2011 Spinach Fertilizer Evaluations

University of California Cooperative Extension, Monterey County
Richard Smith and Aaron Heinrich, Farm Advisor and Staff Research Assistant

Background

Nitrogen fertilizer programs for spinach will be challenging under regulations proposed by the Central Coast Regional Water Quality Control Board (CCRWQCB). These regulations propose a 1.0 nitrogen (N) balance ratio of nitrogen applied to the crop versus nitrogen taken up by the crop. These regulations will be difficult to comply with because nitrogen use efficiency in spinach is made difficult because of 1) shallow root system, 2) high quality demands (need for deep green leaf color) and 3) other issues such as production on soils susceptible to nitrate leaching, irrigation uniformity, etc. These studies evaluated fertilizer application rates on growth and nitrogen uptake of spinach. Trials were conducted on high and low residual soil nitrate fields to evaluate the potential of residual soil nitrate to provide the needs of a shallow rooted crop such as spinach.

Summary

Four trials were conducted to understand the nitrogen fertilizer uptake by spinach grown in modern high-density, 80 inch wide beds. Two trials were carried out on first crop spinach production fields, and given wet spring weather of 2011, the fields had low residual soil nitrate levels at the onset of the trials. Two trials were also conducted in second crop spinach fields following lettuce or cole crops. The first crop spinach trials both had low residual soil nitrate (5-10 ppm nitrate-N). Ammonium sulfate was applied at various rates at-planting. Ammonium was chosen as the source of N because it is attracted to the cation exchange sites in the soil and would be less susceptible to leaching losses during the application of germination water. In both first crop fertilizer trials the spinach responded to nitrogen up to 40 lbs N/A. This was surprising because spinach only took up about 20 lbs of N/A in the first two weeks of production. We did not change any of the grower's fertilizer practices beyond the at-planting applications. Even with robust amounts of supplemental fertilizer applications starting at the 1-2 true leaf stage (approximately 14-18 days after germination water), the low at-planting fertilizer treatments (0 and 20 lbs N/A) had reduced spinach yield. In the second crop spinach trials, spinach responded well to residual soil nitrate. In one trial, the grower skipped at-planting N applications. We applied the fertilizer treatments at the 1-2 true leaf stage in this trial and observed that there was no response to fertilizer. This trial indicated that in spite of the shallow root system, spinach is capable of absorbing sufficient quantities of residual soil nitrate-N from the soil to meet a large portion of its needs.

In general, first crop spinach crops with low levels of residual soil nitrate will need robust at-planting applications of N fertilizer to achieve acceptable levels of yield and quality. Second crop spinach can be managed with reduced fertilizer N inputs and can be successfully grown with lower rates of N. However, achieving the 1.0 requirement proposed by the CCRWQCB may only be possible for second crop spinach.

Methods

Trial No. 1: First crop field conducted in Gonzales – teenage spinach. The soil was Metz fine sandy loam. Each plot was one 80-inch bed wide by 20 feet long and randomized three times in

a randomized complete block design. The trial area was treated with four at-planting treatment rates: 0, 20, 40 and 80 lbs N/A as ammonium sulfate. The field was seeded to the variety 'Lazio' on April 14 and the first germination water was applied on April 16. See Table 1 for details on rates and dates of nitrogen fertilizer applications.

Trial No. 2: First crop field conducted in San Juan Bautista – baby spinach. The soil at the site was Sorrento silty clay loam. Each plot was one 80-inch bed wide by 20 feet long and randomized three times in a randomized complete block design. The trial area was treated with four at-planting treatment rates: 0, 20, 40 and 80 lbs N/A as ammonium sulfate. The field was seeded to the variety 'Lazio' on April 15 and the first germination water was applied on April 16. See Table 2 for details on rates and dates of nitrogen fertilizer applications.

Trial No. 3: Second crop field west of Salinas – teenage spinach. The soil at the site was Salinas loam. Each plot was one 80-inch bed wide by 20 feet long and randomized three times in a randomized complete block design. No preplant or at-planting nitrogen fertilizer was applied because there were high levels of residual soil nitrogen at this site as the crop was following the previous lettuce crop. Five topdress fertilizer treatments were applied on August 1at the 1-2 true leaf stage: 0,25,50,75, and 105 (grower standard). The field was seeded on July 15 and first water was applied on July 16. See Table 3 for details on rates and dates of nitrogen fertilizer applications.

