Longevity of turf response to urea, coated urea, and blends

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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. Treatments were applied June 7, 2011 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 2012. 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 June – October 2011 are presented in Figures 2 and 3.

Visual ratings. There were significant differences in visual ratings of turf colour by 6

Table 1. Treatments

Trt #	Description	Application program
1.	Untreated control	All treatments were applied once (June 7, 2011) at 1 lb / 1000 sq ft actual N (4.88 g m^{-2})
2.	100% urea	
3.	15% XCU, 85% urea	
4.	30% XCU, 70% urea	
5.	50% XCU, 50% urea	
6.	100% XCU	
7.	AAT DS 24-2-11 w/ 40% XCU	
8.	15% SCU, 85% urea	
9.	30% SCU, 70% urea	
10.	50% SCU, 50% urea	
11.	100% SCU	
12.	Lesco 24-2-11 w/ 40% SCU	

Figure 1. Plot area July 2, 2011 (25 DAT).

DAT (Table 2). The differences persisted until 5 weeks after treatment, but by 7 weeks after treatment they were no longer significant. Other visual performance ratings (quality, uniformity, and density) generally did not differ significantly, though the mean value for untreated control plots was low.

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

Table 2. Visual ratings of treated plots.

Treatment	pre	6 DAT	13 DAT	21 DAT	34 DAT	49 DAT	78 DAT
				Colour			
100% SCU	6.00[1]	6.25 abc	7.00 a	7.50 a	7.75 a	7.00	8.00 a
100% urea	6.00	6.75 abc	7.25 a	7.75 a	7.50 ab	6.75	8.00 a
100% XCU	6.00	5.25 c	6.75 ab	8.00 a	7.75 a	6.75	7.75 ab
15% SCU, 85% urea	6.00	6.50 abc	7.25 a	7.50 a	7.00 ab	7.00	8.00 a
15% XCU, 85% urea	6.00	6.75 abc	7.25 a	7.75 a	7.50 ab	7.00	8.00 a
30% SCU, 70% urea	6.00	7.00 ab	6.75 ab	7.25 a	7.25 ab	7.75	7.50 ab
30% XCU, 70% urea	6.00	5.75 bc	6.75 ab	7.75 a	7.50 ab	7.50	8.00 a
50% SCU, 50% urea	6.00	7.50 a	7.25 a	7.75 a	7.50 ab	7.50	8.00 a
50% XCU, 50% urea	6.00	6.50 abc	7.00 a	8.25 a	8.00 a	8.00	8.00 a
AAT DS 24-2-11 w/ 40% XCU	6.00	7.00 ab	7.50 a	7.50 a	7.50 ab	7.00	7.25 b
Lesco 24-2-11 w/ 40% SCU	6.00	6.25 abc	6.50 ab	7.25 a	7.50 ab	7.25	8.00 a
Untreated control	6.00	5.50 bc	5.25 b	6.13 b	6.50 b	6.63	7.88 ab
msd p=0.05	NS	1.56	1.63	1.12	1.21	NS	0.71
				Quality			
100% SCU	5.00[1]	6.75	6.75	7.50 a	7.00	7.50	7.75
100% urea	5.00	7.25	7.25	7.25 ab	7.25	7.00	7.75
100% XCU	5.25	7.00	7.00	6.75 ab	7.00	7.50	7.75
15% SCU, 85% urea	5.00	6.75	6.75	7.25 ab	6.75	7.25	7.50
15% XCU, 85% urea	5.25	7.00	7.00	7.50 a	7.00	7.00	7.75
30% SCU, 70% urea	5.25	7.00	7.00	7.75 a	7.00	7.50	7.75
30% XCU, 70% urea	5.25	6.25	6.25	6.75 ab	6.50	7.50	7.50
50% SCU, 50% urea	5.00	7.00	7.00	7.25 ab	7.25	7.25	7.75
50% XCU, 50% urea	5.25	7.00	7.00	7.50 a	7.25	7.75	8.00
AAT DS 24-2-11 w/ 40% XCU	5.00	7.00	7.00	7.25 ab	7.00	7.00	7.75
Lesco 24-2-11 w/ 40% SCU	5.25	6.75	6.75	7.25 ab	6.75	7.25	8.00
Untreated control	5.13	5.75	5.75	6.25 b	6.38	7.00	7.63
msd p=0.05	NS	NS	NS	1.18	NS	NS	NS
				Uniformity			
100% SCU				6.75[1]	7.00	7.25	7.75
100% urea				6.50	6.75	7.00	7.75
100% XCU				6.25	6.50	7.50	7.75
15% SCU, 85% urea				6.75	6.25	7.50	7.50
15% XCU, 85% urea				7.00	6.00	7.00	7.75
30% SCU, 70% urea				7.50	6.50	7.50	8.00
30% XCU, 70% urea				6.25	6.25	7.25	7.50
50% SCU, 50% urea				6.75	6.75	7.25	7.75
50% XCU, 50% urea				7.00	7.25	7.50	8.00
AAT DS 24-2-11 w/ 40% XCU				6.75	6.50	7.50	7.50
Lesco 24-2-11 w/ 40% SCU				7.00	6.50	7.50	7.75
Untreated control				6.63	6.25	6.75	7.63
msd p=0.05				NS	NS	NS	NS
				Density			
100% SCU				7.25[1]	7.25	7.75	8.00
100% urea				6.75	7.25	7.25	8.00
100% XCU				7.25	7.25	7.75	8.00
15% SCU, 85% urea				7.25	6.75	7.75	8.00
15% XCU, 85% urea				7.25	7.00	8.00	8.00
30% SCU, 70% urea				7.25	7.25	8.00	8.00
30% XCU, 70% urea				7.00	6.75	8.00	8.00
50% SCU, 50% urea				7.25	7.00	7.75	8.00
50% XCU, 50% urea				7.25	7.75	8.00	8.00
AAT DS 24-2-11 w/ 40% XCU				7.00	6.75	8.00	8.00
Lesco 24-2-11 w/ 40% SCU				6.25	6.75	7.75	8.00
Untreated control				6.88	6.50	7.25	7.88
msd p=0.05				NS	NS	NS	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).

