

Longevity of Turf Response to Urea, Coated Urea, and Blends – 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 urea-based 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.

Table 1. Treatments

<u>Treatment</u>	<u>Application program</u>
1. Untreated control	
2. 100% urea	
3. 15% XCU, 85% urea	All treatments were applied once (May 17, 2012) at
4. 30% XCU, 70% urea	
5. 50% XCU, 50% urea	
6. 100% XCU	
7. 15% SCU, 85% urea	
8. 30% SCU, 70% urea	1 lb / 1000 sq ft actual N (4.88 g m ⁻²)
9. 50% SCU, 50% urea	
10. 100% SCU	

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,



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

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

There were few significant differences in visual ratings of turf color compared to the trial done in 2012. Color differences between treated and control plots appeared by 12 DAT (Table 2), but no differences between fertilizer treatments

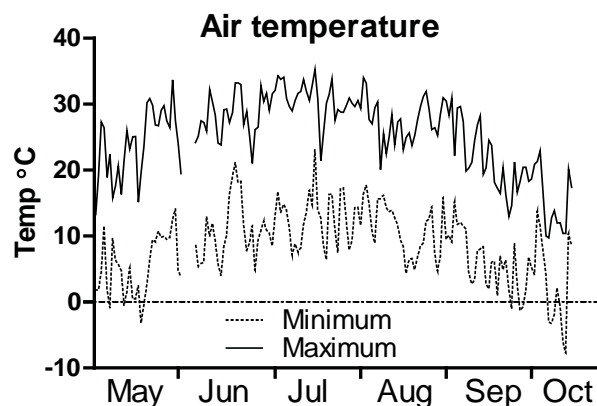


Figure 2. Daily air temperatures at GTI, summer 2012.

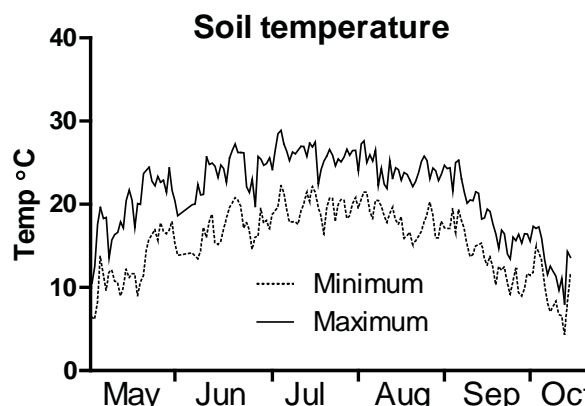


Figure 3. Daily soil temperatures at GTI, summer 2012.

Table 2. Visual ratings of treated plots.

Treatment	Color			Uniformity
	12 DAT	28 DAT	40 DAT	28 DAT
100% SCU	7.5 a ¹	8.3 a	7.3 ab	7.3
100% urea	8.5 a	7.8 a	7.8 a	7.5
100% XCU	7.8 a	8.5 a	8.3 a	8.0
15% SCU, 85% urea	8.3 a	7.8 a	8.0 a	7.5
15% XCU, 85% urea	8.3 a	8.0 a	8.0 a	7.0
30% SCU, 70% urea	8.0 a	8.3 a	7.5 a	7.8
30% XCU, 70% urea	8.0 a	8.3 a	7.8 a	7.8
50% SCU, 50% urea	8.3 a	7.5 ab	8.0 a	7.0
50% XCU, 50% urea	8.3 a	8.0 a	8.3 a	7.3
Untreated control	5.5 b	6.0 b	5.8 b	7.0
msd p=0.05	1.8	1.6	1.5	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).