Trial No. 4: Third crop field south of Gonzales – teenage spinach. The soil at the site was a Metz fine sandy loam. Each plot was one 80-inch bed wide by 20 feet long and randomized three times in a randomized complete block design. The trial area was treated with four at-planting treatment rates: 0, 20, 40 and 80 lbs N/A as ammonium sulfate. The field was seeded to the variety 'Agate' on September 23 and the germination water was applied on September 24. See Table 4 for details on rates and dates of nitrogen fertilizer applications.

Details common to all trials: Ammonium sulfate was the form of N applied in trials 1, 2 and 4. It was chosen to minimize nitrate leaching potential with the first germination water (ammonium binds to the soil particles, reducing its loss with irrigation water); it was applied it by hand. In trial 1, 2 and 4 15-8-4 was the form of N used in the by the grower in the remainder of the field; it was sprayed on with after planting with a commercial rig (analysis of the N in 15-8-4: 3.0% is nitrate, 5.5% is ammonium and 6.5% is urea). Measurements of soil mineral nitrogen in all trials were taken to 12 inches deep with a ¾ inch soil probe on a weekly basis; biomass and tissue N content evaluations were made two to three times during the growth cycle from 0.5 m^2 areas in each plot. All fields were irrigated with sprinklers throughout the growing cycle. Following harvest, a root pit was excavated in trials 1, 3 and 4 to conduct evaluations of root density and distribution of nitrate in the soil profile. A grid with 4"x 4" openings was used and the number of roots where counted in each grid as well as soil samples collected for nitrate analysis. Deep soil sampling to three feet deep were collected in trial No. 1 and analyzed for nitrate. See tables for treatments and evaluation dates.

Results

Trial No. 1: This was a first-crop spinach planting and the site had a sandy soil. Following a wet winter and spring rains the levels of residual soil nitrate were in the range of 5-6.0 ppm (Table

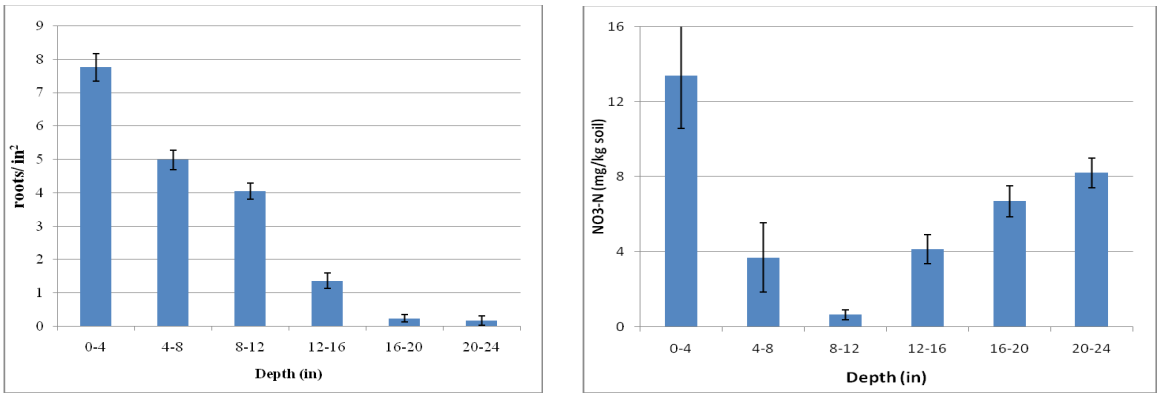
1). Ammonium levels were also low (<1.0 ppm) at planting. Treatment N applications were made at planting; all at-planting N fertilizer treatments were followed by a top dress application and two sprinkler applications (Table 2). Soil ammonium levels increased in the high yielding plots on April 20 and May 11, reflecting the at-planting fertilizer application and the May 2 topdress application. Soil nitrate levels increased in the April 27 sampling date, which was still measuring the impact of the at-planting applications. Interestingly, the May 20 sampling date did not show elevated levels of soil nitrate even though all fertilizer applications had been made by that time. Furthermore deep sampling did not measure nitrate deep in the bed (Figure 2 and Table 1). Even though more nitrogen was applied to the spinach than was taken up by the crop, the fate of the extra nitrogen is not entirely clear. Biomass and yield evaluations indicated that at-planting applications of nitrogen statistically topped out at 40 lbs N/A, but there is a trend indicating further yield increase up to 80 lb N/A (Table 2). N uptake in the tops of the spinach also peaked at 40 lbs N/A applied at planting and the highest N uptake ranged from 88 to 110 lbs N/A. The highest N uptake ranged from 7.6 to 8.3 lb N/A/day. Ninety percent of all roots were measured in the top 12 inches of soil (Figure 1).

