Demonstration of presidedress soil nitrate test as an N managment tool

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Objective
Demonstrate the reliability of using presidedress soil NO_3-N concentration to guide N application rates in lettuce production.

Summary

Nitrate pollution of groundwater in the Salinas Valley is widely recognized to be a serious environmental issue that threatens to disrupt the vegetable industry. In response to this issue both industry groups such as the California Lettuce Research Advisory Board as well as the CDFA-FREP have supported research into practical techniques to improve N fertilizer management. One product of that research has been the adaptation of the presidedress soil nitrate test (PSNT, widely used in the Midwest to predict corn sidedress N requirements) to irrigated vegetable production.

Through a series of 11 replicated trials in commercial lettuce fields conducted in 1996-97 it was shown that sidedressing can be delayed as long as residual soil NO_3-N in the top foot of soil exceeds 20 PPM. Four subsequent trials in 1998 showed that maximum yields could be achieved in fields with lower soil NO_3-N levels by sidedressing only enough to raise soil NO_3-N concentration to 20 PPM. Collectively, these trials demonstrated an average seasonal reduction in N application of approximately 70 lb N/acre compared to the cooperating growers' N regime, with no loss of crop productivity or quality.

Eleven additional field demonstrations were conducted in 1999 on commercial farms in the Salinas Valley to demonstrate the reliability of the PSNT approach in determining sidedress N requirements of lettuce on a field-specific basis. Ten of the field demonstrations were conducted with iceberg lettuce, and one with romaine. Sites were selected to encompass a range of geographical locations, soil types, grower practices, and seasonality (spring through fall). The majority of each field received the growers' standard N management program. A 36 row-wide plot the full length of the field was established at each site, in which

sidedress N was applied based on residual nitrate-nitrogen (NO_3-N) in the top foot of soil prior to each sidedress application the grower made. In these PSNT plots no sidedress N was applied as long as soil NO_3-N was > 20 PPM; whenever soil NO_3-N was < 20 PPM the N application rate at that sidedressing was calibrated to raise soil NO_3-N up to the 20 PPM threshold. PSNT plots received the same preplant fertilization as the grower standard treatment, as well as any late-season water-run N application. Soil and plant N status were monitored throughout the season. Both the PSNT plots, and adjacent portions of the field receiving the grower standard N treatment, were harvested by commercial crews.

The cooperating growers applied an average of 247 lb N/acre, 189 lb/acre of which was applied as sidedress or water-run; the growers used 1 to 4 sidedress applications. Following the PSNT approach reduced seasonal N application by 45%, to an average of 135 lb/acre; sidedress N application in PSNT plots averaged only 77 lb/acre. The majority of the N savings came at the first sidedressing (SD#1); only 3 of the 11 fields were below the 20 PPM soil NO_3-N threshold at SD#1. Average yield was virtually identical in PSNT and grower standard plots. Evaluations made after 10-14 days of cold storage showed that N treatment had no effect on postharvest quality. Plant N monitoring showed that all plots remained above established tissue critical levels throughout the season. Less than 10% of the N applied by the growers above that applied in the PSNT plots was even taken up by the crop; soil sampling showed that the majority of this extra fertilizer N remained, in NO_3-N form, in the soil profile after harvest.

Including trials conducted in prior years, a total of 26 commercial field trials have now been conducted on lettuce evaluating PSNT as a management practice to improve N use efficiency. Using PSNT has consistently reduced N application rate (by an average of > 80 lb/acre), without loss of yield or product quality.

Methods

Nitrogen fertilization trials were conducted in 11 commercial lettuce fields in the Salinas Valley, 10 with iceberg lettuce, one with romaine. The fields were spread geographically from Castroville to Soledad, with harvest dates spread from early June to late September. Soil types ranged from sandy loam to clay. All fields were conventionally irrigated with sprinkler and/or furrow irrigation. In each field a non-replicated split-field comparison of two N management practices was conducted. The majority of each field received the cooperating growers' normal N application. A 36 row-wide plot the full length of the field was establish in which sidedress N was applied based on residual nitrate-nitrogen (NO_3-N) in the top foot of soil prior to each sidedress application the growers made. This approach is called the pre-sidedress soil nitrate testing method, or PSNT.

