GRANT NUMBER:	20100084	**Progress Report**	Final
		Reporting Period:	February 24, 2010 to June 30 2011
		Submittal Date	July 6, 2011

Agency Name: University of California Cooperative Extension, Monterey County

Project Title: Optimizing irrigation and nitrogen management in strawberries for improved water quality

Contractor Name: Michael Cahn

Project Director: Michael Cahn (Printed Name) — Michael Cahn (Signature)

Table of Deliverables

(Place your Table of Deliverables here for both your midterm and final reports. It should be the same Table of Deliverables that was sent to Foundation along with your signed award letter. See sample below.)

Table 1. Deliverables Schedule

Tasks	Description of Deliverables	Due Date	% of work completed	Date Submitted
1.0	Determine water and nitrogen use in strawberries and estimate nitrate leaching		100%	7/6/11
1.1	Photo documentation of established field sites	04/30/10	100%	8/30/10
1.2	Field table with water use information	Updated in mid, draft and final reports	100%	5/26/11
1.2	Water use uptake curves	12/31/10	100%	5/26/11
1.3	Field table with nitrogen use information	Updated in mid, draft and final reports	100%	5/26/11
1.3	Nitrogen use uptake curves	12/31/10	100%	5/26/11
1.4	Field table with nitrate leaching losses information	12/31/10	100%	7/15/11
2.0	Analyze, report, and extend results to the strawberry industry		100%	7/15/11
2.1	Summary report with analysis and field trial results	06/30/11	100%	7/15/11
2.1	List of potential management practices	06/30/11	100%	7/15/11
2.2	Description of management practices and implementation recommendations	06/30/11	100%	7/15/11
2.3	Copies of meeting agendas where results are presented	05/30/11	100%	7/15/11
2.4	Copies of newsletters and trade journal articles where results are presented	05/30/11	100%	7/15/11
3.0	REPORTING			
3.1	Progress reports by the twentieth (20th) of the month following the end of the project quarter (April, July, October, January)	04/20/10 07/20/10 10/20/10 01/20/11 04/20/11 07/20/11	100%	
3.2	50% Midterm report	11/30/10	100%	11/30/10

3.3	Draft and Final Project Reports			
3.3.1	Draft Project Report	06/30/11	100%	7/15/11
3.3.2	Final Project Report	08/31/11	100%	8/15/11

List of Deliverables Submitted For Midterm *(by subtask number, please clearly mark the subtask number at the top left hand corner of each deliverable)*

- 1.1, 1.2, 1.3, 1.4
- 2.1,2.2,2.3

Progress Report Narrative

(Provide a brief introduction or summary of the report (e.g., "During the reporting period, project activities focused on completing design of the three sediment basins"…. Or "Activities were largely focused on organizing and hosting 4 tailgate meetings to discuss …" Or "Water Quality data was collected monthly at 6 sites, with data analysis indicating that…" etc.)

Introduction:

Commercial strawberries are often produced using high rates of water and nitrogen fertilizer which can potentially lead to a loss of nitrate-nitrogen by leaching. Despite the economic importance of strawberries and their potential impacts to water quality, little data exists on typical water use and nitrogen fertilization practices in commercial production. This project proposes to gather base-line data that will determine current water-use and nitrogen management practices in commercial strawberry fields. The project will also estimate nitrate leaching losses, develop nitrogen uptake guidelines, and water use model for strawberries. Results from the trials will be presented to the agricultural community through oral presentations, and in newsletter and trade journal articles by the co-PI's of the project.

Summary of Activities

Task 1 – Determine water and nitrogen use in strawberries and estimate nitrate leaching (100% complete)

(Describe by sub-task activities, problems, successes, milestones… If a deliverable is complete, please state that, and add a copy of the deliverable (listed above). If a deliverable is not complete, please state that, and describe progress towards completing the deliverable).

Subtask 1.1. Establish Field Sites (100% complete). Meet with grower cooperators; determine appropriate field sites; interview growers for standard practices for management of water and nitrogen fertilizer. This task includes installing flow meters and dataloggers, measuring the irrigated area, collecting soil samples for physical and chemical analyses, collecting samples of irrigation water for chemical (salinity, nitrate, etc) analyses.

We met with grower cooperators during February of 2010, determined appropriate field sites, and interviewed participating growers for standard practices for management of water and nitrogen fertilizer. A total of 17 sites were established (7 more than was originally proposed) for the 2010 production season. We collected soil samples for physical and chemical analyses, as well as irrigation water for chemical (salinity, nitrate, etc) analyses. The sites have been photo documented, and were sent to regional board staff.

