Pre-sidedress Soil Nitrate Testing Identifies Processing Tomato Fields Not Requiring Sidedress N Fertilizer

Henry Krusekopf, Jeff Mitchell and Tim Hartz
Department of Vegetable Crops and Weed Science, University of California, Davis
Telephone (559) 646-6565, Fax (559) 646-6593, (mitchell@uckac.edu)

Gene Miyao
University of California, Cooperative Extension Yolo and Solano Counties, Woodland, CA

Don May
University of California, Cooperative Extension Fresno County, Fresno, CA

Michael Cahn
University of California, Cooperative Extension Monterey County, Salinas, CA

Abstract

Overuse of chemical N fertilizers has been linked to nitrate contamination of both surface and ground water. Excessive use of fertilizer also is an economic loss to the farmer. Typical N application rates for processing tomato (*Lycopersicon esculentum* Mill.) production in California are 150 to 250 kg_ha^{-1}. The contributions of residual soil NO_3-N and in-season N mineralization to plant nutrient status are generally not included in fertilizer input calculations, often resulting in overuse of fertilizer. The primary goal of this research was to determine if the pre-sidedress soil nitrate test (PSNT) could identify fields not requiring sidedress N application to achieve maximum tomato yield; a secondary goal was to evaluate tissue N testing currently used for identifying post-sidedress plant N deficiencies. Field experiments were conducted during 1998 and 1999. Pre-sidedress soil nitrate concentrations were determined to a depth of 60 cm at ten field sites. N mineralization rate was estimated by aerobic incubation test. Sidedress fertilizer was applied at six incremental rates from 0 to 280 kg_ha^{-1} N, with six replications per field. At harvest, only four fields showed a fruit yield response to fertilizer application. Within the responsive fields, fruit yields were not increased with sidedress N application above 112 kg_ha^{-1}. Yield response to sidedress N did not occur in fields with pre-sidedress soil NO_3-N levels >16 mg·kg^{-1}. Soil sample NO_3-N levels from 30 cm and 60 cm sampling depth were strongly correlated. Mineralization was estimated to contribute an average of 60 kg_ha^{-1} N between sidedressing and harvest. Plant tissue NO_3-N concentration was found to be most strongly correlated to plant N deficiency at fruit set growth stage. Dry petiole NO_3-N was determined to be a more accurate indicator of plant N status than petiole sap NO_3-N measured by a nitrate-selective electrode. The results from this study suggested that N fertilizer inputs could be reduced substantially below current industry norms without reducing yields in fields identified by the PSNT as having residual pre-sidedress soil NO_3-N levels >16 mg·kg^{-1} in the top 60 cm.

Introduction

A number of studies have documented a correlation between NO_3-N concentration in the top 30 cm of soil prior to sidedressing and crop yield response to sidedress N (Magdoff et al., 1984; Hartz et al., 2000). A pre-sidedress nitrate test (PSNT) can thus indicate a critical level of soil NO3-N above which crop yield will not be increased by subsequent sidedress N application. The objective of our research was to determine if the PSNT technique is useful for predicting the necessity of sidedress N fertilizer on a field-by-field basis in commercial processing tomato production in California.

Materials and Methods

The project was carried out at 3 commercial farm sites and one research station site in 1998, and 5 farm sites and one research station site in 1999 (Table 1). At the two research station sites (fields 4 and 8), an unfertilized winter cover crop of wheat (*Triticum aestivum* L.) and a summer crop of Sudangrass (*Sorghum sudanense* [Piper] Stapf) were grown, mowed, and all above-ground residue removed prior to planting of tomatoes in order to reduce soil nitrate concentrations. Commercial tomato plantings followed standard crop rotations for the region and the individual grower's cultural practices including pre-plant and/or pre-sidedress N fertilization (Table 1). Common hybrid processing tomato varieties were grown at all locations (Table 1).

All fields received a single sidedress application of urea at rates between 0 to 280 kg_ha^{-1} N in six increments (0, 56, 112, 168, 224, 280 kg_ha^{-1} N) when plant height was approximately 10-15 cm. Fertilizer was banded using a standard applicator to a depth of 15 cm, and at a distance of 15 cm from the plant row. Experimental design in all fields was randomized, complete-block with all treatments represented in each field. All fields were furrow irrigated, and other cultural practices typical of the commercial tomato industry were followed.

Prior to sidedress N application, pre-sidedress soil nitrate testing was conducted at all sites to a depth of 60 cm in 30 cm increments. Soil cores (2.5 cm diameter) were taken from shoulders of beds approximately 60 cm away from bed centers to avoid pre-sidedress fertilizers applied by individual growers (Table 1) and analyzed for nitrate using standard procedures at the UC DANR Analytical Laboratory.