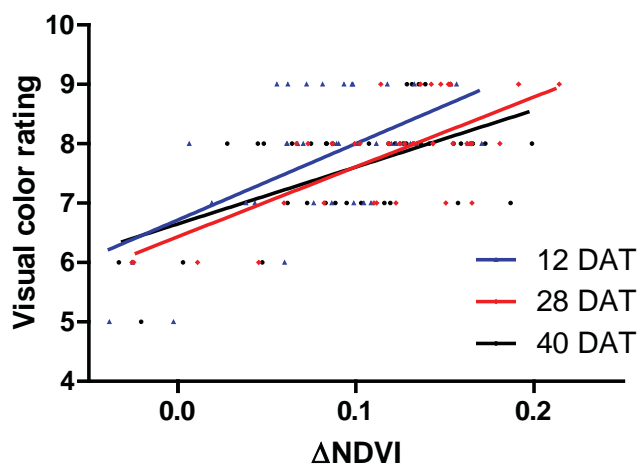


Figure 4. Relationship between visual color ratings and change in canopy reflectance in treated plots. The association is not tight, but the pattern is consistent across observation dates. Points graphed are plot means for Δ NDVI values, and plot values for visual color.

were seen for color, 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 maximum fertilizer response in 2012 (~ 0.13 units) was about double the maximum response in the 2011 trials, but the background (raw NDVI values) showed a sharp reduction during the hot dry summer in 2012, which was not seen in 2011.

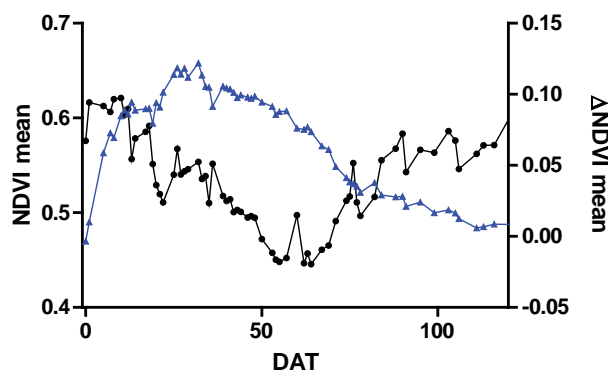


Figure 5. Changes in overall mean NDVI (black \bullet) and Δ NDVI (corrected to remove control value; blue \blacktriangle) during the experiment.

There were significant differences in canopy reflectance among the treatments beginning 5 DAT and lasting consistently until 74 DAT (Table 3), and sporadically until 90 DAT. By 17 DAT all treatments had significantly larger canopy reflectance values than the untreated control. Generally there were no strong patterns among the fertilizer treatments in NDVI values *per se*.

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 various 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

$$\Delta\text{NDVI} = 4 \cdot A \cdot e^{(-0.7 \cdot \text{DAT}/C)} \cdot (1 - e^{(-0.7 \cdot \text{DAT}/C)})$$

in which there are two fitted parameters: A, which varies with maximum Δ NDVI, and C, which varies with days to maximum Δ NDVI (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 Δ NDVI values for each treatment were

Table 3. Change in canopy reflectance (Δ NDVI) in treated plots.