Flow meters were installed in 6 additional commerial fields in October 2010 to measure applied water for establishment of strawberries and soil nitrate status during the fall and winter period (Table 4). Transplants were established with drip irrigation in 2 of the fields and the remaining 4 fields were irrigated with overhead sprinklers during crop establishment and then switched to drip after establishment.

Subtask 1.2. Measure applied water and estimate water use of strawberries (100% complete)
Flow meters will be installed in the drip system to monitor water applied to a 1 to 2-acre area. During establishment of plants in the fall, flow meters will be located on the sprinkler main lines to monitor applied water. The date and duration of the irrigations as well as the applied volume of water will be recorded using data loggers interfaced with the flow meters. Soil moisture will also be monitored in the irrigation blocks using soil moisture sensors. Soil texture and bulk density will be characterized at each site to determine the water holding capacity of the soil. The irrigation water will be analyzed for salinity and nitrate at each site. Strawberry water use will be estimated using CIMIS evapotranspiration data and crop coefficient estimates based on measurements of canopy cover. Canopy cover measurements will be made from infra-red photos. This subtask will be coordinated by Michael Cahn

Flow meters were installed in approximately 0.5- to 1-acre sections of 17 commercial strawberry fields throughout the Salinas-Watsonville production region between January and February of 2010. The flow meters were interfaced with dataloggers to record the irrigation scheduling pattern and granular matrix blocks and tensiometers were installed at each site to monitor soil moisture. Periodic infra-red photos of the canopy development were processed for estimating crop coefficients for strawberry. Spatial CIMIS was used to estimate the reference ET associated with each field site. Samples of irrigation water were collected for analysis of nitrate and salinity content. Undisturbed cores of soil were collected for determining the water retention pattern for each soil type. Soil samples were also collected for texture analysis. Flow meters were installed at 6 additional sites in October 2010 so that the volume of water used for transplant establishment could be determined.

Results:

Total applied water to strawberries between January and October 2010 for 17 sites is summarized in Fig. 1 and Table 2. The average amount was 21.0 inches and the median amount was 20.8 inches. Crop ET estimates for the sites, developed from measures of canopy cover (Fig. 2 and Table 1) and spatial CIMIS reference ET data (Fig. 3), showed that the average amount of water applied was 94% of crop ET (Fig. 4) but ranged from 55% to 161% of crop ET. These initial results suggest that more than half of growers were under irrigating their crops during the production season and about 10% were over-irrigating during the same period. Winter rainfall ranged from 11.9 to 17.6 inches, and averaged 14.2 inches across all sites. Although some rainfall likely supplemented the water needs of the crops, 90% of the precipitation occurred between January and April when crop water needs were minimal due to low reference ETo values and small canopy cover (Fig. 2). Crop ET averaged 1.9 inches between January and April (Table 1) and applied water averaged 1.6 inches during the same period (Table 2), demonstrating that growers applied more than 90% of their irrigation water after rain events had ceased.

These preliminary results demonstrated that a majority of growers were not over-irrigating during the production season, and were unlikely to significantly contribute to the leaching of nitrate-N beyond the root zone. Also, the average volume of water applied per irrigation was 0.26 inches across all sites, and ranged from 0.15 and 0.4 inches per irrigation. These volumes of applied water would be unlikely to exceed the water holding capacity of the soil and therefore would minimize drainage. Most of the potential leaching of nitrate-N would likely have been during the rainy season when the sum of applied water and rainfall would have exceeded crop ET. Nevertheless, because the beds were covered with plastic mulch, only precipitation that entered the planting holes and furrows would contribute to leaching.

The total volume of water applied during the production season did not differ significantly among sites with different soil textures (Fig. 5). The average volume of water applied to fields with clay and silt loam textures was similar to the volumes applied to sandy loam textured soils.

Our data confirmed that the fields with the lowest system flow rates were usually where less water than crop ET was applied (Fig. 6). For all but 2 fields, measured flow rates were less than rates estimated from the manufacturers' drip tape discharge rates. The average seasonal flow rate for the 17 fields was 76% of the expected flow rates and the lowest measured flow rate was 27% of the expected flow rate.

A likely cause for this deviation between actual and expected system flow rates may be due to a lack of pressure regulation of the drip systems. We noted that growers were not using pressure regulators to optimize the drip tape pressure to the manufacturers recommended pressure. Rather they hand adjusted a gate valve to a desired pressure, often determined by squeezing the drip tape. Reliance on this practice for regulating system pressure resulted in significant variation in flow rate among individual irrigation events within the same field. The coefficient of variation in the system flow rates averaged 17% among individual irrigation events and was as high as 29% for some sites.

