2012 Nitrogen Technology Evaluation

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Summary: Trial 1 was designed to compare a standard fertilizer program (155 lbs N/A) with a moderate amount of N (105 lbs N/A) with and without various fertilizer additives. The concept is that the moderate amount of N does not supply sufficient N to achieve maximum lettuce yield; however, if the fertilizer additives can improve the nitrogen use efficiency of applied N, then we can measure that improvement and compare it with the standard treatment. We evaluated three formulations of nitrification inhibitors including two formulations of DCD, as well as DMPP (Entec®) which is a nitrification inhibitor used in Europe. We also evaluated the polyurethane coated urea product Duration 45 (D45) applied prior to planting and urea triazone (N-Sure) applied through the drip. Prior to planting the trial a cover crop was grown, chopped and removed from the site to reduce the levels of residual soil nitrate. The soil nitrate levels were low over the cropping cycle in the standard fertilizer treatment (155 lbs N/A). It is not clear why that was the case, but the soil at the site is gravelly and has coarse sands and irrigation water was applied at 120% of ET; all of these factors may have contributed to an extreme situation where nitrate was easily and rapidly lost, even in the moderate and standard fertilizer treatments. This situation was ideal for testing the efficacy of the fertilizer technologies included in the trial. The bottom line in this trial is that Agrotain Plus, DMPP, N-Sure and polyurethane coated urea improved the yield of lettuce over the moderate rate of N alone. This was a very important observation and indicated that these materials may have a role in improving nitrogen management of leafy green vegetables. Trial No. 2 tested the effect of applying Agrotain Plus with a tractor on the effectiveness of the material. No benefits from shanking Agrotain Plus with UN32 by tractor were observed in this trial.

Methods: ***Trial No. 1:*** The trial was conducted at the USDA Spence Research Station south of Salinas. The soil at the site was Chualar loam. A cover crop was grown on the site over the winter prior to conducting the experiment and was chopped and removed to help reduce the levels of mineral nitrogen in the soil. The field was blank listed June 11. The Duration 45 (D45) treatments were applied with a commercial rig provided by Crop Production Services on June 21 into the listed beds. The beds were then shaped and the romaine cultivar 'Green Towers' was seeded on June 26. The site tends to be crusty and it was necessary to apply an anti-crustant to assure a good stand. 7-7-0-7 was applied at the rate of 35 gallons/A following planting on June 27 and provided 25 lbs N/A to all treatments. Each plot was 2 40-inch beds wide by 130 feet long and replicated 4 times in a RCBD. The field was sprinkler irrigated through thinning; drip tape was installed on July 26 and was used to irrigate the field the rest of the growth cycle. First and second sidedress of the liquid fertilizer treatments were injected into the drip irrigation system by use of a multi-port manifold with backflow prevention valves which fed two inch layflat that provided water and fertilizer for each treatment (see photo). Injector ports in each layflat were used to inject the appropriate rate of UAN 32 liquid fertilizer and fertilizer additive. Battery powered pumps were used to inject fertilizer and additives into the layflat (see Table 1 for treatments and rates); all injections were made during the middle third of irrigation events. Irrigation levels were managed at 120% of ET (see Figure 1). Soil nitrate-N and ammonium-N levels in the top foot of soil were evaluated weekly and soil samples to three feet were conducted

at the beginning, middle and end of the cropping season. Chlorophyll readings were conducted on August 16 by using a CM 1000 Chlorophyll Meter (Spectrum Technologies) and whole leaf samples were collected for total N analysis on August 17. Yield evaluations were conducted on August 29 by harvesting 72 heads from each plot and weighing them and collecting a subsample for total N analysis to measure total N uptake by the crop.

Trial No. 2: The head lettuce variety Hallmark was direct seeded on March 19, 2012 on 80 inch wide beds with five seedlines. The soil was Metz complex soil with a loamy sand texture. The field was sprinkler irrigated throughout the growth cycle. On April 18 after the field was thinned, a sidedress application of fertilizer was applied by tractor. Strips one bed width by the length of the field (1530 feet) were fertilized with UN32 and had the following treatments applied : 1) standard fertilizer rate (106 lbs N/A); 2) half standard rate (53 lbs N/A); and 3) half standard rate (53 lbs N/A) plus Agrotain Plus (applied at the rate of 15 lbs/ton of UN32). The plots were then farmed as the rest of the field for the remainder of the crop cycle. Soil mineral nitrogen was measured on four dates following the sidedress nitrogen application and yield evaluations were conducted on May 30.