Treatment	DAT											
	-16	-13	-9	0	1	5	7	8	10	11	12	
100% SCU	-0.028 ¹	-0.019	-0.010	-0.025	-0.006	0.035 ab	0.049 ab	0.048 ab	0.066 ab	0.066 ab	0.070 ab	
100% urea	-0.045	-0.034	-0.023	-0.015	-0.004	0.069 a	0.087 a	0.086 a	0.099 a	0.106 a	0.105 a	
100% XCU	-0.046	-0.032	-0.025	-0.018	-0.006	0.047 ab	0.059 ab	0.057 ab	0.079 ab	0.089 ab	0.082 ab	
15% SCU, 85% urea	-0.029	-0.017	-0.006	0.005	0.020	0.084 a	0.104 a	0.100 a	0.123 a	0.125 a	0.124 a	
15% XCU, 85% urea	-0.014	-0.004	-0.004	-0.006	0.012	0.078 a	0.096 a	0.094 a	0.113 a	0.109 a	0.105 a	
30% SCU, 70% urea	-0.005	0.001	0.002	0.002	0.012	0.058 ab	0.074 a	0.063 ab	0.076 ab	0.086 ab	0.087 a	
30% XCU, 70% urea	-0.006	-0.002	0.010	-0.002	0.018	0.064 a	0.078 a	0.072 a	0.093 a	0.099 a	0.095 a	
50% SCU, 50% urea	0.039	0.041	0.047	0.021	0.037	0.075 a	0.080 a	0.079 a	0.088 a	0.090 ab	0.086 a	
50% XCU, 50% urea	-0.023	-0.009	-0.006	0.005	0.016	0.078 a	0.100 a	0.097 a	0.112 a	0.117 a	0.111 a	
Untreated control	-0.002	0.001	0.000	-0.002	0.000	0.000 b	0.001 b	-0.001 b	-0.001 b	0.001 b	-0.002 b	
msd p=0.05	NS	NS	NS	NS	NS	0.063	0.066	0.071	0.081	0.090	0.084	
	13	14	17	18	20	21	22	25	26	27	28	
100% SCU	0.077 ab	0.074 ab	0.075 a	0.074 a	0.083 a	0.079 a	0.087 a	0.095 a	0.105 a	0.096 a	0.099 a	
100% urea	0.113 ab	0.107 a	0.110 a	0.101 a	0.111 a	0.104 a	0.115 a	0.125 a	0.135 a	0.130 a	0.135 a	
100% XCU	0.097 ab	0.084 a	0.081 a	0.082 a	0.085 a	0.082 a	0.093 a	0.112 a	0.118 a	0.119 a	0.125 a	
15% SCU, 85% urea	0.141 a	0.122 a	0.126 a	0.129 a	0.135 a	0.132 a	0.148 a	0.159 a	0.158 a	0.156 a	0.164 a	
15% XCU, 85% urea	0.115 ab	0.106 a	0.105 a	0.104 a	0.111 a	0.105 a	0.120 a	0.138 a	0.144 a	0.135 a	0.134 a	
30% SCU, 70% urea	0.086 ab	0.086 a	0.089 a	0.090 a	0.090 a	0.090 a	0.097 a	0.114 a	0.117 a	0.111 a	0.117 a	
30% XCU, 70% urea	0.109 ab	0.105 a	0.109 a	0.115 a	0.115 a	0.115 a	0.130 a	0.142 a	0.145 a	0.141 a	0.142 a	
50% SCU, 50% urea	0.087 ab	0.086 a	0.089 a	0.088 a	0.085 a	0.077 a	0.088 a	0.103 a	0.113 a	0.101 a	0.109 a	
50% XCU, 50% urea	0.121 a	0.116 a	0.113 a	0.117 a	0.126 a	0.124 a	0.134 a	0.150 a	0.150 a	0.150 a	0.155 a	
Untreated control	-0.001 b	0.002 b	0.001 b	0.001 b	0.000 b	0.000 b	0.002 b	0.001 b	0.000 b	0.001 b	0.002 b	
msd p=0.05	0.116	0.075	0.054	0.055	0.072	0.071	0.074	0.069	0.062	0.080	0.081	
	29	32	33	35	36	39	40	41	42	43	44	
100% SCU	0.100 a	0.103 a	0.095 a	0.091 ab	0.076 a	0.090 ab	0.087 ab	0.088 ab	0.085 ab	0.082 ab	0.087 ab	
100% urea	0.124 a	0.138 a	0.127 a	0.124 a	0.108 a	0.124 a	0.122 a	0.120 a	0.116 a	0.114 a	0.117 a	
100% XCU	0.119 a	0.138 a	0.123 a	0.119 a	0.103 a	0.124 a	0.121 a	0.123 a	0.123 a	0.121 a	0.121 a	
15% SCU, 85% urea	0.149 a	0.162 a	0.150 a	0.140 a	0.121 a	0.137 a	0.137 a	0.137 a	0.136 a	0.127 a	0.126 a	
15% XCU, 85% urea	0.128 a	0.142 a	0.138 a	0.125 a	0.112 a	0.130 a	0.125 a	0.127 a	0.123 a	0.118 a	0.121 a	
30% SCU, 70% urea	0.113 a	0.118 a	0.113 a	0.094 a	0.086 a	0.097 a	0.098 a	0.095 a	0.091 ab	0.089 ab	0.090 ab	
30% XCU, 70% urea	0.139 a	0.148 a	0.137 a	0.122 a	0.109 a	0.123 a	0.126 a	0.120 a	0.117 a	0.110 a	0.115 a	
50% SCU, 50% urea	0.097 a	0.112 a	0.104 a	0.089 ab	0.073 ab	0.084 ab	0.082 ab	0.086 ab	0.081 ab	0.079 ab	0.081 ab	
