CALIFORNIA LETTUCE RESEARCH BOARD
April 1, 2014 – March 31, 2015

Title: Evaluation of best management irrigation and nutrient best management practices (BMP) to safeguard water quality

Project Investigators: Richard Smith, and Mike Cahn, UCCE, Monterey County

SUMMARY

For growers using high nitrate wells, the nitrogen (N) content of irrigation water constitutes a substantial portion of the overall ranch N budget; an acre foot of water at 40 PPM N contains > 100 lb N. This project evaluated the effect of high nitrate in the irrigation water on the yield of lettuce and the use of N fertilizer. The commercial trials conducted in this study demonstrated that fertilizer N can often be reduced without jeopardizing yield when the soil has high levels of mineral nitrogen and/or the irrigation water contains high concentrations of N. Using the soil nitrate quick test to evaluate mineral N before fertilizing and accounting for N applied in the irrigation water was a useful approach for guiding N fertilizer rates.

Nitrogen fertilizer technology includes controlled release fertilizer such as plastic coated urea and nitrification inhibitors such as nitrapyrin, dimethylpyrazole phosphate (DMPP) and dicyandiamide (DCD). These materials reduce the levels of leachable nitrate in the soil and have the potential to improve nitrogen use efficiency. In evaluations carried out in 2014, soil nitrate levels were high due to the lack of leaching during the dry winter. This made it difficult to observe statistical difference in yield among the fertilizer treatments in three trials (2 on spinach and 1 on baby lettuce). The most significant observation from these trials was significant differences in the soil ammonium levels among treatments. Nitrapyrin, Novatec (DMPP) and SuperU (DCD) had higher soil ammonium levels in one trial than the equivalent amount of N applied as ammonium sulfate. This may indicate that these materials have the ability to improve the retention of N in the soil because it is in a form that can absorb to the negative charges on clay and organic matter and thereby resist leaching for a period of time that presumably would be longer than untreated ammonium fertilizer.

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Abstract:

Many growers have no choice but to use irrigation water with high nitrogen content. Surveys by the Monterey County Water Resource Agency have suggested that regionally more than a third of wells used for irrigation may exceed the 10 PPM NO_3-N federal drinking water standard. In many wells concentrations above 20 PPM NO_3-N are common, with some wells exceeding 40 PPM. Additionally, recycled water from the Monterey Regional Water Pollution Control Agency (MRWPCA) that is delivered to growers in the Blanco District of Monterey County averages approximately 30 to 40 PPM total N (10-15 PPM NO_3-N, and the remainder in the form NH_4-N (http://www.mrwpca.org/recycling/water_quality.php). For growers using high nitrate wells, or receiving water from the MRWPCA, the N content of irrigation water constitutes a substantial portion of the overall ranch N budget; an acre foot of water at 40 PPM N contains > 100 lb N. The commercial trials conducted in this study demonstrated that fertilizer N can often be reduced without jeopardizing yield when the soil has high levels of mineral nitrogen and/or the irrigation water contains high concentrations of N. Using the soil nitrate quick test to evaluate mineral N before fertilizing and accounting for N applied in the irrigation water was a useful approach for guiding N fertilizer rates. Evaluations of nitrogen technology in 2014 were made difficult due to high levels of residual soil nitrate following the dry 2013-14 winter. As a result, we did not observe statistically significant differences among the fertilizer technology treatments. However, we did observe greater levels of soil nitrate in the Nitrapyrin, Novatec (DMPP) and SuperU (DCD) treatments which is an indirect indication of improved nitrogen use efficiency due to the reduce leaching potential of ammonium vs nitrate in the soil.

Objectives:

1. Document lettuce N uptake and N recovery efficiency (NRE) of irrigation water with elevated levels of nitrate (e.g. 20-40 PPM) on commercial farms in northern and southern Salinas Valley
2. Evaluation of nitrogen technologies (controlled release fertilizers and nitrification inhibitors) to improve nitrogen use efficiency of spinach production

PROCEDURES

1. Document lettuce N uptake and N recovery efficiency (NRE) of irrigation water with elevated levels of nitrate (e.g. 20-40 PPM) on commercial farms in northern and southern Salinas Valley

Results of replicated trials conducted during the 2013 season showed that nitrate levels in the irrigation water of 20-40 PPM NO_3-N can substantially contribute to the yield of head lettuce. To corroborate these results under commercial conditions, we conducted replicated trials at 2 commercial farms, one in north (trial 1) and one in south county (trial 2) to evaluate the impact of N in the irrigation water. Trial 1 received recycled water that was high in NH4-N; Trial 2 received water that was high in NO3-N (Table 1). Both trials were seeded with iceberg lettuce on 40-inch wide beds and established with overhead sprinklers, and subsequently irrigated with drip after thinning. Fertilizer treatments commenced after the crop was thinned. Treatments were replicated 4 times following a randomized complete block design in plots measuring 325 feet in length and 12, 40-inch beds in width at trial 1 and 4, 40-inch beds in width at trial 2.

