FINAL REPORT

For the period 1/1/00 – 12/31/01

Evaluating and Demonstrating the Effectiveness of In-Field Nitrate Testing for Drip and Sprinkler Irrigated Vegetables

CDFA Contract # 99-0756

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OBJECTIVES

An on-farm research, demonstration and education program has been conducted during the 2000 and 2001 season in cooperation with the Santa Clara Valley Water District's (SCVWD) Nitrate Management Program. The primary objective was to assist the Basin's growers in evaluating and adopting the use of in-field nitrate testing and nitrogen management planning to improve fertilizer use efficiency and profitability, while enhancing the potential for reducing nitrate loading to ground- and surface water. On-farm soil and petiole sampling was used to monitor nitrogen (N) fertility and characterize nitrate dynamics in a number of cool and warm season crops under sprinkler and drip irrigation.

These data were used to support an outreach and educational effort to growers in the Coyote and Llagas Basins that is providing information and training through a variety of methods. Regular field visits were made with some cooperating growers and/or ranch managers. Training on the use of in-field quick test methods and equipment was provided on request. Monthly or bi-monthly written summaries were provided, as well, as annual written reports. Additionally seven presentations were made to regional growers at various meetings. In-season monitoring information was provided to directly demonstrate the utility of soil and petiole quick tests. Post-season reports have allowed growers to analyze the effectiveness of their N fertilization programs. This final report summarizes key aspects and findings of this project.

EXECUTIVE SUMMARY

Elevated nitrate levels in various surface bodies and groundwater of the Pajaro River watershed are believed to be due to excessive loading from residential septic systems, animal enclosures, agricultural fertilizer, and other non-point and point sources. This is particularly of concern in the Llagas Basin in Santa Clara and San Benito Counties and the CRWCB has implemented first phase of a nutrient TMDL for the Basin. The Santa Clara Valley Water District (SCVWD) manages groundwater and surface water resources in the majority of this region. A mid 1990's study found that 56.5% of wells in the Llagas Basin had nitrate levels >45 ppm and 20% were >70 ppm. Agricultural fertilization was determined to be principal source of nitrate in groundwater. Estimates of potential nitrogen loading to groundwater from cropland fertilization in the Santa Clara County portion of the Basin has been estimated to be 22.7 x 10^4 lbs per year [SCVWD, 1996]. One of the recommendations from that study was development of technical studies, outreach and education for agricultural producers.

The region comprises approximately 330,000 acres with 71,500 of agricultural lands. Vegetable production, particularly lettuce, peppers, corn, baby greens and onions, is an important sector of the agricultural economy in the Basin region. The high value of these crops along with market demands for quality, make growers reluctant to increase economic risk by reducing nitrogen and/or irrigation inputs. However, until recently, no specific research and/or outreach efforts have been done with regional growers to determine current N and irrigation practices and their effectiveness.

During the 2000 and 2001 season, the field team monitored soil nitrate levels in twenty-one (21) fields and twenty-eight (28) crop sequences. Prior to or immediately after planting soil samples were regularly (weekly or bi-weekly) collected for nitrate determinations. Leaf petiole samples were also collected for nitrate and potassium analysis in all pepper crops, but only after plants had developed some size. When and where possible, small plots or strips were used to assess the effect on production when N fertilization was reduced. In each monitored field the grower's irrigation system was evaluated by the Santa Clara County Mobile Irrigation Lab Program. The SCVWD has also provided a number of complete well water tests for many of the participating growers.

The fields that were monitored for soil nitrate-N were on very different soil types and were located between the Morgan Hill area and south almost to the Santa Clara County line. This included: a) seven (7) head lettuce fields grown with sprinklers exclusively or a mix of sprinkler and drip, b) nine (9) pepper fields primarily grown with drip, although two used sprinkler irrigation for seed germination, c) four (4) celery fields grown with a mix of drip and sprinklers, d) three (3) baby green crops, e) one white onion crop, f) one cabbage crop, and g) one broccoli crop with sprinkler irrigation that followed one of the lettuce crops (Table 1)

As expected, grower irrigation and N fertilization scheduling varied significantly. There were high residual soil nitrate-N levels in a number of fields in 2000, with the exception of a pepper field with plastic-mulched beds. Cool weather in late spring appears to have led some growers to increase N applications to 'push' their crops. In 2001, with more favorable weather some pepper crops received less N fertilizer than the previous year. The critical factors affecting soil nitrate dynamics and residual N are irrigation system type, irrigation/fertilization scheduling, and for drip systems the timing of N injection during any set, soil texture, and the growth stage and relative condition of the crop. It was found that these cooperating growers could reduce N fertilizer levels for a number of crops.

Monitoring of fields suggests that substantial reductions in N fertilizer applications could be made for certain crops. In many cases, crop use efficiency of applied fertilizer may be less than ideal. Generally all of the irrigation systems had good to excellent distribution uniformity. Differences between sprinkler- and drip-irrigated fields were less significant than differences due to vastly different irrigation scheduling for similar crops. In-season leaching may often occur on coarse- and fine-textured soils with high gravel content, and it appears that some growers 'over-correct' with increased fertilization. Soil sampling methods must be adapted to differences in fertilizer placement and the wetted zone where roots are active. Integrating the use of tensiometers complements the soil and petiole nitrate monitoring and has identified both problems and successes of growers' irrigation systems and scheduling. Some of the well waters tested contain high levels of nitrate-N that could be supply agronomically significant quantities of available N. This information has and will provide the five grower cooperators with, not just a season 'picture' of the outcome of their N fertilization programs and irrigation scheduling, but specific reasons why soil nitrate quick testing can improve the efficiency and ultimately the per acre cost of this critical production input. However, it was found that the quick testing approach is not appropriate to every grower's operation due and adoption may be hindered by the structure of farming enterprise, background of managers/workers, and availability of guidelines for specific crops.

Collaboration with the SCVWD's Mobile Irrigation Lab to provide irrigation system evaluations has enhanced the scope of this project's field work and, ultimately the value of our work with the cooperating growers and participants of public events. In cooperation with the SCVWD, Santa Clara County UCCE and Farm Bureau, Dr. Buchanan has made a total of seven presentations related to this project. Year-end reports have twice been prepared for each field and grower. These reports included graphic presentations of monitoring data, in some cases, a N budget for each field, and interpretation. Discussion meetings were offered to each grower to allow concurrent training in the use and analysis of in-field soil and petiole testing approaches.

In order to meet the objectives of the SCVWDs Nitrate Management Program continued direct assistance, training, and followup is essential. Only a fraction of the region's growers attend workshops offered by UCCE and the SCVWD. Of the five cooperators that participated in this project only two took the time to sample field soils and alter fertilization decisions based on the results. However, this project has been very successful in 'jump starting' that effort and as of Winter 2002, the SCVWD has initiated a continuing outreach assistance program, largely based on the scope and success of this project.

WORK DESCRIPTION

Task 1. Evaluate and Demonstrate In-field Nitrate Test in Drip and Sprinkler Irrigated Fields

Subtask 1.1. Select appropriate grower fields

The cooperating growers were recruited based on recommendations from Directors of Santa Clara County UCCE and Santa Clara County Farm Bureau. Our primary selection criteria were location within the Llagas Basin, crop and soil type, and irrigation method. In year one we wanted to target field monitoring in lettuce and pepper crop systems, as lettuce occupies the largest annual acreage planted in the County and peppers, another widely planted crop has not been typically included in similar 'quick test' projects in the neighboring Salinas Valley. Table 1 provides a summary of each field that was monitored during the project.

Subtask 1.2. Sample total inorganic N in plots within each field to a depth of one meter prior to crop planting. Estimate N mineralization in soil from upper depth interval. Determine the inorganic N content of irrigation water at each cooperating site.

We performed either weekly or bi-weekly soil and petiole. Soil samples (10 to 40 replicates per field) were typically collected from the top foot of soil. In selected fields we collected soil samples from the 0-1, 1-2, and 2-3 foot depth intervals prior to and following a crop sequence in order to enhance our analysis of nitrate dynamics and the presentations/discussions with these cooperating growers. In most cases samples were collected in a fixed grid pattern or point from three to four replicate areas in a field (Figure 1). In selected fields we collected soil samples from the top foot after cropping, placed a subsample into 0.5 mil plastic bags, which were buried in soil for subsequent sequential sampling to estimate mineralization (actually nitrification). Well water samples were collected in early 2000 and the SCVWD provided complete water quality analyses.

Subtask 1.3. Establish crops, carry out cultural practices and harvest crop[s]

Table 1 identifies crop systems and fields monitored during the project.

Subtask 1.4. Install tensiometers to provide routine estimates of soil water potential under drip and sprinkler irrigated fields

Tensiometers were placed in replicated stations in most fields to monitor soil water potential at various depths under drip and sprinkler irrigation. In all of these fields tensiometers were installed at 6, 12, and 18 inch depths with readings collected up to 4 times per week, as close as feasible, to the start and completion of an irrigation set.

Subtask 1.5. During each crop sequence sample soil and plant tissue prior to N additions [sidedress/fertigation] and analyze for nitrate N. Determine total crop N uptake and yield/quality

Following crop establishment routine weekly or bi-weekly soil samples were collected from the 0-6 inch (early development) and 0-12 inch depth interval. Soil sampling methods were adjusted based on bed spacing, drip tape layout, and/or fertilizer placement in order to estimate nitrate-N levels in the effective rooting zone of these crops. In all pepper crops petiole samples were taken for determination of nitrate-N and, later in the season potassium. All analyses were performed with Cardy meters. At the beginning of the season we split some soil samples and submitted them to a commercial lab for correlation/validation of our quick test result. We completed hand harvest of small plots in selected fields, and established subplots where N fertilization was reduced. This comparison was made for the spring lettuce crops, where either the second sidedress or final fertilizer injection was skipped. Comparison plots were also established for pepper crops by closing off drip tubes during the injection period. However we were not able to secure access to a large plant dryer for crop N uptake estimation.

Table 1. Summary of crops and soils for each grower cooperator

Grower-crop	Irrigation Method	Field Size (acres)	Soil type
C&E Farms			
2000			
Spring Lettuce	Buried Drip	12	sandy clay loam
Late Summer Lettuce	Sprinkler/Buried Drip	10	sandy loam
Spring Celery	Buried Drip	20	sandy clay loam
Fall Celery	Buried Drip	15	gravelly s. loam
Pimento Peppers	Buried Drip	30	gravelly s. loam
2001			
Spring lettuce	Surface Drip	11	sandy clay loam
Spring lettuce	Surface Drip	12	sandy clay loam
Late summer lettuce	Furrow-Surface Drip	40	clay loam
Baby spinach [2 rotations]	Sprinkler	11	sandy clay loam
Mixed baby greens	Sprinkler	8	sandy loam
Spring celery	Sprinkler-Surface Drip	40	sandy loam
Late summer celery	Sprinkler-Surface Drip	12	gravelly sandy loam
El Camino Packing			
2000			
Spring Lettuce	Sprinkler	25	silty clay loam
Summer Broccoli	Sprinkler	25	silty clay loam
Bell Peppers [seed]	Sprinkler/Buried Drip	30	gravelly clay loam
2001			
Winter cabbage	Sprinkler	25	gravelly clay loam
Spring lettuce	Sprinkler	3	gravelly clay loam
Bell peppers [seed]	Sprinkler-Surface Drip	20	fine sandy loam
Bell peppers [transplant]	Sprinkler-Buried Drip	30	clay loam
White globe onions	Sprinkler	15	loam
Uesugi Farms			
2000			
Bell Peppers	Buried Drip	40	sandy clay loam
Bell Peppers	Buried Drip	30	gravelly sandy loam
2001			
Jalapeno peppers	Buried Drip	3	sandy clay loam
Colored bell peppers	Buried Drip	48	sandy clay loam
Chiala Farms			
2000			
Anaheim Peppers	Sprinkler/Buried Drip	10	gravelly sandy loam
2001			
Jalapeno peppers	Buried Drip	10	gravelly sandy loam
LJB Farms			
2000			
Jalapeno Peppers	Buried Drip	15	sandy clay loam

Subtask 1.6 Following crop harvest, sample total inorganic N within each field to a depth of one meter and use aerobic incubation method to assess between crop N mineralization

As noted in Subtask 1.2, we collected soil samples in selected fields after cropping. Large representative samples were placed in 'mineralization bags' and buried in soil. Nitrate-N was be extracted at regular intervals from subsamples. Nitrification was estimated by subtraction of the initial nitrate-N content of the large sample. These analyses were done for soils following the two spring lettuce crops and one of the celery crops.

Subtask 1.7 Document labor and material costs associated with in-field testing and compare to possible production input savings.

We have generally assessed the time and material costs associated with use of quick test during the season.

Subtask 1.8 Submit interim report

Seven (7) interim reports were prepared and submitted during the project.

Task 2. Conduct Seminars, Workshops, and Field Days

SubTask 2.1. Organize kick-off workshop event in Jan-Feb. with SCVWD to provide summary of project objectives, additional discussion concerning N management issues within the region.

Two workshops were offered in January and February 2000 as part of the SCVWD's annual series. The first was titled, Nutrient, Irrigation and Pesticide Management for Lettuce Growers and the second titled, Nutrient, Irrigation and Pesticide Management for Vegetable Growers (flyers submitted in previous interim report).

The first had a relatively small attendance while the second was very well attended. Frances Brewster of the SCVWD had thought that a workshop targeting lettuce would be appropriate, however in hindsight it appeared to be too specific, thus limited the potential audience. The second allowed for recruitment of additional interested growers. A handout and participant survey form was given to each participant. Additional nitrate quick test kits will be provided to those who are interested.

Subtask 2.2. Meet with SCFB and LOTC personnel to organize and provide in-class and practicum education to students. Conduct in-class training session.

Preliminary discussions occurred. However, much of the momentum was lost as the Director of the SC County Farm Bureau who was the catalyst for this activity left the position in early summer 2000. A second blow to the final development occurred due to the transfer of Frances Brewster out of the Nitrate Management Program. A number of attempts were made to re-establish contact with appropriate faculty, however conflicting schedules and other priorities prevented completion of this subtask.

Subtask 2.3. Organize workshop events in early Dec. with preliminary and final results of project and presentation of N balance accounting, etc.

The SCVWD, SC Ag Commisioner and SC-UCCE co-sponsored meetings winter meetings in 2000 and 2001, where Dr. Buchanan provided summary presentations to groups of 35 to 80 attendees. Conference evaluations suggested that the presentations and information provided related to this contract activity were well received.

Subtask 2.4. Prepare first Technical Fact Sheet for distribution at Dec./Jan. workshop

An example of technical sheets made available to meeting attendees are as Attachment I.

Additional Activities

Develop working relationship with SCVWD's Mobile Irrigation Lab Program

Dr. Buchanan was able to work with the Mobile Lab Program's field personnel in identifying, scheduling, and reviewing results of their irrigation system evaluations. All fields that were monitored for soil nitrate had the irrigation systems evaluated at least once. All efforts were made to complete at least one evaluation of each system type when more than one was used to produce a crop (e.g. sprinkler-drip combinations).