50% XCU, 50% urea	0.150 a	0.161 a	0.147 a	0.145 a	0.126 a	0.145 a	0.146 a	0.141 a	0.140 a	0.136 a	0.135 a	
Untreated control	0.001 b	0.000 b	-0.001 b	0.001 b	0.001 b	0.001 b	-0.001 b	-0.001 b	0.001 b	-0.001 b	0.000 b	
msd p=0.05	0.075	0.081	0.074	0.091	0.079	0.096	0.096	0.095	0.103	0.097	0.095	
	46	47	50	53	54	55	57	60	62	63	64	
100% SCU	0.083 ab	0.079 ab	0.077 ab	0.074 ab	0.069 ab	0.073 ab	0.071 ab	0.057 ab	0.058 ab	0.058 ab	0.055 ab	
100% urea	0.112 a	0.118 a	0.114 a	0.112 a	0.106 a	0.111 a	0.108 a	0.096 a	0.100 a	0.103 a	0.100 a	
100% XCU	0.123 a	0.119 a	0.124 a	0.121 a	0.114 a	0.116 a	0.119 a	0.102 a	0.102 a	0.097 a	0.094 a	
15% SCU, 85% urea	0.126 a	0.127 a	0.118 a	0.112 a	0.108 a	0.106 a	0.103 a	0.091 a	0.088 a	0.086 a	0.088 a	
15% XCU, 85% urea	0.127 a	0.125 a	0.129 a	0.121 a	0.115 a	0.116 a	0.120 a	0.111 a	0.107 a	0.109 a	0.106 a	
30% SCU, 70% urea	0.085 ab	0.084 ab	0.079 ab	0.080 ab	0.068 ab	0.077 ab	0.079 ab	0.061 ab	0.064 ab	0.066 ab	0.063 ab	
30% XCU, 70% urea	0.111 a	0.111 a	0.099 ab	0.096 ab	0.095 ab	0.095 ab	0.092 ab	0.075 ab	0.073 ab	0.079 ab	0.071 ab	
50% SCU, 50% urea	0.080 ab	0.074 ab	0.070 ab	0.074 ab	0.063 ab	0.066 ab	0.073 ab	0.064 ab	0.060 ab	0.062 ab	0.059 ab	
50% XCU, 50% urea	0.132 a	0.135 a	0.133 a	0.123 a	0.120 a	0.118 a	0.117 a	0.103 a	0.102 a	0.108 a	0.101 a	
Untreated control	0.000 b	0.000 b	0.000 b	0.001 b	0.001 b	0.000 b	0.001 b	0.000 b	0.000 b	0.000 b	0.001 b	
msd p=0.05	0.095	0.105	0.107	0.098	0.102	0.099	0.092	0.077	0.086	0.086	0.084	
	67	68	69	70	71	72	73	74	75	76	77	
100% SCU	0.057 ab	0.058 ab	0.058 ab	0.055 ab	0.031 ab	0.044 ab	0.031 ab	0.029 ab	0.027	0.026	0.022 ab	
100% urea	0.096 a	0.100 a	0.103 a	0.100 a	0.067 ab	0.086 a	0.067 ab	0.055 ab	0.052	0.059	0.043 ab	
100% XCU	0.102 a	0.102 a	0.097 a	0.094 a	0.061 ab	0.072 ab	0.061 ab	0.047 ab	0.044	0.042	0.042 ab	
15% SCU, 85% urea	0.091 a	0.088 a	0.086 a	0.088 a	0.055 ab	0.066 ab	0.055 ab	0.043 ab	0.041	0.036	0.035 ab	
15% XCU, 85% urea	0.111 a	0.107 a	0.109 a	0.106 a	0.082 a	0.093 a	0.082 a	0.071 a	0.071	0.068	0.063 a	
30% SCU, 70% urea	0.061 ab	0.064 ab	0.066 ab	0.063 ab	0.036 ab	0.052 ab	0.036 ab	0.033 ab	0.026	0.035	0.026 ab	
30% XCU, 70% urea	0.075 ab	0.073 ab	0.079 ab	0.071 ab	0.048 ab	0.060 ab	0.048 ab	0.040 ab	0.035	0.034	0.035 ab	
50% SCU, 50% urea	0.064 ab	0.060 ab	0.062 ab	0.059 ab	0.039 ab	0.047 ab	0.039 ab	0.033 ab	0.027	0.022	0.029 ab	
50% XCU, 50% urea	0.103 a	0.102 a	0.108 a	0.101 a	0.073 a	0.090 a	0.073 a	0.060 ab	0.060	0.087	0.056 ab	
Untreated control	0.001 b	0.000 b	0.000 b	0.001 b	0.000 b	0.001 b	0.000 b	0.001 b	0.001	0.000	0.001 b	
msd p=0.05	0.077	0.086	0.086	0.084	0.069	0.074	0.069	0.060	NS	NS	0.057	
	78	82	84	88	90	91	95	99	103	105	106	
100% SCU	0.017	0.027 ab	0.018	0.019	0.031 ab	0.013	0.020	0.009	0.008	0.018	0.004	
100% urea	0.042	0.047 ab	0.037	0.039	0.035 ab	0.029	0.028	0.021	0.026	0.026	0.019	
100% XCU	0.033	0.034 ab	0.030	0.021	0.031 ab	0.016	0.020	0.017	0.015	0.023	0.014	
15% SCU, 85% urea	0.029	0.036 ab	0.030	0.024	0.028 ab	0.019	0.022	0.007	0.007	0.012	0.004	
15% XCU, 85% urea	0.057	0.073 a	0.054	0.057	0.054 a	0.042	0.048	0.041	0.046	0.043	0.032	
30% SCU, 70% urea	0.025	0.030 ab	0.022	0.023	0.037 ab	0.018	0.021	0.016	0.019	0.048	0.014	
30% XCU, 70% urea												