Research in previous years had shown that there was no short-term response of lettuce to N application if residual soil NO_3-N was greater than 20 PPM. In the PSNT plots no N was applied as long as soil NO_3-N remained > 20 PPM; whenever soil NO_3-N was < 20 PPM, N was sidedressed by the following formula:

PPM soil NO_3-N	lb N / acre applied
0 – 5	80
5 – 10	60
10 – 15	40
15 - 20	20

These application rates were designed to raise soil NO_3-N in the top foot to approximately the 20 PPM level. Soil NO_3-N analysis to determine sidedress N application rate was done by the 'quick test' method described in detail in previous FREP project reports; accuracy of this method was evaluated by comparison with conventional laboratory analysis. The PSNT plots received the same preplant fertilizer application as the standard grower treatment, as well as any water-run fertilizer.

N status of both soil and crop was monitored throughout the season. Soil samples (top 3 feet, by 1 foot increments) were collected in each plot prior to first sidedressing (SD#1), in the middle of the season, and at harvest; all samples were analyzed for NO_3-N concentration. Whole plant and whole leaf total N content was evaluated at SD#2 and at harvest; midrib NO_3-N at SD#2 was also determined.

The potential contribution of soil organic N to mineral N supply was evaluated by a laboratory incubation. Soil (top foot) collected in the grower standard plots at SD#1 was brought to approximately field capacity moisture content in a pressure apparatus and then incubated aerobically at 77^oF for 8 weeks. The change in mineral N (NH_4-N and NO_3-N) concentration over that period represented net mineralization of organic N.

In most fields the plots were harvested by commercial crews. In one field (which was harvested for bulk lettuce) coordination with the harvest crew was not possible, so comparison of productivity between the N treatments was done by determining the total weight of 100 plants selected at random from each plot. In nine of the fields the effect of N treatment on postharvest quality was evaluated on 48 heads per N treatment. These heads were transported to UC Davis and stored from 10-14 days at 41^oF. Visual quality and the severity of decay and discoloration (due to bruising and/or russet spotting) were evaluated.

Results

The cooperating growers varied widely in their N management practices, with seasonal N application ranging from 158 – 339 lb/acre (Table 1), including 1-4 sidedressings. Average grower N application was 247 lb/acre. Following the PSNT approach reduced seasonal N application by 45%, to an average of 135 lb N/acre. Much of that reduction in N application occurred a first SD#1; eight of the trial fields were above the 20 PPM soil NO_3-N threshold and received no N at SD#1 in the PSNT plot. The PSNT plots in two fields received no sidedress N all season, and two more received only a late-season water-run N application. As expected, the spring fields (planted after winter fallow conditions) had somewhat lower soil NO_3-N at SD#1 than did the summer/fall fields, which were planted after incorporation of spring crop residues.

Despite the large differences in sidedress N application, crop N uptake was similar between the N treatments at all sites (Table 2). Total above-ground crop biomass N in the grower standard plots averaged 117 lb N/acre, equivalent to 47% of seasonal N application. By contrast, the PSNT plots contained an average of 111 lb N/acre, or 81% of seasonal N application. The fertilizer uptake efficiency of the additional N used by the growers in excess of that applied to the PSNT plots was only 5% (6 lb N additional uptake with 112 lb N additional fertilizer). Whole leaf N concentration in all PSNT plots was comfortably above established tissue critical levels at both SD#2 and at harvest, indicating no N stress in any field.

In the laboratory incubation test the rate of mineralization of soil organic N ranged from 0.18 to 0.49 PPPM/day, equivalent to approximately 0.8 to 2.0 lb N/acre/day. The lower range of values were from fields of light textured soils (which typically contain less organic N than heavier textured soils), and from the spring-planted fields in which the most recent incorporation of plant residue had been the previous fall. Mineralization rates of this magnitude, if maintained through a crop cycle, could contribute substantially to crop need, particularly in a relatively low N uptake crop such as lettuce.