Present and discuss project objectives with SCVWD's Agricultural Water Advisory Committee

Two progress presentations were made in 2000 and 2001 to the Committee at which time the overall project objectives and an update on the season's activities were discussed.

RESULTS AND DISCUSSION: Field Monitoring

Soil monitoring was performed for each of the crops shown in Table 1. The following section is organized by example crop system and will generally summarize results and analysis. These examples are meant to highlight general findings and trends observed. Detailed reports were written for each grower and an example of the format and level of analysis and recommendations is shown by the example report in Attachment IV. The intent in developing these field data sets was to provide the growers with a 'snapshot' of soil nitrate dynamics in relation to their fertilization and irrigation scheduling. This provided specific and compelling examples of how and when in-field quick tests could enhance the efficiency of their N inputs.

LETTUCE

Table 2 summarizes irrigation and fertilization information for six lettuce crops monitored. All of the irrigation systems were well designed and maintained and generally irrigation uniformity was excellent for these fields. Table 3 shows results of three lettuce trials where the grower's typical practice was compared with plots where the final sidedress N was eliminated. All of the lettuce crops typically received about 20 to 25 lbs of N as pre-plant, about 75 to 125 lbs of liquid N (AN-20) in first sidedress, followed by 25 to 75 lbs N in a second sidedress. In all of these trials there was no significant difference in yields when N fertilizer was reduced by up to 73 lbs per acre (approximately 57%).

All of these spring lettuce crops likely benefit from N release from soil and fall crop residues after soil temperatures increase in April that eliminates the need for the second sidedress. Soil sampling for one crop provided a direct demonstration of how soil temperature influences the temporal and spatial availability of N. Cold soil temperatures in early spring limited the rapid development of the crop and the grower had considered applying more N in early April to 'push' the crop. He was provided with monitoring information that convinced him to wait a week as it appeared that fertilizer N was not moving into the root zone. Figure 1 shows the relationship between soil temperature (data from Morgan Hill CIMIS station) and nitrate-N in the rooting zone and the fertilizer band in that field. It suggests that a significant portion of ammonium-N had not been nitrified until soil temperatures reached 60 degrees F. Subsequent monitoring revealed another spike in soil nitrate-N concurrent with rapid crop growth.

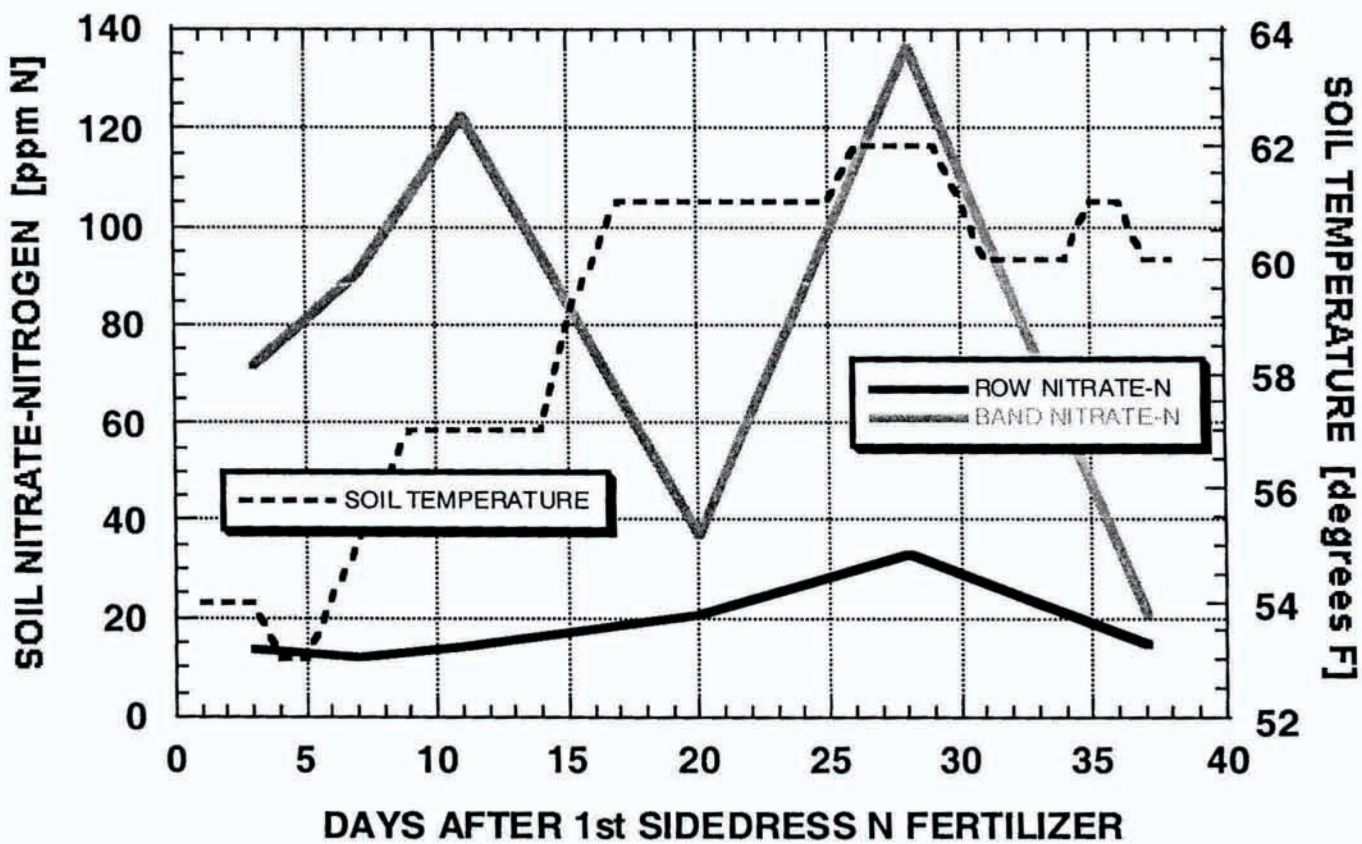
Table 2. Summary for lettuce crops

Crop-System	DU	IE	N Fertilizer* [lbs. N/acre]
	----- % -----		
Sprinkler	83 (57)a	--	165
Furrow	78	75	
Drip	80	80	203
Drip	95	92	143
Drip			199
Sprinkler-Drip	97	97	167
Furrow-Drip	--	--	167

Table 3. Comparison of production of drip- and sprinkler-irrigated spring lettuce with grower's full N fertilizer program and a reduced N application

Treatment [lbs N/acre]	Stand	Cut %	Cartons	Tons	Wt./head [lbs.]
	----------	---------- [per acre]	----------	----------	
Spring 2000					
181	24061	86.8	786	21.0	1.90
203	24061	88.0	794	19.5	1.80
Spring 2000					
98	27670	88.7	972	24.0	2.00
171	27160	89.5	945	26.0	2.10
Spring 2001					
167	25290	85.2	906	20.1	1.85
199	25168	80.7	891	20.9	1.95 a

Figure 1. Changes in soil nitrate-N in fertilizer band and in lettuce row as related to soil temperature



Figures 2 and 3 show soil monitoring data during selected lettuce crop (early spring and fall) rotations. Generally it was found that soil nitrate-N never exceeded 30 ppm in spring crops due to slow nitrification from soil and fertilizer N. However, pre-plant soil nitrate levels for summer or fall crops (Figure 3) were greater than 50 ppm N due to residual fertilizer N and release from soil and prior residues under warm soil temperatures. However, it is difficult to convince growers that this later season residual N can eliminate the need for pre-plant N fertilizer.

Figure 4 compares soil nitrate-N at 1, 2 and 3 foot depths before and after three lettuce crops in 2000. For the spring lettuce grown primarily on drip there was a significant accumulation if nitrate-N in the top foot of soil that suggests a lower use efficiency of N fertilizer. Soil nitrate-N at the 2 to 3 foot depth interval declined significantly. Given the relatively high soil moisture at this depth, due in part to a seasonal water table that reaches as high as 5 feet during the winter, it is assumed that denitrification rather than in season leaching may have caused the decline. Tensiometers installed to 18 inches did not fluctuate greatly following irrigation events with the greatest changes occurring as roots reached this depth late in the crop sequence. There was a similar increase in soil nitrate-N in the top foot of soil following the spring lettuce grown with sprinkler- and furrow-irrigation and little to suggest that there was significant in-season leaching. However, for the late summer lettuce grown on a sandy loam soil, it would appear that a portion of the sprinkler applied N was leached below the effective root zone of lettuce.

BROCCOLI

The only broccoli crop was a second rotation crop shown in Figure 3. The irrigation system was assumed to be well designed and maintained based on the earlier season evaluation done for lettuce crop grown in this field.

Due to release of nitrate from fertilizer and lettuce residues, as well as, soil organic matter, there was no need for pre-plant N. The grower has determined from experience that no mid-season pre-plant is necessary for this rotation scheme. Table 5 shows results of our N mineralization incubations with soil from this field in plastic bags that correlated with field measurements. The grower used a topdress of AN-20 for weed control and a sidedress N application about 3 weeks later resulted in a large increase in soil nitrate-N, which was rapidly absorbed by the crop. The irrigation schedule, which actually under-irrigated the crop, allowed the crop to utilize much of the residual N from the lettuce crop, in addition to the N applied to the broccoli crop. The greater rooting depth appears to have allowed the crop to utilize nitrate-N that was present down to the two-foot depth. Early in the rotation broccoli roots began drawing water from the 18 inch depth, which also suggests that active absorption of water and N occurred to at least two feet during the later stages of the rotation. The irrigation schedule largely replenished soil moisture in the top foot only, and therefore did not appear to cause any leaching of nitrate down and out of the effective root zone. The broccoli effectively reduced soil nitrate-N, which resulted in an efficient fertilizer program and minimized post-crop residual nitrate-N at 2- and 3-foot soil depths.

Figure 2. Changes in soil nitrate-N in relation to irrigation scheduling for lettuce-broccoli rotation

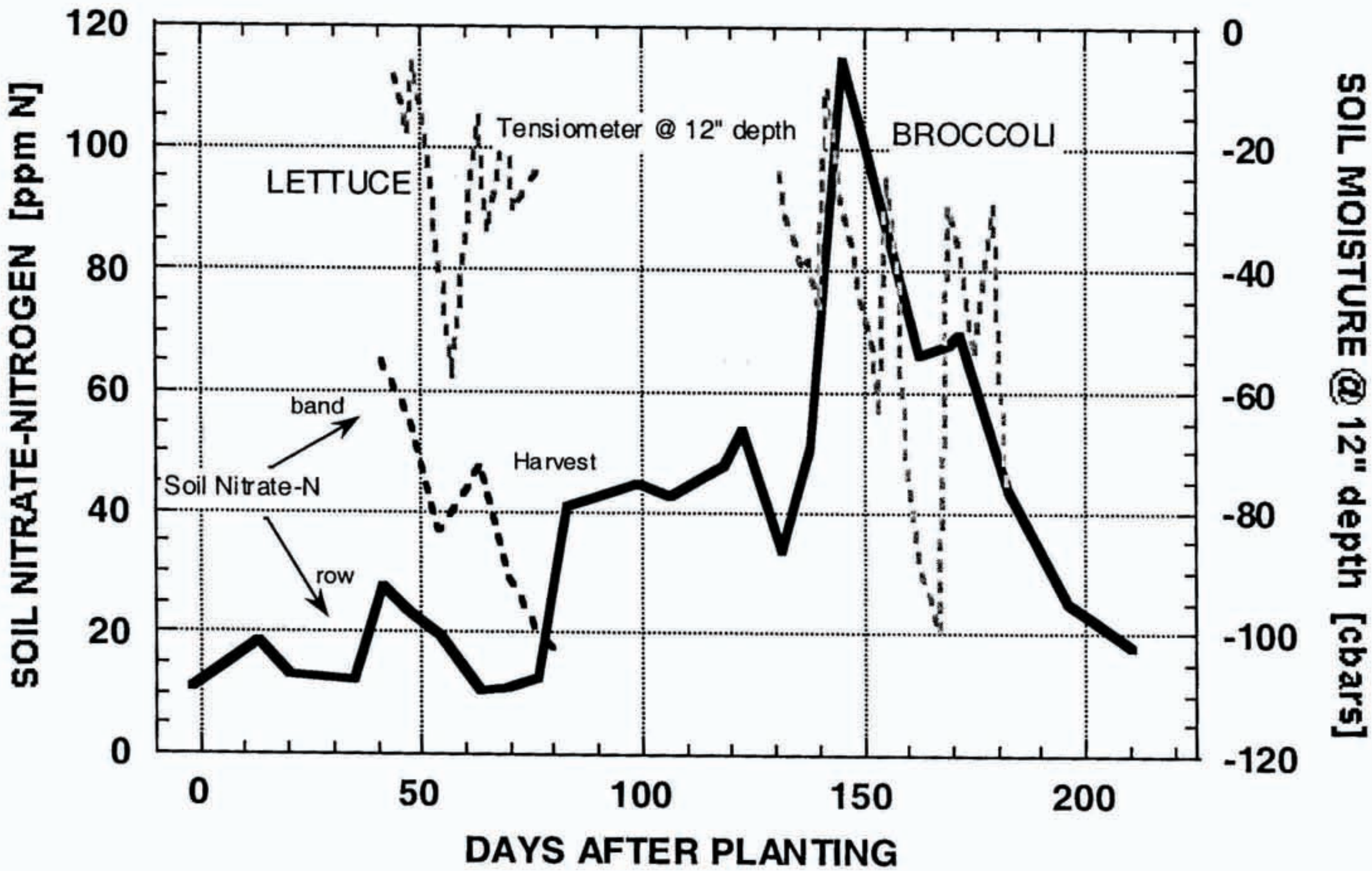


Figure 3. Soil nitrate-N for fall lettuce crop with sprinkler and surface drip irrigation