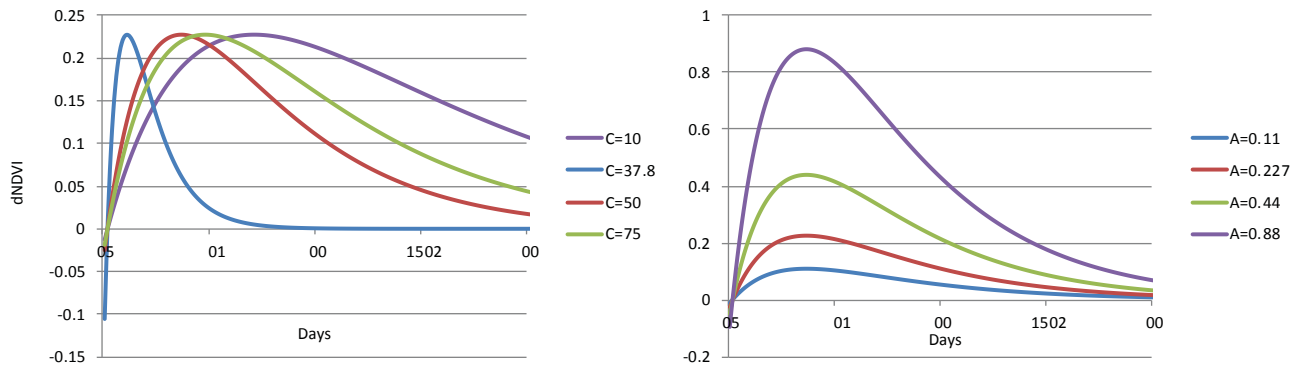


Figure 6. Families of curves of the function $\Delta NDVI = 4 * A * e^{(-0.7 * DAT / C)} * (1 - e^{(-0.7 * DAT / C)})$ illustrating the effects of varying the parameters A and C. The curve with A=0.2274 and C=37.8 is the actual curve fitted to the 100% SCU treatment.

