Soil Testing to Optimize Nitrogen Management for Processing Tomatoes

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Project Objectives:

1) Develop and extend information on pre-sidedress soil testing as a means for optimizing nitrogen management for processing tomatoes

2) Evaluate the effectiveness and utility of fresh petiole sap testing using the Cardy Meter for decision making in tomato nitrogen management

3) Investigate relationships between fresh sap nitrogen testing, dry tissue testing, and current sufficiency levels used by commercial testing labs for nitrogen fertilizer recommendations

Executive Summary:

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 $kg \cdot ha^{-1}$. 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 $kg \cdot ha^{-1}$ 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 $kg \cdot ha^{-1}$. Yield response to sidedress N did not occur in fields with pre-sidedress soil NO_3-N levels >16 $mg \cdot kg^{-1}$. 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 $kg \cdot ha^{-1}$ 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 $mg \cdot kg^{-1}$ in the top 60 cm.

Introduction:

Excessive N application is an economic loss to growers in terms of unnecessary input costs, and may also result in greater pest management problems (Jannson and Smilowitz, 1986; Rossi and Strong, 1991). From an environmental perspective, overuse of chemical N fertilizer has been associated with increased levels of nitrate-nitrogen (NO_3-N) in ground and surface water (Blackmer, 1987). For these reasons, development of a better system for recommending fertilizer rates is a major goal of agricultural research.

Nitrogen is a major yield-limiting factor in row-crop production systems in California's Central Valley (Clark et al., 1999). Processing tomatoes are one of the state's most important crops in value and acreage, and California accounts for about 90% of total U.S. production (Flint, 1998). The largest N fertilizer input for processing tomatoes generally occurs at sidedressing when plants are 10 to 15 cm tall. Recommended sidedress N application rates for processing tomato production are 134 to 202 $kg{\cdot}ha^{-1}$ N (Flint, 1998), but growers typically apply 150 to 250 $kg{\cdot}ha^{-1}$ N to ensure maximum yield (Hartz, personal communication). Fall and early spring soil NO_3-N analyses are often conducted prior to planting as part of routine, comprehensive soil analysis (P, K, micronutrients, etc.), but results are not commonly used for determining sidedress N inputs.

Research by Magdoff et al., 1984; Magdoff, 1991, and others (Fox et al., 1989; Heckman et al., 1995; Schmitt and Randall, 1994; Spellman et al., 1996) has shown a correlation between NO_3-N concentration in the top 30 cm of soil prior to sidedressing and corn yield response to sidedress N. Additional research by Hartz et al. (2000) has documented a similar correlation for California coastal valley lettuce and celery production. The evidence suggests that a pre-sidedress soil nitrate test (PSNT) can indicate a critical level of soil NO_3-N above which crop yield will not be increased by subsequent sidedress N application. Although the PSNT method has not been widely used to determine specific sidedress N application rates in fields testing below a critical level, it has been found helpful at identifying fields where no sidedress N fertilizer is required to maintain yields (Fox et al., 1989; Heckman et al., 1995; Meisinger et al., 1992).

The main objective of our research was to determine if the PSNT technique was useful for predicting the necessity of sidedress N fertilizer on a field-by-field basis in conventional processing tomato production in California. We further sought to establish a critical level of pre-sidedress soil NO_3-N above which no fruit yield increase would occur with subsequent sidedress N application. A secondary goal was to test methods of plant tissue analyses for indicating post-sidedress N deficiency.

Work Description:

Task 1 **Conduct on-farm demonstration strip trials to determine production functions between pre-sidedress soil nitrogen testing and yields, and estimated net returns from fertilization**

Subtask 1.1 **Secure grower cooperators and field sites for processing tomato on-farm strip trials with a range of existing soil N levels and precious cropping histories**

Subtask 1.2 **Conduct pre-sidedress soil nitrogen testing at each field site and at the University of California West Side Research and Extension Center (WSREC)**

Subtask 1.3	**Apply sidedress applications of nitrogen fertilizer at thinning and/or layby. Grower cooperators carry out in-season crop cultural practices**
Subtask 1.4	**Plant tissue nitrogen sampling**
Subtask 1.5	**Yield and quality determinations**
Subtask 1.6	**Determine production function relationships between pre-sidedress soil nitrogen levels and yields, and estimate net returns from various fertilization rates**

California's Central Valley is characterized by a semi-arid Mediterranean climate. Total annual rainfall in the Central Valley ranges from 400 to 500 mm in the north to 180 to 200 mm in the south, with rainfall occurring almost exclusively during the winter months (November-March). Summer irrigation of crops is required with water typically supplied from river-fed canal systems and/or on-farm wells. NO_3-N concentration in irrigation water is typically <5 mg·kg^{-1}. Mean daytime Central Valley temperatures are 23° to 35°C during the summer growing season. Most agricultural soils in the Central Valley are recently deposited alluvium. Soil organic matter is typically <10 g·kg^{-1}, and organic N content <1 g·kg^{-1}. Predominate soil classification at each site was: Cerini sandy loam (field 1), fine-loamy, mixed, superactive, thermic Fluventic Haplocambids; Ciervo, wet-Ciervo complex, saline-sodic (field 2), fine, smectitic, thermic Vertic Haplocambids; Cerini clay loam (fields 3, 4, 6, 7, 8), fine-loamy, mixed, superactive, thermic Fluventic Haplocambids; Excelsior sandy loam (field 5), coarse-loamy, mixed, superactive, calcareous, thermic Typic Torrifluvents; Yolo silt loam (field 9), fine-silty, mixed, nonacid, thermic Mollic Xerofluvents; Shanghai Variant (field 10), sandy over loamy, mixed, nonacid, thermic Aquic Xerofluvents.