remove background variation, since the NDVI value is affected by mowing, moisture status, and other factors in addition to nitrogen status. Figure 4 shows the pattern of change of the raw NDVI values (averaged across all plots) and the ΔNDVI values (averaged across all non-control plots) during the experiment.

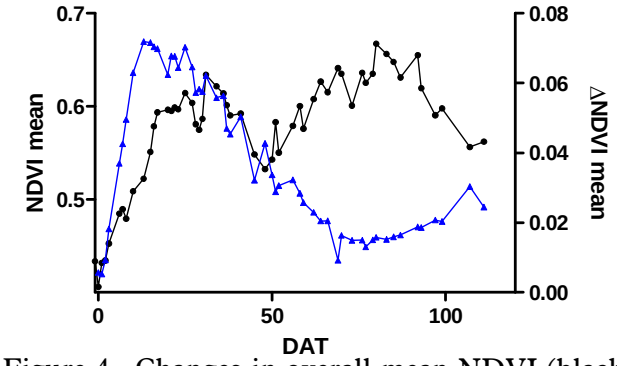

Figure 4. Changes in overall mean NDVI (black) and NDVI corrected to remove control value (blue) during the experiment.

There were significant differences in canopy reflectance among the treatments beginning 6 DAT and lasting until 41 DAT (Table 3). By 13 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 ΔNDVI 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 ΔNDVI 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 $\Delta NDVI = 4 \star A \star e^{(-DAT/C)} \star (1-e^{(-DAT/C)})$, in which there are two fitted parameters: A, which varies with maximum ΔNDVI , and C, which varies with days to maximum ΔNDVI (Figure 5). The suitability was judged based on the combination of goodness of fit, minimum number of parameters, and interpretability of the parameters.