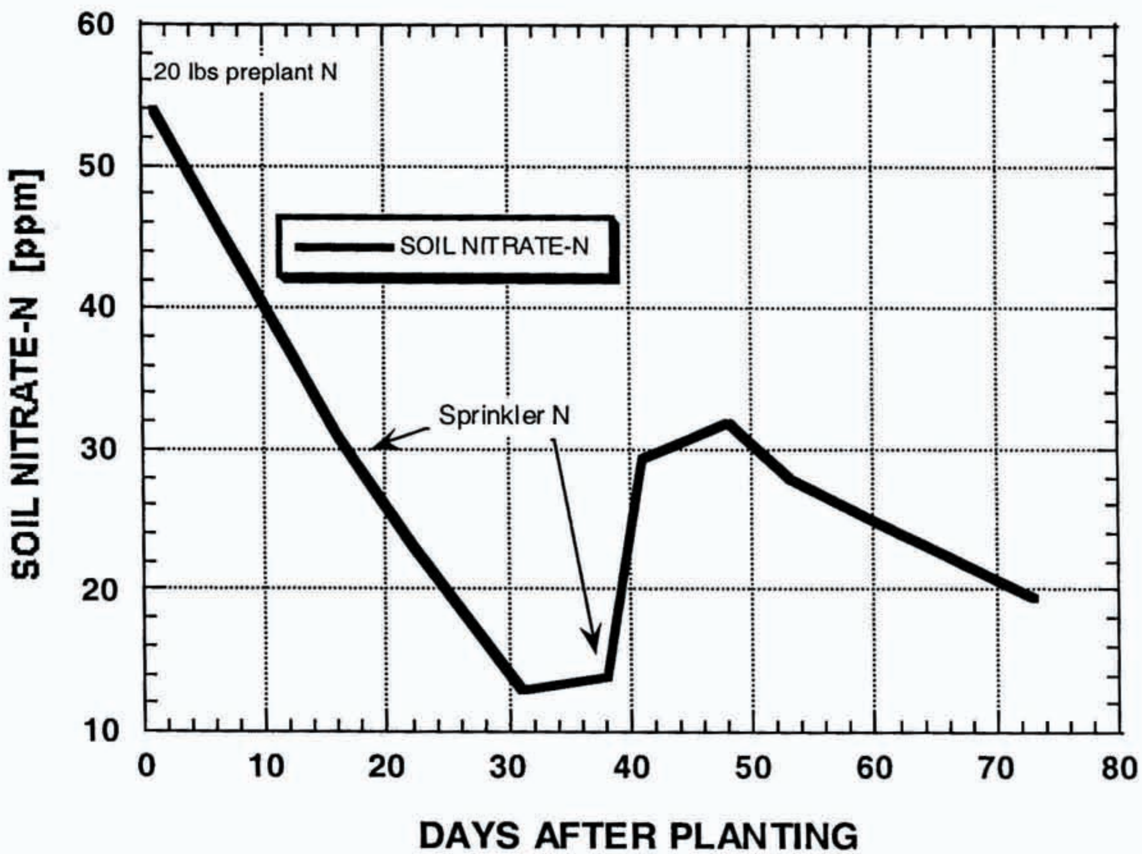
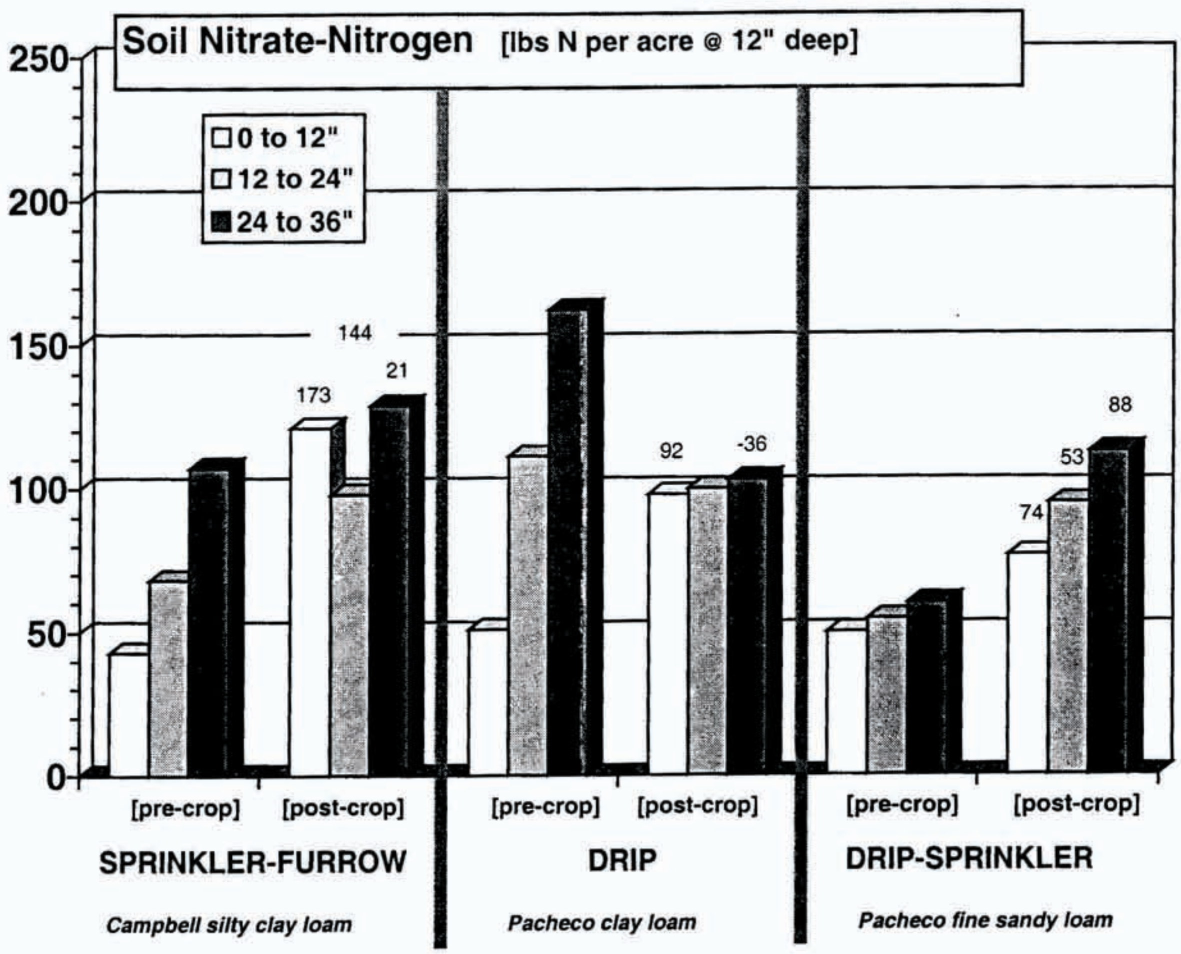


Figure 4. Distribution of soil nitrate-N prior to and following harvest of head lettuce



(Numbers above bars indicate statistically significant change in % from pre-crop levels)

Table 5. Residual; soil nitrate-N increases due to breakdown of lettuce residues
[clay loam soil]

Crop	Wks. after Harvest	Nitrate-Nitrogen Soil [lbs./acre]	Nitrate-Nitrogen +Residues [lbs./acre]
Lettuce	At Harvest	51	51
	3	83	104
	4	92	116
	7	121	175
	15	188	375
	20	222	435
	Average Nitrate-N Release Rate [lbs. N/day]	1.5	3.1

CELERY

While celery production is rather limited in Santa Clara County, it is a crop that typically receives large inputs of N. We monitored soil nitrate-N in three crops produced by the same grower in spring, summer, and fall seasons. Table 6 summarizes irrigation and fertilization information for the four celery crops monitored. Generally irrigation uniformity was excellent for these fields.

Celery was grown with a 'hybrid' system using sprinkler and partially buried or surface drip irrigation. Pre-plant N is typically 25 lbs. as 5-17-17, followed by a topdress of 63 lbs. N as AN-20 soon after transplanting. An additional sidedress application of 78 lbs. N as 13-13-13 is made within two weeks of transplanted, followed by an initial drip injection of 52 lbs. as CAN-17, and weekly injections of 20 lbs. as CAN-17 and N-furic. Sprinkler irrigation is used for one week following transplanting.

Figure 6 shows the changes in soil nitrate-N during the spring and fall crops and compares that with changes in soil moisture at the 12" depth. With the large loading of fertilizer N early, soil levels stay high for almost 4 weeks. However part of that large decrease (between about 45 and 48 days) was due to movement of nitrate-N out of the effective rooting zone. Figure 5 shows the results of routine sampling of soil (0-12 inch depth) adjacent to drip tape, at the bed shoulder, and in the middle of the furrow. It would appear that drip applied water moves a bulk of early fertilizer nitrate past the plant row and ultimately towards the furrow. Between 35 days [when sampling started] and about 60 days, we did not find any celery roots in the furrow position. From day 60 on we found more rooting in this zone, however they were not very deep in soil (only about 9 inches) in comparison to over 2 feet deep in the bed. Therefore it is likely that following the large application of fertilizer N early, a significant portion is leached or at least moved out of the effective rooting zone.

There had been a number of discussions with this ranch manager regarding the heavy fertilization of these celery crops. The data shown in Figure 5 made a large impression and he hopes to lower the total amount of N applied immediately post-transplanting and rely more on drip applied N adjusted for the development stage of the crop.

Table 6. Summary for celery crops

Crop-System	DU	IE	N Fertilizer*
	----- % -----		[lbs. N/acre]
Drip	90	95	368
Drip	--	--	362
Drip	89	90	388
Drip	84	73	342

Figure 5. Soil nitrate flux in tape, bed shoulder, and furrow positions in a celery crop

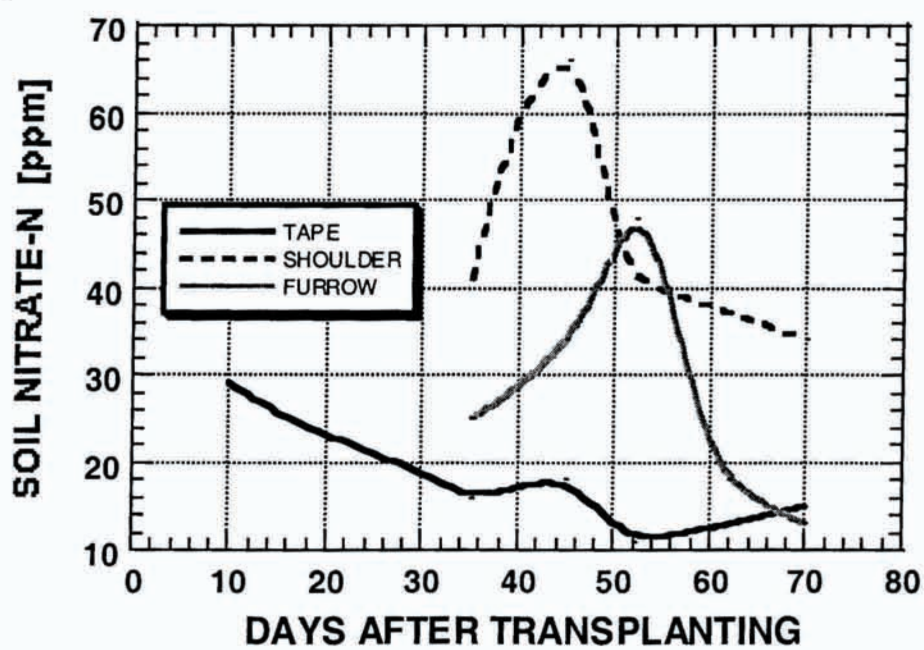


Figure 6 shows the changes in soil nitrate-N during spring and fall crops. The patterns of soil nitrate-N were similar for both crops for both crops, reflecting the similarity of soil type and fertilization scheduling. However, due to the early season plowdown of lettuce and weed residues plus release from soil organic matter, there was about 200 lbs. of available N in the top foot of soil at planting. The difference in soil nitrate-N during transplanting of the fall and spring crops was approximately 100 lbs. N in the top foot of soil. This is approximately the same difference found (~90 lbs. N) when comparing post-crop residual soil N. This suggested again that the grower could have reduced the amount of pre-plant and post-transplant N.

During 2000 and 2001 monitoring of these celery crops, grown with identical N fertilization, suggested that there could be potential savings in N fertilizer. Eliminating the heavy fertilization early and making a pre-plant test of soil nitrate-N prior to mid- and late season crops. The accumulation of soil nitrate-N following the plowdown of early season crops or winter cover crops should be credited when calculating fertilization requirements.

BABY GREENS

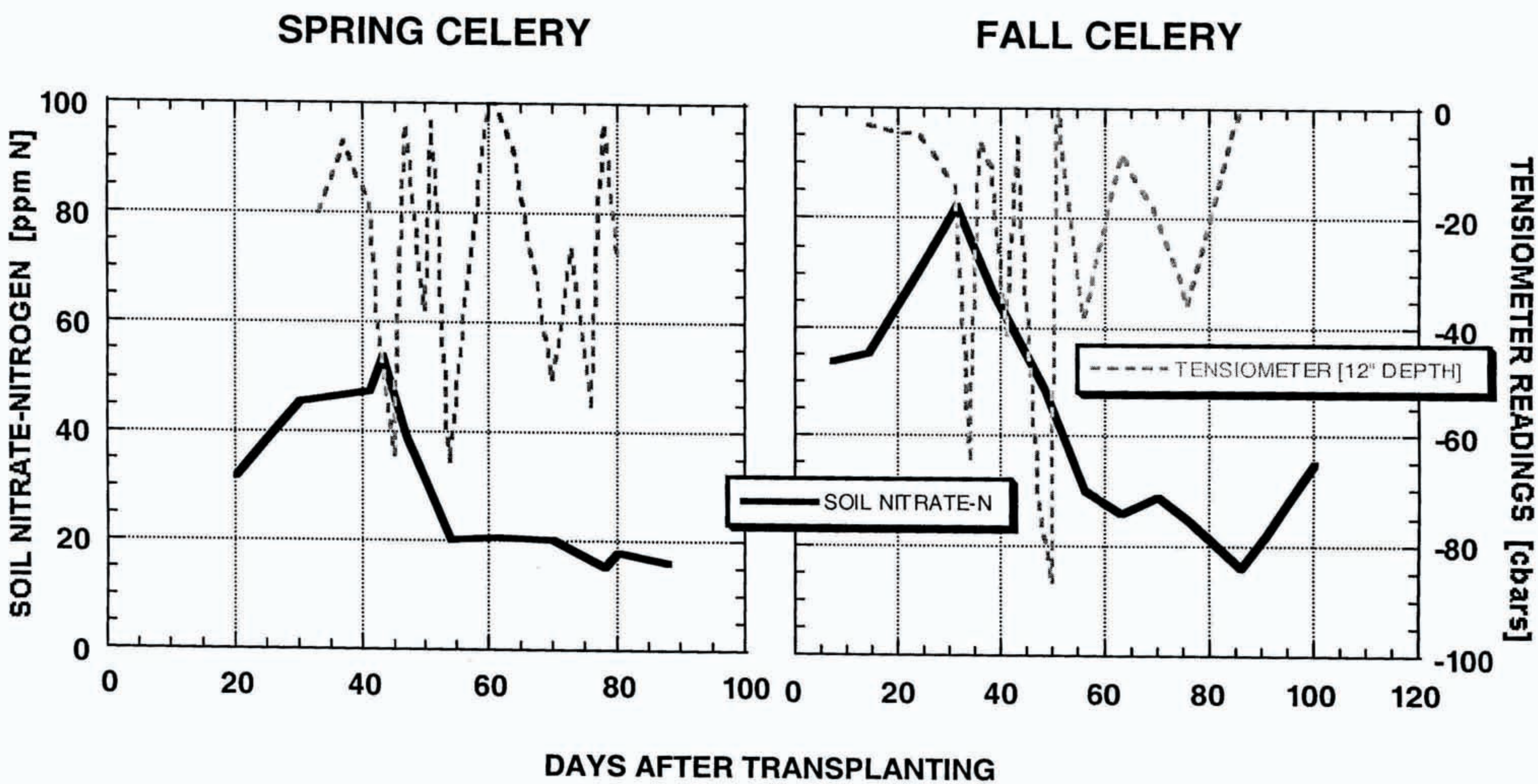
In the last 5 to 6 years in this region, the production of young leafy green vegetables (sic. baby greens) expanded rapidly. One of our cooperators produces up to 5 crop rotations per season on the same block. The mix includes spinach, chard, mazuna-type mustard, red and green leaf lettuces. So, while the average fertilization per crop is relatively small and efficient, the cumulative loading in a season can become quite high (>500 lbs). This cooperator typically applies 39 lbs N as pre-plant, followed by 62 lbs as liquid topdress after seeding (>1,000,000 seeds/acre) on 80 inch beds. Early monitoring found that residual nitrate-N may be as low as 10 ppm for the first crop but increases to as high as 25 following the second crop. Therefore in the 2001 season we used soil monitoring and small plot trials to determine the efficacy of pre-plant N following a first crop of either baby greens or lettuce. Given the very short rotation soil monitoring was for residual N. In some cases the ranch manager also collected samples concurrently with the field team for comparison of results.