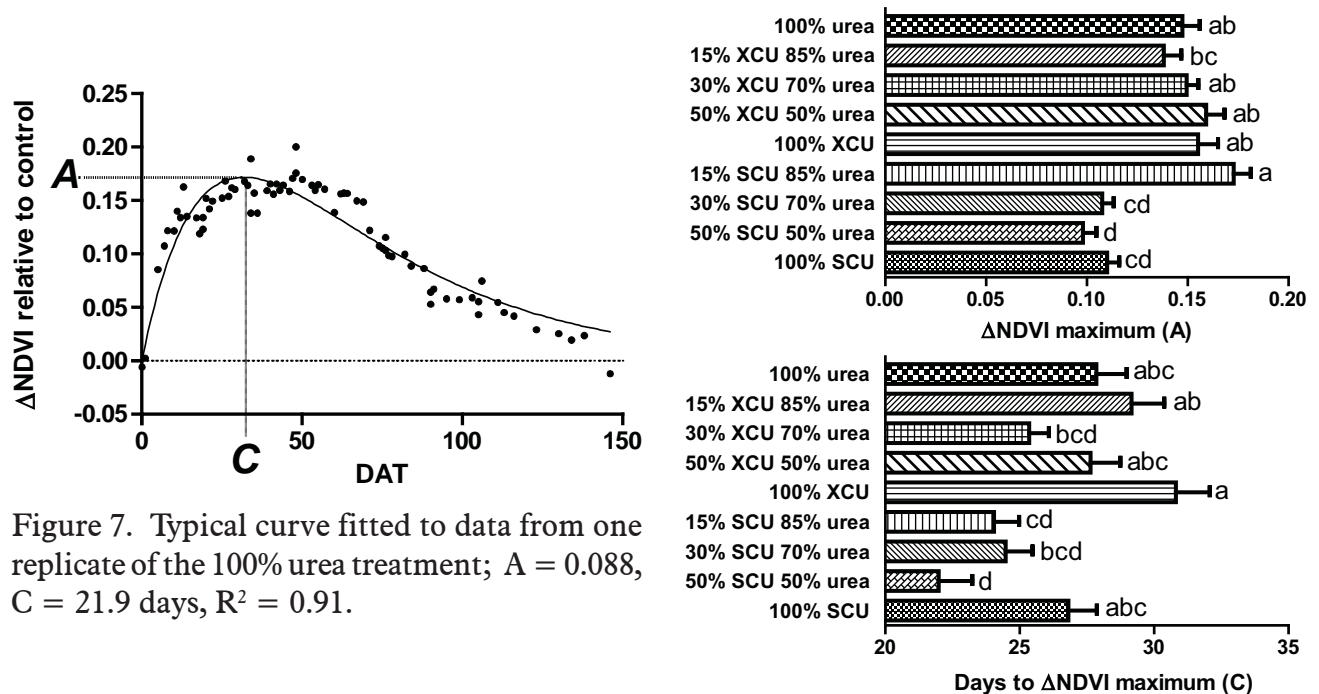


Figure 7. Typical curve fitted to data from one replicate of the 100% urea treatment; A = 0.088, C = 21.9 days, R² = 0.91.

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

Treatment	A	C
100% SCU	0.110 cd ¹	26.81 abc
100% urea	0.147 ab	27.85 abc
100% XCU	0.155 ab	30.81 a
15% SCU, 85% urea	0.173 a	24.05 cd
15% XCU, 85% urea	0.138 bc	29.16 ab
30% SCU, 70% urea	0.108 cd	24.48 bcd
30% XCU, 70% urea	0.150 ab	25.35 bcd
50% SCU, 50% urea	0.098 d	21.99 d
50% XCU, 50% urea	0.159 ab	27.64 abc

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

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).

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 Figures 9 – 11.