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. Research station fields had four replicates (22 m *x* 1.5 m) and farm sites had six replicates (30 to 60 m *x* 1.5 m). 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). Each soil sample consisted of eight subsamples per replicate block per depth; all samples were stored at 4°C to inhibit N mineralization until processed. A 10 g subsample of field-moist soil from each sample was placed in a tube with 40 ml of 2 N KCl, shaken by hand until soil aggregates were thoroughly dispersed, allowed to settle until the supernatant was cleared, then the liquid decanted. Samples were sent to the University of California's Division of Agriculture and Natural Resources (UC DANR) Analytical Laboratory for determination of NO_3-N concentration using a diffusion-conductivity analyzer (Carlson et al., 1990). Dry weight NO_3-N concentration was calculated for each sample by using pre- and post-oven-dried weights.

Soil samples from the 0 to 30 cm depth from three replicate blocks in each field were mixed together to make composite samples that were air-dried, ground, and assayed for total N (combustion gas analyzer method; Pella, 1990), and organic matter (modified Walkley-Black; Nelson and Sommers, 1982).

Net mineralization of soil N was determined following eight-week aerobic incubations of the composite samples described in the preceding paragraph. Samples were air-dried, sieved through 5-mm mesh screen, and moisture equilibrated at 0.03 MPa in a pressure apparatus for 3 days. Subsamples of each field soil were then immediately extracted in 2 N KCl for determination of dry weight mineral N (NH_4-N plus NO_3-N) using a diffusion-conductivity analyzer (Carlson et al., 1990) and the procedures described previously. The remainder of each subsample was incubated aerobically at 29°C in sealed 800 ml containers to maintain moisture content. Head space in each container was over 700 ml, providing sufficient oxygen for microbial activity. Containers were also opened after 4 weeks for additional aeration. After 8 weeks, four subsamples of each field soil were analyzed for dry weight mineral N concentration using a diffusion-conductivity analyzer (Carlson et al., 1990) and the procedure previously described. Nitrogen mineralization rate was calculated as the increase in mineral N over the incubation period. Total soil N was determined by the method of Pella (1990), and soil organic matter by the method of Nelson and Sommers (1982).

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. Petioles were oven-dried, ground, extracted with 2% acetic acid solution and analyzed for NO_3-N using the method of Carlson et al. (1990). During the 1999 growing season, additional plant tissue sampling was conducted. Fresh petiole samples from plants in each plot in all fields were mechanically squeezed with a modified 5-ton arbor press immediately following collection to extract fresh sap for NO_3-N measurement by a battery-operated nitrate-selective electrode (Cardy Meter, Horiba Corp., Kyoto, Japan). Whole-leaf samples (third leaf from a growing point) were collected from plants in all fields at fruit set, oven-dried, ground, and tested for total N concentration using the method of Sweeney (1989).

Fruit yields were determined by mechanically harvesting plots into a scale-equipped GTO dumpster weigh wagon (Gilmore-Tatge Mfg. Co., Inc., Clay Center, KS). Samples of unsorted fruit were collected from the harvester from each plot for determination of fruit maturity and percent defects. Fifty red fruit from each plot were evaluated for soluble solids content (SS, °brix) and blended juice color (ratio of green [566 nm] to red [650 nm] light reflected from the juice). 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.

In 2000, two additional trials were conducted at the WSREC. In the first of these, soil nitrogen had been depleted by growing a previous crop of wheat and a crop of sudangrass in 1999 with no nitrogen fertilizer, and the crops were cut and removed from the field. Tomatoes were planted March 17, 2000. The plot was direct seeded with the variety H8892, and preplant fertilizer was 100 lbs of 11-52-0. DXL510 (a proprietary product) was mixed at two quarts per acre into the nitrogen fertilizer UN32. Three nitrogen rates of 50, 100, and 150 lbs per acre were applied with the two quarts of DXL510 per acre. Comparable rates of nitrogen were 0, 50, 100, 150, 200 and 250 lbs per acre as in the previous two years. Nitrogen and DXL treatments were sidedressed at furrow depth, 12" on each side of the tomato row on May 15, 2000. This was at the first bud stage of growth of the tomato plant.

In the second trial, soil nitrogen was not depleted where the previous crop grown was cotton. The study was transplanted to H9553 on May 17. Treatments are shown in Table 5. The soil type was a Panoche clay loam. Data collected included yields by machine harvesting all tomatoes in each plot. Before fruit sorting, a five-gallon bucket of unsorted tomatoes was collected on the harvester and taken and hand sorted for red and green and broken and rotten fruit. Fifty red fruit were randomly taken from each sample and weighed for fruit weight. This 50 fruit sample was then taken to the Processing Tomato Advisory Board Quality Grading Station for % solids and fruit color.