Table 7 shows results of two trials where baby spinach followed head lettuce and where chard followed baby spinach. There was 18 and 22 ppm nitrate-N in the soils prior to the application of pre-plant. The amount of N release from residues can be important when the closely mowed crop is allowed to re-grow for up to 10 days prior to incorporation for next rotation. Continued monitoring of residual N found that baby leaf lettuce leaves up to 125% more residual nitrate-N (data not shown) than does mazuna mustard given identical fertilizer and water inputs.

Table 7. Yields of baby greens with and without pre-plant N

Treatment	lbs/plot	lbs/acre
Baby spinach [7/3]		
+ preN	7.96 a	11,556 a
No-preN	7.85 a	11,397 a
Baby chard [8/28]		
+ preN	6.42 a	9,430 a
No-preN	6.62 a	9,614 a

Figure 6. Comparison of soil nitrate-N and irrigation scheduling for spring and fall drip-irrigated celery



PEPPERS

Table 8 summarizes irrigation and fertilization information for pepper crops monitored in 2000 and 2001. Peppers are among the most heaviliy fertilized vegetable crops and indeed one of the cooperating growers applied approximately 380 lbs N to green bell crop in 2000. A number of different pepper types and systems were monitored during the 2 seasons, including Pimento-type, chili-type, green bell and colored bell peppers. Evaluations of the irrigation systems revealed some problems with sprinklers used for germination or setting transplants in certain fields. However, the buried drip systems that were used were well designed and maintained and generally irrigation uniformity was excellent for these fields. The following summarizes observations from some selected fields monitored in either 2000 or 2001.

Pimento Peppers (Drip)- This crop was grown from transplants set in early May 2000. A pre-plant application of 25 lbs. N as 5-17-17 was followed with a topdress of 84 lbs. N as AN-20 after plants were set, with approximately weekly injections of 10.5 lbs. N as CAN-17 and N-furic. Figure 7 compares the changes in soil nitrate-N and soil moisture during most of the crop period. After day 50, there was the steady increase in soil nitrate-N that suggests that N additions were much higher than crop removal. The straight line and slope suggests that the soil was gaining about 9 lbs. of nitrate-N per week. The increases in soil nitrate-N suggest either declining crop uptake during bulking of the first 'tier' of fruit or increases due to N loading from irrigation water or release from soil organic matter. Later after bulking of that first fruit set was complete, there appears to be increased uptake late in the crop cycle approaching harvest.

As this was the first time this grower grew this type of pepper, he was concerned in during the mid-season because the plants did not appear to be putting on new growth while there was a good set of fruit on the first 'tier' of the plants. Other pepper fields that were a part of this season's project showed a similar pattern during bulking of the first fruit set. Temperatures were cool (or at least below normal) during much of this period. While this was discussed with the grower at the time, he was reluctant to adjust the fertilization schedule.

Green Bell Peppers (Sprinkler-Drip) - This crop was grown from seed in 2000 and 2001. In 2000 there was 20 lbs. of pre-plant N as 6-20-20 applied the previous fall, followed by a sidedress of 74 lbs. N as AN-20 after thinning and cultivation, then 11 to 22 lbs. N injected weekly as AN-20. Figure 8 compares the changes in soil nitrate-N and soil moisture during most of both crop periods. Pre-season sampling suggested that likely that the fall-applied pre-plant N had likely been converted to nitrate and leached during the winter. The increase after planting was probably due to N release from soil and breakdown of last season's crop residues, along with nitrate added to soil from irrigation water (Table 11, East Gilroy well).

Soil nitrate and petiole levels fluctuated a great deal during the 2000 season. Figure 8 shows the fluctuations of nitrate in the pepper petioles in relation to soil nitrate-N levels, and also shows a rapid decrease as soil nitrate-N dropped after the excessive irrigation. The drop in soil nitrate continued in the early season, some due to uptake by the crop, but also due to the fact that there were problems with the grower's fertilizer injection schedule. Discussion with the grower's foreman corrected this and for a period after this soil nitrate levels remained stable, suggesting that the crop was removing a greater portion of each N application. After day 130 it was apparent that the irrigation and injection schedule exceeded the capacity of crop to utilize the applied water and N.

Figure 7. Soil nitrate-N and moisture at 12 inch depth for pimento peppers on surface drip

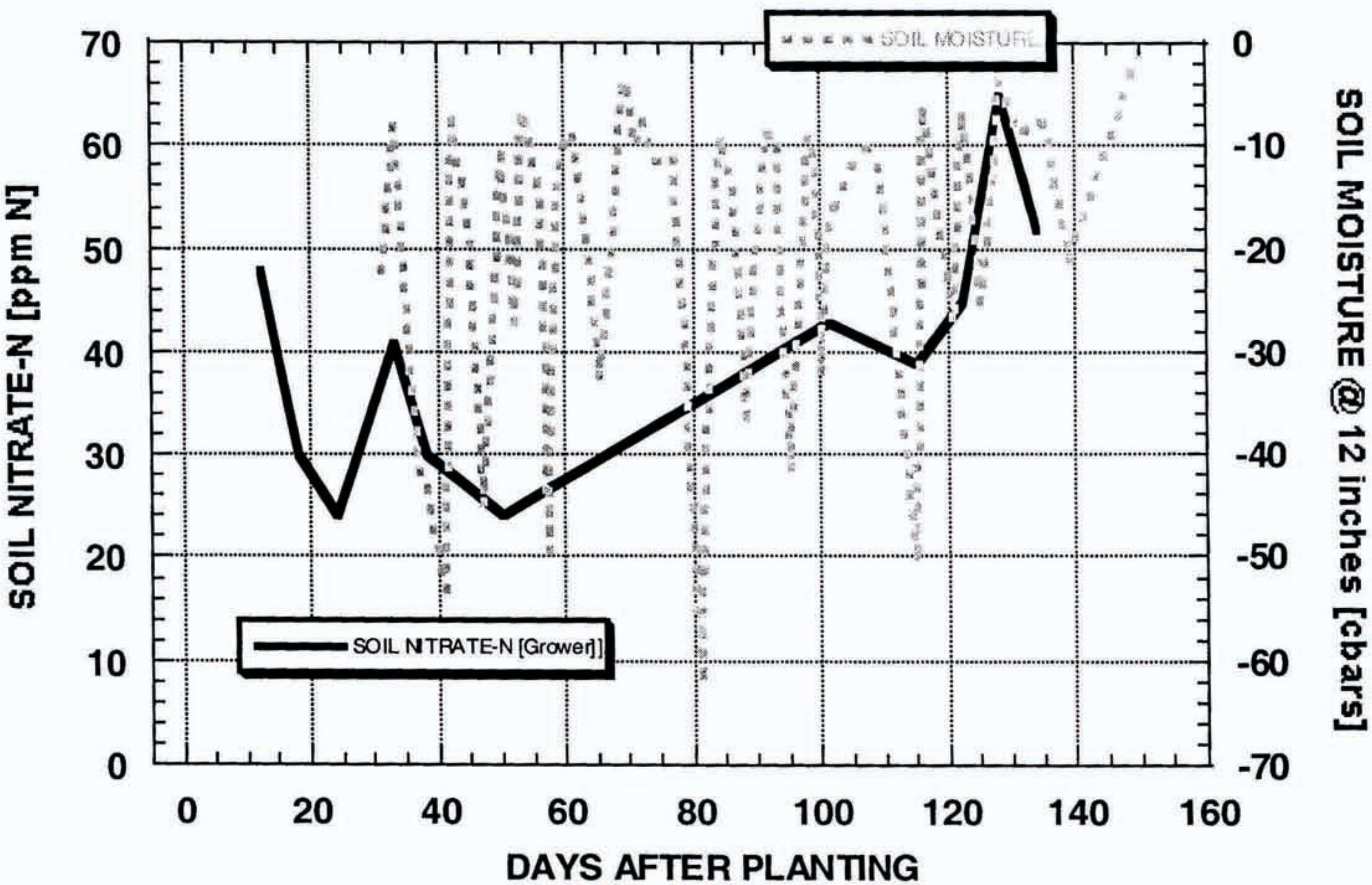
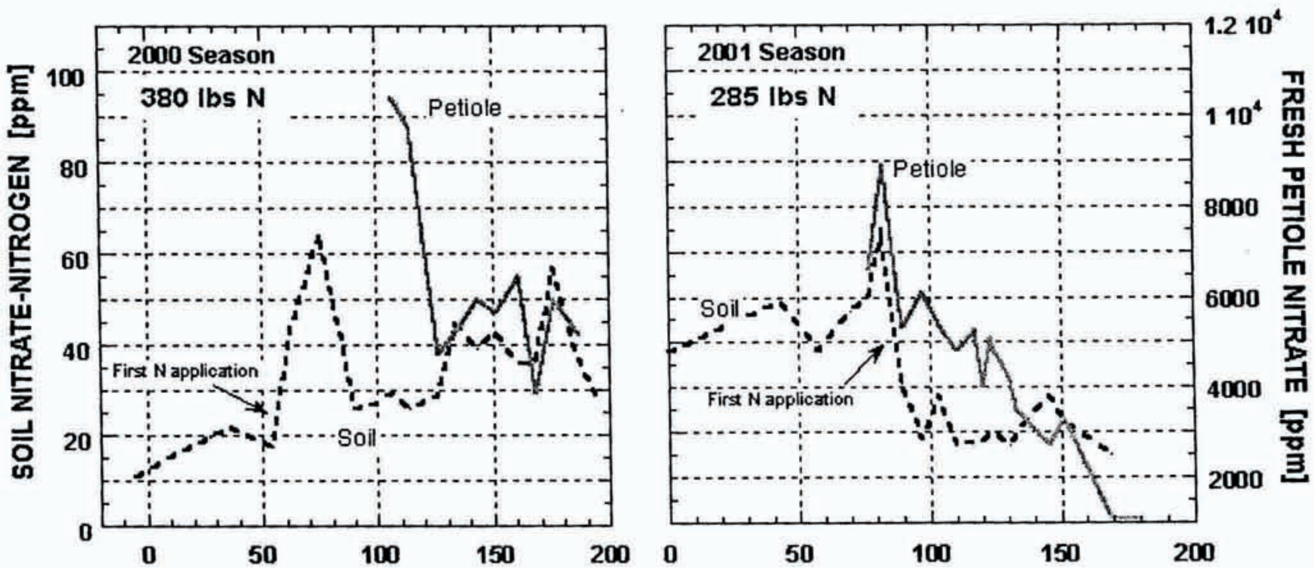


Figure 8. Comparison of N fertilizer applied, soil and petiole nitrate-N following change in a grower's practice in 2001



Use of a quick test for petiole-potassium confirmed that available potassium was seriously low after the first harvest. Plants were not putting on new growth and petiole potassium levels were dropping rapidly. Figure 9 show the results of petiole potassium monitoring and the impact of one application of potassium as KTS. This information allowed the grower to make a decision to inject potassium, and subsequently there was a burst of new leaf growth and fruit set.

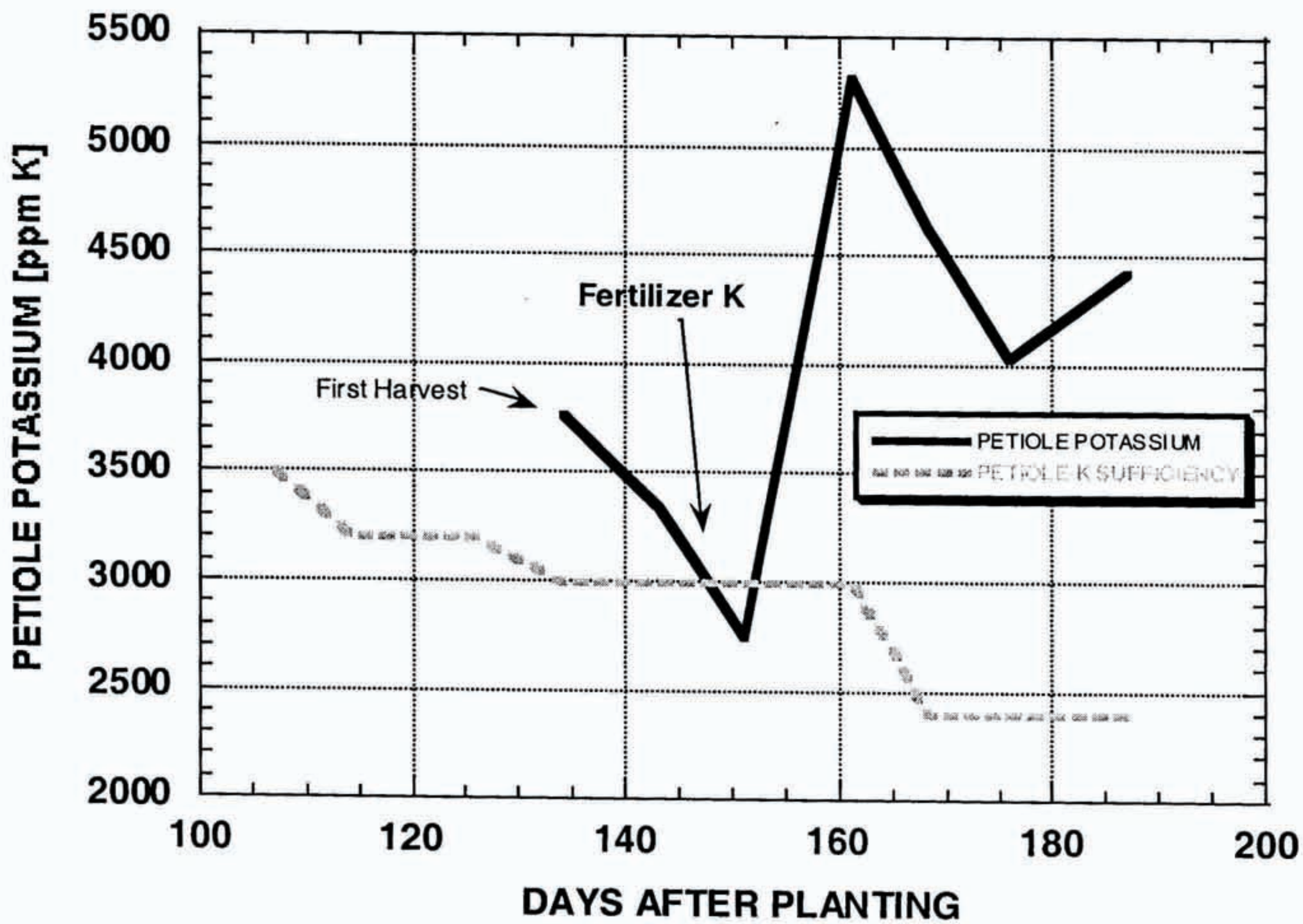
In the 2001 season, and after review of the data provided for 2000, the grower decided to change the fertilization approach for this crop. Figure 8 compares soil and petiole nitrate-N levels in 2000 and 2001. Pre-plant N was eliminated, as was the large post-thinning N application. Weekly soil sample results were sent to the grower during stand establishment. Residual nitrate-N remained adequate and no fertilizer was applied to the crop until well after thinning. Substantial reductions in total N fertilizer were possible. Petiole nitrate-N levels were also lower but not ever deficient. Post-crop residual N was much lower in 2001 season while the crop was equivalent to the previous year and fertilizer N was reduced by approximately 100 lbs/acre.