Results: ***Trial No. 1:*** The trial was designed to compare a standard fertilizer program (155 lbs N/A) with a moderate amount of N (105 lbs N/A) with and without various fertilizer additives. The concept is that the moderate amount of N does not supply sufficient N to achieve maximum lettuce yield; however, if the fertilizer additives can improve the nitrogen use efficiency of applied N, then we can measure that improvement and compare it with the standard treatment. We evaluated three formulations of nitrification inhibitors including two formulations of DCD, as well as DMPP (Entec®) which is a nitrification inhibitor used in Europe. We also evaluated a triazone material (N-Sure) and the polyurethane coated urea product Duration 45 (D45) which was applied prior to planting (see Table 1 for more details). Water was applied in excess of crop needs as determined by evapotranspiration (ET) in order to evaluate if the materials could help reduce the pool of nitrate in the soil and thereby reduce nitrate leaching (see Figure 1).

The trial site had low levels of soil nitrate-N over the course of the crop cycle (Table 2). It is not clear why even the standard treatment never had soil nitrate-N levels above 10.5 ppm. Only the D45 treatments had soil nitrate-N levels typical of what we commonly observe in soils during the cropping cycle (e.g. >14.0 ppm). Ammonium-N levels were low in the untreated control and increased to > 3.0 ppm in the standard and DMPP treatments on some sampling dates, and to much higher levels in the 155 lbs N/A D45 treatments (Table 3).

There were visual differences in the size and color of the various treatments related to N nutrition (see photos). The untreated and moderate treatments were both stunted and yellow, whereas the standard and D45 treatments were vigorous and dark green (see photos). The chlorophyll index evaluation measures the intensity of green color and thereby provides a measure of chlorophyll content of the plant. Measurements were taken on August 16 and indicated that the untreated, moderate and G77 treatments had chlorophyll index values <205; Agrotain Plus was intermediate (231) and all other treatments were >250 chlorophyll index units (Table 4). Those same exact trends were confirmed by measuring the N content of a recently matured whole leaf on August 17. The yield evaluation on August 29 also showed this same trend in that the untreated control, the moderate and the G77 treatments were the lowest yielding. Agrotain Plus was intermediate

and the standard, DMPP, N-Sure and D45 treatments had the highest yields. The moderate treatment as D45 followed by 50 lbs N in the first fertigation application had the highest yield. Mean head weight, N concentration in the tissue and total N uptake by the crop also followed this trend. It is important to note that some fertilizer additives or controlled release fertilizers at a moderate level of fertilizer gave the same yield as the standard treatment.

There were significant differences in the movement of nitrate to deeper levels of the soil profile. Ideally, the fertilizer additives would improve the yield of lettuce and reduce nitrate leaching beyond the root zone of lettuce (i.e. top two feet of soil). The most telling in this regard are the nitrate concentrations at the 3rd foot of soil at the end of the growth cycle. There are minor differences in the nitrate concentrations of at the 3rd foot of the untreated, standard and moderate N treatments on August 31 (2 days after harvest) (Table 5 and Figure 2); however the D45 treatments all had statistically higher nitrate-N concentrations at the third foot than all other treatments indicating greater movement of nitrate to that soil depth.

Trial No. 2: On May 2 there was higher nitrate in the Moderate + Agrotain Plus treatment than in the other three fertilizer treatments (Table 6). On all other dates there were no differences in the levels of mineral N in the soil among treatments. There were no difference in yield among the treatments (Table 7).

Photos of the drip manifolds used to apply the various treatments to the lettuce crop

Photos showing clear differences in color of the various treatments

Table 1. Trial No. 1. Application timing, dates and rates (lbs N/A)

Material	Preplant Lbs N/A June 21	At planting 7-7-0-7 Anticrustant June 27	First Fertigation Thinning July 27	Second Fertigation August 8	Total Applied N/A	Mode of action of the fertilizer additive
Untreated	0	25	0	0	25	---
Standard[1]	0	25	65	65	155	---
Moderate[1]	0	25	40	40	105	---
Moderate + Agrotain Plus[2,3]	0	25	40	40	105	Urease inhibitor and nitrification inhibitor (dicyandiamide DCD)
Moderate + G77[2, 4]	0	25	40	40	105	nitrification inhibitor (dicyandiamide DCD)
Moderate + DMPP[2,5]	0	25	40	40	105	nitrification inhibitor (Entec®)
Moderate + N-Sure [6]	0	25	40	40	105	urea triazone
Moderate as D45[7]	80	25	0	0	105	polyurethane coated urea
Moderate as D45[7] + sidedress	80	25	50	0	155	polyurethane coated urea
Standard as D45[7]	130	25	0	0	155	polyurethane coated urea