Trial No. 2: This was a first-crop spinach planting and the site had a clay loam texture. In spite of the heavier soil texture, there were sufficient rains over the winter, the soil nitrate levels were <10 ppm, and soil ammonium levels were also low at planting – in the range of 1.0-1.2 ppm (Table 3). Treatment N applications were made at planting; all at-planting N fertilizer treatments were followed by one N fertilizer application made through the sprinklers (Table 4). Soil ammonium levels increased on the April 21 sampling date, which were in response to the at-planting N fertilizer applications (Table 3). Soil ammonium levels remained high in the 80 lb N/A treatment through the remainder of the growing season, but were not seen at the equivalent standard fertilizer treatment rate. Soil nitrate levels increased to >14 ppm in the highest N fertilizer rate treatments on April 26 and soil nitrate levels increased to >15 ppm in all treatments except the untreated control on May 4. The lag in the increase in soil nitrate levels in the lower at-planting N application rates probably explains the lower yields observed in those treatments. The at-planting applications of nitrogen statistically topped out at 40 lbs N/A (Table 4). N uptake in the tops of the spinach also peaked at 40 lbs N/A applied at planting and the highest N uptake ranged from 67 to 88 lbs N/A. This field was a baby spinach field which explained the lower yield and N uptake.

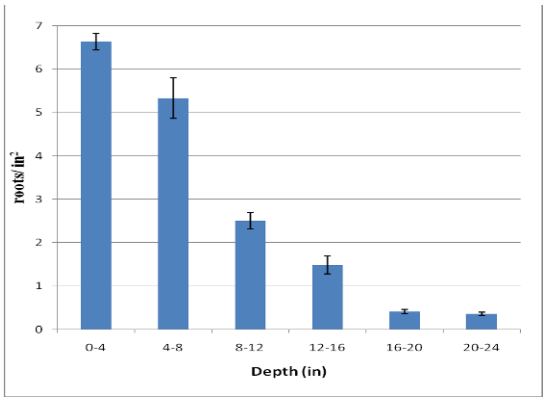
Trial No. 3: This was a second crop spinach field following lettuce. Residual soil nitrate-N levels at planting were at 28 ppm (Table 5). As a result of these high soil nitrate-N levels, the grower decided to skip the at planting N applications; we followed his practices and did not apply at-planting fertilizer applications. Treatment N fertilizer applications were made at the 1-2 true leaf stage and were timed to coincide with the grower's first fertilizer N applications. Soil ammonium levels increased on the August 4 evaluation date in response to the topdress applications made on August 1 (Table 5). Soil nitrate-N levels were highest on July 26 and August 4 (>24 ppm) and then declined on the subsequent two evaluation dates. There was no statistically significant fertilizer yield response in any of the treatments over the zero N/A topdress application (Table 6) indicating residual soil nitrate can provide much of the needs of spinach during the middle of the spinach growing season. Nitrogen uptake by the spinach ranged from 83 to 97 lbs N/A at harvest. 87% of all roots were measured in the top 12 inches of soil (Figure 30). In spite of good N management, there were elevated levels of nitrate in the soil at

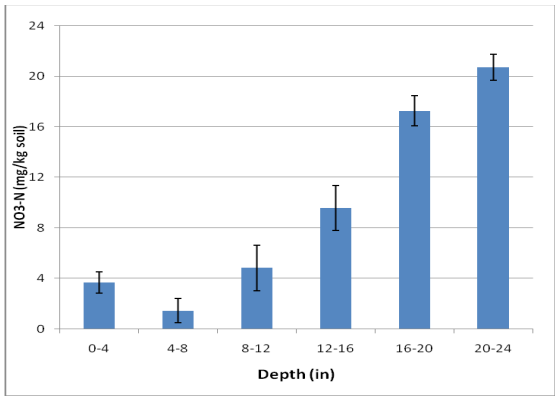
two feet deep following harvest of the spinach. Crop uptake of phosphorus and potassium were measured on three dates at this site. The concentration of phosphorus generally ranges from 0.2 – 0.5% in plant tissues, but were measured at >0.76% at harvest (Table 7). The uptake of phosphorus was >12.2 lbs P/A which is comparable to that taken up by lettuce. Potassium uptake by spinach at this site was also very high. The concentration of potassium > 8.4% and >1.29 lbs K/A at harvest.

