PRE-SIDEDRESS SOIL NITRATE TESTING (PSNT) IMPROVES N MANAGEMENT IN LETTUCE PRODUCTION

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ABSTRACT
A series of 11 replicated trials in commercial iceberg lettuce (Lactuca sativa L.) fields conducted in 1996-97 showed that sidedressing could be delayed with no loss of crop productivity or quality as long as residual soil NO_3-N in the top foot of soil exceeded 20 ppm at the time of initial sidedress N application. Ten non-replicated field demonstrations were conducted in 1999 on commercial farms in the Salinas Valley to determine the reliability of the pre-sidedress soil nitrate testing (PSNT) approach in determining sidedress N requirements of lettuce on a field-specific basis, regardless of initial residual soil NO_3-N concentration. 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. 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 254 lb N/acre, 194 lb/acre of which was applied as sidedress or water-run. Following the PSNT approach reduced seasonal N application by 44%, to an average of 142 lb/acre; sidedress N application in PSNT plots averaged only 81 lb/acre. 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. We conclude that the use of PSNT is a reliable technique that can dramatically improve N use efficiency and reduce NO_3-N pollution potential.

INTRODUCTION

The pollution of groundwater with nitrate of fertilizer origin has been recognized as a serious environmental issue in areas of intensive agriculture around the world. The problem is particularly severe in the coastal valleys of central California, where many wells now exceed the US Environmental Protection Agency drinking water standard of 10 ppm NO_3-N. Production of cool-season vegetables such as lettuce dominates agriculture in these valleys. Fields in vegetable rotations typically produce two or three crops annually, with frequent irrigation and N application rates far in excess of N removal in harvested product. Many N fertilizer rate studies have been conducted on lettuce, with widely varying results. Gardner and Pew (1972, 1974) reported that head lettuce yields peaked with 90-135 lb/acre fertilizer N, while Welch et al. (1979) and MacKay and Chipman (1961) reported yield increases up to at least 220 lb/acre N. This variability in crop response to applied N undoubtedly reflected differences among sites in soil characteristics and irrigation management. Clearly, a reliable method to predict field-specific N requirement is needed.

Presidedress soil NO_3-N testing (PSNT) has been shown to be effective in assessing sidedress N requirement in both rainfed (Heckman et al., 1995; Fox et al., 1989; Magdoff, 1991; Schmitt and Randall, 1994) and irrigated (Spellman et al., 1996) corn (*Zea Mays* L.) production. In these studies soil NO_3-N concentration (top foot) greater than approximately 20 ppm when corn was 6 inches tall (the growth stage at which sidedressing is usually done) indicated that crop response to applied N was unlikely. PSNT in corn production has been so widely applicable because in-season soil NO_3-N level is an indirect measurement of soil N mineralization potential; also, most soil NO_3-N present at the time of sampling will remain available for crop uptake, since the crop N uptake is accelerating at that point in the season, and in-season NO_3-N leaching losses tend to be small (Magdoff, 1991). PSNT is most effective at identifying fields in which no response to applied N is likely; it has been less effective in predicting appropriate sidedress N rates in fields testing below the sufficiency threshold (Meisinger et al., 1992; Fox et al., 1989; Heckman et al., 1995).

In previous work (Hartz et al, 2000) we showed that sidedress N fertilization could be delayed or eliminated in lettuce fields with > 20 ppm soil NO_3-N at the time of first sidedressing. The objective of the study reported here was to determine whether PSNT was a reliable N management tool in irrigated lettuce production, regardless of initial residual soil NO_3-N concentration.

MATERIALS AND METHODS

Nitrogen fertilization trials were conducted in 10 commercial lettuce fields in the Salinas Valley. 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 program. A 36 bed-wide plot the full length of the field was establish in which sidedress N was applied based on residual NO_3-N in the top foot of soil prior to each sidedress application the grower made.