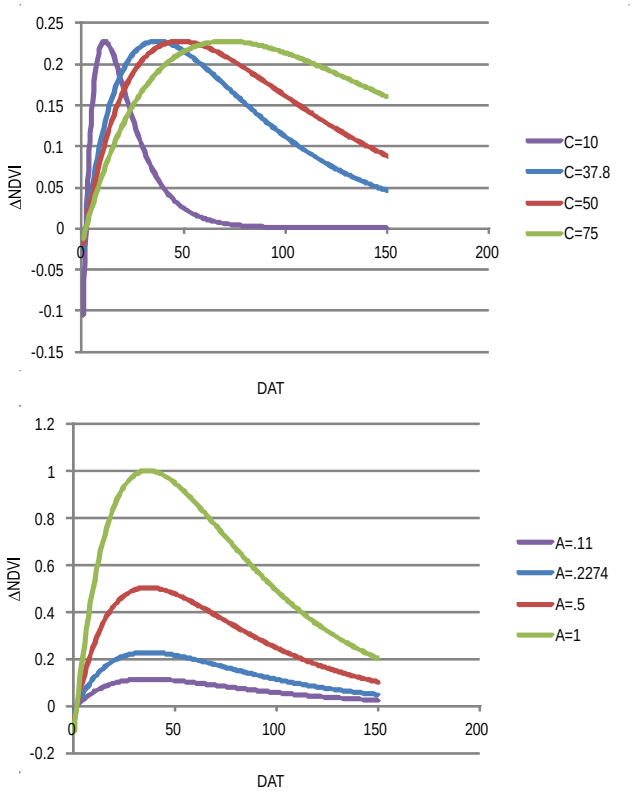

Figure 5. Families of curves of the function $\Delta NDVI = 4 \star A \star e^{(-DAT/C)} \star (1 - e^{(-DAT/C)})$ illustrating the effects of varying the parameters A and C. The curve with A=0.2274 and C=37.8 is the actual curve fitted to the 100% SCU treatment.

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 6, and the fitted curves are shown in Figures 7 – 11.

Table 4. Multiple comparisons of estimated parameters for fitted curves of ΔNDVI.

Treatment	A		C	
100% SCU	0.0566	a[1]	38.68	de
100% urea	0.0739	ab	19.62	a
100% XCU	0.0664	ab	24.98	abc
15% SCU, 85% urea	0.0571	ab	22.95	a
15% XCU, 85% urea	0.0690	ab	28.36	abc
30% SCU, 70% urea	0.0775	b	27.05	abc
30% XCU, 70% urea	0.0673	ab	32.45	bcd
50% SCU, 50% urea	0.0753	b	27.02	abc
50% XCU, 50% urea	0.0698	ab	37.83	cde
AAT DS 24-2-11 w/ 40% XCU	0.0806	b	24.51	ab
Lesco 24-2-11 w/ 40% SCU	0.0673	ab	46.11	e