In addition to water applied during the production season, an average of 4.2 inches of water was applied to establish new strawberry plantings between October and December 2010 (Table 4, Fig. 7). An average volume of 1.5 inches was applied before planting so that the soil moisture was optimal for listing beds, and an average of 1.7 inches was applied after transplanting. Rainfall averaged 6.2 inches for these sites during November and December. Although the rainfall amount was more than adequate to satisfy crop ET requirements during this period, supplemental water would still be needed between storm events to maintain adequate moisture around the root balls of the transplants. Soil nitrate leaching was not monitored during crop establishment using suction lysimeters, nor was soil moisture monitored, during this period since these tasks were not part of the project agreement. Apart from determining the volume of water used in crop establishment, the time period of focus for this project was during the production season.

Subtask 1.3 Measure soil nitrogen status and nitrogen uptake of crop (100% complete). Plant N status and soil nitrate level will be determined every 6-8 weeks in all fields; in a subset of fields whole plant sampling for total crop N uptake will be performed to allow the development of a N uptake curve for strawberries. Grower fertilizer practices will be surveyed for each of the field sites.

A total of 30 strawberry fields throughout the Watsonville-Salinas production area were monitored monthly for root zone soil nitrate concentration from March through August at monthly intervals (Fig. 8, Table 11). Cores were collected from the top 10 inches of soil, and extracted with 2 N KCl for determination of NH_4-N and NO_3-N. Concurrent with the soil sampling, leaf and petiole samples were collected and analyzed for total N and NO_3-N, respectively.

In four of these fields 12 whole plants per field were collected at monthly intervals; two fields were planted with the day-neutral cultivar 'Albion', and two with a proprietary day-neutral cultivar. Fruit were removed, and vegetative dry weight and total N content were determined. Fruit samples were dried for measurement of N concentration; N uptake in fruit was estimated from grower-reported yield and fruit N concentration.

<u>Results:</u>

Across 30 fields monitored there was a trend toward declining soil NO_3-N as the season progressed (Fig. 8). From May through August mean root zone NO_3-N was maintained around 5 PPM. Among fields there were substantial differences in N management, with some fields remaining below 2 PPM NO_3-N for extended periods, while in other fields N fertigations caused spikes in soil NO_3-N above 10 PPM. (Note: one field was not included in this analysis, due to concern that on several sampling dates the soil samples were contaminated by inclusion of controlled release fertilizer pellets, which biased the results).

Crop N content in vegetative tissue increased linearly throughout the season (Fig. 9 and Table 5). Averaged across fields, vegetative N content increased by just over 0.5 lb per acre per day, and totaled 83 - 102 lb/acre by the end of August (Table 6). Across fields, fruit N concentration averaged between 1.2 - 1.5 % on a dry weight basis, with fruit averaging approximately 9% dry matter. Multiplying the grower-reported seasonal marketable yield by the mean fruit N concentration estimated seasonal fruit N content, which ranged among fields from 64 - 99 lb/acre. Therefore, estimated seasonal N content in above-ground biomass ranged from 147 - 199 lb/acre (Table 6).

It should be noted that these estimates are lower than actual values, for several reason. Cull fruit was not included, and some early leaves dry down and are lost before late season whole plant sampling. Assuming that cull fruit represent approximately 15% of the total produced, and loss of leaf tissue by the final sampling date represents 10% of the total produced during the season, total plant N uptake into above-ground biomass could approach 220 lb N/acre. The other important consideration is plant population. All four of these fields were planted in a two-row configuration at a plant population of approximately 21,000/acre. Some fields in the Watsonville-Salinas region, and most fields in the Santa Maria area, are planted on a 4 row configuration at plant populations as high as 30,000/acre on beds. Preliminary data from 4-row fields in Santa Maria, sampled as part of a separate project, indicated that vegetative N uptake was at least 20% higher than in the 2-row fields reported here. We found that plant population did not affect fruit N concentration, so fruit N content was proportional to fruit yield, regardless of plant population.

Complete fertilization records were obtained for 17 of the 30 fields monitored (Fig. 10, Table 7); other growers were reluctant to share that information, or kept incomplete records. While fertilization practices varied widely among growers, the mean seasonal N application was 187 lb N/acre; the mean preplant and fertigated N application was 96 and 92 lb N/acre, respectively. These estimates do not include NO_3-N contained in irrigation water. Irrigation water NO_3-N concentration was determined for 23 of the 30 monitored fields. NO_3-N was greater than 10 PPM in 4 of these fields, and greater than 20 PPM in 2 fields (Table 12).