Trial No. 4: Spinach was the third vegetable crop grown at this site in 2011 following broccoli and romaine. Residual soil nitrate-N levels at planting were 23.9 ppm. Treatment N applications were made at planting; all at-planting N fertilizer treatments were followed by a sprinkler application of fertilizer (Table 9). Soil ammonium levels increased on September 28 in response to the at-planting application and again on October 13 in response to the sprinkler application on October 9 (Table 8). Soil nitrate levels were elevated in all but the untreated control treatment prior to the October 9 sprinkler application. Following the sprinker N application soil nitrate-N levels were high. There were no statistical differences in the yield of the spinach due to at-planting applications. Nitrogen uptake by the crop at harvest ranged from 79-84 lbs N/A. The number of roots at various depths was similar to the other evaluations with 81% of roots in the top 12 inches of soil (Figure 5). At this site, a large amount of residual soil nitrate-N remained in the top four inches of soil after harvest (Figure 6).

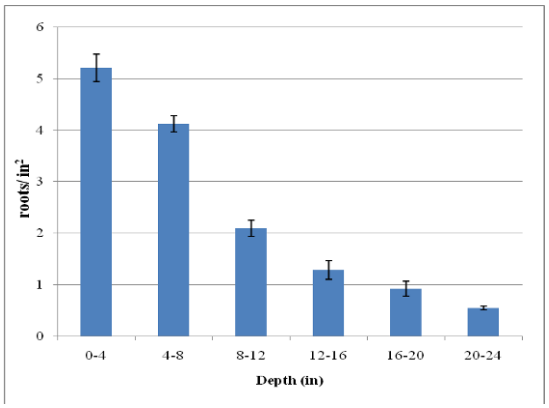


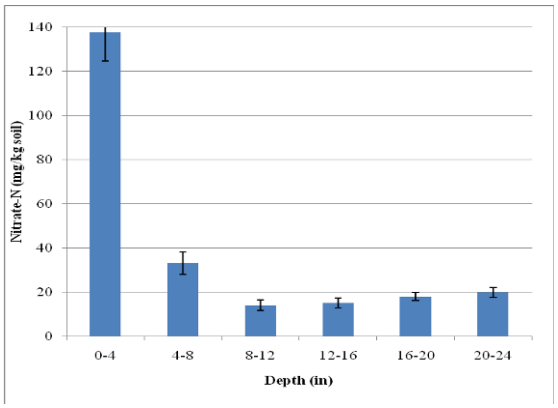
Figures &2. Trial No. 1. Root density by depth on leftt and soil nitrate-N by depth following harvest.





Figures 3&4. Trial No. 3. Root density by depth on leftt and soil nitrate-N by depth following harvest.





Figures 4&6. Trial No. 4. Root density by depth on left and soil nitrate-N by depth following harvest.


Overview of trial showing low N plots


Zero N treatment


40 lbs N/A treatment


80 lbs N/A treatment

Table 1. Trial No. 1. Gonzales. Soil nitrate and ammonium-N on four dates and deep soil sampling on May 20.