Table 8. Summary for pepper crops

Crop-System	DU	IE	N Fertilizer*
	----- % -----		[lbs. N/acre]
Peppers (Bell)			
Sprinkler	61(65)c	68	
Drip	88	100	380
Drip	86	99	??
Drip	68(87)d	99	??
Drip	75	>100	276
Drip	--	--	280
Peppers (Pimento)			
Drip	78 (72)e	80	348
Peppers (Jalapeno)			
Drip	87	99	380 – 422
Drip	47	>100	168*
Peppers (Anaheim)			
Sprinkler	44	--	
Drip	83	100	??

*Crop lost to Fusarium wilt

Figure 9. Petiole potassium for green bell peppers in response to mid-season fertilization



Red Bell Peppers (Buried Drip) - This crop is grown from transplants exclusively with the drip-irrigation system where two lines tape are buried 6 to 8 inches deep in a plastic mulched double-row 60 inch bed. Pre-plant N is applied through the drip system and variable amounts of N iare injected once per week. The grower uses a contracted service for petiole monitoring and then uses this as the basis for weekly adjustments to fertilizer program

In 2000 this crop system was only sampled bi-weekly, while in 2001 it was generally weekly, although at time multiple samples were collected within a week to address specific questions related to irrigation scheduling. This field was also the only one we sampled with 60 inch beds with mulch and, additionally the only with two buried drip lines. Figure 10 suggests that this may be due to a larger wetted zone that allows more uniform distribution of N and a larger root system for any one plant. This field averaged (based on 14 soil samples) approximately 18.5 ppm nitrate-N or about 75 lbs. per acre in the top foot of soil, and it had the lowest residual nitrate-N of any field monitored this season.

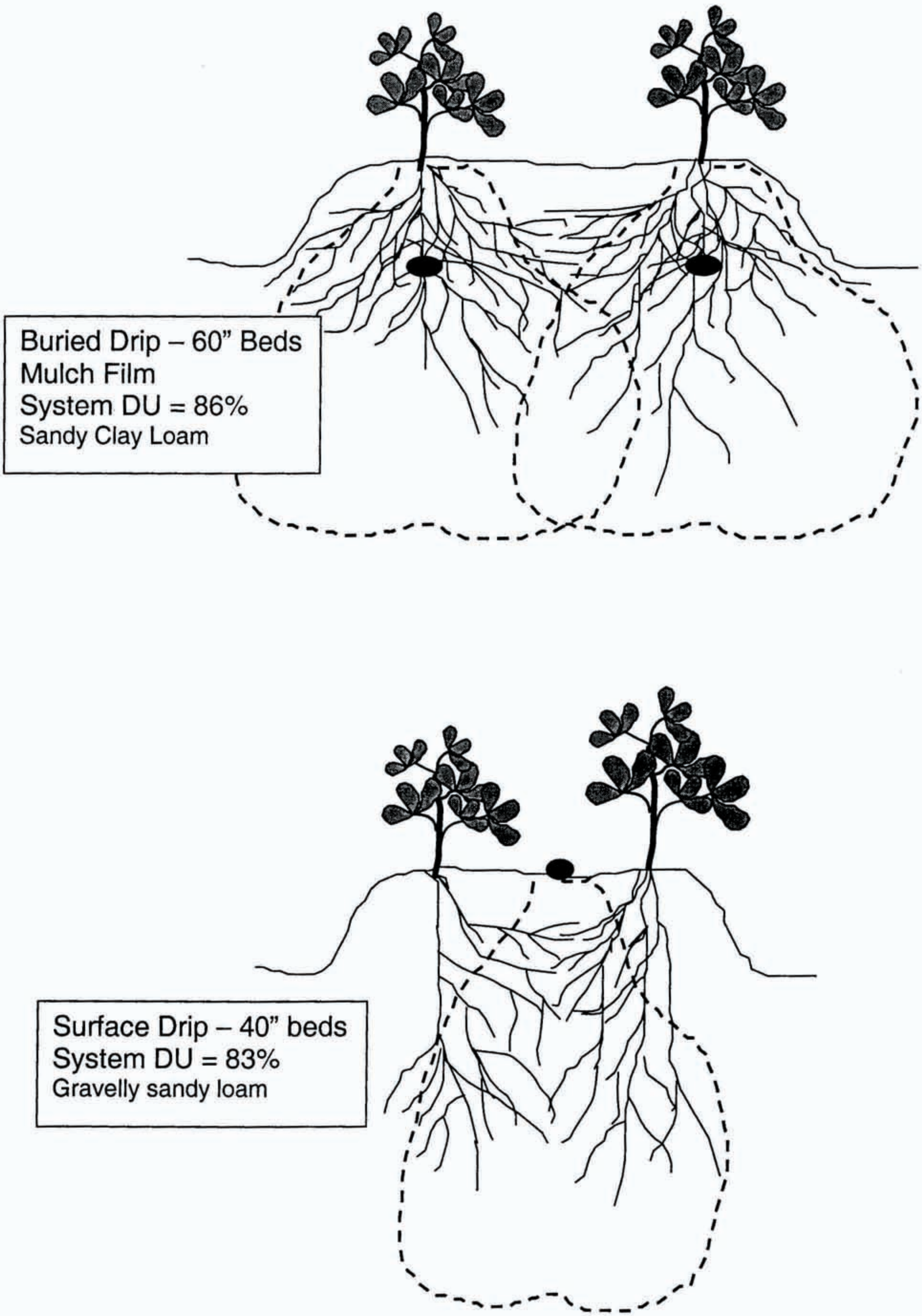
Chili-type Peppers (Buried Drip) - Table 8 shows the results of the irrigation system evaluation. This crop was grown from transplants exclusively with the drip-irrigation system where tape is buried 4 to 8 inches deep in a single row 40 inch bed. Pre-plant N is applied through the drip system and at this time we do not have confirmation of the grower's fertilization program. . As observed in a number of pepper fields, soil nitrate-N generally increased substantially during the entire season. The residual nitrate-N in soil (>180 lbs/acre) was the highest measured in both seasons. Petiole nitrate-N levels were almost always above the assumed sufficiency levels, although they dropped significantly and hovered at the sufficiency level after the first harvest. There was no apparent response to the increasing soil nitrate levels. We also noted that there was probably non-uniform distribution of fertilizer within the field. Figure 15 attempts to depict how the design of the drip system design could have such an effect. We believe that the shorter 'transit' time for fertilizer during injection allowed for more to be placed on the 'short' north side of the block in comparison to the portion south of your injection location.

Chili (Anaheim Peppers - Partial Buried Drip) - This crop was grown from transplants with sprinklers and drip-irrigation where tape is partially buried to as deep as one inch in a double row 40 inch bed. The new ranch manager wanted to try such a system for this chili pepper, despite the fact that no other regional grower produces chili-types in a double row configuration. The experiment failed due to a number of reasons, related to early heat and water stress, irrigation system efficiency and soil type. Petiole nitrate-N were deficient for much of the season prior to and after first fruit set, root systems were small and poorly distributed in the profile, despite continuous weekly applications of AN-20. Water and N use was clearly poor and the gravelly coarse sandy loam texture of the soil contributed to a restricted root system on the plants.

Table 9 shows the result of the small trials in both seasons where N applied was reduced to a few beds during the injection cycle. There were no statistically significant differences in fruit weight as a result of reducing N. The 40% reduction for the green bell crop did reduce the amount of #1 size fruit, but there was a greater amount of #2 size fruit in this case. In 2001 the red bell pepper plots with 60 lbs less N had more marketable fruit at the first pick.

Large quantities of fertilizer N are applied to peppers in the Santa Clara Valley. Monitoring of fields producing bell pepper and specialty hot pepper varieties suggests that substantial reductions N fertilizer applications might not have negative impacts on yields and quality. Typically we found high residual soil nitrate-N in all of these fields, with the exception of the field with mulched beds. There has been little research work done to establish a 'critical' action level for soil nitrate-N in bell peppers as has been done for some cool season vegetables in this region. Additionally, much of the work in these cool season crops has been done in fields

Figure 10. Drip system design may effect N fertilizer use efficiency



irrigated by sprinkler- and furrow-irrigation, where fertilization methods and scheduling are quite different than for drip-irrigated vegetables. The use of a quick test for petiole potassium could be used by pepper growers and, in one case, allowed a mid-season adjustment that prevented yield loss due to potassium deficiency.

There are high probabilities for substantial in-season and winter season leaching on drip-irrigated soils with significant gravel contents, regardless of clayey or sandy textures. Changes in drip tape layout and irrigation/fertilization scheduling could reduce this potential, while reducing overall N fertilization.

Table 9. Comparison of yields for drip-irrigated red pimento, green bell peppers, and red bell peppers with grower's full N fertilizer program and reduced N in small plots.

Crop-Treatment [lbs. N/acre]	#1	#2	Total
	---------- [lbs. per plot]		-----------
Pimento [sandy loam]			
275	59.8	63.4	123.2
233	55.0	64.7	119.7
Green Bell [gravelly clay loam]			
236	36.3 a	46.1a	82.4
300	44.0	34.1	78.1
380	43.1	28.1	71.2
Red Bell peppers [sandy clay loam]			
4 picks			
276	69.5	64.3	133.8
216	66.2	69.5	128.3
1st pick			
196	12.8	4.6	17.4
136	18.9 a	6.6	25.5 a

Any value with letter following is significantly different within same column and crop

FIELD NITROGEN BUDGETS

A field N budget approach was occasionally used to illustrate the many potential sources of N, other than fertilizer, for grower's crops. Some growers received reports that contained N budgets for particular fields or rotations. This N budget approach attempts to account for N release from soil organic matter, N fertilizer, N in irrigation water, N supplied by residues and organic wastes (if applied) to determine how closely a grower's program may match crop need. Attachment III gives an example of a handout used at grower meetings and Table 10 shows an example developed from a double crop of head lettuce. Well water samples were collected early in the 2000 season and are shown in Table 11. Most grower cooperators were surprised by these results, but none can imagine actually adjusting fertility programs without specific field

Table 10. Nitrogen management budget sheet for vegetables

Head lettuce double crop – clay loam soil
65 day spring crop – 60 day late summer crop

Nitrogen Source	Crop 1	Crop 2
	------------ lbs N per acre	-----------
Mineralized Soil N *(1-2 lbs per day)*	91	84
Crop Residue N *(Residue N) X .5*	--	30
Residual Soil N *(Test)*	20	80
Fertilizer N	200	120
Organic N (wastes, manure, compost) *(tons X lbs N per ton) X (.1 to .25 per crop)*	--	--
Irrigation N (assumes 10 ppm N) *(NO_3-N X 2.71) X acre ft. applied)*	32	40
TOTAL N INPUT	351	354
Crop N *(Yield)*	100	90
Residue N	60	50
TOTAL N REMOVED	160	140
Potentially Excess N *(N Input – N Removed)*	191	214

Table 11. Summary of selected well water chemical characteristics

Location	NO_3	NO_3-N	**N/ac. ft.**	Ca/Mg	Conductivity	Chloride
	--- ppm ---		[lbs.]		[μmhos]	[ppm]
E. Gilroy	88	19.8	**54**	1.16	709	49
S. Gilroy	44	10.0	**27**	2.36	637	30
S. Gilroy	62	14.0	**38**	1.54	1040	106
S. Gilroy	33	7.5	**20**	1.85	1130	104
S. Gilroy	35	7.8	**21**	2.37	501	23
S. Gilroy	26	5.9	**16**	2.46	520	18
S. Gilroy	28	6.3	**17**	2.12	601	44
S. Gilroy	23	5.2	**14**	1.71	605	21
San Martin	46	10.4	**28**	--	--	--
'Blue'	4	0.9	**2.5**	2.05	519	66

trial data demonstrating the agronomic significance of this additional source of N. As shown in Table 5, direct field measurements of N release from soil and soil with crop residues provide a direct demonstration of how significant these sources of N can be as well.

However, the use of this approach as a teaching tool requires some 'continuing' education for most growers, beyond that usually allotted in traditional meetings. It was found that most of the cooperators could not remember or had not been exposed to the basic soil fertility concepts required to quickly grasp this concept.

IRRIGATION SYSTEMS AND SCHEDULING

As has been stated previously most of the cooperator's irrigation systems had good to excellent DUs according to test performed by the Mobile Irrigation Lab. However, in the 2000 season soil moisture monitoring in a number of fields suggested that a number of cooperating growers could improve irrigation scheduling for certain crops. Particularly in drip irrigated peppers it was noted that fixed irrigation scheduling often resulted in slight under-irrigation early in the season and over-irrigation later in the season. Figure 11 and 12 show the results of full season monitoring in 2000 and 2001 for two example fields. Problems with irrigation scheduling also caused poor matches of N fertilizer application with crop N absorption leading to unnecessary accumulation of nitrate-N in soil (Figure 13). This problem is particularly challenging for some of the cooperators who have many irrigation personnel spread over different areas, and feel that training them is too difficult. In other fields we found other problems related to poor distribution uniformity of N due to field and irrigation sub-block shape and drip system design (Figure 13 and 14).