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

Table 3. Canopy reflectance in treated plots

	DAT									
Treatment	pre	0	1	2	3	6	7	8	10	13
100% SCU	0.431	0.396	0.422	0.423	0.447	**0.482 ab**	**0.482 ab**	**0.473 ab**	**0.502 a**	**0.524 ab**
100% urea	0.429	0.412	0.431	0.435	0.452	**0.491 ab**	**0.502 a**	**0.493 a**	**0.527 a**	**0.554 ab**
100% XCU	0.439	0.416	0.437	0.433	0.449	**0.473 ab**	**0.470 ab**	**0.460 ab**	**0.494 ab**	**0.522 b**
15% SCU, 85% urea	0.438	0.405	0.432	0.440	0.455	**0.485 ab**	**0.495 ab**	**0.485 a**	**0.518 a**	**0.528 ab**
15% XCU, 85% urea	0.431	0.405	0.433	0.436	0.453	**0.495 ab**	**0.499 a**	**0.495 a**	**0.524 a**	**0.556 ab**
30% SCU, 70% urea	0.423	0.402	0.431	0.438	0.461	**0.505 a**	**0.508 a**	**0.500 a**	**0.535 a**	**0.571 a**
30% XCU, 70% urea	0.431	0.404	0.428	0.433	0.458	**0.483 ab**	**0.490 ab**	**0.482 a**	**0.510 a**	**0.553 ab**
50% SCU, 50% urea	0.422	0.395	0.428	0.434	0.452	**0.497 ab**	**0.505 a**	**0.500 a**	**0.534 a**	**0.555 ab**
50% XCU, 50% urea	0.432	0.406	0.436	0.434	0.455	**0.490 ab**	**0.496 a**	**0.480 a**	**0.511 a**	**0.522 b**
AAT DS 24-2-11 w/ 40% XCU	0.442	0.416	0.437	0.443	0.461	**0.498 a**	**0.502 a**	**0.490 a**	**0.527 a**	**0.550 ab**
Lesco 24-2-11 w/ 40% SCU	0.440	0.414	0.438	0.441	0.465	**0.497 ab**	**0.506 a**	**0.497 a**	**0.521 a**	**0.537 ab**
Untreated control	0.434	0.402	0.427	0.425	0.437	**0.454 b**	**0.453 b**	**0.438 b**	**0.456 b**	**0.455 c**
msd p=0.05	NS	NS	NS	NS	NS	**0.0437**	**0.0425**	**0.0408**	**0.0424**	**0.0481**
	15	**16**	**17**	**20**	**21**	**22**	**23**	**25**	**27**	**28**
100% SCU	**0.547 a**	**0.576 a**	**0.590 a**	**0.595 a**	**0.593 a**	**0.598 ab**	**0.599 ab**	**0.620 a**	**0.626 a**	**0.582 ab**
100% urea	**0.567 a**	**0.592 a**	**0.608 a**	**0.608 a**	**0.609 a**	**0.609 ab**	**0.609 ab**	**0.626 a**	**0.637 a**	**0.590 ab**
100% XCU	**0.547 a**	**0.584 a**	**0.601 a**	**0.607 a**	**0.608 a**	**0.618 ab**	**0.615 ab**	**0.633 a**	**0.648 a**	**0.605 a**
15% SCU, 85% urea	**0.551 a**	**0.578 a**	**0.593 a**	**0.591 a**	**0.592 a**	**0.597 b**	**0.593 b**	**0.610 a**	**0.619 a**	**0.570 b**
15% XCU, 85% urea	**0.564 a**	**0.588 a**	**0.605 a**	**0.610 a**	**0.603 a**	**0.606 ab**	**0.600 ab**	**0.620 a**	**0.642 a**	**0.585 ab**
30% SCU, 70% urea	**0.574 a**	**0.599 a**	**0.612 a**	**0.612 a**	**0.610 a**	**0.609 ab**	**0.608 ab**	**0.622 a**	**0.639 a**	**0.588 ab**
30% XCU, 70% urea	**0.559 a**	**0.587 a**	**0.603 a**	**0.607 a**	**0.602 a**	**0.606 ab**	**0.606 ab**	**0.626 a**	**0.643 a**	**0.589 ab**
50% SCU, 50% urea	**0.573 a**	**0.597 a**	**0.612 a**	**0.616 a**	**0.614 a**	**0.619 ab**	**0.612 ab**	**0.629 a**	**0.641 a**	**0.591 ab**
50% XCU, 50% urea	**0.560 a**	**0.586 a**	**0.600 a**	**0.609 a**	**0.608 a**	**0.608 ab**	**0.611 ab**	**0.627 a**	**0.637 a**	**0.601 ab**
AAT DS 24-2-11 w/ 40% XCU	**0.570 a**	**0.605 a**	**0.617 a**	**0.619 a**	**0.620 a**	**0.627 a**	**0.623 a**	**0.642 a**	**0.641 a**	**0.596 ab**
Lesco 24-2-11 w/ 40% SCU	**0.565 a**	**0.589 a**	**0.603 a**	**0.608 a**	**0.599 a**	**0.602 ab**	**0.596 ab**	**0.615 a**	**0.622 a**	**0.587 ab**
Untreated control	**0.491 b**	**0.519 b**	**0.535 b**	**0.541 b**	**0.538 b**	**0.541 c**	**0.542 c**	**0.555 b**	**0.557 b**	**0.532 c**
msd p=0.05	**0.044**	**0.0376**	**0.037**	**0.0343**	**0.0318**	**0.0301**	**0.0283**	**0.0339**	**0.0394**	**0.0326**
	29	**30**	**31**	**34**	**36**	**37**	**38**	**41**	45	48
100% SCU	**0.578 a**	**0.587 a**	**0.642 ab**	**0.624 ab**	**0.622 a**	**0.607 a**	**0.593 a**	**0.614 ab**	0.559	0.544
100% urea	**0.585 a**	**0.593 a**	**0.639 ab**	**0.618 ab**	**0.612 a**	**0.592 ab**	**0.588 ab**	**0.601 ab**	0.534	0.494
100% XCU	**0.593 a**	**0.611 a**	**0.653 ab**	**0.652 a**	**0.640 a**	**0.623 a**	**0.608 a**	**0.631 ab**	0.543	0.499
15% SCU, 85% urea	**0.566 a**	**0.575 a**	**0.620 b**	**0.612 b**	**0.611 a**	**0.590 ab**	**0.581 ab**	**0.606 ab**	0.539	0.520