Average commercial yield was nearly identical between the PSNT and grower standard treatments (Table 3). In several fields (#1 and 11) yield in the grower standard plot was about 8% greater than in the PSNT plots, but these differences were offset by 6% and 17% yield differences favoring the PSNT plots in fields #3 and 7, respectively. In all other fields yields of the N treatments were within 5% of each other. Since crop N status between treatments was so similar (and well above deficiency levels) in all fields, yield differences between N treatments were apparently due to field variability. Postharvest evaluation showed virtually identical visual quality, decay and discoloration rankings between N treatments in all fields.

From an environmental standpoint, fertilizer N not taken up by the crop presents a potential threat to ground- and surface water quality. Sampling at harvest showed that the grower standard plots averaged approximately 60 lb/acre more NO_3-N in the top 3 feet of soil than did the PSNT plots. That additional NO_3-N presents a leaching hazard, particularly in fields entering the rainy winter fallow period.

The quick test technique for soil NO_3-N analysis again proved to be reasonably accurate, with the results correlating well with conventional laboratory analysis (r = 0.93, Fig. 1). Laboratory analysis will generally be of higher accuracy, and, when practical, should form the basis for applying the PSNT technique. Nitrate analysis of lettuce midribs, another diagnostic procedure widely used in the industry, did not correlate with either concurrent soil NO_3-N or leaf total N concentration (r = 0.08 and 0.05, respectively, Fig. 2). A number of midrib samples of both N treatments had NO_3-N concentration below the 4000 PPM ‘deficiency’ level commonly used for coastal lettuce, but the trial results clearly showed that N was not a limiting factor in crop growth or yield in any plot. These results, consistent with those obtained in prior years of PSNT research, suggest that midrib NO_3-N testing is of very limited value in determining field- specific sidedress N requirements.

In summary, the PSNT approach to determining sidedress N requirement was consistently successful in maintaining lettuce yield and quality, while minimizing unnecessary sidedress N application. The cost of soil NO_3-N monitoring, whether done by the quick test method or by conventional laboratory analysis, would generally be more than offset by reduced fertilizer costs. Monitoring midrib NO_3-N status did not provide reliable information on which to based sidedressing decisions.

Outreach Activities

A field day was held at site # 10 on September 28, just prior to harvest. Results of the earlier trials were distributed and discussed, and the ‘quick test’ technique for soil NO_3-N estimation was demonstrated. Approximately 25 people attended. Presentations of trial results were made at grower meetings in Seaside (October 12, 1999), Watsonville (October 27), Salinas (November 16), Morgan Hill (February 10, 2000), and Salinas (February 25). Cumulative attendance for these presentations was approximately 350. An article was prepared which was printed in the UCCE Monterey County vegetable crops newsletter, which is sent to more than 1000 people statewide.

Table 1. Site characteristics and N application rates of the 1999 PSNT trials.

Field	Location	Crop	Soil type	Harvest date	Soil NO_3-N at SD#1	Total N applied (lb/acre) Grower	Total N applied (lb/acre) PSNT	Sidedress N applied (lb/acre) Grower	Sidedress N applied (lb/acre) PSNT
1	Salinas	iceberg	clay loam	July 1	27	326	176	296	146
2	Soledad	iceberg	clay loam	June 16	18	339	189	300	150
3	Soledad	iceberg	silt loam	June 7	37	213	124	189	100
4	Salinas	iceberg	clay	June 14	10	270	230	210	170
5	Castroville	iceberg	clay loam	Aug 12	26	158	51	122	15
6	Chualar	iceberg	sandy loam	Aug 31	59	276	116	160	0
7	Soledad	iceberg	clay loam	Aug 27	39	307	142	205	40
8	Salinas	iceberg	clay	Sept 28	15	198	146	144	92
9	Salinas	iceberg	clay loam	Sept 24	26	250	130	220	100
10	Soledad	iceberg	silt loam	Sept 30	53	207	112	95	0
11	Castroville	romaine	clay loam	Sept 22	55	173	68	137	32
ave					**33**	**247**	**135**	**189**	**77**

Table 2. Nitrogen status of PSNT and grower standard plots.