Shoot growth

Clippings were collected periodically to

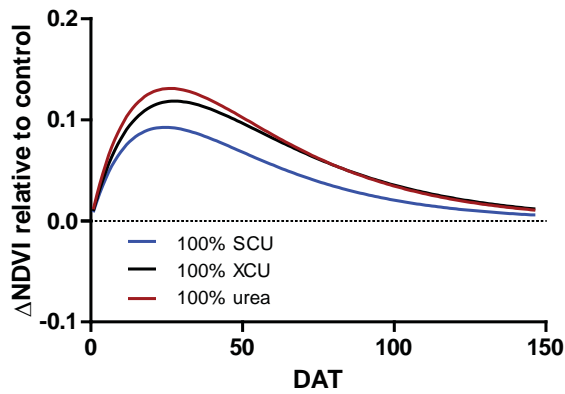


Figure 9. Curves fitted to fertilizer response as estimated by Δ NDVI. See Table 4 for estimates of A (max Δ NDVI) and C (days to max Δ NDVI). Curves were fitted to four replicates per date.

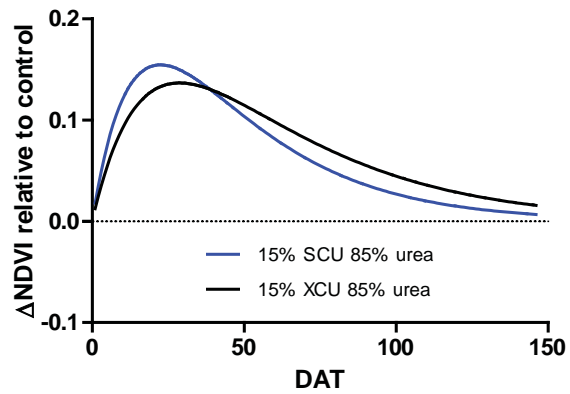


Figure 10. Curves fitted to fertilizer response as estimated by Δ NDVI. See Table 4 for estimates of A (max Δ NDVI) and C (days to max Δ NDVI). Curves were fitted to four replicates per date.

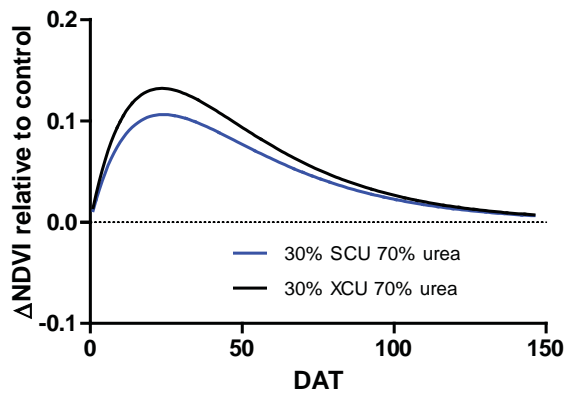


Figure 11. Curves fitted to fertilizer response as estimated by Δ NDVI. See Table 4 for estimates of A (max Δ NDVI) and C (days to max Δ NDVI). Curves were fitted to four replicates per date.

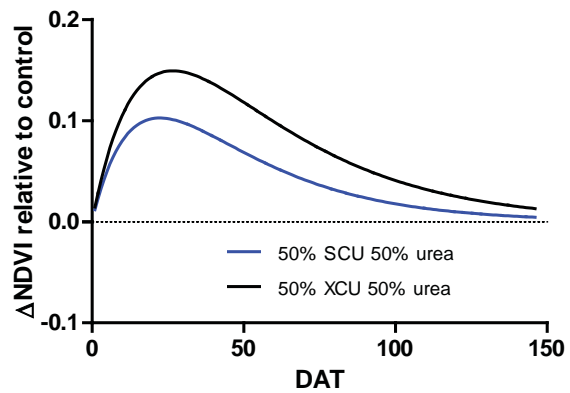


Figure 12. Curves fitted to fertilizer response as estimated by Δ NDVI. See Table 4 for estimates of A (max Δ NDVI) and C (days to max Δ NDVI). Curves were fitted to four replicates per date.