At-planting Treatments Lbs N/A	NH4-N (mg/kg soil)					NO3-N (mg/kg soil)					Deep Soil Samples – May 20 NO3-N (mg/kg soil)		
	Apr 14	Apr 20	Apr 27	May 2	May 11	Apr 14	Apr 20	Apr 27	May 2	May 11	0-12" depth	12-24" depth	24-36" depth
0	0.4	0.4	0.4	0.4	18.4	5.8	4.3	4.6	2.9	7.1	8.7	6.0	6.9
20	0.3	6.3	1.4	0.6	17.2	5.5	10.3	16.7	6.7	7.7	6.3	4.7	5.9
40	0.4	14.5	6.1	1.7	17.5	6.2	11.0	21.9	11.1	6.2	4.4	4.9	5.6
80	0.3	19.7	9.4	10.1	14.8	5.7	13.5	32.4	28.0	3.3	5.3	5.3	5.6
80 Standard	0.4	8.1	7.1	1.5	32.2	5.3	25.4	31.5	18.5	7.9	5.4	3.6	5.0
Pr>Treat	0.761	<0.001	0.084	<0.001	0.078	0.718	<0.001	<0.001	<0.001	0.120	0.017	0.425	0.537
Pr>Block	0.081	0.286	0.150	0.481	0.709	0.021	0.004	0.419	0.807	0.816	0.004	0.096	0.044
$LSD_{0.05}$	NS	3.4	NS	2.5	NS	NS	2.2	11.1	3.7	NS	2.4	NS	NS

Table 2. Trial No. 1, Gonzales. Treatment N applications and total N applications and biomass evaluations on May 2

At-planting Treatments Lbs N/A	Topdress[3] May 2 1-2 true leaf	Sprinkler[4] May 9 Mid-growth	Sprinkler[5] May 12 preharvest	Total Lbs N/A	May 2 (19 DAG)				
					Fresh (lbs/A)	Fresh (tons/A)	Dry (lbs/A)	%N	lbs N/A
0	63	38.5	32.1	133.6	2,349	1.2	237	4.4	10.6
20[1]	63	38.5	32.1	153.6	2,902	1.5	306	4.6	14.2
40[1]	63	38.5	32.1	173.6	3,226	1.6	330	5.0	16.5
80[1]	63	38.5	32.1	213.6	3,408	1.7	347	5.5	19.1
80[2] Standard	63	38.5	32.1	213.6	4,134	2.1	421	5.4	22.7
Pr>Treat					0.009	0.009	0.002	0.001	<0.001
Pr>Block					0.050	0.050	0.021	0.201	0.021
$LSD_{0.05}$					800	0.4	64	0.4	3.7

1 – ammonium sulfate applied immediately post planting; 2 – 15-8-4 applied immediately post planting;
3 – ammonium sulfate; 4 – CN9; 5 – CAN17

Table 2 (continued). Trial No. 1, Gonzales. Biomass evaluation on May 11 and yield evaluation on May 16

At-planting Treatments Lbs N/A	May 11 (19 DAG)						May 16 (33 DAG)					
	Fresh (lbs/A)	Fresh (tons/A)	Dry (lbs/A)	%N	lbs N/A	Uptake (lbs N/d)	Fresh (lbs/A)	Fresh (tons/A)	Dry (lbs/A)	%N	lbs N/A	Uptake (lbs N/d)
0	7,392	3.7	949	3.3	31	2.3	16,771	8.4	1,797	3.6	65	6.6
20[1]	9,722	4.9	1,200	3.5	42	3.1	18,869	9.4	1,852	3.9	72	5.9
40[1]	10,873	5.4	1,298	3.6	47	3.4	22,999	11.5	2,175	4.1	88	8.3
80[1]	13,401	6.7	1,556	4.6	72	5.9	25,931	13.0	2,466	4.5	110	7.6
80[2] Standard	12,943	6.5	1,552	4.2	65	4.7	25,031	12.5	2,309	4.2	98	6.5
Pr>Treat	0.004	0.004	0.002	<0.001	<0.001	NA	0.010	0.010	0.062	0.189	0.006	NA
Pr>Block	0.166	0.166	0.148	0.695	0.235	NA	0.598	0.598	0.574	0.591	0.805	NA
$LSD_{0.05}$	2,860	1.4	269	0.5	13	NA	5,221	2.6	NS	NS	23	NA

1 – Ammonium sulfate applied immediately post planting; 2 – 15-8-4 applied immediately post planting.

Table 3. Trial No. 2, San Juan Bautista. Soil nitrate and ammonium and total mineral nitrogen on five dates.