15% XCU, 85% urea	**0.581 a**	**0.590 a**	**0.640 ab**	**0.628 ab**	**0.620 a**	**0.605 a**	**0.593 a**	**0.615 ab**	0.550	0.549
30% SCU, 70% urea	**0.582 a**	**0.595 a**	**0.639 ab**	**0.630 ab**	**0.623 a**	**0.613 a**	**0.599 a**	**0.635 ab**	0.553	0.563
30% XCU, 70% urea	**0.585 a**	**0.593 a**	**0.642 ab**	**0.623 ab**	**0.614 a**	**0.605 a**	**0.595 a**	**0.627 ab**	0.564	0.569
50% SCU, 50% urea	**0.584 a**	**0.597 a**	**0.646 ab**	**0.624 ab**	**0.618 a**	**0.603 a**	**0.592 a**	**0.614 ab**	0.551	0.534
50% XCU, 50% urea	**0.596 a**	**0.609 a**	**0.659 a**	**0.646 ab**	**0.637 a**	**0.622 a**	**0.613 a**	**0.627 ab**	0.559	0.540
AAT DS 24-2-11 w/ 40% XCU	**0.592 a**	**0.602 a**	**0.659 a**	**0.632 ab**	**0.627 a**	**0.613 a**	**0.604 a**	**0.610 ab**	0.551	0.539
Lesco 24-2-11 w/ 40% SCU	**0.579 a**	**0.595 a**	**0.635 ab**	**0.631 ab**	**0.622 a**	**0.614 a**	**0.604 a**	**0.638 a**	0.576	0.572
Untreated control	**0.526 b**	**0.538 b**	**0.582 c**	**0.573 c**	**0.565 b**	**0.561 b**	**0.553 b**	**0.558 b**	0.519	0.495
msd p=0.05	**0.0354**	**0.0362**	**0.0357**	**0.0354**	**0.0334**	**0.0377**	**0.0375**	**0.0794**	NS	NS
	50	51	52	56	58	59	62	64	66	69
100% SCU	0.556	0.591	0.564	0.593	0.624	0.587	0.613	0.635	0.629	0.645
100% urea	0.519	0.566	0.532	0.559	0.608	0.565	0.599	0.616	0.602	0.643
100% XCU	0.528	0.567	0.538	0.561	0.614	0.565	0.587	0.608	0.602	0.621
15% SCU, 85% urea	0.533	0.572	0.541	0.570	0.605	0.566	0.596	0.617	0.611	0.646
15% XCU, 85% urea	0.551	0.588	0.553	0.588	0.622	0.577	0.610	0.632	0.617	0.639
30% SCU, 70% urea	0.559	0.596	0.566	0.593	0.621	0.581	0.611	0.628	0.624	0.638
30% XCU, 70% urea	0.564	0.602	0.567	0.594	0.625	0.588	0.623	0.636	0.620	0.647
50% SCU, 50% urea	0.547	0.590	0.561	0.588	0.621	0.577	0.618	0.634	0.616	0.647
50% XCU, 50% urea	0.558	0.593	0.566	0.594	0.629	0.594	0.631	0.647	0.632	0.652
AAT DS 24-2-11 w/ 40% XCU	0.543	0.581	0.548	0.576	0.607	0.577	0.609	0.625	0.608	0.630
Lesco 24-2-11 w/ 40% SCU	0.572	0.613	0.575	0.608	0.634	0.602	0.630	0.648	0.640	0.656
Untreated control	0.516	0.557	0.525	0.551	0.582	0.554	0.589	0.609	0.597	0.633
msd p=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	70	73	76	77	79	80	83	85	87	92
100% SCU	0.644	0.613	0.644	0.635	0.645	0.677	0.666	0.673	0.644	0.667
100% urea	0.623	0.585	0.621	0.609	0.620	0.641	0.640	0.648	0.614	0.636
100% XCU	0.622	0.587	0.622	0.611	0.624	0.654	0.643	0.652	0.621	0.641
15% SCU, 85% urea	0.637	0.598	0.632	0.625	0.633	0.669	0.651	0.656	0.622	0.648
15% XCU, 85% urea	0.637	0.600	0.639	0.629	0.637	0.675	0.661	0.670	0.635	0.662
30% SCU, 70% urea	0.640	0.603	0.639	0.624	0.638	0.671	0.657	0.663	0.629	0.653
30% XCU, 70% urea	0.640	0.606	0.639	0.626	0.634	0.673	0.657	0.665	0.631	0.655
50% SCU, 50% urea	0.639	0.603	0.639	0.630	0.642	0.673	0.663	0.670	0.640	0.666
50% XCU, 50% urea	0.652	0.617	0.648	0.638	0.651	0.681	0.672	0.672	0.649	0.671
AAT DS 24-2-11 w/ 40% XCU	0.627	0.597	0.634	0.627	0.631	0.668	0.657	0.659	0.632	0.654
Lesco 24-2-11 w/ 40% SCU	0.651	0.622	0.658	0.644	0.653	0.684	0.677	0.689	0.651	0.681
Untreated control	0.620	0.588	0.622	0.613	0.622	0.653	0.643	0.637	0.618	0.639
msd p=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	93	97	99	107	111	118	121	132		
100% SCU	0.632	0.601	0.605	0.576	0.577	0.631	0.573	0.574		
100% urea	0.599	0.560	0.561	0.523	0.524	0.575	0.530	0.538		
100% XCU	0.610	0.560	0.574	0.537	0.542	0.607	0.549	0.560		
15% SCU, 85% urea	0.609	0.578	0.589	0.535	0.542	0.618	0.555	0.568		
15% XCU, 85% urea	0.625	0.601	0.608	0.571	0.577	0.643	0.569	0.578		
30% SCU, 70% urea	0.620	0.600	0.605	0.563	0.573	0.638	0.570	0.574		
30% XCU, 70% urea	0.621	0.595	0.604	0.567	0.575	0.644	0.571	0.590		
50% SCU, 50% urea	0.629	0.604	0.606	0.566	0.576	0.638	0.568	0.579		
50% XCU, 50% urea	0.638	0.612	0.617	0.585	0.584	0.636	0.573	0.568		
AAT DS 24-2-11 w/ 40% XCU	0.622	0.595	0.602	0.555	0.560	0.631	0.563	0.577		
Lesco 24-2-11 w/ 40% SCU	0.640	0.626	0.632	0.589	0.596	0.664	0.596	0.580		
Untreated control	0.604	0.573	0.579	0.530	0.542	0.607	0.551	0.559		
msd p=0.05	NS	NS	NS	NS	NS	NS	NS	NS		