Figure 11. Fixed irrigation schedule does not match crop need as shown by tensiometer measurements and CIMIS ET_o (2000 season: surface drip, double row peppers, 40 inch beds)

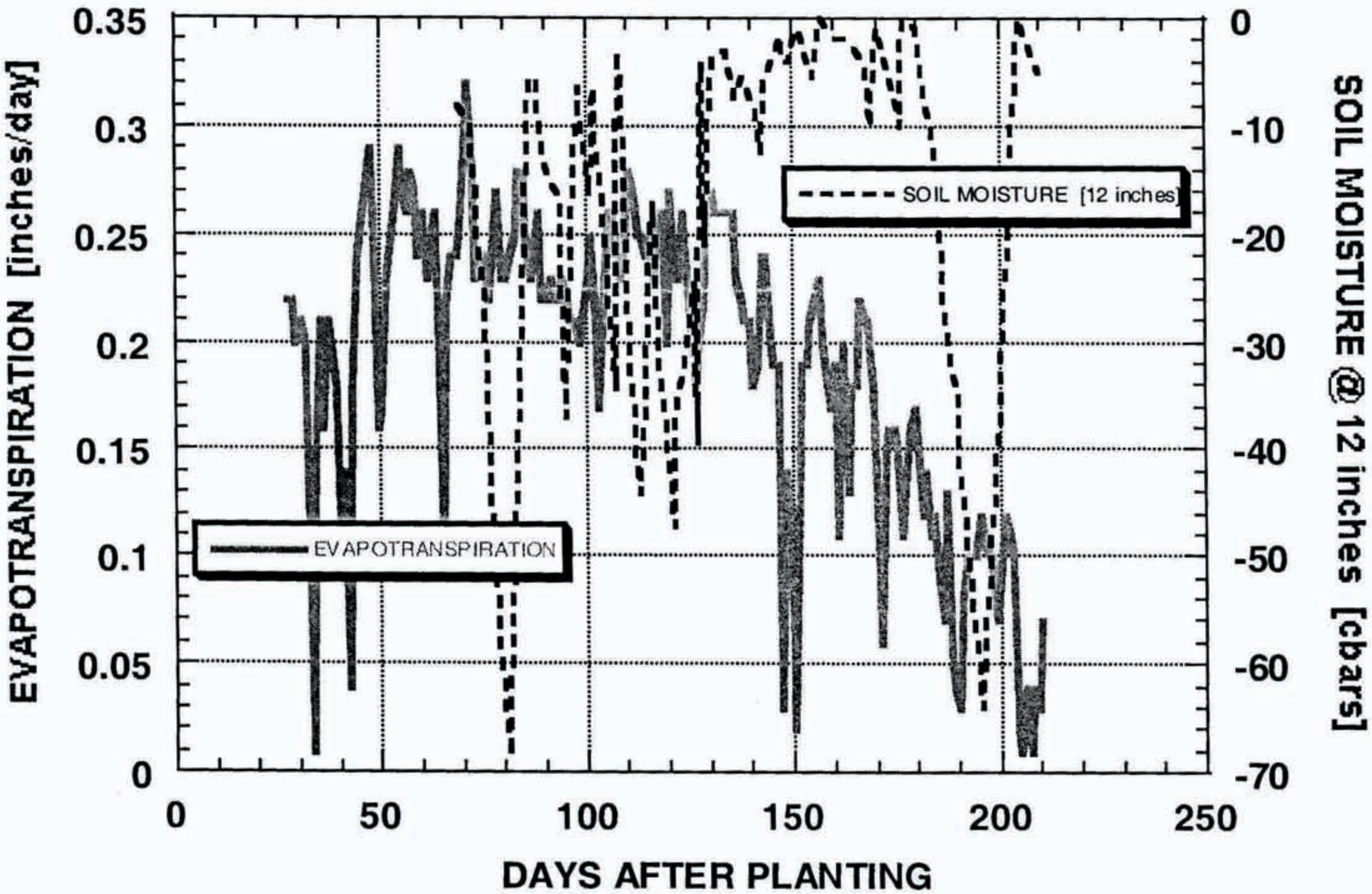


Figure 12. Fixed irrigation schedule does not match crop need as shown by tensiometer measurements and CIMIS ET_o (2001 Season: buried drip, double row peppers, 60 inch beds)

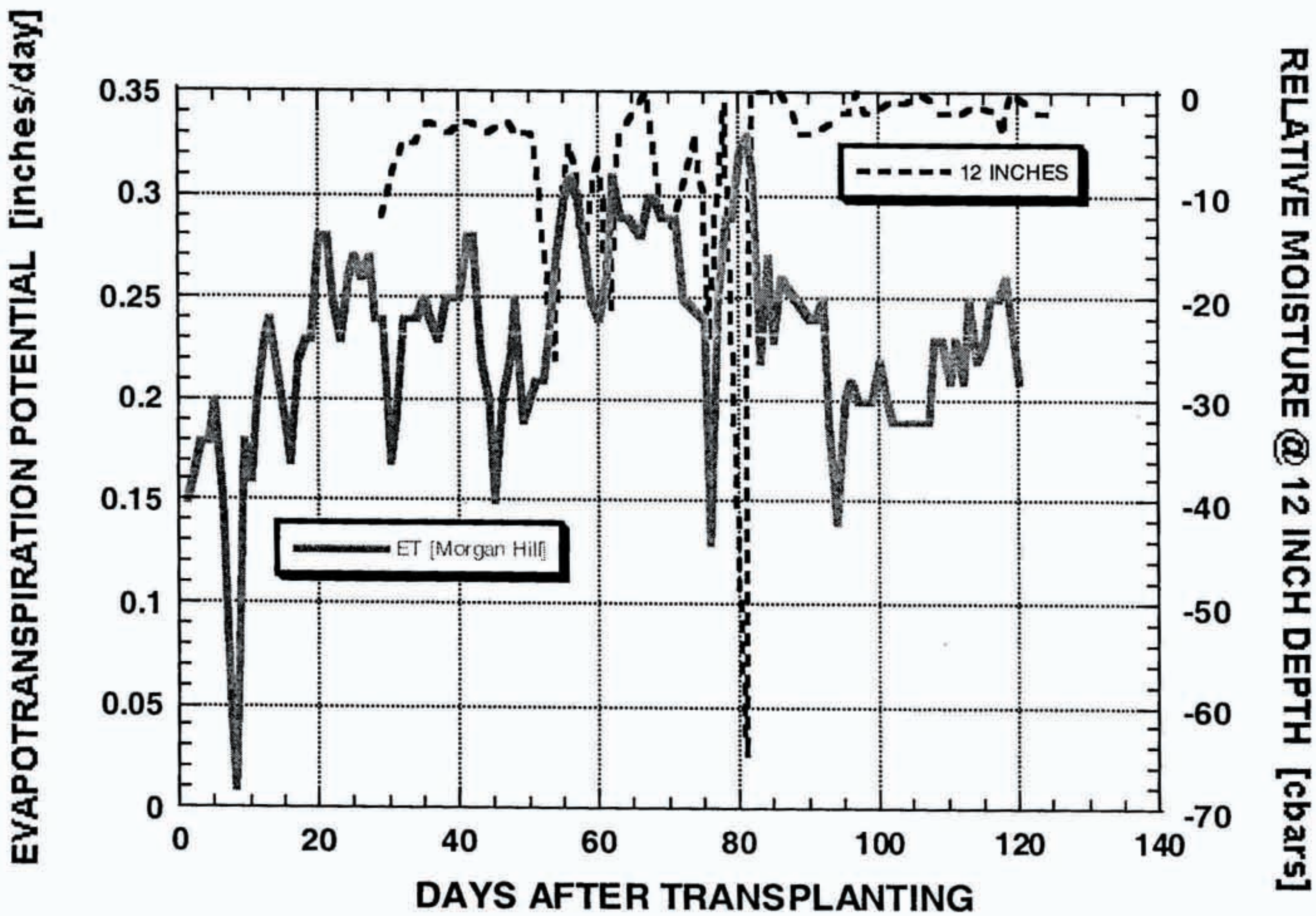


Figure 13. Under-irrigation reduces crop utilization of applied N and increases soil nitrate-N

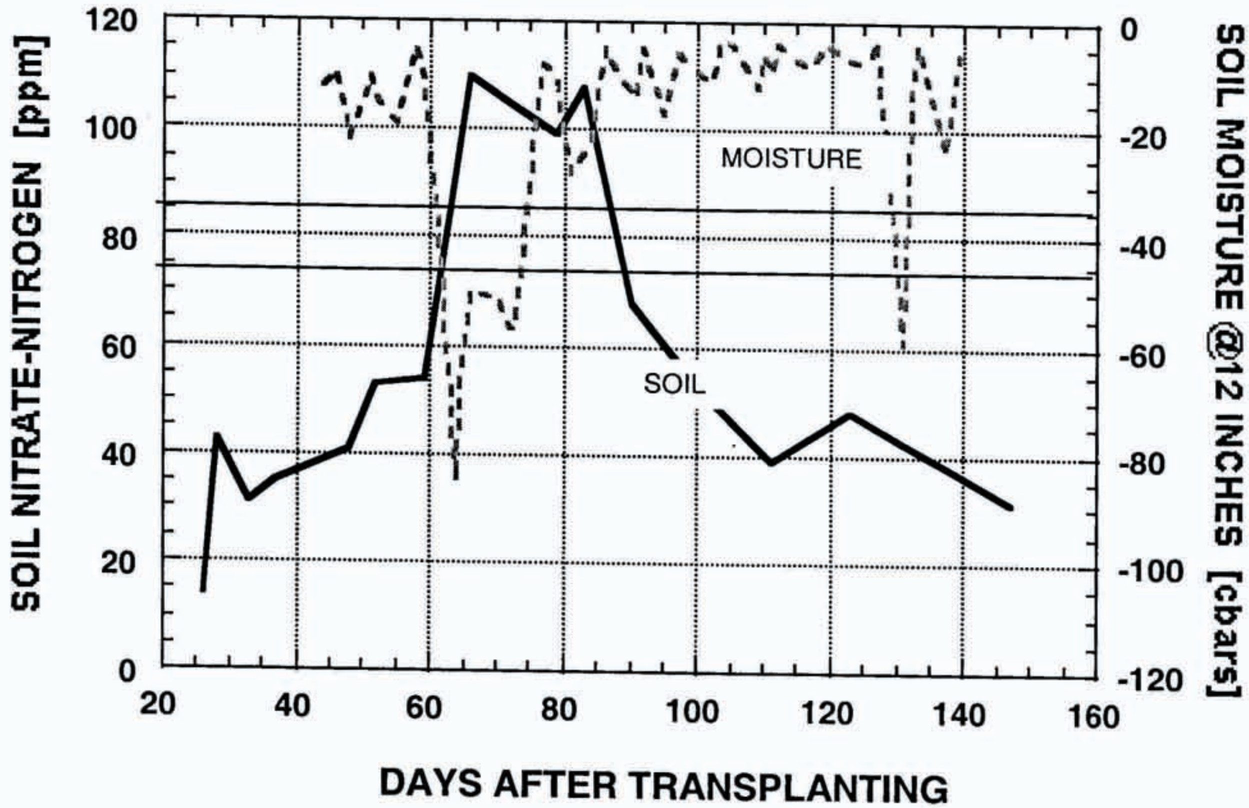


Figure 14. Poor uniformity of applied N resulting from irregularly shaped and sized irrigation sub-blocks