At-planting Treatments Lbs N/A	NH4-N (mg/kg soil)					NO3-N (mg/kg soil)					NO3+NH4-N (mg/kg soil)				
	Apr 14	Apr 21	Apr 26	May 4	May 9	Apr 14	Apr 21	Apr 26	May 4	May 9	Apr 14	Apr 21	Apr 26	May 4	May 9
0	1.2	0.7	2.1	2.1	2.4	10.2	5.4	4.4	12.4	18.6	11.3	6.1	6.5	14.5	20.9
20[1]	1.0	1.5	2.3	1.6	2.4	8.5	7.7	9.8	15.5	18.3	9.5	9.2	12.2	17.1	20.8
40[1]	1.1	3.4	2.9	2.7	2.3	9.2	11.6	9.5	17.8	20.7	10.4	15.0	12.5	20.5	23.0
80[1]	1.2	8.5	7.9	10.2	6.5	6.7	11.4	17.7	27.5	30.3	7.9	19.9	25.6	37.7	36.8
80[2] Standard	1.2	6.7	1.8	2.9	2.5	9.2	13.9	14.7	18.4	27.1	10.4	20.6	16.4	21.4	29.6
Pr>Treat	0.988	0.127	0.002	0.019	0.102	0.264	0.007	<0.001	0.180	0.216	0.176	0.001	<0.001	0.083	0.142
Pr>Block	0.472	0.168	0.423	0.329	0.585	0.904	0.276	0.878	0.087	0.822	0.945	0.084	0.839	0.111	0.961
$LSD_{0.05}$	NS	NS	2.7	5.2	NS	NS	4.3	4.3	NS	NS	NS	6.4	5.1	NS	NS

Table 4. Trial No. 2, San Juan Bautista. Treatment N applications and total N applications

and biomass evaluations on April 29

At-planting Treatments Lbs N/A	Sprinkler[3] May 2 lbs N/A	Total lbs N/A	April 29 (15 DAG)				
			Fresh (lbs/A)	Fresh (tons/A)	Dry (lbs/A)	%N	lbs N/A
0	42.8	42.8	495	0.2	51	4.3	2.2
20[1]	42.8	62.8	918	0.5	80	5.0	4.0
40[1]	42.8	82.8	981	0.5	93	5.1	4.7
80[1]	42.8	122.8	937	0.5	84	5.4	4.6
80[2] Standard	42.8	122.8	977	0.5	91	4.4	4.0
Pr>Treat			0.001	0.001	0.005	0.066	0.004
Pr>Block			0.120	0.120	0.072	0.738	0.144
$LSD_{0.05}$			182	0.1	18.7	NS	1.1

1 – Ammonium sulfate applied immediately post planting; 2 – 15-8-4 applied immediately post planting; 3 – CAN 17 applied at 1-2 true leaf stage

Table 4 (cont.). Trial No. 2, San Juan Bautista. Biomass evaluation on May 4 and yield evaluation on May 13

At-planting Treatments Lbs N/A	May 4 (18 DAG)						May 13 (27 DAG)					
	Fresh (lbs/A)	Fresh (tons/A)	Dry (lbs/A)	%N	lbs N/A	Uptake (lbs N/d)	Fresh (lbs/A)	Fresh (tons/A)	Dry (lbs/A)	%N	lbs N/A	Uptake (lbs N/d)
0	1,933	1.0	160	5.0	8.0	1.2	7,214	3.6	741	3.6	26.4	2.8
20[1]	3,582	1.8	303	5.1	15.6	2.3	13,873	6.9	1,248	3.7	45.7	4.9
40[1]	3,795	1.9	319	5.4	17.3	2.5	16,454	8.2	1,341	4.3	58.0	6.1
80[1]	4,002	2.0	344	5.6	19.2	2.9	18,469	9.2	1,521	4.4	67.3	7.0
80[2] Standard	3,545	1.8	283	5.4	15.4	2.3	16,005	8.0	1,361	3.6	53.2	5.4
Pr>Treat	<0.001	<0.001	<0.001	0.001	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	
Pr>Block	0.558	0.558	0.634	0.020	0.474		0.111	0.111	0.582	0.206	0.137	
$LSD_{0.05}$	748	0.4	56.8	0.2	3.1		3,426	1.7	231	0.4	9.4	

1 – Ammonium sulfate applied immediately post planting; 2 – 15-8-4 applied immediately post planting.

Table 5. Trial No. 3, Salinas. Soil nitrate and ammonium and total mineral nitrogen on four dates.