Fertilizer N treatments were based on 1. Grower's standard practice, 2. soil nitrate quick test, and 3. The combination of using the soil nitrate quick test and accounting for the N in the irrigation water. The online decision support tool, *CropManage* (ucanr.edu/cropmanage) was used for determining the N needs of the crop from the soil nitrate concentration at the 1 foot depth and the N uptake pattern of the crop. Composite soil samples of the treatments were collected 1 to 2 days before fertilizing. N contribution from the irrigation water was determined by the following equation:

N applied in water (lbs N/acre) = ppm of N in irrigation water × inches of water applied × 0.23

A manifold was used to divide the irrigation water to the 3 treatments and to fertigate each treatment separately. Flow meters were used to record the amount of water that was applied. Water samples of the applied water were collected during each irrigation event to monitor the N concentration of the irrigation water. Treatments were evaluated for marketable carton yield at crop maturity using commercial harvesting crews and equipment.

2. Evaluation of nitrogen technologies (controlled release fertilizers and nitrification inhibitors) to improve nitrogen use efficiency of spinach production

Three trials were conducted. ***Trial No. 1:*** The trial was conducted on a commercial spinach production field with a cooperating grower near Castroville. The soil at the site was Salinas clay loam. This was the first crop of the season on this block. Each plot was one 80-inch bed wide by 20 feet long with four replications and laid out in a randomized complete block design. All fertilizer except for the 160 lbs/A ammonium sulfate (AS) treatment was applied prior to planting and mulched into the bed with the bed shaper on May 5. The 160 lbs N/A AS treatment had 120 lbs applied and incorporated as described above and 40 lbs applied as a dry topdress on May 27. The spinach variety 'Piano' was seeded on May 6 and was watered on May 9. Nitrapyrin (nitrification inhibitor) was applied two ways: 1) treated AS granules at the rate of 0.5 lb ai/A, and 2) mixed with UN 32 liquid fertilizer and sprayed on the bedtop; both were mulched into the bedtop as described above. Novatec is AS treated with DMPP (nitrification inhibitor). Duration ST is polymer coated urea (44% N) and SuperU is DCD (nitrification inhibitor) treated urea prills. The spinach was harvested on June 10 (32 days after the first germination water) by hand harvesting an area 0.5 m^2 in each plot. The harvested spinach was weighed and a subsample was dried, ground and sent to the UC Davis analytical laboratory for total nitrogen analysis. ***Trial No. 2:*** The trial was conducted on a commercial baby lettuce production field with a cooperating grower south of Gonzales. The soil at the site was Mocho silt loam. Each plot was one 80-inch bed wide by 30 feet long with four replications and laid out in a randomized complete block design. All materials were spread on the bedtop prior to planting on September 2 and mulched into the soil the bed shaper the same day. The trial was planted with green romaine lettuce on September 4 and the first sprinkler applied on September 6. The baby lettuce was harvested on

October 8 (32 days after the first germination water) by hand harvesting an area 0.5 m^2 in each plot. The harvested lettuce was weighed and a subsampled was dried, ground and sent to the UC Davis analytical laboratory for total nitrogen analysis. ***Trial No. 3:*** The trial was conducted on a commercial spinach production field with a cooperating grower north of Salinas. The soil at the site was Chualar loam. This was the second crop of the season. Each plot was one 80-inch bed wide by 20 feet long with four replications laid out in a randomized complete block design. All materials were spread on the bedtop on September 4 and mulched into the soil the same day. The spinach variety 'Piano' was seeded on September 6 and first water was started on September 7. The spinach was harvested on October 6 (30 days after the first germination water) by hand harvesting an area 0.5 m^2 in each plot. The harvested spinach was weighed and a subsample was dried, ground and sent to the UC Davis analytical laboratory for total nitrogen analysis.