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 Hartz et al (2000); accuracy of this method was evaluated by comparison with conventional laboratory analysis of 2N KCl extracts of these field-moist soils. 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) and at harvest; all samples were analyzed for NO_3-N concentration by conventional laboratory technique. 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 moisture equilibrated in a pressure apparatus at 0.03 MPa and then incubated aerobically at 77°F 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 all fields both the PSNT and grower plots were harvested by commercial crews. In 8 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°F.

Visual quality and the severity of decay and discoloration (due to bruising and/or russet spotting) were evaluated. Visual quality was rated on a scale of 1 – 10, with 10 being optimum quality. Decay and discoloration were rated on a scale of 1 – 5, with 1 being no decay or discoloration.

RESULTS AND DISCUSSION

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 seasonal grower N application was 254 lb/acre. Following the PSNT approach reduced seasonal N application by 44%, to an average of 142 lb N/acre. Much of that reduction in N application occurred at first SD#1; 7 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 status 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 only 46% of seasonal N application. By contrast, the PSNT plots contained an average of 111 lb N/acre, or 78% 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 ppm/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.

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 presented 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, a 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). 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 base sidedressing decisions.

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

Field	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	clay loam	July 1	27	326	176	296	146
2	clay loam	June 16	18	339	189	300	150
3	silt loam	June 7	37	213	124	189	100
4	clay	June 14	10	270	230	210	170
5	clay loam	Aug 12	26	158	51	122	15
6	sandy loam	Aug 31	59	276	116	160	0
7	clay loam	Aug 27	39	307	142	205	40
8	clay	Sept 28	15	198	146	144	92
9	clay loam	Sept 24	26	250	130	220	100
10	silt loam	Sept 30	53	207	112	95	0
ave			**31**	**254**	**142**	**194**	**81**

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
ave	**grower**	**4.4**	**3.7**	**3.5**	**7,800**	**117**
	PSNT	**4.3**	**3.6**	**3.4**	**7,700**	**111**

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

Field	N treatment	Boxes/acre 24s [z]	Boxes/acre Total	Bulk wt. harvested (lb/acre)	Postharvest rating [y] 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	835		7.1	1.3	1.8
	PSNT	730	803		7.2	1.3	1.8
3	grower	850	942		7.0	2.1	2.5
	PSNT	1013	1106		7.1	1.9	2.3
4	grower	595	919		6.9	1.6	1.6
	PSNT	663	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	936				
	PSNT	774	888				
9	grower	470	470		6.4	2.3	2.2
	PSNT	470	470		6.6	2.1	2.1
10	grower	1040	1044		6.9	2.0	2.0
	PSNT	968	991		6.7	1.7	2.1
ave	**grower**	**836**	**905**		**6.7**	**2.0**	**2.0**
	PSNT	**842**	**900**		**6.9**	**1.8**	**1.9**

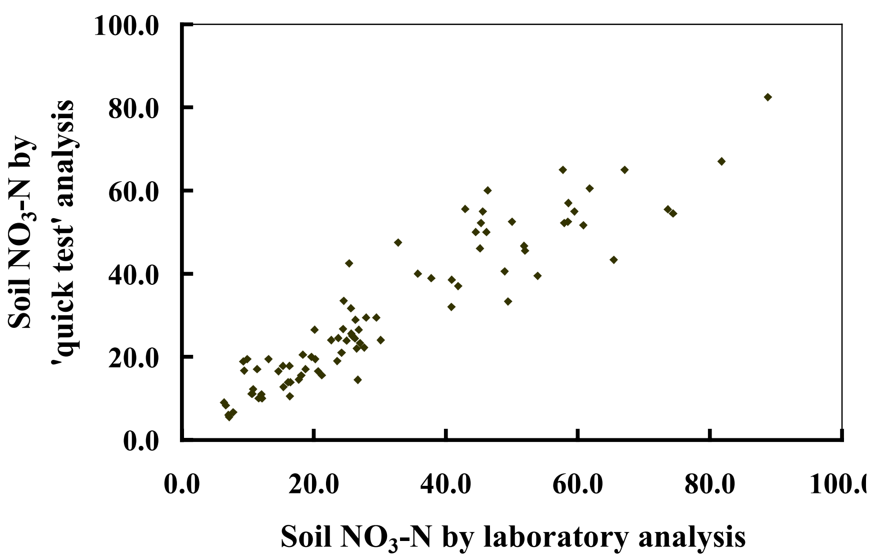

Fig. 1. Correlation of the 'quick test' and laboratory analysis for determination of soil NO_3-N concentration.