Although the average rate of fertilizer N applied during the season was comparable to the average amount of N taken up by the crops, significant variation was observed among fields. Total applied N for the season varied from 123 to 301 lbs N/acre. Preplant fertilizer N amounts varied from 24 to 234 lbs N/acre. Nitrogen applied by fertigation ranged from 3 to 223 lbs N/acre.

Subtask 1.4 Estimate nitrate leaching losses (100% complete). Nitrate leaching losses during several irrigation events will be measured in 3 to 4 fields. Nitrate leaching will be calculated from estimates of percolation during irrigation events and by sampling leachate from below the root zone of the crop, using an automated suction lysimeter. This subtask will be coordinated by Michael Cahn and Tim Hartz

Suction lysimeters (6 per field, 24" depth) were installed in 3 fields in June 2010. Once per week through August, a 20 centibar vacuum was applied to these lysimeters during an irrigation event, and samples of gravitational water were collected and analyzed for NO_3-N concentration. On each day of leachate collection root zone soil NO_3-N was also measured. Drainage volume was estimated by the following relationship:

Drainage volume (inches) = Applied Water (inches) – Crop ET (inches) – change soil moisture (inches)

Applied water was measured using the flow meter installed on the submain of the field. Rainfall volume was negligible during the period of monitoring (June –August) and was not factored into the calculations. Crop ET was estimated by the procedures described above. Volumetric soil moisture sensors were used to estimate the change in soil moisture storage. Nitrate leaching loads were estimated by multiplying the volume of drainage by the concentration of nitrate-N of the leachate samples.

Results:

The 3 fields in which leachate samples were collected showed varying trends (Fig. 11, Table 8). In field D-1 relatively low leachate NO_3-N (11 ppm) in June increased as the grower increased N fertigation during July and August. Field D-2 began with relatively high leachate NO_3-N (69 to 112 ppm) in June, with values trending lower through the season as root zone NO_3-N declined. Soil NO_3-N was maintained at a low concentration in the root zone of Field D-16 throughout the season (1 to 3 ppm, Table 11), and leachate NO_3-N remained low as well (3 to 17 ppm in Table 8). Averaged across fields, the seasonal average concentration of NO_3-N in the leachate was 25 ppm.

Drainage volumes were also generally low during the production season during the period monitored from June through August. In field D-16, irrigation was marginally less than estimated crop ET for most of the sampling period, with a significant leaching volume occurring only in week 3. In fields D-1 and D-2, irrigation exceeded crop ET over the sampling period (June – August) by 5.1 and 2.5 inches, respectively (Fig. 11).

Combined with relatively small leaching volumes in these drip irrigated fields, estimated NO_3-N loading was modest in comparison with other cropping systems in the coastal region. Average NO_3-N leaching loads ranged from 0 to 16.4 lb N/acre per irrigation and averaged 2.1 lb N/acre per irrigation (Table 10). Over this 13 week period (early June through August), the estimated NO_3-N leaching load was 25, 24 and 2 lb N/acre in fields D-1, D-2 and D-16, respectively.

Subtask 1.5 Midterm report (100% complete). We will submit a midterm progress report summarizing accomplishments. This subtask will be coordinated by Michael Cahn.

This subtask was completed with the review and acceptance by the Central Coast Regional Water Control Board Staff.

Task 2 – Analyze, report, and extend results to the strawberry industry (100% complete)
Results from field sites will be analyzed to identify potential management practices that may improve water and nitrogen management in strawberries. Results will be extended to growers through educational meetings and newsletter and trade journal articles. Specific tasks are outlined in the subtasks below:

Subtask 2.1 Analysis and summary of results (100% complete). We will analyze data collected from the field sites described in Task 1 to characterize the nitrogen uptake pattern and water use of strawberries. We will also estimate leaching losses of nitrogen from specific irrigation events. We will compare nitrogen fertilizer and water applications with the nitrogen and water uptake pattern of the crop. The results of the analysis will be used to identify potential management practices that may improve water and nitrogen management in strawberries.