Experimental Findings

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 $mg \cdot kg^{-1}$ 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 $g \cdot kg^{-1}$) and total soil organic N content (0.7 to 1.7 $g \cdot kg^{-1}$) were within typical ranges observed for California 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 $kg \cdot ha^{-1}$ N, consistent with typical input rates used by the industry.

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 $kg \cdot ha^{-1}$ N were not significantly different to those achieved with higher fertilization rates. In field 4, a significant yield increase was observed up to 112 $kg \cdot ha^{-1}$ N. There were no fields with yield response to sidedress N application that had pre-sidedress soil NO_3-N concentrations above 15.7 $mg \cdot kg^{-1}$ at 0 to 30 cm depth (Figure 1A) or 15.8 $mg \cdot kg^{-1}$ 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. In field 4 there was a significant quadratic response of fruit color to N rate (Table 3), with the unfertilized and the 280 treatments showing the lowest color score (most intense red color). Similarly, fruit SS showed a quadratic relationship to N rate in field 4, with the intermediate N rates having lower SS. In field 8, fruit SS decreased linearly with increasing N. Percent red and rotten fruit did not show any significant response to N rate.

Petiole NO_3-N concentration was most closely related to relative yield at the fruit set growth stage (Figure 2). Petiole NO_3-N concentration from treatments with significant yield response to N application were most clearly demarcated from non-responsive treatments at fruit set (Figure 2B). In N-responsive fields, all plants with less than 2300 $mg \cdot kg^{-1}$ petiole NO_3-N concentration at fruit set had positive yield response to sidedress N. Plants in approximately 80% of plots with dry petiole NO_3-N levels >2300 $mg \cdot kg^{-1}$ at fruit set achieved at least 95% relative yield (Figure 2B).

There was considerable variability in the relationship of petiole sap and dry petiole NO_3-N concentration. Pearson correlation (SAS Institute, 1998) determined the strongest linear relationship of petiole sap and dry petiole NO_3-N concentration was found at fruit set (r^2=.64; Figure 3). All treatments with significant yield response to N application had <40 $g \cdot kg^{-1}$ total leaf N at fruit set (Figure 4).

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 $kg \cdot ha^{-1}$ 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 $kg \cdot ha^{-1}$ 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. Similarly, Binford et al. (1992) found that the predictive value of soil nitrate tests was only slightly improved by sampling to 60 cm depth instead of 30 cm, and that the difference was probably not great enough to justify additional costs for deeper sampling. Pottker et al. (1987) found nitrate concentration in the top 0 to 30 cm of soil to be proportional to nitrate distribution in the surface 1.5 m layer of soil.

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 $kg \cdot ha^{-1}$ 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 $kg \cdot ha^{-1}$ N to plants during the growing season (Figure 5). 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.

Two of four fields with yield response to fertilizer treatment (4, 8) were located at the Westside Research Station, where an unfertilized winter cover crop had been grown, harvested, and all crop residue removed prior to tomato planting in order to lower soil nitrate concentrations (Table 1). Fields 1, 2 and 5 also had low PSNT levels, but did not show yield response to sidedress N application. This result suggested that in-season N mineralization may have been higher than the estimated range, or the crop was able to access mineral N at soil depth >60 cm.

A PSNT level of $\approx$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.

Petiole NO_3-N at fruit set stage proved to be the most accurate indicator of plant N status. Data from this study suggested a sufficiency threshold level for dried petiole NO_3-N concentration of 2300 $mg \cdot kg^{-1}$ at fruit set, below which post-sidedress plant N deficiency was likely. A more conservative deficiency level of 2500 $mg \cdot kg^{-1}$ NO_3-N at fruit set would still be considerably lower than the 4000 $mg \cdot kg^{-1}$ NO_3-N threshold suggested by Lorenz and Tyler (1983) for the same growth stage. Fruit set petiole sampling was also early enough in crop development that corrective action could be taken through later-season N fertilizer applications.

Petiole sap NO_3-N concentration as measured by the nitrate-selective electrode showed a modest relationship (r^2=.64) with dried petiole NO_3-N at fruit set, but there was no relationship at first bloom, and had a weaker correlation (r^2=.44) at fruit. Although portable nitrate-selective electrodes could be advantageous by providing results quickly in the field, evidence from this study suggested that those results would be less accurate in determining plant N deficiencies than dried petiole NO_3-N sampling.

All treatments in all fields exceeded the 30 $g \cdot kg^{-1}$ N sufficiency threshold for leaf total N suggested by Lorenz and Tyler (1983). Plants in all treatment replications defined as N-limited had $\leq$40 $g \cdot kg^{-1}$ total leaf N (Figure 4). Although there was only one year of data for whole leaf sampling in this study, the high total leaf N levels may indicate a sufficiency threshold >30 $g \cdot kg^{-1}$ at fruit set.