RESULTS

1. Document lettuce N uptake and N recovery efficiency (NRE) of irrigation water with elevated levels of nitrate (e.g. 20-40 PPM) on commercial farms in northern and southern Salinas Valley

At both commercial trials we demonstrated that N applications could be significantly reduced by using the soil nitrate quick test and accounting for the N in the irrigation water without reducing marketable yield of iceberg lettuce. Trial 1 which was conducted near the coast on a clay loam soil received a total of only 4.8 inches of water of which 2.3 inches was applied by drip. In contrast; trial 2 received a total of 20.1 inches of water, of which 11.6 inches was applied by drip (Table 1). Hence, approximately 19 and 82 lbs of N/acre was applied from the irrigation water at trials 1 and 2, respectively during the drip phase of the crops. The grower applied 54 lbs N/acre at trial 1, which is much lower than the average amount that is typically applied to lettuce produced in the spring. However, due to the high soil nitrate concentration and an average of a 37 ppm N concentration in the water, N applications were reduced 32 and 27 lbs N/acre for the treatments 2 and 3, respectively. Marketable carton yields were not significantly different at harvest among the different N management treatments (Table 3). Yields were above the county average for all treatments. Nitrogen fertilizer applied in the grower treatment of trial 2 totaled 250 lbs N/acre (Table 4). N fertilizer was reduced to 135 lbs N in treatment 2 using the soil nitrate quick test, and additionally to 118 lbs N/acre in treatment 3 when soil nitrate and N in the irrigation water was considered. Despite reducing N applications for the crop by as much as 52% in treatment 3, no differences in yield were measured among treatments (Table 5). Note that average carton yields at trial 2 were significantly lower than the county average; presumably due to poor stand establishment that reduced the overall plant population.

2. Evaluation of nitrogen technologies (controlled release fertilizers and nitrification inhibitors) to improve nitrogen use efficiency of spinach production

Trial No. 1: The May 5 soil sampling established a baseline of soil mineral N; soil ammonium levels were 1.5 ppm on this date, but soil nitrate levels were 52.5 ppm (Table 6). The high soil nitrate levels were probably the result of the dry/warm winter weather that allowed for mineralization over the winter and little leaching of nitrate. The May 13 soil sampling date showed a dramatic increase in soil ammonium levels in all treatments except Duration ST, UN32 + nitrapyrin and the untreated control; the high soil nitrate levels generally declined on this date. On the May 19 soil sampling, Novatec and SuperU had the highest ammonium levels followed by

AS+nitrapyrin and AS at 160 lbs N/A; soil nitrate levels declined to 28.7 ppm in the untreated control and were significantly higher in all other treatments. On the May 27 sampling date ammonium levels in all treatments had returned to background levels except for SuperU which was significantly higher; all treatments had significantly higher soil nitrate than the untreated control except for Duration ST. On the June 3 sampling date the 160 lb N/A AS treatment had the highest ammonium treatment which was probably due to the topical application made on May 27; the soil nitrate levels in the untreated control had dropped to 5.4 ppm and all other treatments except UN32+nitrapyrin and Duration were significantly higher. On the June 9 sampling date the 160 lbs N/A AS treatment and Novatec had the highest ammonium levels followed by AS+nitrapyrin and Duration ST; soil nitrate levels had declined and only AS+nitrapyrin, Novatec, SuperU and 160 lbs N/A AS had elevated levels. All treatments had higher yield than the untreated control, but there were no differences among treatments. UN32+nitrapyrin had lower percent N and dry and fresh weight. This may provide evidence that this method of applying nitrapyrin may not be effective for spinach production. ***Trial No. 2:*** On the September 24 soil sampling date Novatec had significantly greater soil ammonium levels (Table 7); soil nitrate levels were higher in the Duration ST and AS treatment. On the October 8 soil sampling Novatec also had the highest ammonium levels; soil nitrate levels were significantly higher in the Novatec, Duration ST and As treatments. There were no significant differences in yield in this trial. ***Trial No. 3:*** On all of the soil sampling dates (Sept 15 to Oct 6) the soil ammonium levels were significantly higher in the AS+nitrapyrin and Novatec treatments than the AS treatment (Table 8). Soil nitrate levels at this trial site were 63.5 at the beginning of the trial and declined to 21.8 ppm by the end of the trial; the high residual soil nitrate levels made detecting differences among the treatments difficult. There were no significant differences in yield among the treatments.

Table 1. Summary of plant dates, soil type, applied water, estimated ET, and N concentration of irrigation water at trial sites 1 and 2.

				Applied Water				Irrigation Water Mineral N		
Trial	Soil	plant date	harvest date	sprinkler	drip	total	Crop ET	NO_3-N	NH_4-N	Total
				-----------------	inches	-----------		------------	ppm	-------------
1	clay loam	4/11/14	6/16/14	2.5	2.3	4.8	5.2	5.0	31.6	36.6
2	silt loam	4/18/14	6/25/14	8.5	11.6	20.1	8.7	30.5	0.4	30.9

Table 2. Applied fertilizer and average soil nitrate concentrations at site 1.