1 – UAN 32 applied by drip injection; 2 – mixed with UAN 32 and applied by drip injection in both fertigations; 3 – application rate of Agrotain was equivalent to 15 lbs/ton UAN 32; 4 – G77 rate = 2 gallons/A (it contains 4.7 gallons of N as a carrier in the 2 gallons so the rate of UAN 32 was adjusted down to accommodate the N provided by the G77; 5 – DMPP applied at 0.21% vol/vol with UAN 32; 6 – 50% of the N was applied as UAN 32 and 50% as N-Sure (28%N, 10.7 lbs/gallon, 3.0 lbs N/gallon); 7 – Polyurethane coated urea (44% N), applied preplant with a commercial tractor rig;

Figure 1. Trial No. 1. Applied water vs crop ET on eight drip irrigation events

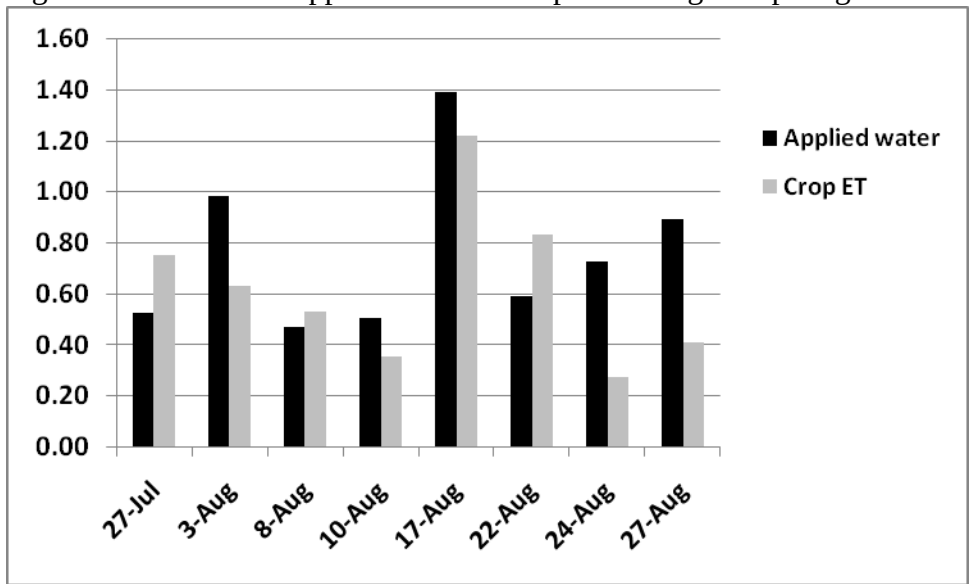

Table 2. Trial No. 1. Soil nitrate-N levels over the course of the crop cycle

Treatments	N/A applied[1]	July 2[2]	July 17[3]	July 31	August 7	August 15	August 22	August 31
Untreated	25	7.66	5.4	6.0	2.3	2.4	3.6	0.56
Standard	155	7.66	NA	8.4	7.2	8.9	10.5	1.22
Moderate	105	7.66	NA	12.6	4.7	1.1	3.0	1.94
Mod. + Agrotain Plus	105	7.66	NA	8.3	6.9	2.1	5.1	0.5
Mod. + G77	105	7.66	NA	7.8	4.9	1.2	2.1	2.45
Mod. + DMPP	105	7.66	NA	7.9	5.1	1.7	4.2	0.72
Mod + N-Sure	105	7.66	NA	8.4	6.0	6.4	8.7	1.21
Mod. as D45	105	7.66	15.7	28.3	12.3	15.0	21.2	2.54
Mod. as D45 + sidedress	155	7.66	29.7	40.4	21.8	15.9	18.6	2.53
Standard as D45	155	7.66	19.5	33.7	18.3	17.2	14.4	12.65
Pr>F treat		NA	0.0204	<0.0001	<0.0001	0.0003	0.0031	0.4287
LSD 0.05		NA	13.7	9.1	5.4	7.5	9.5	NS

1 – See Table 1 for details; 2 – background soil test; 3 – only the D45 treatments had been applied on this date.