[1]Normalized-difference vegetation index: mean of 4 replicates; means within columns followed by the same letter are not significantly different (Tukey's HSD test, p=0.05). Readings in bold are from dates with significant treatment effects.

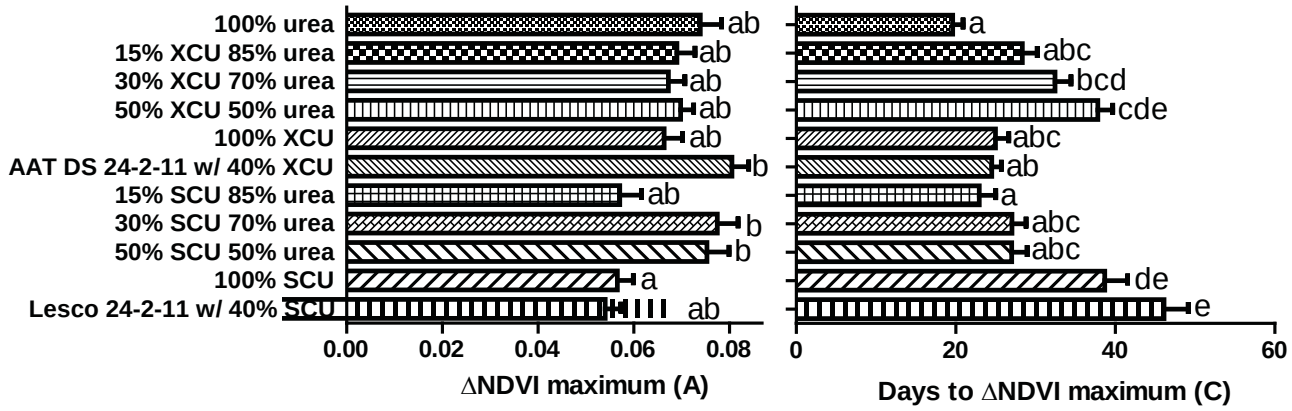

Figure 6. Parameters A and C for curves fitted to fertilizer response as estimated by ΔNDVI. Parameter estimates are all significantly different except where a common letter is present on the bars (Tukey's multiple comparison test, p=0.05).