				Nitrogen Fertilizer Treatment		
Date	Crop Stage	Soil NO_3-N	Fertilizer	Standard	Quick NO_3 test	Quick NO_3 test + water NO_3
		ppm		---------------	lbs N/acre	--------------
5/23/2014	1st drip fertigation	31.3	CAN-17	43	0	0
6/2/2014	2nd drip fertigation	20.0	CAN-17	11	32	27
Total				54	32	27

Table 3. Marketable iceberg yields for fertilizer treatments at site 1.

Treatement	Carton Yield				Marketable Yield			
	Jumbo	24-size	30-size	Total	Jumbo	24-size	30-size	Total
	---------- cartons/acre-----------				------------- lbs/acre---------------			
Standard	169	951	6	1126	3439	15836	89	19364
Quick Nitrate Test	163	992	1	1156	3399	17341	13	20753
Quick Nitrate Test + Water	276	836	3	1115	5540	15075	40	20655
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	NS	NS

NS means are not statistically different at $p < 0.05$ level

Table 4. Applied fertilizer and average soil nitrate concentrations at site 2.

Date	Crop Stage	Soil NO_3-N	Fertilizer	Nitrogen Fertilizer Treatment		
				Standard	Quick NO_3 test	Quick NO_3 test + water NO_3
		ppm		--------------- lbs N/acre --------------		
4/23/2014	Bed listing	28.8	13-13-13	39	39	39
5/17/2014	1st sidedress	26.3	UAN-32	118	0	0
5/31/2014	1st drip fertigation	13.0	AN-20	42	50	42
6/7/2014	2nd drip fertigation	32.9	Nphuric 15-0-0-49	10	0	0
6/18/2014	3rd drip fertigation	11.8	AN-20	42	46	37
Total				250	135	118

Table 5. Marketable iceberg yields for fertilizer treatments at site 2.

Treatement	Carton Yield			Marketable Yield		
	24-size	30-size	Total	24-size	30-size	Total
	---------- cartons/acre-----------			---------- lbs/acre-----------		
Standard	142	402	544	2500	6361	8861
Quick Nitrate Test	118	439	557	1931	7065	8996
Quick Nitrate Test + Water	79	583	662	1305	10029	11334
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS

NS means are not statistically different at $p < 0.05$ level

Table 6. Trial No. 1. Yield, nitrogen content of spinach on June 10 and mineral nitrogen in the soil on six dates.

Treatment	Amount lbs N/A	Fresh (lbs/A)	Fresh (tons/A)	Dry (lbs/A)	%N	lbs N/A in spinach	mg ammonium-N/kg soil					
							May 5*	May 13	May 19	May 27	June 3	June 9
AS[1] nitrapyrin	120 0.5 ai/A	34135.1	17.1	1962.8	5.9	115.0	1.5	28.8^{A}	14.1^{B}	1.7^{B}	1.9^{BC}	7.5^{B}
UAN 32 nitrapyrin	120 0.5 ai/A	29958.0	15.0	1685.3	5.4	91.4	1.5	6.1^{B}	3.1^{C}	1.3^{B}	1.7^{BC}	2.1^{C}
Novatec	120	33917.9	17.0	1869.5	5.9	110.6	1.5	37.6^{A}	23.9^{A}	3.1^{B}	2.5^{B}	13.1^{A}
Duration ST	120	32547.8	16.3	1797.7	5.7	102.1	1.5	8.7^{B}	5.8^{C}	2.1^{B}	1.7^{BC}	5.8^{B}
SuperU	120	34352.3	17.2	1863.5	5.8	107.8	1.5	24.1^{A}	23.1^{A}	7.8^{A}	1.9^{BC}	1.6^{C}
AS	120	34235.3	17.1	1927.6	5.7	109.6	1.5	23.8^{A}	5.1^{C}	1.3^{B}	1.6^{C}	2.0^{C}
AS	160	34486.0	17.2	1903.1	6.0	115.0	1.5	23.0^{A}	8.6^{BC}	1.6^{B}	4.6^{A}	15.5^{A}
Untreated	0	19231.3	9.6	1130.4	5.4	60.5	1.5	1.7^{C}	1.8^{C}	1.5^{B}	1.5^{C}	2.0^{C}
Pr>F treat	---	<0.0001	<0.0001	<0.0001	0.0475	<0.0001	NA	<0.0001	<0.0001	0.0004	0.0002	<0.0001
LSD $_{0.05}$	---	5148.6	2.5	273.6	0.4	18.1	NA	---	---	---	---	---

