Polygon 42-0-0 SGN 250 treatment gave a significant improvement in colour and growth compared to the untreated control. Fertilizer effects were observable by 10 days after treatment in the canopy reflectance data, and persisted (with two exceptional dates) in significant amounts until data collection ceased for the season (20 weeks after treatment). The average gain of fertilized treatments over control was about 2.5 ranks on the visual colour rating scale (6.5 to 9), or about 0.12 units on the canopy reflectance index. The untreated control plots were at an acceptable colour and quality level (>5) through most of

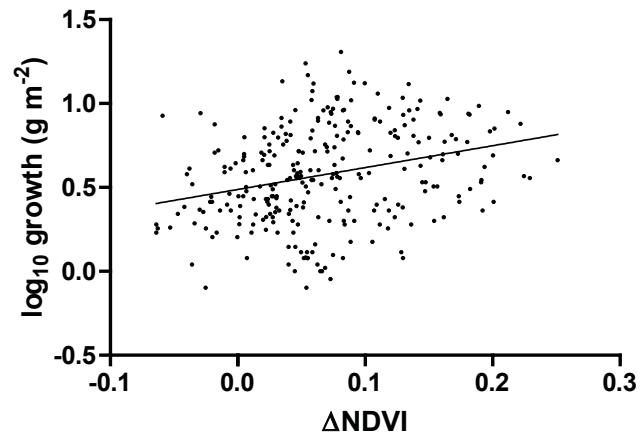


Figure 11. Relationship between increase in canopy reflectance and shoot growth as estimated by dry matter accumulation. Points are plot means; all clipping collections data are plotted. Dry matter accumulation is log-transformed to give a linear relationship.

the trial. There was no strong or consistent pattern date by date distinguishing the fertilizer treatments from one another, either in visual ratings, or canopy reflectance, or growth, except for the Polygon 42-0-0 SGN 250 treatment. The Polygon 42-0-0 SGN 250 only began to affect the turf towards the end of the growing season. This treatment had a similar, though less striking, pattern in the 2011 data.

Using the release curves fitted to the seasonal pattern of Δ NDVI suggests that the ranking of the fertilizer treatments for strength of response (A) was ProTurf 44-0-0 SGN 190 > ProTurf 44-0-0 SGN 250 > Polyon 43-0-0 SGN 190 > XCU 43-0-0 SGN 190 > Polyon 43-0-0 SGN 250 > XCU 43-0-0 SGN 260 > Polyon 42-0-0 SGN 250 > ProTurf Turf N (Poly-S) 40-0-0 > Urea 46-0-0.

Similarly, the ranking of the treatments for days to maximum release (C) was Polyon 42-0-0 SGN 250 > Polyon 43-0-0 SGN 190 > Polyon 43-0-0 SGN 250 > ProTurf 44-0-0 SGN 190 > ProTurf 44-0-0 SGN 250 > ProTurf Turf N (Poly-S) 40-0-0 > Urea 46-0-0 > XCU 43-0-0 SGN 190 > XCU 43-0-0 SGN 260.

The rate effect of different N rates in the treatments was confounded a bit by the formulation differences, but the higher rates tended to have their maximum release (C) longer after application. There seemed to be less connection between N rate and maximum increase in NDVI (A).