In the first 2000 study, there was a nitrogen response, though all treatments were not significantly different. The addition of two quarts per acre of DXL510 increased yields two to four tons per acre over the same nitrogen rate: DXL510 and 50 lbs nitrogen per acre yielded 1.75 tons per acre more than 50 lbs or nitrogen alone. DXL510 and 100 lbs nitrogen yielded 4.27 tons more per acre than 100 lbs nitrogen alone. DXL510 and 150 lbs of nitrogen increased yield 2.66 tons per acre more than 150 lbs nitrogen alone (Table 4). In the second study which was comparable to a grower's field where tomatoes followed cotton with no crops grown to deplete soil nitrogen, tomatoes yields were not significantly different between nitrogen rates (Table 5).

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.

Task 2 **Plan and conduct field days and meeting presentations that highlight the project's objectives and findings**

Field day presentations were conducted in each of the project's years as part of Tomato Day at the WSREC in each July of the project and at the January Fresno County Tomato Day meetings. Also, the findings of this project were presented at the 2000 Annual Meeting of the American Society for Horticultural Science in Orlando, FL. Finally, a manuscript was submitted and accepted for publication in *HortScience*, a journal of the American Society for Horticultural Science. A complete summary of the project's outreach activities is provided below.

Outreach

July 31, 2001. Pre-sidedress soil nitrate testing for processing tomatoes. 2001 Tomato Field Day. University of California West Side Research and Extension Center, Five Points, CA. Jeff Mitchell. Oral field presentation. 25 participants.

September 18, 2000. Soil testing to optimize nitrogen management for processing tomatoes. Annual Report Summary for 2000 Fertilizer Research and Education Program Conference. Tulare, CA.

July 31, 2000. Pre-sidedress soil nitrogen testing as a means to improve fertilizer application use efficiencies. Processing tomato field day 2000. UC West Side Research and Extension Center, Five Points, CA. 20 participants.

July 25, 2000. H.H. Krusekopf, J.P. Mitchell, T.K. Hartz, D.M. May, E.M. Miyao and M.D. Cahn. Pre-sidedress soil nitrate concentrations and yield response to fertilizer applications in processing tomatoes. Abstract. HortScience. 35(3):444. 97th International Conference of the American Society for Horticultural Science. Orlando, FL.

June 12, 2000. Sustainable tomato production – The California experience. 7th International Society for Horticultural Science Symposium on the processing tomato. Hyatt Regency. Sacramento, CA. 50 participants.

January 28, 2000. Nutrition – Fertility. Los Gatos Grower Education Day. Sponsored by Novartis Crop Protection. Harris Ranch, Coalinga, CA. 29 participants.

January 26, 2000. Nitrogen management program in processing tomatoes. Quad County Tomato Day. San Joaquin, Stanislaus, Sacramento and Contra Costa Counties. UC Cooperative Extension Auditorium. Stockton, CA. 150 participants.

January 6, 2000. Optimizing nitrogen management with pre-sidedress soil testing. South Sacramento Valley Processing Tomato Production Meeting. Heidrick Agricultural Machinery Museum. Woodland, CA. 300 participants.

November 30, 1999. Mitchell, J., D. May, T.K. Hartz, G. Miyao, M. Cahn and H. Krusekopf. Soil testing to optimize nitrogen management for processing tomatoes. In Proceedings Fertilizer Research and Education Program Conference Proceedings. Modesto, CA. 200 participants.

December 7, 1999. Soil testing to optimize nitrogen management for processing tomatoes. Annual Research Review Meeting. California Tomato Research Institute. University of California Buehler Alumni Center. Davis, CA.

November 1997. The pre-sidedress soil nitrate test (PSNT) as a means to improve fertilization efficiencies in processing tomatoes. California Tomato Research Institute Annual Summary Report.

September 1999. Soil testing to optimize nitrogen management for processing tomatoes. California Department of Food and Agriculture. Fertilizer Research and Education Program. Interpretive Summary for 1999 FREP Proceedings.

June 1999. Optimizing tomato fertilization practices. California Department of Food and Agriculture. Fertilizer Research and Education Program Annual Report.

January 22, 1999. Soil testing to optimize N fertilization of processing tomatoes. Tomato Day. West Side Research and Extension Center. Five Points, CA. 70 participants.

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List of Figures

Fig. 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.

Fig. 2. Relationship of petiole NO_3-N from all fields at all N treatment means at (A.) first bloom, (B.) fruit set and (C.) fruit color sampling stages to relative fruit yield. Symbols indicate whether treatment means were (∘) or were not (▲) N-limited, as determined by orthogonal contrast.

Fig. 3. Linear relationships between treatment means of fresh petiole sap and dried petiole NO_3-N concentrations measured at first bloom, fruit set, and fruit color sampling.

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Fig. 5. Relationships of (A.) soil organic matter and (B.) total soil organic N with net N mineralization in an 8-week aerobic incubation at 29 °C.

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.

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

Table 4. Effects of DXL compared to different rates of fertilizer on yield and quality of processing tomato using UAN-32.