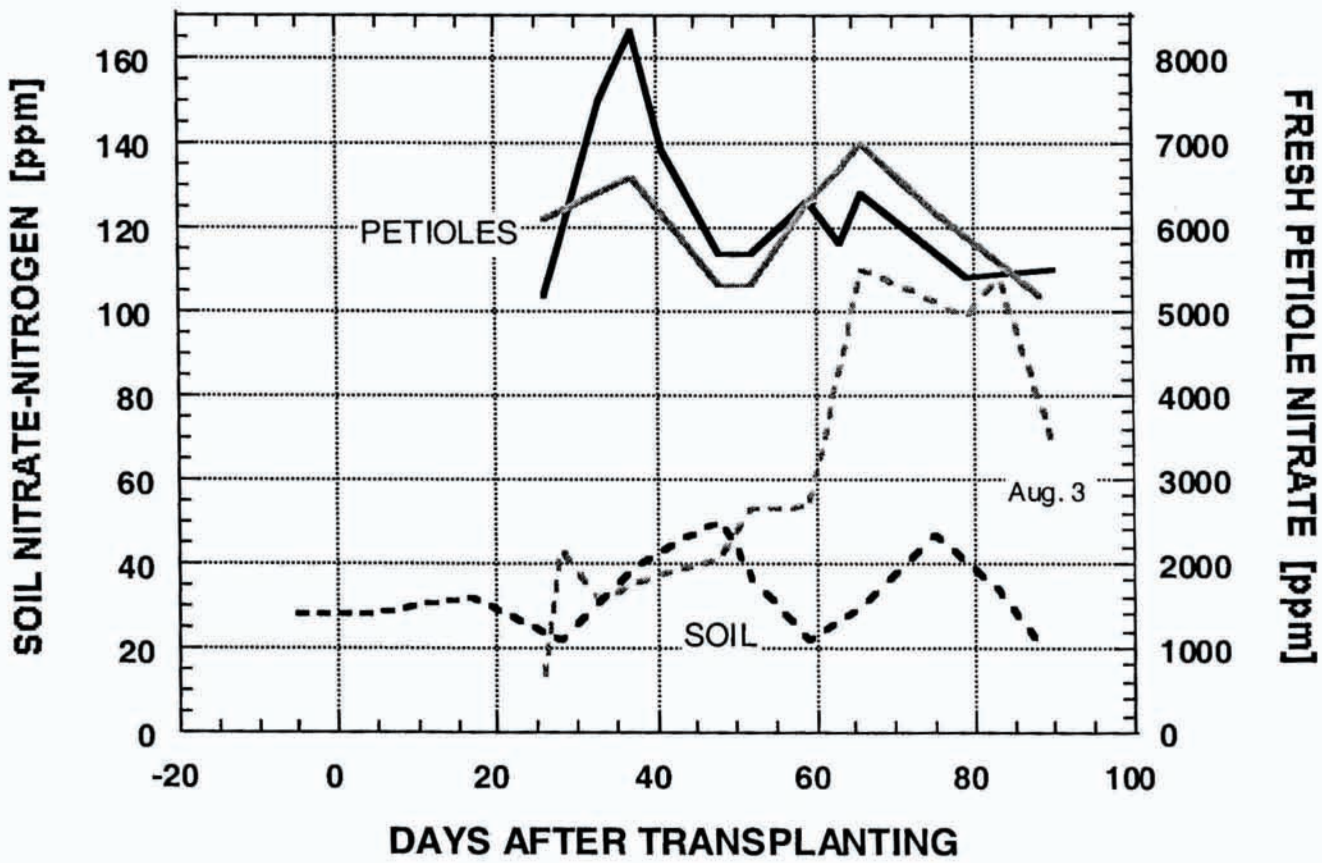
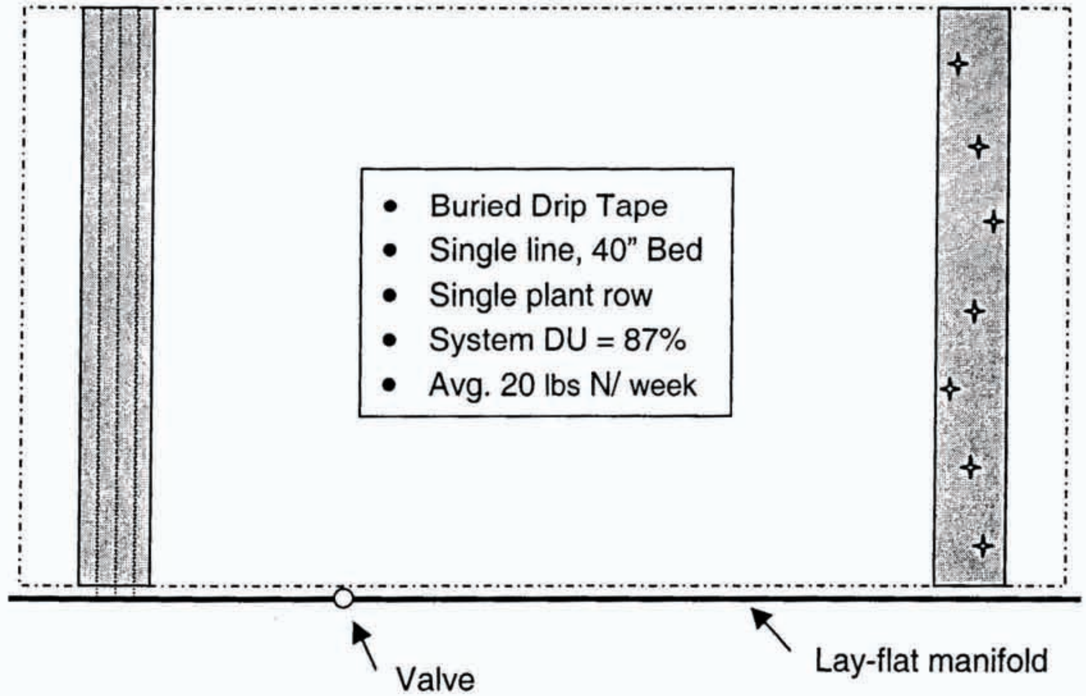
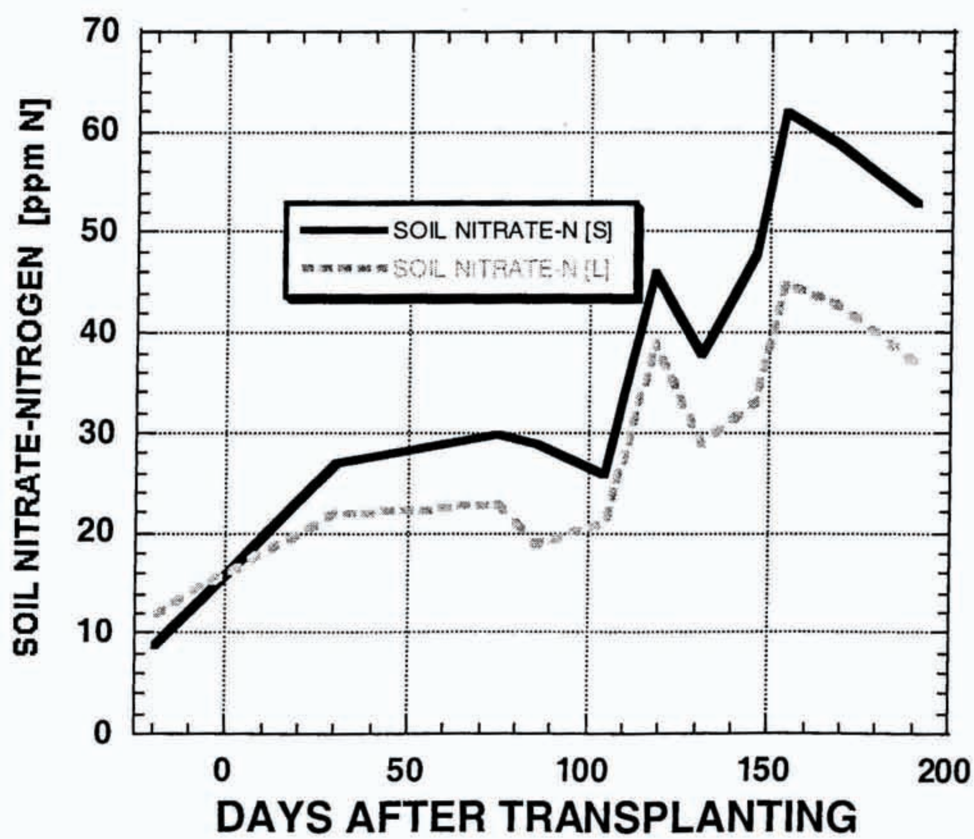


Figure 15. Drip systems design may affect fertilizer-N distribution uniformity across a field





CONCLUSIONS

The project monitored soil nitrate and moisture in twenty-one (21) fields and twenty-eight (28) crop sequences typical of the Santa Clara Valley with sprinkler and drip-irrigation. The results suggest that in many cases crop use efficiency of applied fertilizer may be less than ideal. Differences between sprinkler- and drip-irrigated fields were less significant than differences due to vastly different fertilization and irrigation scheduling for similar crops. In-season leaching may often occur on coarse- and fine-textured soils with high gravel content, and it appears that some growers 'over-correct' with increased fertilization. There were high residual soil nitrate-N levels in a number of fields in 2000, with the exception of a pepper field with plastic-mulched beds. Cool weather in late spring appears to have led some growers to increase N applications to 'push' their crops. In 2001, with more favorable weather some pepper crops received less N fertilizer than the previous year. The critical factors affecting soil nitrate dynamics and residual N are irrigation system type, irrigation/fertilization scheduling, and for drip systems the timing of N injection during any set, soil texture, and the growth stage and relative condition of the crop.

Soil sampling methods had to be adapted to differences in fertilizer placement and the wetted zone where roots are active. Integrating the use of tensiometers complemented the soil and petiole nitrate monitoring and has identified both problems and successes of growers' irrigation systems and scheduling. The data generated by season monitoring provides a picture of the grower's fertilization and irrigation scheduling and where adjustments could be made.

Soil nitrate quick testing is effective for determination of residual N, scheduling of sidedress/topdress/fertigation and assessing problem spots in fields. The five grower cooperators received, not just a season 'picture' of the outcome of their N fertilization programs and irrigation scheduling, but specific reasons why soil nitrate quick testing can improve the efficiency of this critical production input. However, it was found that the quick testing approach is not appropriate to every grower's operation due and adoption may be hindered by the structure of farming enterprise, background of managers/workers, and availability of guidelines for specific crops. It was found that these cooperating growers could reduce N fertilizer levels for a number of crops. These growers can also improve irrigation scheduling thus improve N fertilizer use efficiency. Collaboration with the SCVWD's Mobile Irrigation Lab to provide irrigation system evaluations has enhanced the scope of this project's field work and, ultimately the value of our work with the cooperating growers and participants of public events.

However, in order to meet the objectives of the SCVWDs Nitrate Management Program continued direct assistance, training, and followup is essential. Only a fraction of the region's growers attend workshops offered by UCCE and the SCVWD. Of the five cooperators that participated in this project only two took the time to sample field soils and alter fertilization decisions based on the results. However, this project has been very successful in 'jump starting' that effort and as of Winter 2002, the SCVWD has initiated a continuing outreach assistance program, largely based on the scope and success of this project.

PROJECT EVALUATION

This project has met the SCVWDs goals of initiating a significant outreach effort to growers in the region. Field data and observations have provided all grower cooperators with a new interpretations and perspectives on the N fertilizer programs. However, it has been found that the use of in-field quick tests for soil and petioles is not a good fit for all growers for a variety of reasons. All of these growers have expressed interest in getting a bit more hands-on-training with the in-field quick test methods, but they also feel that they would benefit by additional small plot trials to evaluate the impact of alternate fertilization schemes. The public presentations, 9 have been well received.

OUTREACH ACTIVITIES

1/26/00 "Fine-Tuning Nitrogen Fertilization for Lettuce Production" Nutrient, Irrigation, and Pesticide Management for Lettuce", Gilroy, CA: 20 participants, growers, NRCS personnel, others

2/10/00 "Fine-tuning Nitrogen Fertilization" Nutrient, Irrigation, and Pesticide Management for Vegetables", Gilroy, CA 40 participants: growers, NRCS personnel, others

7/23/00 "Progress on In-field Nitrate monitoring Program for South County Vegetable Growers" SCVWD Ag. Water Advisory Committee, San Jose, CA: growers, ranchers, staff

12/14/00 "In-Field Nitrate Monitoring Demonstration Project: Results and Analysis for Vegetable Crops"
"Field Nitrogen Budgets: A Tool for Efficient N Fertilizer Management"
"Demonstration of Soil and Petiole Quick Testing for Nitrate and Potassium"
Gilroy, CA 45 participants: growers, landscapers, others

11/5/01 "Update of Nitrate Monitoring Project" SCVWD Ag. Water Advisory Committee, San Jose, CA: growers, ranchers, staff

12/5/01 "Summary of In-Field Nitrate Monitoring Project for 2001" Gilroy, CA: 35 growers

ATTACHMENT I

In-Field Soil Nitrate Testing for Drip and Sprinkler Irrigated Vegetables in Santa Clara County

SUMMARY FOR 2000 SEASON

The primary objective of this two-year project is to provide Santa Clara County vegetable growers an opportunity to evaluate the use and value of in-field soil nitrate quick testing to improve fertilizer use efficiency and profitability, while potentially reducing nitrate movement to ground- and surface water. Recent studies and preliminary results from the first season of this project suggest that significant reductions in nitrogen fertilization can be made without negative effects on production and quality. The soil nitrate quick test and a modified quick test provided reliable results when used with good representative soil samples.

- The fields monitored were on sandy to clay loam soil types and included a variety of peppers, head lettuce, celery and broccoli under sprinkler and drip irrigation.
- Generally the cooperating grower irrigation systems met or exceeded the standard for good distribution uniformity (80% for drip and 75% for sprinkler)
- Lettuce yields from plots where the last N sidedress was skipped were similar to those receiving the grower's full N program
- Pepper yields from plots where fertilizer N was reduced from 15 to almost 40% were similar to those receiving the grower's full N program
- One bell pepper crop field appeared to be quite productive while maintaining substantially lower soil nitrate levels than other fields throughout the season. This may have been due to the drip system design and efficient N fertilizer scheduling
- In some cases, significant amounts of plant available N may be supplied from certain agricultural wells in the South County region.
- Data for lettuce crops suggest that drip irrigation can greatly reduce nitrate leaching below the root zone during the season
- In-season leaching of nitrate below the root zone is more likely with sprinkler and furrow irrigation, on sandy soils, and on any soil with substantial gravel content
- The critical factors affecting differences in residual soil nitrate after harvest appear to be irrigation/fertilization scheduling, field and bed layout, drip system design, other soil/climate factors influencing crop development and to some degree soil texture, in addition to the total fertilizer N applied
- Soil sampling methods are critical and must be adjusted for different crops, bed spacing, irrigation and fertilization methods
- The soil nitrate quick test could be used to determine residual and/or pre-plant available N, scheduling of efficient sidedress N applications, and assessing problem areas in a field

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For more information, you may contact Dr. Marc Buchanan at 831-459-6857 or via e-mail at marcusb@got.net

ATTACHMENT II

SOIL SAMPLING FOR IN-SEASON NITRATE TESTING FOR VEGETABLES

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The value of any soil test is directly related to the quality of the field sample. Every field will have unique characteristics, e.g. soil texture, fertilization method, bed/plant spacing that may require a specific sampling method. The in-field nitrate quick test should provide a representative check of the 'effective root zone' for a growing crop over the entire block. Therefore proper soil sampling is a critical factor for the successful use of nitrate quick tests.

Sample Area – The area to be sampled should generally be no more than 20 acres. Smaller areas within a 20 acre block may be sampled when the soil is not uniform throughout the field or when past history has shown stronger or weaker areas within the field.

Sample Location - Traditional annual soil sampling for nutrient analysis may call for random sample collection in a field. However, when soil may be sampled more than one time during the growing season to adjust fertilization or irrigation scheduling, a more structured or grid method should be used. This will assure that you are sampling approximately the same locations in the field over the crop rotation or season that will allow meaningful comparison of test results. An example grid pattern for collection of up to 20 sub-samples is shown in Figure 1 below. This type of sampling pattern would allow an irrigator to collect samples during a typical sprinkler pipe move.

Sample Collection - Tools that may be used to collect a sample include a shovel, soil sample probe, or soil auger. Either a pail or large bag is also required to hold each field or grid 'sub-sample'. Depending on the field or grid size 10 to 20 sub-samples should be collected in the pail or bag. After field collection these sub-samples should be completely mixed, prior to selecting a small portion to add to the nitrate extraction tube. Sample depth must be adjusted to the crop type and development stage to determine the nitrate in the 'effective root zone'. For most crops the soil sample should be from 6 to 12 inches deep. Soil samples from a furrow or bed shoulder will likely miss the majority of root zone. Figure 2 shows an ideal sampling location with a core-type sampler in a 40 inch bed.

Figure 1. An example of a grid soil sampling method for a 20 acre field

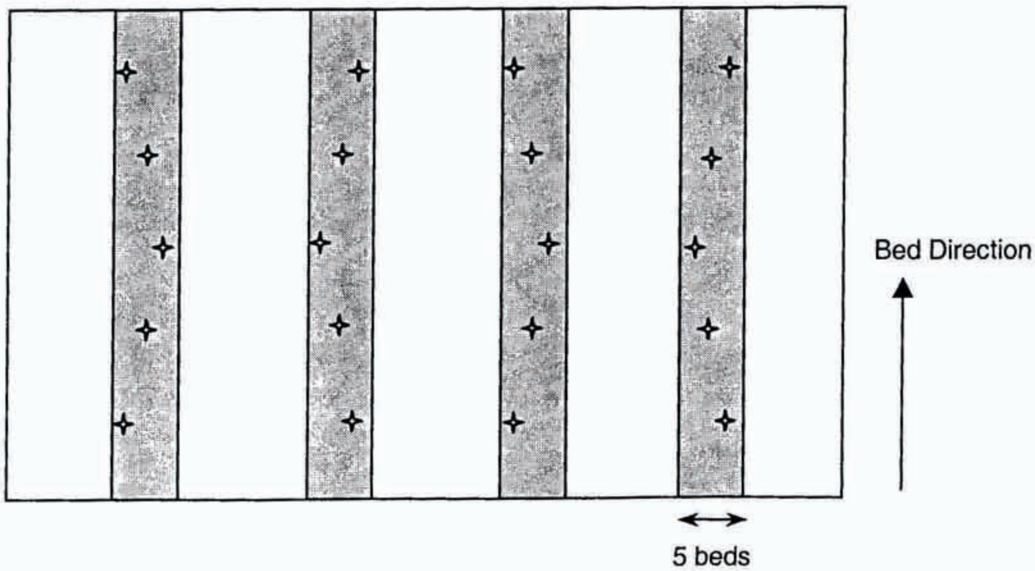
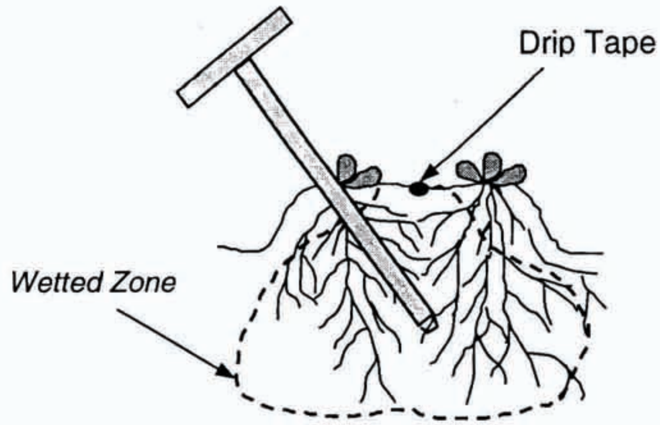


Figure 2. A good method for sampling the effective root zone in a double row bed



Time to Sample - The nitrate quick test can be used at a number of times during the growing season:

- Prior to planting to assess pre-plant N requirements,
- During crop development to determine proper timing or quantity of sidedress N application,
- Assess soil levels following a number of injection sets and allow adjustment,
- Determine degree of leaching following rain or overly long irrigation set,
- Assess residual available N in the middle of a double-crop rotation.