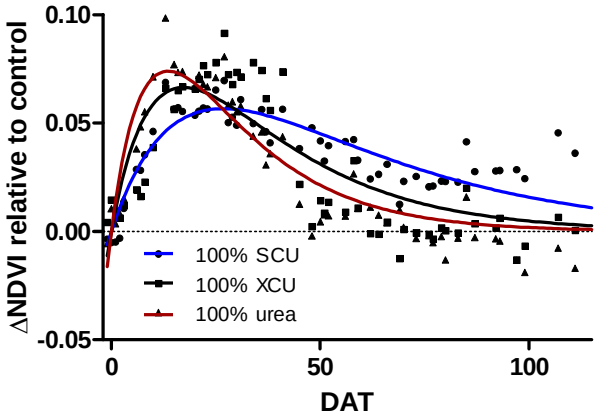

Figure 7. Curves fitted to fertilizer response as estimated by ΔNDVI. See Table 4 for estimates of A (max ΔNDVI) and C (days to max ΔNDVI). Points are means of 4 replicates; curves were fitted to replicates.

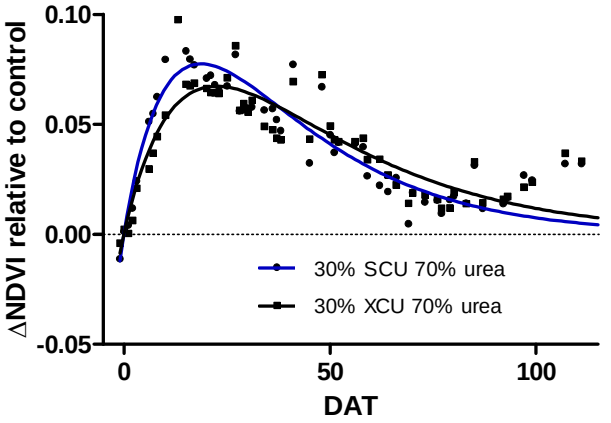

Figure 9. Curves fitted to fertilizer response as estimated by ΔNDVI. See Table 4 for estimates of A (max ΔNDVI) and C (days to max ΔNDVI). Points are means of 4 replicates; curves were fitted to replicates.

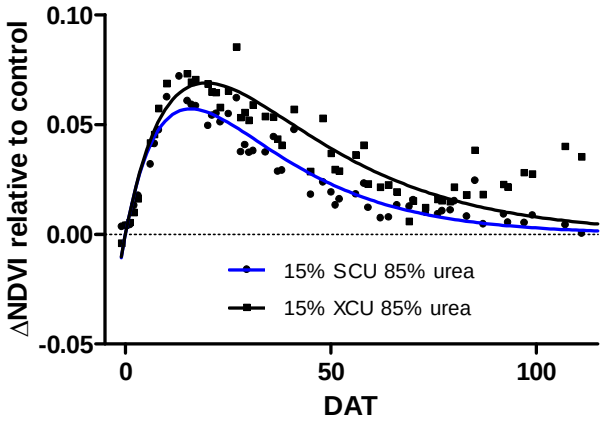

Figure 8. Curves fitted to fertilizer response as estimated by ΔNDVI. See Table 4 for estimates of A (max ΔNDVI) and C (days to max ΔNDVI). Points are means of 4 replicates; curves were fitted to replicates.

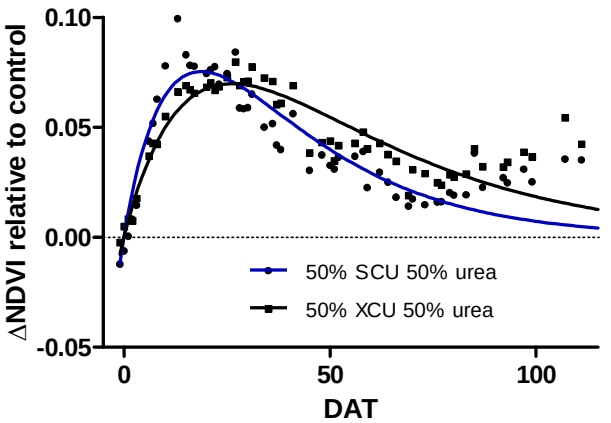

Figure 10. Curves fitted to fertilizer response as estimated by ΔNDVI. See Table 4 for estimates of A (max ΔNDVI) and C (days to maxΔNDVI). Points are means of 4 replicates; curves were fitted to replicates.