We have conducted analyses of collected data which were presented in Tables 1 -11 and Figures 1-11 and discussed in the above text. Our main conclusions are:

1. Average water applied during the production season roughly equaled crop ET for strawberries. Approximately 90% of growers applied volumes slightly above or less than the ET requirement of their crops. Hence the drainage, which could potentially move nitrate-N into ground water, was minimized at most sites.
2. A significant amount of variation in total applied water was measured among field sites during the production season which could not be explained by variation in crop ET, soil type, or planting configuration. A lack of consistent operation of the drip systems appeared to be the most likely explanation for the variation in flow rates and applied volumes of water.
3. Average applied N rates for the season roughly equaled estimated amounts of N taken up by the crops. Consequently, soil mineral N levels were low most of the production season (April through October). Note that N mineralized from compost applications or nitrate in the irrigation water was not included in our analysis, although the potential contribution would have been small compared to applied N from fertilizer. The combination of low soil nitrate concentrations during the irrigation season and minimal volume of irrigation drainage minimize leaching of nitrate-N during the season. This conclusion was further supported by direct monitoring of leachate in 3 commercial fields where total amounts of leached N were less than 25 lb N/acre during the period of June – August.
4. The total amount of fertilizer N applied varied significantly among growers, ranging from 123 to 301 lb N/acre. Additionally, the proportion of N applied as preplant and fertigated during the season varied significantly among sites. The variation in fertilizer N practices among sites was unlikely due to differences in crop N uptake patterns and more related to differences in growers' standard fertilizer practices.

Our main recommendations to improve water and nitrogen use in strawberries are:

1. *Match irrigation applications with crop water needs.* The combination of using crop ET estimates and soil moisture monitoring would allow growers to optimize irrigation water for production and minimize drainage that can contribute to nitrate leaching.
2. *Optimize the design and operation of the drip system to maximize distribution uniformity.* The pressure in drip systems should be consistently maintained at the tape manufacturer's recommended pressure. Using pressure reducing valves at the submain in-place of gate valves could help maintain consistent pressures and flow rates in the irrigation system.
3. *Match fertilizer N applications with crop N needs during the production season*. Fertigation applications of N during the production season should match crop needs which will range from 1 – 2 lb N/acre/day depending on the planting configuration and bed width. Fertigation in excess of this rate is likely to be unnecessary and inefficient.
4. *Implement management practices to minimize nitrate leaching during the winter months when rainfall is likely to leach nitrate-N.* Nitrate is most likely to be lost by leaching during the winter months if high N levels are maintained in the soil. For fields in which strawberries follow vegetable crops significant soil nitrate-N is likely to be present at the time of strawberry crown establishment; minimizing the leaching volume of irrigation during crown establishment should retain some of this N in the developing root zone until crop uptake is possible. The use of controlled release fertilizer (CRF) is widespread in the

industry, but this practice could be made more efficient as well. Three ways to potentially improve CRF efficiency are:

a) choose a CRF with a release rate appropriate to the crop N uptake pattern. In the Watsonville-Salinas area significant crop N uptake does not occur until March, roughly 5 months after crown establishment. Some currently popular CRFs release N much more rapidly than crop uptake occurs.

b) apply the CRF as close in time as possible to crown planting. Currently some growers apply CRFs a month or more in advance of planting, and during that period significant N release undoubtedly occurs.

c) Reduce the amount of CRF applied, and compensate with earlier N fertigation once active growth begins in the spring; this should limit the opportunity for winter nitrate leaching.

It should be noted that these strategies have not yet been validated in commercial field tests.

Assessment of project success:

This project was successful at a number of levels. We met our overall goal of assessing water and nitrogen fertilizer use in strawberry production on the central coast and determining the nitrogen uptake pattern for this crop. To our knowledge, this was the most comprehensive study on water and nitrogen management practices in strawberries conducted to date on the central coast. From our results we also were able to identify potential management practices that could improve water and nitrogen use efficiency in strawberries. These practices would need to be validated before recommending them to growers. We were also successful in meeting the deliverables of the project, including intensively monitoring water use on 17 fields, 7 more than the originally 10 proposed field sites, as well as monitoring the total water applied on an additional 18 fields (34 total). In addition, we monitored soil nitrate in the root zone of strawberries in 20 fields more than the originally 10 proposed sites. This additional data allowed our conclusions to be based on a larger sample size than was originally proposed. The project was successful in extending the findings of the study. The PIs made 8 oral presentations at grower sponsored and UC meetings and produced 2 newsletter articles. Finally, we were successful in meeting the reporting deliverables of the project.

Subtask 2.2 Grower educational meetings (100% complete). We will present the results from field sites described in Task 1 at educational meetings hosted by UC Cooperative Extension. Additionally, we will present the trial results at grower-industry meetings. This subtask will be coordinated by Michael Cahn and Mark Bolda.