Treatments Lbs. Of N Applied	Tons/A.	% Solid	Tons Solids	Color	% Red	% Green	% Rot	Wt./ 50 Fruit
6. 250	45.28	5.3	2.41	23.5	90.83	1.17	8.00	5.28
9. 150 + DXL 2 qt./A.	42.04	4.9	2.05	24.5	89.15	0.00	10.85	5.83
5. 200	41.94	5.5	2.25	23.8	89.57	0.04	10.39	5.36
4. 150	39.38	5.5	2.16	23.5	88.84	0.00	11.16	5.16
8. 100 + DXL 2 qt./A.	36.21	5.2	1.87	24.3	86.18	0.70	13.12	5.43
7. 50 + DXL 2 qt./A.	32.52	5.5	1.75	23.3	89.38	0.79	9.83	5.94
3. 100	31.94	5.5	1.75	23.0	87.33	1.26	11.42	5.61
2. 50	30.76	5.1	1.57	22.5	89.72	1.78	8.51	6.43
1. 0	22.14	5.1	1.13	26.0	86.62	6.62	6.76	7.04
Grand Mean	**36.4**	**5.3**	**1.9**	**23.8**	**88.6**	**1.2**	**10.2**	**5.8**
C.V. (%)	**15.9**	**8.1**	**14.1**	**8.8**	**4.8**	**133.9**	**36.3**	**10.2**
LSD @ 5%	**8.3**	**NS**	**0.4**	**NS**	**NS**	**2.3**	**NS**	**0.8**

Table 5. Effects of DXL compared to different rates of fertilizer on yield and qulaity of processing tomato using UAN-32. (Field 36)

Treatments Lbs. Of N Applied	Tons/A.	Solids	Tons Solids	Color	% Red	% Green	% Rot	Wt./ 50 Fruit
3. 100	39.99	4.7	1.88	27.8	80.35	17.62	2.04	4.95
4. 150	39.87	4.8	1.93	26.0	87.49	11.07	1.45	5.35
5. 50 + DXL 2 Qt./A	39.81	4.7	1.86	26.8	82.93	13.53	3.53	4.57
8. 100 + DXL 1 Qt./A	38.15	5.3	2.01	27.5	84.16	11.67	4.17	4.52
7. 150 + DXL 2 Qt./A	37.41	5.0	1.88	28.0	90.82	8.68	0.50	5.22
2. 50	36.88	5.0	1.82	25.8	87.52	11.14	1.33	4.20
6. 100 + DXL 2 Qt./A	35.83	4.9	1.74	24.8	86.57	10.61	2.82	4.46
1. 0	30.42	5.1	1.53	24.5	90.06	7.92	2.01	4.36
Grand Mean	**37.3**	**4.9**	**1.8**	**26.4**	**86.3**	**11.5**	**2.2**	**4.7**
C.V. (%)	**13.3**	**9.4**	**14.3**	**8.5**	**8.3**	**68.7**	**105.9**	**21.3**
LSD	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Sidedress application was done on July 6,2000

The DXL product was mixed in with UAN-32

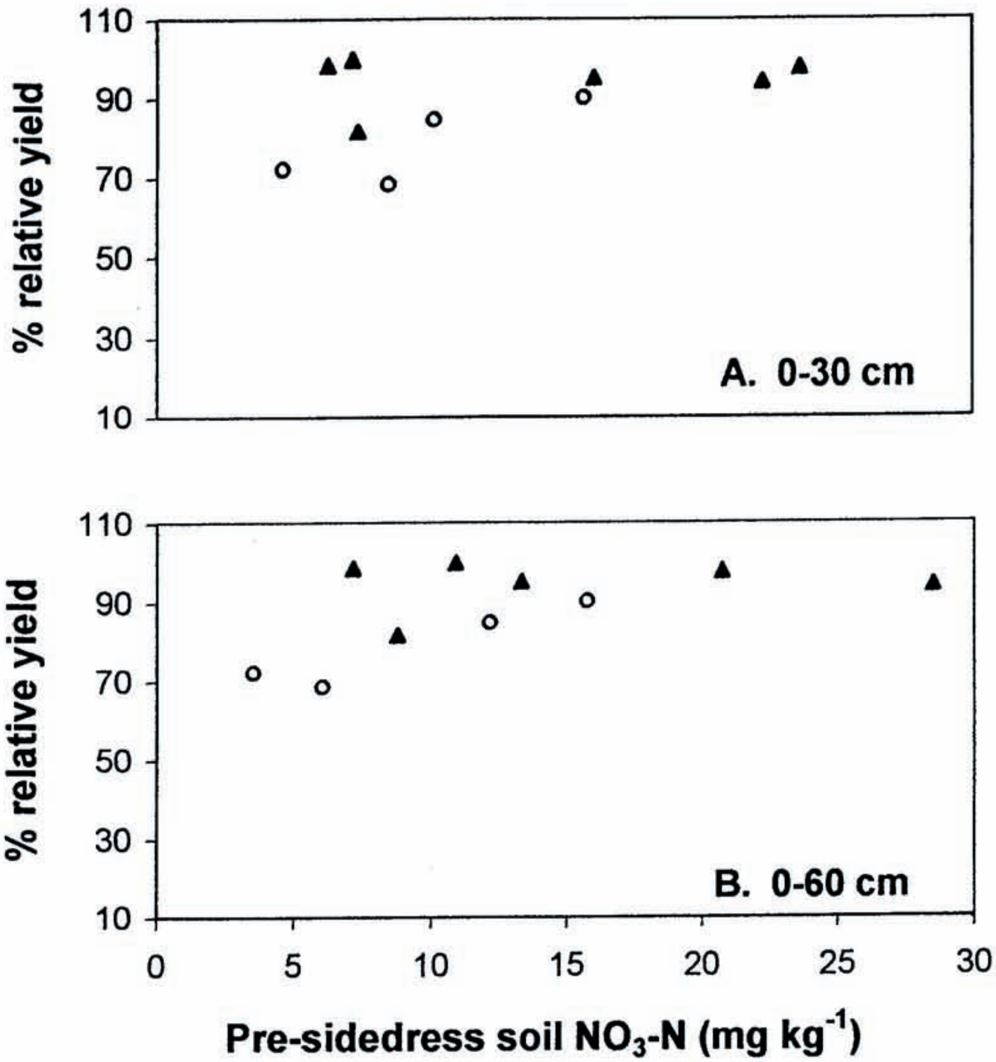
Table 3. Effect of sidedress N rate on fruit quality parameters.