Topdress	NH4-N (mg/kg soil)	NO3-N (mg/kg soil)	NO3+NH4-N (mg/kg soil)

Treatments[1] Lbs N/A												
	Jul 26	Aug 4	Aug 8	Aug 12	Jul 26	Aug 4	Aug 8	Aug 12	Jul 26	Aug 4	Aug 8	Aug 12
0	1.1	3.1	0.7	1.6	28.0	27.8	9.0	6.9	29.1	30.8	9.6	8.6
20	1.1	5.4	4.7	2.8	28.0	25.9	13.1	10.5	29.1	31.2	17.9	13.3
40	1.1	20.0	8.2	9.3	28.0	32.3	13.8	14.4	29.1	52.3	22.0	23.7
80	1.1	13.9	18.8	10.6	28.0	24.2	15.9	14.7	29.1	38.0	34.7	25.3
105 Standard	1.1	13.1	22.0	21.5	28.0	27.3	17.7	16.6	29.1	33.6	39.7	38.1
Pr>Treat	NA	0.219	<0.001	<0.001	NA	0.403	0.052	0.132	NA	0.140	<0.001	0.008
Pr>Block	NA	0.710	0.777	0.897	NA	0.010	0.026	0.462	NA	0.722	0.117	0.661
$LSD_{0.05}$	NA	NS	4.0	6.7	NA	NS	5.5	NS	NA	NS	7.0	13.7

1 – Ammonium sulfate topdressed at the 1-2 true leaf stage on August 1 (only nitrogen made.

Table 6. Trial No. 3, Salinas. Biomass and nitrogen uptake evaluations on two dates

Topdress Treatments Lbs N/A	August 4 (19 DAG)					August 8 (23 DAG)					
	Fresh (lbs/A)	Fresh (tons/A)	Dry (lbs/A)	%N	lbs N/A	Fresh (lbs/A)	Fresh (tons/A)	Dry (lbs/A)	%N	lbs N/A	Uptake (lbs N/d)
0	4,974	2.5	385	4.95	19.1	13,101	6.6	930	5.34	49.9	7.7
25	5,273	2.6	403	5.13	20.7	14,367	7.2	996	5.53	55.3	8.6
50	5,338	2.7	414	5.20	21.5	13,434	6.7	957	5.50	52.7	7.8
75	5,315	2.7	420	5.46	22.9	14,411	7.2	1000	5.71	57.2	8.6
105 Standard	4,898	2.4	398	5.35	21.3	14,256	7.1	989	5.58	55.2	8.5
Pr>Treat	0.453	0.453	0.529	0.130	0.360	0.909	0.909	0.882	0.087	0.181	
Pr>Block	0.012	0.012	0.014	0.170	0.093	0.387	0.387	0.325	0.004	0.002	
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	

Table 6 (continued). Trial No. 3, Salinas. Yield and nitrogen uptake.

Topdress Treatments	August 12 (27 DAG)					
	Fresh	Fresh	Dry	%N	lbs N/A	Uptake

Lbs N/A	(lbs/A)	(tons/A)	(lbs/A)			(lbs N/d)
0	26,291	13.1	1532	5.42	83.5	8.4
25	28,201	14.1	1664	5.74	95.6	10.1
50	27,135	13.6	1528	5.75	87.9	8.8
75	28,823	14.4	1564	5.86	91.7	8.6
105 Standard	28,556	14.3	1621	6.03	97.8	10.7
Pr>Treat	0.627	0.627	0.247	0.077	0.103	
Pr>Block	0.298	0.298	0.037	0.039	0.010	
$LSD_{0.05}$	NS	NS	NS	NS	NS	

Table 7. Trial No. 3, Salinas. Evaluation of potassium and phosphorus concentration and uptake by spinach on three dates