Results of the study were extended in 8 oral presentations. Tim Hartz and Michael Cahn each made presentations at the California Strawberry Commission Water Quality Roundtable on September 22, 2010, the Reiter affiliated companies meeting in Watsonville, on December 7, 2010, and at the UC strawberry meeting that was held in Watsonville, CA on February, 1 2011. In addition Michael Cahn presented at the Driscoll's grower meeting in Watsonville, CA on April 15, 2011 (Appendix 2), and Tim Hartz presented at the Driscoll's grower meeting in Santa Maria on January 26, 2011.

Subtask 2.3 Final report, newsletter and trade journal articles (100% complete).
Results of the project will be reported in the final report, as well as summarized in newsletter and trade journal articles. Reports and articles will be coordinated by Michael Cahn and Tim Hartz

We have written the final report and 2 newsletter articles, presented in appendix 1. The newsletter articles will be published in crop notes and then adapted into trade journal articles.

Tables:

Table 1. Cumulative crop ET for commercial strawberry sites 1 – 17.

	Cumulative Crop ET by Site																	
month	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	D-9	D-10	D-11	D-12	D-13	D-14	D-15	D-16	D-17	Avg
	inches																	
January	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.2	0.0	0.1
February	0.1	0.1	0.1	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.5	0.1	0.2
March	0.3	0.6	0.6	1.0	0.9	0.9	0.8	0.6	0.6	0.6	0.5	0.8	0.8	0.5	0.9	1.5	0.6	0.7
April	0.9	1.7	1.6	2.5	2.3	2.3	2.1	1.7	1.7	1.7	1.5	2.0	2.1	1.5	2.2	3.1	1.8	1.9
May	2.5	4.4	3.9	5.4	4.9	4.9	4.5	4.2	4.3	4.2	3.8	4.5	4.6	3.7	4.8	5.9	4.7	4.4
June	5.6	8.7	7.5	9.7	8.7	8.5	8.0	8.3	8.5	8.1	7.5	8.2	8.3	7.4	8.6	9.7	9.1	8.3
July	9.4	13.4	11.2	14.3	12.5	12.2	11.4	12.8	13.0	12.1	11.1	12.4	12.5	11.6	12.9	13.6	14.2	12.4
August	13.6	18.1	15.2	18.8	16.6	16.2	15.2	17.2	17.4	16.2	15.0	16.8	16.9	16.0	17.3	17.8	19.5	16.7
September	17.3	22.1	18.9	22.7	20.3	20.0	18.7	21.1	21.4	20.1	18.7	20.6	20.8	19.9	21.3	21.5	24.1	20.6
October	19.9	24.8	20.1	--	22.3	21.9	21.2	23.1	23.5	21.5	20.8	23.2	22.7	21.7	23.2	24.1	26.6	22.5
November	20.5	25.8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table 2. Cumulative applied water for commercial strawberry sites 1 – 17.

	Cumulative Applied Water by Site																	
month	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	D-9	D-10	D-11	D-12	D-13	D-14	D-15	D-16	D-17	Avg
	inches																	
January	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.8	0.1
February	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	1.4	0.1
March	0.5	0.9	1.2	0.4	0.7	0.0	0.0	0.1	0.3	0.9	0.6	0.0	0.3	0.9	0.5	0.4	4.3	0.7
April	2.0	1.4	1.7	1.5	1.5	0.2	1.2	0.6	1.9	1.5	1.3	0.9	0.8	1.8	0.9	1.9	5.4	1.6
May	6.5	6.1	4.0	4.8	3.6	1.4	4.4	2.3	4.9	4.0	2.7	4.2	3.1	4.1	2.3	5.1	9.1	4.3
June	11.4	12.6	6.4	9.1	6.5	3.2	7.8	6.6	9.7	8.4	6.5	8.9	6.4	8.7	6.8	9.4	14.6	8.4
July	17.8	17.7	8.2	13.8	9.2	5.7	10.9	9.7	13.2	12.9	8.8	15.2	9.8	14.1	10.9	12.0	18.3	12.3
August	23.7	22.4	12.1	16.4	10.8	8.2	13.2	13.0	16.5	17.6	10.4	19.2	14.9	18.5	15.2	15.4	22.2	15.9
September	29.6	27.4	16.7	18.9	13.5	9.5	15.2	15.9	20.3	22.4	14.4	21.7	20.3	22.4	18.5	18.6	25.7	19.5
October	33.3	30.0	17.9	--	15.4	10.7	16.0	16.9	20.9	23.8	16.6	23.6	21.9	24.4	20.2	20.1	27.9	21.2
November	34.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table 3. Monthly rainfall amounts for commercial strawberry sites 1 – 17.