	Field	Sidedress kg ha^{-1} N	Fruit quality indicator color[y]	Fruit quality indicator solids[z]
	4	0	20.0	4.9
		56	22.0	4.9
		112	22.8	4.9
		168	23.0	4.5
		224	21.8	4.7
		280	21.5	5.0
Linear			NS	NS
Quadratic			*	*
	8	0		4.4
		56		4.5
		112		4.4
		168		4.1
		224		4.2
		280		4.1
Linear				*
Quadratic				*

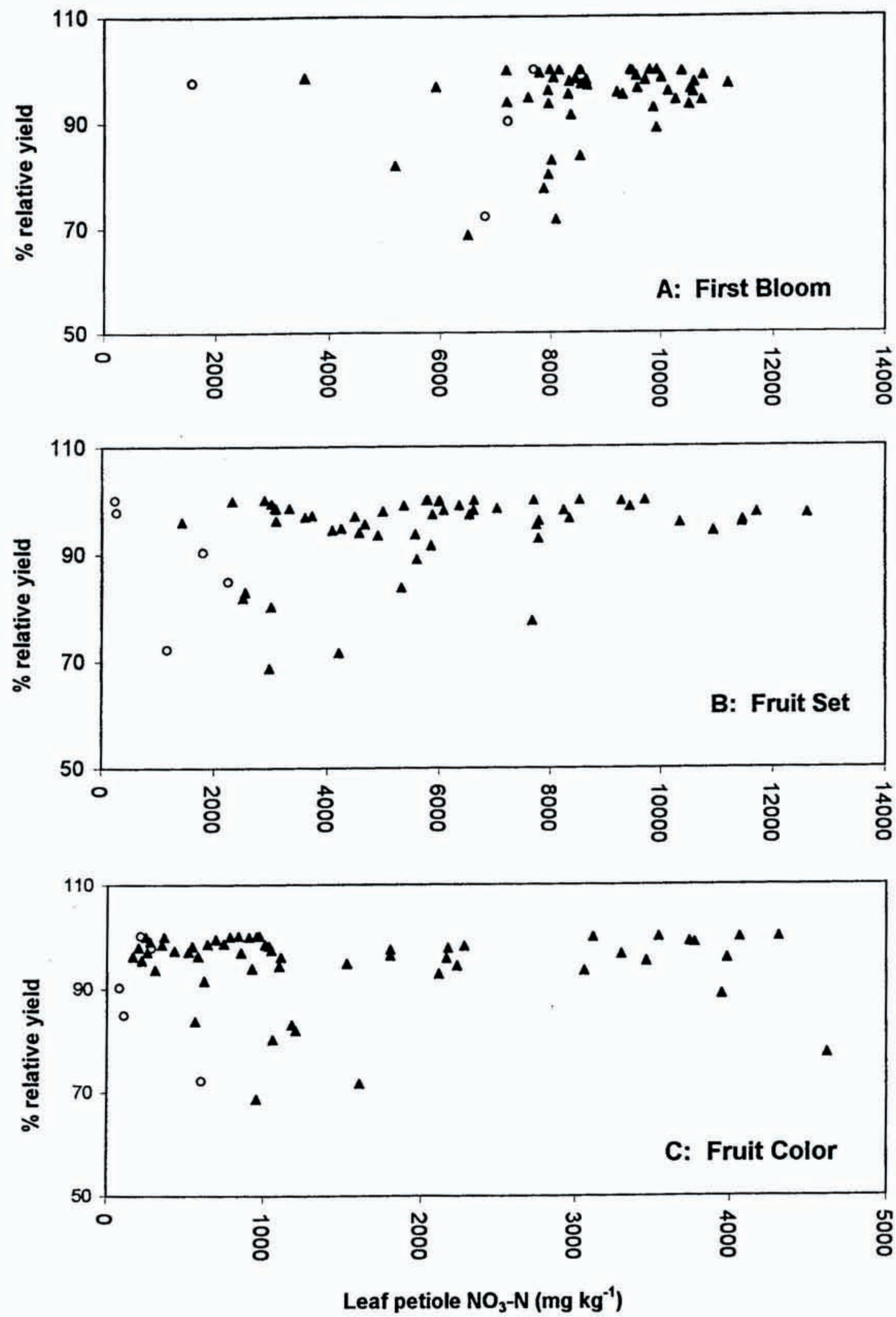
* significant at P=0.05

[y] blended juice color; ratio of green (566 nm) to red (650 nm) light reflected from juice