Field	N treatment	% leaf N SD#2	% leaf N harvest	% N in harvested head	Midrib NO_3-N at SD#2	Total crop biomass N (lb/acre)
1	grower	4.9	4.0	3.8	10,600	127
	PSNT	4.5	3.7	3.5	8,500	119
2	grower	4.4	4.1	3.9	5,700	129
	PSNT	4.4	4.0	3.8	6,900	125
3	grower	3.8	3.8	3.6	3,200	114
	PSNT	3.7	3.6	3.4	3,500	121
4	grower	3.9	3.1	2.9	8,600	108
	PSNT	4.0	3.0	2.8	9,200	96
5	grower	4.4	4.2	4.0	11,800	169
	PSNT	4.6	4.1	3.9	12,100	155
6	grower	4.2	3.5	3.6	7,700	112
	PSNT	4.0	3.1	3.3	7,900	107
7	grower	5.0	4.0	3.5	6,700	128
	PSNT	4.4	3.9	3.3	7,700	114
8	grower	4.3	3.0	2.7	3,000	94
	PSNT	4.4	3.1	2.7	3,300	94
9	grower	4.6	3.7	3.0	9,900	76
	PSNT	4.8	3.5	2.9	9,400	70
10	grower	4.2	3.3	2.8	10,800	107
	PSNT	4.2	3.6	2.9	8,800	106
11	grower	4.2	3.3	4.0	11,200	
	PSNT	4.2	3.4	3.9	8,900	
ave	**grower**	**4.4**	**3.7**	**3.5**	**8,100**	**117**
	PSNT	**4.3**	**3.6**	**3.4**	**7,800**	**111**

Table 3. Effect of N treatment on lettuce yield and postharvest quality.

Field	N treatment	Boxes/acre			Bulk wt. harvested (lb/acre)	Postharvest rating		
		24s	30s	Total		Visual quality	Decay	Discoloration
1	grower	963		963		6.8	1.8	1.5
	PSNT	893		893		6.7	1.5	1.3
2	grower	760	75	835		7.1	1.3	1.8
	PSNT	730	73	803		7.2	1.3	1.8
3	grower	850	92	942		7.0	2.1	2.5
	PSNT	1013	93	1106		7.1	1.9	2.3
4	grower	595	324	919		6.9	1.6	1.6
	PSNT	663	219	882		6.8	1.8	1.5
5	grower	1013		1013		6.5	2.1	1.7
	PSNT	982		982		7.1	1.9	2.0
6	grower				32,900			
	PSNT				34,600			
7	grower	1024		1024		6.1	2.5	2.3
	PSNT	1089		1089		6.8	2.3	2.1
8	grower	813	123	936				
	PSNT	774	114	888				
9	grower	470		470		6.4	2.3	2.2
	PSNT	470		470		6.6	2.1	2.1
10	grower	1040	4	1044		6.9	2.0	2.0
	PSNT	968	23	991		6.7	1.7	2.1
11	grower				32,600	7.3	1.5	
	PSNT				29,900	7.2	1.5	
ave	**grower**	**836**	**69**	**905**	**32,750**	**6.7**	**2.0**	**2.0**
	PSNT	**842**	**58**	**900**	**32,250**	**6.9**	**1.8**	**1.9**