Table 1. Soil N concentration prior to sidedress fertilizer application, soil organic matter (SOM) and soil organic N as measured by depth, grower's fertilizer N inputs, and tomato cultivar.

		NO_3-N (mg kg^{-1})		SOM (g kg^{-1})	Organic N (g kg^{-1})	Grower inputs (kg ha^{-1} N)		
Year	Field	0 - 30 cm	0 - 60 cm	0 - 30 cm	0 - 30 cm	pre-sidedress	sidedress[y]	Cultivar
1998	1	6.3	7.2	7.9	0.8	30	119	BOS 3155
	2	7.4	8.8	8.3	0.9	51	99	La Rossa
	3	22.3	28.5	8.3	0.8	30	119	BOS 3155
	4[z]	8.5	6.1	7.3	0.7	28	-----	Heinz 8892
1999	5	7.2	10.9	6.8	0.7	127	146	Lipton 599
	6	23.7	20.7	6.8	0.9	64	198	Heinz 9557
	7	16.0	13.3	7.1	0.8	44	198	CXD 152
	8[z]	4.7	3.5	8.0	0.8	13	-----	Heinz 8892
	9	15.7	15.8	22.5	1.8	7	134	BOS 3155
	10	10.1	12.2	15.2	1.1	16	134	RC 32

[y] sidedress N inputs by growers in non-experimental rows within trial fields.
[z] fields at University of California's Westside Research and Extension Center received only experimental sidedress N inputs.

Net mineralization of soil N was determined following eight-week aerobic incubations of the composite samples (procedures outlined in Krusekopf, 2001)

Approximately 30 petioles (third petiole from a growing point) were collected from plants in all field plots at three plant growth stages: early bloom, fruit set (earliest fruit approximately 2.5 cm diameter), and fruit bulking/early fruit color development and analyzed for NO_3-N using the method of Carlson et al. (1990).

Fruit yields were determined by mechanically harvesting plots into a scale-equipped GTO dumpster weigh wagon. Relative fruit yield for each treatment was calculated by dividing the mean yield for each treatment by the mean of the highest yielding treatment in that field. Fields, described by the terms N-limited or N-responsive, were defined as those showing significant yield response to fertilizer treatment.

Results

Concentrations of soil NO_3-N, organic matter (SOM), and total organic N as measured by pre-sidedress soil testing varied widely among fields (Table 1). Pre-sidedress soil NO_3-N levels across all fields ranged from 3.5 to 28.5 mg·kg^{-1} N. However, there was little difference (r^2=0.84) in soil NO_3-N levels within individual fields between 0 to 30 cm and 0 to 60 cm soil depth. SOM (6.8 to 22.5 g·kg^{-1}) and total soil organic N content (0.7 to 1.7 g·kg^{-1}) were within typical ranges observed for Central Valley soils. Total N application (pre-sidedress plus sidedress N) by commercial growers in non-experimental rows at project sites ranged from 140 to 274 kg_ha^{-1} N, consistent with typical input rates used by the industry.

Table 2. Effect of sidedress N rate on fruit yield in fields with significant N response.

Sidedress	Fruit yield (t ha^{-1})			
kg ha^{-1} N	Field 4	Field 8	Field 9	Field 10
0	97.2^{z}	88.9^{z}	112.0^{z}	77.5^{z}
56	118.5^{z}	115.6	119.4	88.5
112	129.5	123.0	121.4	90.3
168	138.0	120.7	118.5	91.2
224	137.8	121.0	124.1	89.4
280	141.6	95.4	116.3	87.8

^{z} indicates that mean yield of treatment level was significantly different (*P*=0.05) than the combined mean yield of all higher treatment rates, as determined by orthogonal contrast

Significant yield response to sidedress N application was found in only four of ten fields (Table 2). This overall lack of response to sidedress N, and the observation that even in responsive fields yield increase was limited to the lower treatment levels, suggested that linear and quadratic trend analysis was not the most appropriate analytical technique. Therefore, yield data were analyzed by orthogonal contrasts comparing each N treatment level against all higher N treatment rates. In fields 8, 9 and 10 the application of any sidedress N increased yield compared to unfertilized plots, but yields at 56 kg_ha^{-1} N were not significantly different to those achieved with higher fertilization rates. In field 4, a significant yield increase was observed up to 112 kg_ha^{-1} N. There were no fields with yield response to sidedress N application that had pre-sidedress soil NO_3-N concentrations above 15.7 mg·kg^{-1} at 0 to 30 cm depth (Figure 1A) or 15.8 mg·kg^{-1} at 0 to 60 cm depth (Figure 1B).