Table 3. Trial No. 1. Soil ammonium-N levels over the course of the crop cycle

Treatments	N/A applied[1]	July 2[2]	July 17[3]	July 31	August 7	August 15	August 22	August 31
Untreated	25	2.1	1.9	1.1	0.5	0.7	0.9	0.7
Standard	155	2.1	NA	1.3	0.8	1.8	3.3	0.6
Moderate	105	2.1	NA	0.8	0.6	1.0	0.8	0.6
Mod. + Agrotain Plus	105	2.1	NA	1.4	0.7	0.7	0.9	0.6
Mod. + G77	105	2.1	NA	0.7	0.5	0.5	0.7	0.6
Mod. + DMPP	105	2.1	NA	1.9	1.0	3.8	3.1	1.1
Mod + N-Sure	105	2.1	NA	1.6	0.7	1.0	1.6	0.5
Mod. as D45	105	2.1	4.8	3.6	2.0	4.6	1.4	2.2
Mod. as D45 + sidedress	155	2.1	25.9	9.9	3.1	2.3	3.3	1.0
Standard as D45	155	2.1	25.6	12.5	7.0	1.5	4.0	0.7
Pr>F treat		NA	0.0690	<0.0001	0.0344	0.5687	0.0004	0.4439
LSD 0.05		NA	NS	3.2	3.7	NA	1.4	NS

1 – See Table 1 for details; 2 – background soil test; 3 – only the D45 treatments had been applied on this date.

Table 4. Trial No. 1. Chlorophyll index value (Aug. 16) and whole leaf nitrogen content (Aug. 17) and yield and biomass N evaluations (Aug. 29)

Treatments	N/A applied[1]	Chlorophyll index value[2]	Whole leaf %N	Yield Fresh Wt. tons/A	Yield Dry Wt. lbs/A	Mean Head Wt. lbs	Biomass N %	Lettuce N uptake lbs N/A
Untreated	25	205.3	2.14	14.19 e	2,268.8	0.90	1.65	37.0
Standard	155	253.8	3.64	27.53 abc	3,214.1	1.76	2.96	94.9
Moderate	105	205.0	2.19	15.28 e	2,282.1	0.97	1.81	41.5
Mod. + Agrotain Plus	105	231.3	2.67	21.08 d	2,749.3	1.34	2.08	57.2
Mod. + G77	105	196.8	2.19	15.16 e	2,305.6	0.97	1.62	37.4
Mod. + DMPP	105	259.0	3.19	25.11 c	2,967.8	1.60	2.72	80.9
Mod + N-Sure	105	259.5	3.30	26.61 bc	3,276.0	1.70	2.49	81.5
Mod. as D45	105	258.8	3.70	27.85 ab	3,405.5	1.78	3.11	105.8
Mod. as D45 + sidedress	155	260.0	3.59	29.34 a	3,534.8	1.87	3.21	113.3
Standard as D45	155	260.0	3.65	28.68 ab	3,386.6	1.83	3.22	108.8
Pr>F treat		<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
LSD 0.05		27.6	0.18	2.66	313.5	0.17	0.20	9.1