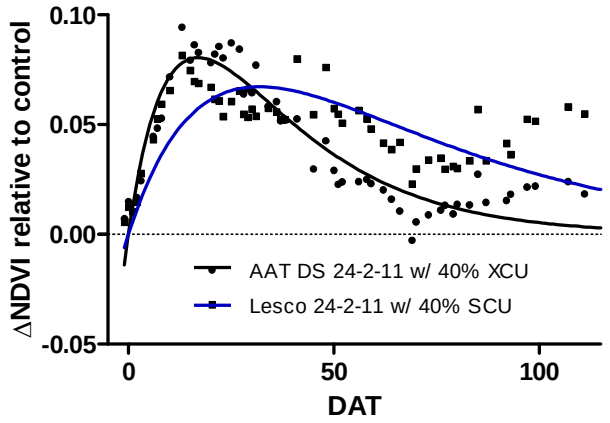

Figure 11. Curves fitted to fertilizer response as estimated by ΔNDVI. See Table 4 for estimates of A (max ΔNDVI) and C (days to max ΔNDVI). Points are means of 4 replicates; curves were fitted to replicates.

Figure 12. 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.

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 m^2 strip (Figure 12). Although there were differences in growth, the noisiness of the data meant that the differences were only significant on the date 4 weeks after application when the maximum fertilizer release was happening (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 13), and ΔNDVI appears to be a good proxy for shoot growth under these conditions.

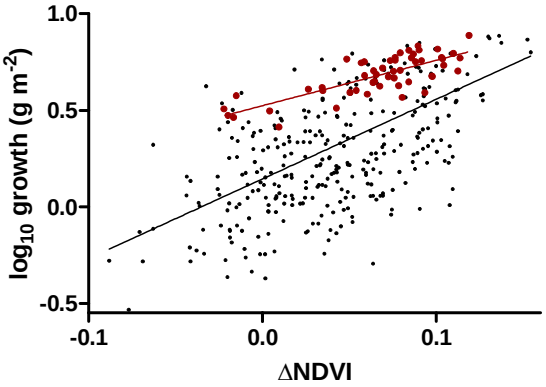

Figure 13. Relationship between increase in canopy reflectance and shoot growth as estimated by dry matter accumulation. Points are plot means; all clipping collections data are plotted. Dry matter accumulation is log-transformed to give a linear relationship. Large red points are the data from 27 DAT, which was the only date when the differences in growth were statistically significant.

Table 5. Dry matter accumulation.

Treatment	13	27	41	58	71	85	120
	DAT						
	g m^{-2}						
100% SCU	5.33[1]	5.33 ab	2.65	1.87	2.55	1.34	1.19
100% urea	4.77	4.80 ab	1.76	1.04	1.70	0.99	0.60
100% XCU	4.65	6.01 a	2.89	1.61	2.44	1.27	0.98
15% SCU, 85% urea	5.54	4.79 ab	2.24	1.32	2.38	1.18	1.09
15% XCU, 85% urea	5.42	5.09 ab	2.63	1.76	2.69	1.43	1.09
30% SCU, 70% urea	5.33	5.26 ab	2.90	2.03	2.85	1.31	1.19
30% XCU, 70% urea	5.91	6.00 a	2.74	1.69	2.38	1.48	1.21
50% SCU, 50% urea	5.71	5.23 ab	2.30	1.83	2.30	1.37	1.19
50% XCU, 50% urea	4.72	4.76 ab	3.01	1.84	2.94	1.46	1.22
AAT DS 24-2-11 w/ 40% XCU	5.75	5.71 a	2.52	1.18	2.09	1.46	1.01
Lesco 24-2-11 w/ 40% SCU	5.12	4.55 ab	2.40	2.04	2.98	1.60	1.42
Untreated control	3.75	3.33 b	1.67	1.14	1.81	1.03	0.80
msd p=0.05	NS	2.12	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.

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 7 weeks after treatment. The average gain of fertilized treatments over control was about 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 100% SCU, 15% SCU < 85% urea, 100% XCU, 30% XCU/70% urea, Lesco 24-2-11 w/ 40% SCU < 15% XCU/85% urea, 50% XCU/50% urea < 100% urea < 50% SCU/50% urea < 30% SCU/ 70% urea < AAT DS 24-2-11 w/ 40% XCU. Similarly, the ranking of the treatments for days to maximum release (C) was 100% urea < 15% SCU/85% urea < AAT DS 24-2-11 w/ 40% XCU, 100% XCU < 50% SCU/50% urea, 30% SCU/ 70% urea < 15% XCU/85% urea < 30% XCU/ 70% urea < 50% XCU/50% urea < 100% SCU < Lesco 24-2-11 w/ 40% SCU.

Differences in growth were only apparent when fertilizer response was near its maximum, about 4 weeks after treatment. At this point the treatments with the highest growth rate had about an 80% increase over the untreated control.

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