Fruit maturity and quality parameters (percent red or percent rotten fruit, blended fruit color, and SS) were unaffected by N treatment in most fields (data not shown).

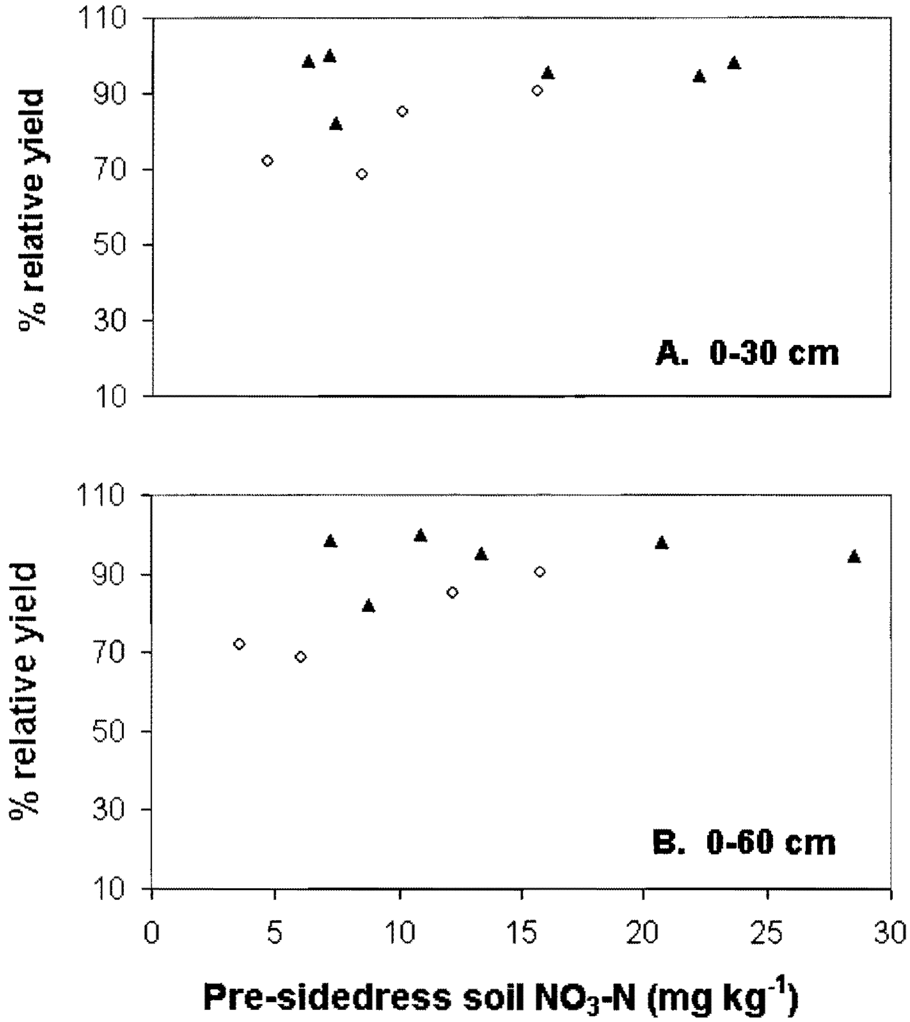

Figure 1. Relationship of pre-sidedress soil NO_3-N as measured at (A.) 0 to 30 cm and (B.) 0 to 60 cm depths and field mean of relative fruit yield by N treatment rate. Symbols indicate fields with (_) or without (_) significant yield response to sidedress N application, as determined by orthogonal contrast.

Discussion

This study showed that both university recommended and common industry sidedress N application rates for processing tomato production in California are excessive and could be substantially reduced without loss of yield or fruit quality. Of the ten fields utilized in this study, only four fields had any significant yield response to sidedress N, and none of these fields demonstrated yield response to sidedress N application above 112 kg_ha^{-1} N. Furthermore, fruit quality was virtually unaffected by sidedress N rate.

Pre-sidedress soil nitrate testing was a useful indicator of soil NO_3-N availability. No fields used for this study that had >16 $mg{\cdot}kg^{-1}$ NO_3-N in the top 60 cm of soil (approximately 140 kg_ha^{-1} NO_3-N, at a typical bulk density of 1.35 $g{\cdot}cm^{-3}$) prior to sidedress demonstrated any yield response to sidedress N application. This observation indicates the possibility of a critical level of residual soil NO_3-N that will be sufficient to sustain proper plant growth and maximum yield without sidedress N application. The similarities between soil NO_3-N levels at the 0 to 30 cm and 0 to 60 cm depths suggested that either sampling depth could be used to estimate NO_3-N availability.