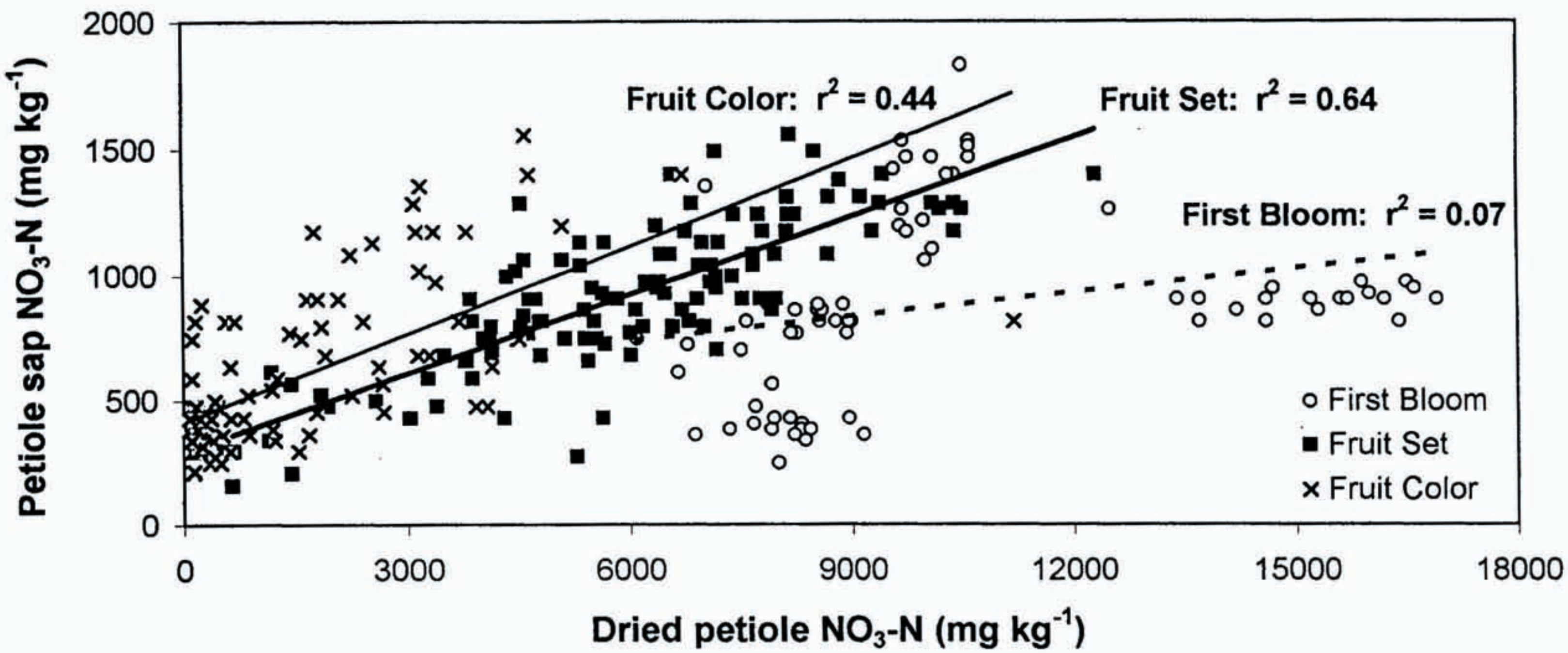
[z] soluble solids content (SS, °brix)