1 – AS = ammonium sulfate

Table 6. continued

Treatment	Amount lbs N/A	mg nitrate-N/kg soil					
		May 5	May 13	May 19	May 27	June 3	June 9
AS nitrapyrin	120 0.5 ai/A	52.5	41.8	48.9	41.7	25.5	14.5
UAN 32 nitrapyrin	120 0.5 ai/A	52.5	54.2	54.9	46.4	14.6	5.6
Novatec	120	52.5	48.3	57.4	44.2	29.2	14.1
Duration ST	120	52.5	39.2	41.1	28.8	15.8	10.2
SuperU	120	52.5	47.9	70.0	78.0	38.4	17.9
AS	120	52.5	39.0	51.7	39.3	25.1	8.4
AS	160	52.5	42.3	55.2	43.7	32.4	24.6
Untreated	0	52.5	36.8	28.7	24.3	5.8	5.1
Pr>F treat	---	NA	0.0777	0.0040	<0.0001	0.0100	0.0006
LSD $_{0.05}$	---	NA	NS	17.1	9.7	16.3	7.9

Table 7. Trial No. 2. Yield, nitrogen content of baby lettuce on October 8 and mineral nitrogen in the soil

Treatment	Amount lbs N/A	Fresh (lbs/A)	Fresh (tons/A)	Dry (lbs/A)	%N lettuce	lbs N/A lettuce	mg ammonium-N/kg soil		mg nitrate-N/kg soil	
							Sept. 24	Oct. 8	Sept. 24	Oct. 8
Novatec	120	22233.2	11.1	1490.6	4.77	71.06	6.8	7.0	45.4	35.3
Duration ST	120	24884.3	12.4	1422.1	5.06	72.26	1.7	3.4	56.0	32.9
AS	120	21854.5	10.9	1387.6	4.47	62.13	1.4	0.5	70.1	35.7
Untreated	0	20807.4	10.4	1223.1	3.74	45.99	0.3	0.2	33.6	3.3
Standard	187	26109.5	13.1	1380.0			0.4	0.3	15.6	4.3
Pr>F treat		0.5066	0.4941	0.1831	0.0027	0.0296	0.0003	0.0185	0.0043	0.0447
LSD $_{0.05}$		NS	NS	NS	0.48	16.95	2.3	4.1	24.7	27.5

Table 8. Trial No. 3. Yield, nitrogen content of spinach on October 6 and mineral nitrogen in the soil

Treatment	Amount lbs N/A	Fresh (lbs/A)	Fresh (tons/A)	Dry (lbs/A)	%N spinach	lbs N/A spinach	mg ammonium-N/kg soil				mg nitrate-N/kg soil			
							Sept. 15	Sept. 26	Oct. 1	Oct. 6	Sept. 15	Sept. 26	Oct. 1	Oct. 6
AS nitrapyrin	80 0.5 ai/A	23475	11.7	1826	6.49	118.50	12.2^{AB}	3.7^{AB}	5.6^{A}	3.7^{A}	61.2	58.8	46.8	29.2
Novatec	80	24411	12.2	1904	6.58	125.28	18.4^{A}	8.2^{A}	7.4^{A}	6.1^{A}	48.2	46.4	36.1	26.4
Duration ST	80	24645	12.3	1835	6.56	120.55	2.5^{D}	2.7^{B}	1.8^{B}	2.8^{A}	63.4	58.4	58.1	42.1
SuperU	80	24210	12.1	1816	6.49	117.78	9.8^{BC}	0.7^{C}	0.3^{C}	0.3^{B}	63.6	57.3	54.7	32.6
AS	80	21637	10.8	1714	6.45	110.66	3.9^{CD}	0.6^{C}	0.3^{C}	0.3^{B}	84.7	69.9	64.8	47.6
Untreated	0	24745	12.4	1849	6.36	117.71	0.7^{E}	0.8^{C}	0.3^{C}	0.3^{B}	63.5	42.7	37.6	21.8
Standard	100	23876	11.9	1861	6.41	119.40	2.0^{DE}	3.4^{B}	2.9^{AB}	0.6^{B}	65.3	57.0	38.5	33.8
Pr>F treat	---	0.7468	0.7410	0.4764	0.2450	0.4583	<0.0001	<0.0001	<0.0001	<0.0001	0.0204	0.0790	0.0288	0.0694
LSD $_{0.05}$	---	NS	NS	NS	NS	NS					17.3	17.4	19.1	17.1