Figure 13. 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						
100% SCU	7.74 ¹	6.02	2.53	1.48	2.45	4.98	2.60
100% urea	11.48	7.83	3.28	1.98	3.53	6.28	3.73
100% XCU	10.80	7.26	3.03	1.70	2.79	5.68	3.35
15% SCU, 85% urea	9.78	7.16	3.18	1.64	3.11	5.78	3.38
15% XCU, 85% urea	8.96	6.05	2.75	1.80	3.34	6.18	3.68
30% SCU, 70% urea	12.44	7.84	3.15	1.68	3.08	6.25	3.38
30% XCU, 70% urea	10.53	6.99	2.85	1.31	2.70	5.43	2.83
50% SCU, 50% urea	11.80	7.22	2.33	1.33	2.55	4.83	3.33
50% XCU, 50% urea	8.50	7.04	3.28	1.58	3.04	5.58	3.53
Untreated control	7.75	4.72	2.03	1.23	2.41	4.15	2.38
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.

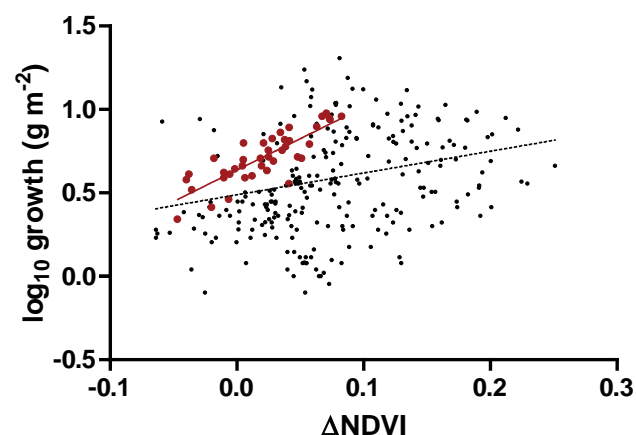


Figure 14. Relationship between increase in canopy reflectance and shoot growth as estimated by dry matter accumulation. Points are plot means; all clipping collections data are plotted. Dry matter accumulation is log-transformed to give a linear relationship. The R² value of the black line is quite low (0.08), but the slope is significant. Individual dates within the data set had better fits of dry matter to ΔNDVI: data from 93 DAT is shown in red; R² = 0.69, even though there were no significant treatment effects detected in dry matter.

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 13). Although there were differences in growth, the noisiness of the data meant that the differences were not statistically significant on any date (Table 5). The general pattern of

increase and decline in growth rates was similar to the response curves as estimated by ΔNDVI. Comparing the plot means for growth with ΔNDVI shows this relationship (Figure 14), and ΔNDVI appears to be a reasonable proxy for shoot growth under these conditions.

DISCUSSION AND CONCLUSIONS

All treatments gave a significant improvement in colour and growth compared to the untreated control. The fertilizer effects were observable within a week after treatment by the canopy reflectance data, and persisted in significant amounts until more than 10 weeks after treatment. The average gain of fertilized treatments over control was at least 2 ranks on the visual colour rating scale (6 to 8), or about 0.07 units on the canopy reflectance index. The untreated control plots were at an acceptable colour and quality level (>5) through most of 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.

Using the release curves fitted to the seasonal pattern of ΔNDVI suggests that the ranking of the fertilizer treatments for strength of response (A) was 15% SCU > 50% XCU > 100% XCU > 30% XCU > 100% urea > 15% XCU > 100% SCU > 30% SCU > 50% SCU, though there was much overlap among the treatments statistically,

and the pattern observed in 2012 had little in common with that observed in 2011.

Similarly, the ranking of the treatments for days to maximum release (C) was 100% SCU > 50% XCU > 30% XCU > 15% XCU > 30% SCU > 50% SCU > 100% XCU > 15% SCU > 100% urea, with significant overlap among the treatments, and a different pattern of ordering in 2012 than was observed in 2011.

The release across all treatments was stronger and slower in 2012 than in 2011, with nearly double the increase in NDVI compared to the control, and about 10 days longer to the maximum increase.