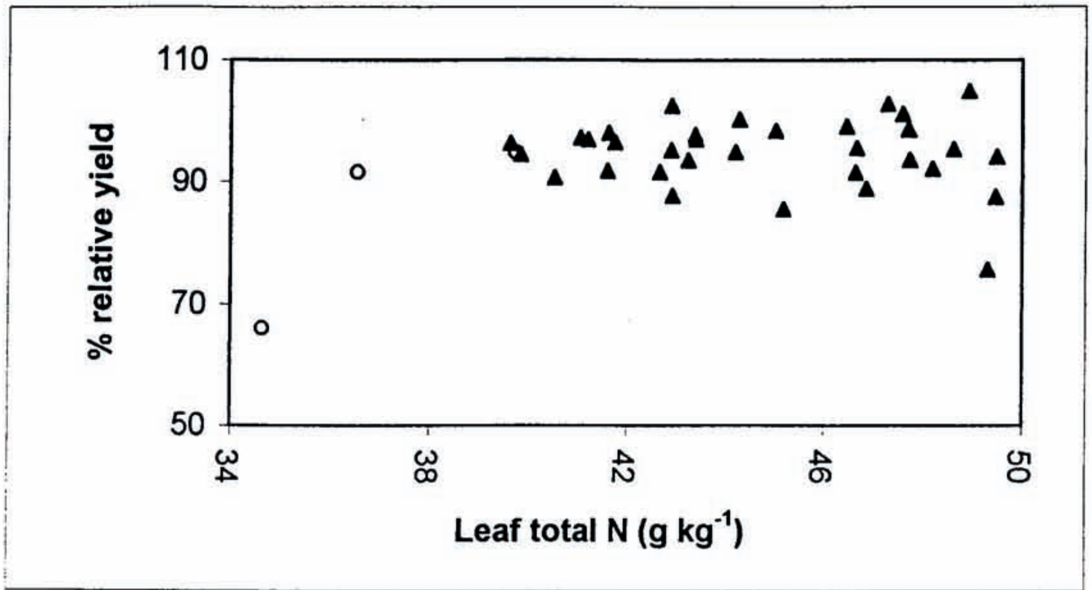
110
90
70
50
30
10
% relative yield
A. 0-30 cm
B. 0-60 cm
0
5
10
15
20
25
30
Pre-sidedress soil NO3-N (mg kg-1)



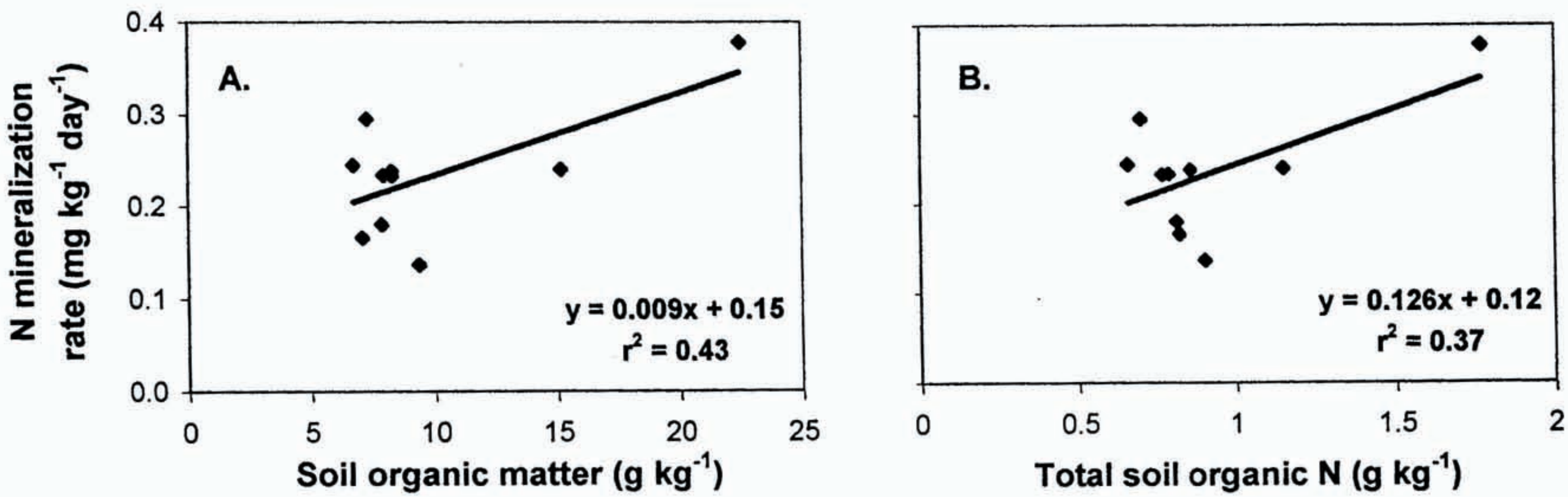
110
90
70
50
% relative yield
A: First Bloom
0
2000
4000
6000
8000
10000
12000
14000
110
90
70
50
% relative yield
B: Fruit Set
0
2000
4000
6000
8000
10000
12000
14000
110
90
70
50
% relative yield
C: Fruit Color
0
1000
2000
3000
4000
5000
Leaf petiole NO3-N (mg kg-1)



Petiole sap NO3-N (mg kg-1)
Dried petiole NO3-N (mg kg-1)
Fruit Color: r2 = 0.44
Fruit Set: r2 = 0.64
First Bloom: r2 = 0.07
First Bloom
Fruit Set
Fruit Color
0
500
1000
1500
2000
0
3000
6000
9000
12000
15000
18000



110
90
70
50
% relative yield
34
38
42
46
50
Leaf total N (g kg-1)


N mineralization rate (mg kg-1 day-1)
0.4
0.3
0.2
0.1
0.0
A.
y = 0.009x + 0.15
r2 = 0.43
0
5
10
15
20
25
Soil organic matter (g kg-1)
B.
y = 0.126x + 0.12
r2 = 0.37
0
0.5
1
1.5
2
Total soil organic N (g kg-1)