month	Monthly Rainfall by Site																	
	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	D-9	D-10	D-11	D-12	D-13	D-14	D-15	D-16	D-17	Avg
	---------- inches ----------																	
January	4.3	5.2	5.2	6.0	5.2	5.2	5.2	6.0	6.0	6.0	5.2	3.7	3.7	3.7	3.7	3.7	4.3	4.9
February	2.8	3.5	3.5	5.1	3.5	3.5	3.5	5.1	5.1	5.1	3.5	2.8	2.8	2.8	2.8	2.8	2.8	3.6
March	1.7	2.9	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.7	2.7	2.7	2.7	2.7	1.7	2.6
April	3.9	2.8	2.9	3.7	2.9	2.9	2.9	3.7	3.7	3.7	2.9	2.8	2.8	2.8	2.8	2.8	3.9	3.1
May	0.6	0.5	0.4	0.6	0.4	0.4	0.4	0.6	0.6	0.6	0.4	0.5	0.5	0.5	0.5	0.5	0.6	0.5
June	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0
July	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
August	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1
September	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
October	0.3	0.6	0.0	--	0.1	0.1	0.8	0.0	0.0	0.0	0.7	0.6	0.1	0.1	0.1	0.6	0.0	0.3
November	0.7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table 4. Applied water for establishment of strawberries for the 2011 season.

Site ID	Pre-irrigation		Transplant establishment		Post Establishment		Applied Water by Month						
	method	volume	method	volume	method	volume	Oct	Nov	Dec	Jan	Feb	Mar	Total
		inches		inches		inches	---------- inches ----------						
92	sprinkler	1.4	sprinkler	1.2	drip	2.0	1.4	0.9	0.3	0.5	1.5	NA	4.7
93	sprinkler	0.5	sprinkler	1.5	drip	2.8	0.5	1.0	0.5	0.7	1.0	1.0	4.7
94	sprinkler	2.1	sprinkler	2.9	drip	4.3	1.0	4.6	0.6	1.0	1.6	0.6	9.2
97	sprinkler	0.8	sprinkler	1.5	drip	3.7	1.0	1.7	0.8	0.9	1.2	0.6	6.1
98	sprinkler	2.2	drip	2.1	drip	4.6	2.2	2.3	2.9	1.1	0.3	0.2	8.9
99	sprinkler	1.8	drip	1.0	drip	3.0	1.8	0.8	0.9	1.3	0.0	0.9	5.8
Average		1.5		1.7		3.4	1.3	1.9	1.0	0.9	0.9	0.7	6.6

Table 5. Estimates of vegetative biomass N (lb/acre).

	Vegetative biomass N (lb/acre)			
	Field D-1	Field D-2	Field D-3	Field D-4
March 22	12	9		
March 30			14	26
April 28	39	34	26	53
May 26	40	50	46	58
June 24	52	54	80	67
July 28	76	72	87	67
August 27	83	87	102	100

Table 6. Above-ground plant nitrogen accumulation; estimates include vegetative N uptake through August, fruit yield through September.

	Above-ground plant biomass N (lb/acre)			
	Field D-1	Field D-2	Field D-3	Field D-4
Vegetative tissue	83	87	102	100
Fruit	64	82	81	99
Total	147	169	183	199

Table 7. Season N fertilizer application (lb/acre)

	Seasonal fertilizer N application (lb/acre)		
Field	preplant	fertigated	total
D-1	78	223	301
D-2	90	36	126
D-3	102	58	160
D-4	90	91	181
D-7	90	142	232
D-16	54	154	208
A-1 *	24	99	123
A-2	108	107	215
A-3	108	116	224
A-4	54	154	208
A-5	234	3	237
A-6	94	34	128
A-7	81	84	165
A-8	95	60	155
A-9	126	28	154
A-10	90	71	161
A-11	108	101	209

* ‘A’ denotes fields monitored under California Strawberry Commission project

Table 8. Mean soil solution NO_3-N (PPM) at 24 inch depth, collected through suction lysimetry.