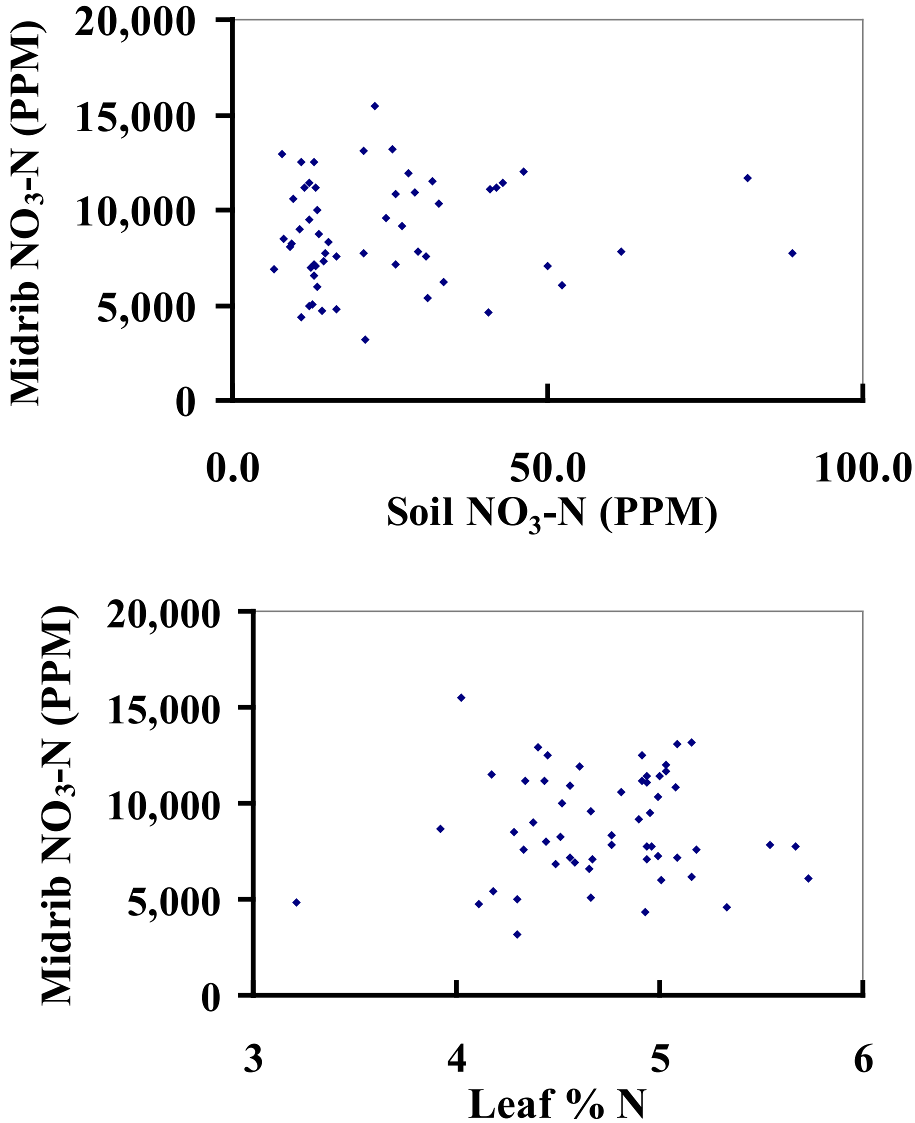

Fig. 2. Correlation of lettuce midrib NO_3-N with concurrent measures of soil NO_3-N or whole leaf total N concentration.