Topdress Treatments Lbs N/A	August 4 (19 DAG)				August 8 (23 DAG)				August 12 (27 DAG)			
	% P	lbs P/A	% K	lbs K/A	% P	Lbs P/A	% K	lbs K/A	% P	lbs P/A	% K	lbs K/A
0	0.73	6.8	8.67	80.8	0.73	6.8	8.67	80.8	0.80	12.2	8.40	129.1
25	0.73	7.2	8.72	87.1	0.73	7.2	8.72	87.1	0.76	12.7	8.44	140.5
50	0.73	6.9	8.41	80.6	0.73	6.9	8.41	80.6	0.82	12.6	8.54	130.5
75	0.73	7.3	8.73	87.4	0.73	7.3	8.73	87.4	0.83	12.9	8.63	135.3
105 Standard	0.72	7.1	8.51	84.2	0.72	7.1	8.51	84.2	0.83	13.5	8.68	141.0
Pr>Treat	0.945	0.462	0.403	0.452	0.945	0.462	0.403	0.452	0.090	0.518	0.907	0.666
Pr>Block	0.340	0.006	0.014	0.004	0.340	0.006	0.014	0.004	0.852	0.076	0.538	0.116
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 8. Trial No. 4, Gonzales. Soil nitrate and ammonium and total mineral nitrogen on four dates.

At-planting Treatments	NH4-N (mg/kg soil)					NO3-N (mg/kg soil)					NO3+NH4-N (mg/kg soil)				
	Sept 20	Sept 28	Oct 4	Oct 13	Oct 19	Sept 20	Sept 28	Oct 4	Oct 13	Oct 19	Sept 20	Sept 28	Oct 4	Oct 13	Oct 19

Lbs N/A															
0	1.5	2.2	0.6	24.0	7.5	23.9	11.3	18.8	90.6	55.5	25.4	13.5	19.4	114.6	63.1
20[1]	1.5	16.0	1.4	24.5	8.7	23.9	18.5	22.6	94.9	60.4	25.4	34.5	23.9	119.3	69.1
40[1]	1.5	41.3	3.9	25.8	13.6	23.9	23.4	28.7	102.3	77.0	25.4	64.7	32.6	128.2	90.6
80[1]	1.5	92.8	11.4	37.8	13.6	23.9	26.6	37.7	118.5	77.6	25.4	119.4	49.1	156.3	91.1
80[2] Standard	1.5	28.3	5.4	26.0	10.3	23.9	31.5	36.5	94.9	51.8	25.4	59.8	41.9	120.9	62.1
Pr>Treat	NA	<0.001	<0.001	0.075	0.056	NA	0.003	<0.001	0.682	0.026	NA	<0.001	<0.001	0.429	0.028
Pr>Block	NA	0.245	0.373	0.933	0.303	NA	0.711	0.031	0.598	0.333	NA	0.410	0.054	0.675	0.310
$LSD_{0.05}$	NA	19.9	2.0	NS	4.8	NA	8.8	7.6	NS	18.5	NA	22.3	9.0	NS	22.5

Table 9. Trial No. 4, Gonzales. Treatment N and total N applications, and biomass on October 13 and Yield on October 18.

At-planting Treatments Lbs N/A	Sprinkler[3] Oct 9 preharvest Lbs N/A	Total Lbs N/A	October 13 (19 DAG)					October 18 (24 DAG)					
			Fresh (lbs/A)	Fresh (tons/A)	Dry (lbs/A)	%N	lbs N/A	Fresh (lbs/A)	Fresh (tons/A)	Dry (lbs/A)	%N	lbs N/A	Uptake (lbs N/d)
0	85.6	85.6	8,152	4.1	693	5.8	40.5	18519	9.3	1305	6.1	79.4	7.8
20[1]	85.6	105.6	8,172	4.1	694	5.9	41.0	19102	9.6	1344	6.1	82.6	8.3
40[1]	85.6	125.6	8,069	4.0	680	6.0	40.6	19435	9.7	1405	6.0	84.1	8.7
80[1]	85.6	165.6	8,194	4.1	690	6.2	42.9	18253	9.1	1320	6.3	83.3	8.1
80[2] Standard	85.6	165.6	7,744	3.9	676	6.1	41.3	18286	9.1	1269	6.3	79.8	7.7
Pr>Treat			0.681	0.681	0.956	0.190	0.508	0.459	0.459	0.056	0.113	0.382	NA
Pr>Block			0.196	0.196	0.384	0.693	0.109	0.013	0.013	0.011	0.002	0.116	NA
$LSD_{0.05}$			NS	NS	NS	NS	NS	NS	NS	88	NS	NS	NA

1 – Ammonium sulfate applied immediately post planting; 2 – 15-8-4 applied immediately post planting; 3 – CAN17