1 – See Table 1 for details; 2 – Scale of 0-999

Table 5. Trial No. 1. Soil nitrate-N levels to three feet on three dates

Treatments	depth (ft)	July 2	August 15	August 31
Untreated	0-1	7.66	2.41	0.56
	1-2	3.52	2.94	0.57
	2-3	1.57	2.87	0.64
155 (Standard)	0-1	7.66	8.92	1.22
	1-2	3.52	20.60	1.51
	2-3	1.57	16.71	2.49
105	0-1	7.66	1.12	1.94
	1-2	3.52	2.16	1.38
	2-3	1.57	3.41	1.93
105 + Agrotain	0-1	7.66	2.11	0.50
	1-2	3.52	6.51	0.45
	2-3	1.57	7.50	0.87
105 + G77	0-1	7.66	1.18	2.45
	1-2	3.52	2.79	1.05
	2-3	1.57	4.04	1.05
105 + DMPP	0-1	7.66	1.71	0.72
	1-2	3.52	8.17	1.05
	2-3	1.57	7.92	1.12
105 + D45	0-1	7.66	15.03	2.54
	1-2	3.52	16.43	3.04
	2-3	1.57	18.08	4.75
155 (incl. sidedress) + D45	0-1	7.66	15.89	2.53
	1-2	3.52	18.68	2.53
	2-3	1.57	13.09	7.04
155 (no sidedress) + D45	0-1	7.66	17.19	12.65
	1-2	3.52	21.70	5.12
	2-3	1.57	16.24	6.07
105 + N-Sure (50:50)	0-1	7.66	6.37	1.21
	1-2	3.52	13.70	3.33
	2-3	1.57	10.56	1.64
0 – 1 foot	Pr>F treat	NA	0.0003	0.4287
	LSD 0.05	NA	7.5	NS
1 – 2 foot	Pr>F treat	NA	<0.0001	0.2774
	LSD 0.05	NA	8.0	NS
2 – 3 foot	Pr>F treat	NA	0.0018	0.0039
	LSD 0.05	NA	7.6	3.3

Figure 2. Trial No. 1. Summary of soil nitrate-N levels (ppm) to three feet on August 31

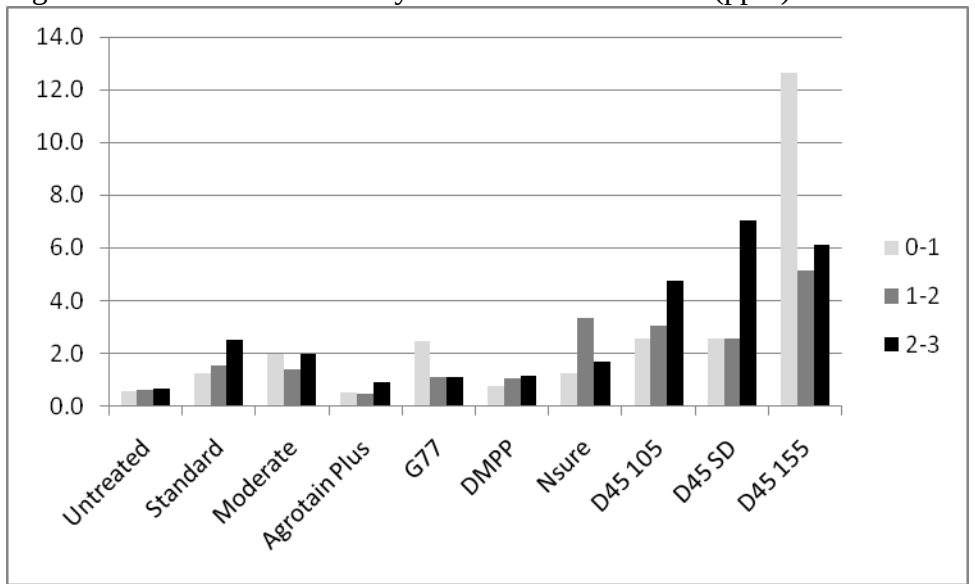

Table 6. Trial No. 2. Mineral nitrogen in the soil over the crop cycle

Treatment	April 19		April 24		May 2		May 16	
	NO3-N	NH4-N	NO3-N	NH4-N	NO3-N	NH4-N	NO3-N	NH4-N
Standard	4.4	0.7	5.0	0.7	4.0	0.5	11.1	3.3
Moderate	4.4	0.7	6.0	0.6	4.6	0.5	9.1	2.8
Moderate + Agrotain Plus	4.4	0.7	5.7	0.6	6.2	1.1	9.9	3.7
Pr>F treat	NA	NA	0.1227	0.3564	0.0150	0.4373	0.5285	0.4740
$LSD_{0.05}$	NA	NA	NS	NS	1.6574	NS	NS	NS

Table 7. Trial No. 2. Yield evaluations on May 30, 2012

Treatment	Yield Fresh Wt. (tons/A)	Yield Dry Wt. (lbs/A)	Mean Untrimmed Head Wt. (lbs)	Biomass N Concentration (%)	N Uptake lbs N/A
Standard	19.61	2007.0	1.1	3.4	67.5
Moderate	19.43	2072.3	1.2	3.2	66.2
Moderate + Agrotain Plus	18.71	1938.5	1.1	3.2	62.2
Pr>F treat	0.4517	0.3951	0.5717	0.8754	0.7745
$LSD_{0.05}$	NS	NS	NS	NS	NS