Additional Tips - Avoid sampling fertilizer bands or only near drip tape as this will not give you an accurate picture of the crop root zone. Be sure that you match the timing of your soil sampling to the specific production question/decision that you have. Anticipate sampling a few days before your typical sidedress N application to assess the need or adjust the quantity applied. For long season crops like peppers on drip, you might want to take a monthly sample to assess the effectiveness of your injection schedule.

Typically the soil samples that you collect will have clods or cores that must be broken up to improve the uniform mixing of the sub-samples. Depending on the soil moisture and texture these clods may be easy or more difficult to break up. Also, there may be small stones/rocks in the sample that should be tossed out or at least not transferred to the soil nitrate extraction tube.

Consistency of sampling is a most critical factor in the successful use of the nitrate quick test. . Be sure you or your employee takes the time required to collect and prepare the soil sample. A sample from the corner or edge of the field that's closest to your truck is unlikely to give you reliable information. With good representative soil samples from the same general locations in a field, you will be able to check or improve the effectiveness of your N fertilization programs.

ATTACHMENT III

FIELD NITROGEN BUDGETS: A TOOL FOR EFFICIENT NITROGEN FERTILIZER MANAGEMENT

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A key to improving the efficiency of nitrogen (N) fertilization is the adoption and use of in-season monitoring of the soil-plant system and maintenance of detailed crop and field records. The main elements essential to optimizing N fertilizer management are:

- *Utilize residual soil N*
- *Credit N release from soil, residues, and additions in irrigation water*
- *Match N application to actual crop need*
- *Soil and plant tissue tests*
- *Recognize the impact of above- and below-ground diseases*
- *Evaluate irrigation efficiency and uniformity*

Match N application to actual crop need

In order to optimize the match of N fertilizer applications to actual crop need, in-season monitoring of soil N, residual N and crop performance should be recorded for each rotation on each field. A simple balance sheet (see Table 1) can provide a grower with a useful record-keeping tool for additional fine-tuning of nitrogen fertilizer programs with time. This allows a means to reasonably estimate N inputs and, with production records, allow you to track the potential efficiency of your current or modified N fertilizer program for any field. While you may not be able accurately determine the actual units of N for certain lines on the sheet, there are some guidelines contained in that tabel. Table 2 provides some guidelines for reasonable estimates of N uptake by some example crops.

Utilize residual soil N

Residual N is defined as the mineral N remaining in the soil following cropping. The quantity of residual N in soil will reflect previous N fertilization and water inputs, the relative portion of N removed from the field in the harvested crop, and the release (mineralization) of N from plowed down residues and soil organic matter. In some fields following a double-cropping sequence, residual nitrate-N in the top foot of soil may be as high as 180 lbs. per acre. Determination of this plant available N prior to the start of the growing season or between crops will allow the grower to adjust, when indicated, pre-plant N applications. Determination of residual N between rotations, may also provide information that may allow for the reduction or elimination of either pre-plant or sidedress N applications.

Credit N release from soil, residues, and additions in irrigation water

As mentioned, a significant portion of available soil N may come from the release of N from residues, soil organic matter, and irrigation water. Research in the Salinas Valley has determined that approximately 50 to 80 lbs. of N may be released from soil organic matter during a typical lettuce crop sequence. Table 1 provides a range of N release values for sandy to clayey soils, assuming that a higher soil organic matter in more clayey soils.

Additionally, there can be significant releases of N from the rapid mid-season decomposition of certain crop residues (lettuce, broccoli, cauliflower) which may raise the total N supply from soil and residues as high as 3 lbs. per acre per day for a period of time during the following crop sequence.

Occasional determination of the nitrate-N content of irrigation water will also allow the grower to adjust N fertilization programs based on the total N potentially added during the crop period. If your irrigation water contains greater than 10 parts per million nitrate-N, then N additions during a typical crop may be significant and therefore should be added as a fertilizer 'credit' for the crop. Table 3 provides a summary of the nitrate-N content of a number of agricultural wells in South Santa Clara Valley. Monitoring of soil nitrate-N during production of a vegetable crop will indirectly measure the N released from soil and residue, applied with water sources and thus may allow the grower to delay or reduce sidedress or fertigation N.

Soil and plant tissue tests

In-season testing of soil and plant tissue is a critical tool for assessing N status. Simple nitrate-N 'quick tests' for soil and plant petiole sap have been developed. These tests are easily performed by a trained worker and have been shown to have a very low break-even cost. Recent lettuce trials on over 15 fields in the Salinas Valley have allowed cooperating growers to reduce N fertilizer inputs by an average of 90 lbs. per acre per crop. When appropriately applied, the soil nitrate-N quick test will allow the grower to rapidly determine the timing and quantity for sidedress N applications and, in some cases, may also be applied to mid-season pre-plant decisions.

Recognize the impact of above- and below-ground diseases

Monitoring of the presence, development and extent of diseases can also have an impact on N fertilization decisions and crop utilization. Any infection that limits crop development may also limit the crop's ability to absorb soil N. For a leaf disease like mildew, there may be limited plant response to additional N, whereas with low incidences of some soil-borne root disease the crop may respond to additional fertilizer N. In both examples, the impact of disease may result in an increase in residual soil N following the crop, which should and can be accounted for in management of a succeeding crop.

Evaluate irrigation efficiency and uniformity

Efficient management of irrigation water will limit the runoff and/or leaching of fertilizer N out of the effective root zone in sprinkler, surface, or drip irrigated crops. Improvement of irrigation systems that increase irrigation uniformity will have direct impact on the efficiency of N fertilizer uptake. Effective application of water in the early stages of crop development, when plant cover and root systems are small may have dramatic positive effects on N fertilizer use efficiency. Irrigation application rates and scheduling that are adjusted for the infiltration and storage capacity of different soil types are also important to maximizing the use of N fertilizer.

ATTACHMENT IV

Uesugi Farms [Joe Aiello]
Red and Yellow Bell Peppers, Mitla Jalapeno

SUMMARY

Soil and petiole monitoring, as well as a small field trial, suggest that increased fertilizer use efficiency is possible for the bell-type peppers. The red and yellow varieties appear to respond a little differently to your fertilization and irrigation program. Red bell peppers may have received a bit too much N prior to fruit bulking as determined by petiole nitrate levels and the results of a small field trial. A comparison of soil nitrate-N with soil in the Mitla block also suggests that there may have been two periods when soil nitrate-N levels were increased higher than necessary. Comparison of petiole nitrate and potassium data suggest that the crops experienced excess or 'luxury' uptake of N and K, particularly early in the season.

It appears that a significant portion of early season N fertilizer may be unused by the crops due to movement of nitrate away from the developing root zone. In the Mitla block we found a sharp increase in nitrate in the furrows 20 days after transplanting followed by rapid declines when there were no roots in this soil zone. There may be some benefits to adjustments in irrigation and fertigation scheduling.

DUC 60 – Red and Yellow Bell

Figure 1 gives details on the sub-blocks and sample locations we used for monitoring the crop[s]. The identical locations were used to collect soil and petiole samples on an average weekly basis. A total of five soil samples and 20 petiole samples were taken in each 6 acre sub-block. Soil samples were kept on ice until extraction and fresh petiole sap was analyzed with a hand-held Cardy meter for nitrate and potassium within 24 hours of collection.

Soil and Petioles

Figure 2 compares soil and petiole nitrate from the north and south sub-blocks with either red or yellow peppers. At the time of writing this report I only have my estimate of N fertilization based on early season information from Robert. Therefore I can only comment on some things from early season up to the first harvest. First, it is obvious that the two different varieties responded differently to your irrigation and fertilization program. Generally the changes in soil nitrate-N in response to fertigation were similar in all sub-blocks, with two peaks at approximately 40 and 70 days after transplanting. However a comparison of petiole nitrate between the two varieties suggests a different response. This is most apparent at approximately day 60. I have assumed that you called for an increased N application as the petiole nitrate levels were falling quite rapidly due to the heavy early fruit set. The rapid rise of petiole nitrate in the red bells indicates 'luxury' consumption of N beyond the actual needs of the crop, while the taller yellow bells appear to have utilized more for additional growth. Also note that petiole levels averaged about 5,000 ppm for red bells and 4,000 for yellow following the first harvest at about 80 days. Figure 3 compares petiole nitrate and potassium and the potassium fluctuations early in the season also suggest some difference in plant development and response to fertilization. Also note that during the period when petiole nitrate levels began to fall, potassium levels were increasing (see end of report for more on this).

The rapid declines in soil nitrate-N after approximately day 70 cannot be completely explained by crop uptake. Rather I believe that irrigation and fertigation scheduling may have caused a significant portion of applied N to be moved out of the root zone. As I understand these blocks were typically fertilized with the first irrigation of the week, then followed later in the week with only water. This may explain a pattern that we observed in your other field and in two other drip irrigated fields we monitored this season. Figure 3 shows the results of sampling soil adjacent to buried drip tape, approximately 8 inches away on the bed shoulder, and in the center of the furrow. Note that at 40 days there is a spike in nitrate-N in the furrow suggesting that water is moving fertilizer to this zone. We did not see any roots at all in the furrow until about day 100. Therefore the N moved to the furrow is likely not used by the crop and may be leached. Figure 4 compares soil nitrate-N at the 1, 2, and 3 foot depth in the middle of the DUC 60 block before transplanting and at last harvest. The overall decline and then the uniformity of nitrate levels in October certainly suggest that leaching below this soil depth might be occurring.

Soil Moisture Monitoring

Figure 5 compares changes in soil moisture at the 12 inch depth with the evapotranspiration (in inches per day) measured at the Morgan Hill CIMIS weather station for both sub-blocks. The moisture data is derived from routine readings of tensiometers (6, 12, and 19 inch depths) installed at three locations in the field. Again, there appear to be some differences in how irrigation scheduling and crop development affected soil moisture. Early in the season there were regular changes in moisture in response to irrigation and crop uptake. During the first heat spell in June (approximately day 58 to 68) the bed shoulders and 6 and 12 inches (not shown) were dry and by the second hot period the red bell crop was stressed for a few days (After two seasons in your area I have noted that the critical moisture stress level for bell-type peppers is between about –35 and –45 cbars as measured by a tensiometer).

I noticed that irrigation frequency and set length was increased then to correct the stress (after day 80). After that the soil under red bell peppers was maintained at almost saturation for much of the remaining season. This suggests that over-irrigation would partly explain the rapid decline in soil nitrate-N levels and the similar levels to 3 feet deep in late October. In comparison the yellow bell crop responded differently to the change in irrigation scheduling. If you compare the soil moisture line to the evapotranspiration you can see how rapidly the potential daily water need dropped after that one stress period. These comparisons also suggest that there may have been over-irrigation. I have noted a similar pattern in other crops in your area. In some cases growers may use a fixed irrigation schedule for much of the crop rotation. As the evapotranspiration rate goes down in mid-July the crops are using less and less of that applied water and nitrogen.

Red Bell Yield Comparison

Table 1 shows the results of a small trial that we conducted in the short beds indicated on the field sampling map (Figure 1). We achieved reductions in N fertilizer by installing in-line valves at the head of the beds (unfortunately they were leaky and were subsequently removed by your irrigator). First, we observed no statistical differences in our plots where our records for the period (provided by Robert) indicate that the 'reduced' plots received 60 less lbs of N. Research has shown that early over-fertilization and 'luxury' consumption of N by peppers leads to delayed maturity as is suggested by the comparison of the first picking from these plots. Figure 6 shows that both petiole nitrate and soil nitrate-N in the beds where N was reduced (gray lines) were lower than the rest of the field, yet did not result in significant reductions in yield.

101 N Mitla Jalapeno

Figure 7 compares the Mitla block with the DUC 60 block. With lower total N application soil nitrate-N does not spike as much or as high. Clearly the sufficiency level for petiole nitrate is likely much lower for chili varieties (no big news here, although UC researchers have no data). Figure 8 shows petiole nitrate and potassium. Generally the declines at about day 80 are largely due to the fruit load and the later increases the result of harvesting and renewed uptake of soil nitrogen and potassium. As was shown for the red and yellow bells in the early portion of the season, nitrate petiole levels fell as potassium levels increased.

ADDITIONAL OBSERVATIONS

Interactions from N and K fertilization

Theoretically, there can be many interactions of fertilizers in soil that lead to changes in plant nutrition. Petiole monitoring of these peppers crops show that you maintained nitrogen and potassium in the assumed sufficiency range. However the small fluctuations in petiole potassium (particularly for red and yellow bells) later in the season when compared with the large fluctuation in nitrate suggest some interaction between N and K.

We have previously discussed the problems that you and other pepper growers experienced when shifting to drip irrigation. While some of this may have been due to low soil potassium, there were likely problems related to the smaller wetted zone that can limit potassium availability due to depletion. Dry soil also limits potassium movement to roots, while soil potassium availability increases sharply at high moisture contents. In response you have added substantial potassium in pre-plant and include KTS with every fertigation. This years monitoring suggest that the crops may have experienced 'luxury' consumption of potassium in addition to nitrate as discussed earlier.

Research generally demonstrates that increased potassium availability and uptake can lead to higher levels of N uptake (particularly from nitrate) by crops. At the same time there is some research that indicates that increased potassium and/or sulfate levels in plants can lead to decreased nitrate-N levels in plant tissue (due to rapid conversion to proteins, etc.). Therefore, as sulfur and potassium availability is increased by the addition of KTS, petiole nitrate levels may decline dramatically even though N nutrition is actually adequate. This may explain the rapid decline in petiole nitrate levels in the red and yellow bell crops during the rapid growth that occurs between 40 and 60 days after transplanting. *Bottom line, all of this suggests that you have supplied more than adequate amounts of nitrogen and potassium to these crops.*

Figure 1. MONITORING LOCATIONS FOR UESUGI FARMS