The lack of yield response to sidedress N application in fields with >16 $mg{\cdot}kg^{-1}$ NO_3-N prior to sidedressing was not surprising, since these soil NO_3-N levels represented more than 60% of seasonal total N uptake (200 kg_ha^{-1} N) for high-yield tomato production (Maynard and Hochmuth, 1997). Pre-sidedress residual soil N in project fields was augmented by in-season N mineralization of soil organic matter. Based on the incubation results, N mineralization could have provided an additional 40 to 80 kg_ha^{-1} N to plants during the growing season. Therefore, in-season mineralization of organic N, coupled with existing soil NO_3-N estimated by PSNT, are likely factors in the overall weak crop response to sidedress N.

A PSNT level of ≈16 $mg{\cdot}kg^{-1}$ NO_3-N in the top 0 to 60 cm (or 0 to 30 cm) of soil could represent a conservative threshold level for determining whether sidedress fertilization is required. This suggested PSNT threshold level for processing tomatoes is slightly lower than those determined for corn (*Zea mays* L.) production in the Northeastern and Midwestern U.S. (Fox et al., 1989; Heckman et al., 1995; Magdoff, 1991; Schmitt and Randall, 1994; Spellman et al., 1996), and California coastal valley lettuce (*Lactuca sativa* L.) and celery (*Apium graveolens* L.) production (Hartz et al., 2000). These studies generally set PSNT thresholds between 20 to 25 $mg{\cdot}kg^{-1}$ NO_3-N.

The results of this study support the use of a pre-sidedress soil nitrate test (PSNT) to identify California processing tomato fields that are unlikely to respond to sidedress N application. Fields with pre-sidedress soil nitrate concentrations of >16 $mg{\cdot}kg^{-1}$ NO_3-N in the top 30 cm of soil would have a low probability of increased yields with sidedress N application. Furthermore, the limited response to sidedress N application, even in fields with minimal residual NO_3-N levels, suggested that sidedress N rates currently used by the commercial tomato industry could be substantially reduced with no loss of yield or fruit quality. Dry petiole NO_3-N sampling at the fruit set stage was determined to be the most effective indicator of post-sidedress plant N deficiency. Plants with dry petiole tissue nitrate-N levels of <2500 $mg{\cdot}kg^{-1}$ NO_3-N at fruit set are likely to be N-deficient and could benefit from late-season fertilizer applications.

Acknowledgement

This summary presentation to the 2002 Annual Meeting of the Califonria Chapter of the Agronomy Society of America has been excerpted from the MS Thesis by Henry Krusekopf submitted in partial fulfillment of his degree requirements at the University of California, Davis. An expanded version of this paper is in press in HortScience.

References Cited

Carlson, R.M., R.I. Cabrera, J.L. Paul, J. Quick, and R.Y. Evans. 1990. Rapid direct determination of ammonium and nitrate in soil and plant tissue extracts. Commun. In Soil Sci. Plant Anal. 21:1519-1529.

Fox, R.H., G.W. Roth, K.V. Iversen, and W.P. Piekielek. 1989. Soil and tissue nitrate tests compared for predicting soil nitrogen availability to corn. Agron. J. 81:971-974.

Hartz, T.K., W.E. Bendixen, and L. Wierdsma. 2000. The value of presidedress soil nitrate testing as a nitrogen management tool in irrigated vegetable production. HortScience 35:651-656.

Krusekopf, H.H. 2001. Pre-sidedress soil nitrate testing identifies processing tomato fields not requiring sidedress N fertilizer. MS Thesis. University of California, Davis.

Magdoff, F.R., D. Ross and J. Amadon. 1984. A soil test for nitrogen availability to corn. Soil Sci. Soc. Am. J. 48:6:1301-1305.

Magdoff, F.R. 1991. Understanding the Magdoff pre-sidedress nitrate test for corn. J. Prod. Agric. 4:3:297-305.

Maynard, D.N. and G.J. Hochmuth. 1997. Knott's handbook for vegetable growers. 4th ed. John Wiley and Sons, Inc., New York.

Schmitt, M.A. and G.W. Randall. 1994. Developing a soil nitrogen test for improved recommendations for corn. J. Prod. Agr. 7:328-334.

Spellman, D.E., A. Rongni, D.G. Westfall, R.M. Waskom, and P. Soltanpour. 1996. Pre-sidedress nitrate soil testing to manage nitrogen fertility in irrigated corn in a semi-arid environment. Commun. Soil Sci. Plant Anal. 27:561-574.