842

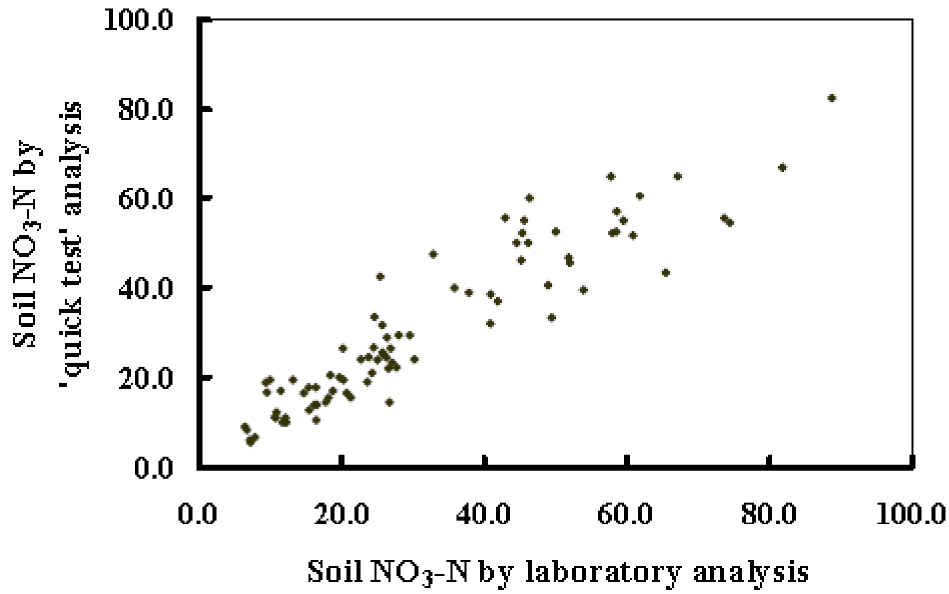

Fig. 1. Correlation of the 'quick test' and laboratory analysis for determination of soil NO_3-N concentration.

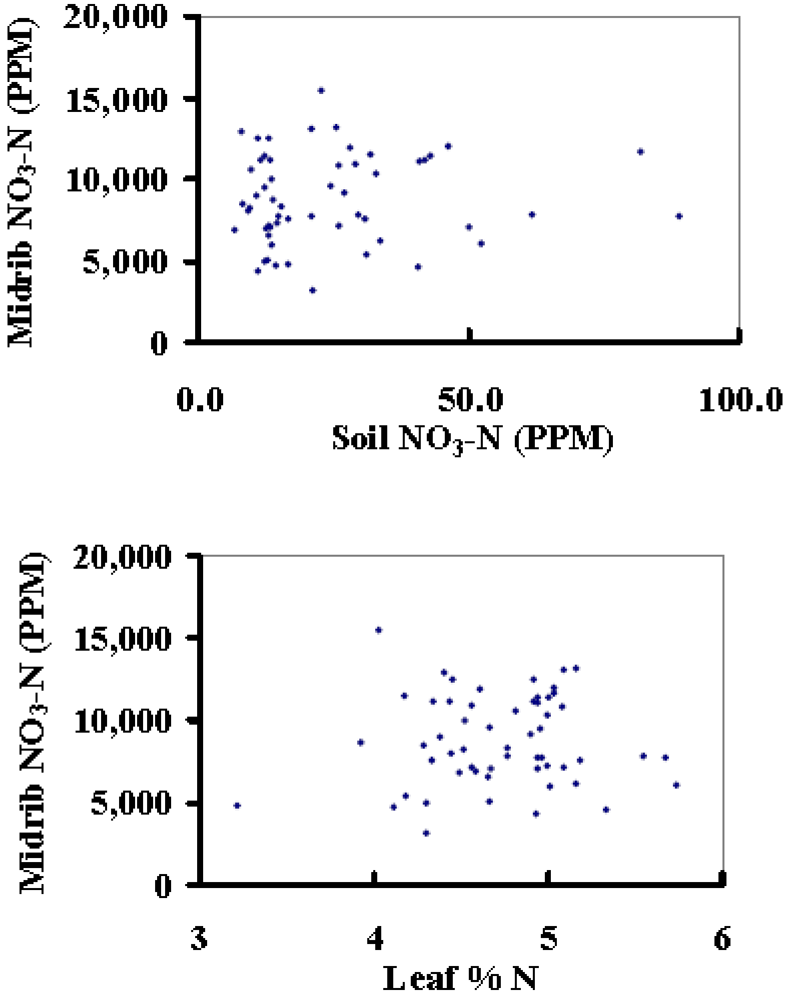

Fig. 2. Correlation of lettuce midrib NO_3-N with concurrent measures of soil NO_3-N or whole leaf total N concentration.