	Mean soil solution NO_3-N			
Sample	D-1	D-2	D-16	Average
	-------- ppm ---------			
7-Jun	11.0	112.0	17.0	46.7
14-Jun	8.0	69.0	16.0	31.0
21-Jun	12.0	63.0	16.0	30.3
28-Jun	7.0	37.0	9.0	17.7
5-Jul	13.0	33.0	*	23.0
12-Jul	19.0	33.0	7.0	19.7
19-Jul	23.0	24.0	6.0	17.7
26-Jul	38.0	25.0	6.0	23.0
2-Aug	36.0	21.0	4.0	20.3
9-Aug	47.0	10.0	3.0	20.0
16-Aug	50.0	12.0	5.0	22.3
23-Aug	69.0	2.0	5.0	25.3
30-Aug	62.0	14.0	5.0	27.0
Average	30.4	35.0	8.3	24.9

*data missing due to lysimeter malfunction.

Table 9. Estimated leaching volume for fields where soil solutions were collected.

	Estimated leaching volume			
Sample week	D-1	D-2	D-16	Average
	-------- inches per irrigation ---------			
7-Jun	0.0	0.7	0.0	0.2
14-Jun	0.2	0.0	0.0	0.1
21-Jun	0.8	0.3	0.7	0.6
28-Jun	0.8	1.1	0.0	0.6
5-Jul	0.8	0.6	0.0	0.4
12-Jul	0.8	0.0	0.0	0.3
19-Jul	0.2	0.0	0.0	0.1
26-Jul	0.6	0.0	0.1	0.2
2-Aug	0.3	0.3	0.0	0.2
9-Aug	0.3	0.3	0.0	0.2
16-Aug	0.1	0.0	0.0	0.0
23-Aug	0.6	0.3	0.0	0.3
30-Aug	0.6	0.0	0.0	0.2
Average	0.5	0.3	0.1	0.3

Table 10. Estimated loads of NO_3-N leached from fields where soil solutions were collected.

	Mean NO_3-N loss			
Sample	D-1	D-2	D-16	Average
	--------	lb/acre/irrigation	---------	
7-Jun	0.0	16.4	0.1	5.5
14-Jun	0.4	0.0	0.0	0.1
21-Jun	2.2	4.3	2.5	3.0
28-Jun	1.2	8.9	0.0	3.4
5-Jul	2.3	4.1	*	3.2
12-Jul	3.2	0.1	0.0	1.1
19-Jul	1.1	0.0	0.0	0.4
26-Jul	5.0	0.1	0.2	1.8
2-Aug	2.6	1.5	0.0	1.4
9-Aug	3.5	0.6	0.0	1.4
16-Aug	1.0	0.0	0.0	0.3
23-Aug	8.6	0.1	0.0	2.9
30-Aug	7.7	0.0	0.0	2.6
Average	3.0	2.8	0.2	2.1

Table 11. Soil NO_3-N values for root zone of strawberry

Field	March	April	May	June	July	August
D-1	9	9	1	5	7	12
D-2	24	17	5	5	2	1
D-3	16	1	10	6	1	1
D-4	12	7	2	2	1	1
D-5	*					
D-6	36	14	11	8	2	9
D-7	7	2	4	4	2	2
D-8	3	3	17	7	5	7
D-9	25	8	8	4	2	1
D-10	4	1	1	4	5	5
D-11		4	7	3	1	5
D-12		24	25	14	11	3
D-13		8	2	4	4	3
D-14		7	8	1	1	1
D-15		7	17	2	1	1
D-16		1	3	1	3	1
D-17		1		1	1	1
A-1	16		2	3	6	1
A-2	9		8	2	4	2
A-3	8		1	2	2	2
A-4	7		2	17	6	5
A-5	4		3		15	12
A-6			5	4	6	4
A-7	33		3	7	10	5
A-8	3		3	2	4	2
A-9	15		15			5
A-10			3	25	3	4
A-11	23		5	13	4	5
A-12	16					
A-13	9		13	3	13	13
AVG	14	7	7	6	5	4

* note: missing data indicate samples not taken (in March for D fields, or April for A fields, or that sample had suspect values (especially for ammonium) that suggested contamination by slow release fertilizer prills

Table 12 Nitrate-N and electrical conductivity of irrigation water at field sites.

site	Nitrate Average (mg NO_3-N L^{-1})	Electrical Conductivity (dS/m)
D-1	8.7	0.49
D-2	5.3	0.63
D-3	9.7	1.27
D-4	5.3	0.70
D-5	0.3	1.36
D-6	2.4	1.31
D-7	0.3	1.06
D-8	0.0	0.49
D-9	<1	0.66
D-10	<1	0.53
D-11	4.1	0.78
D-12	4.0	1.03
D-13	4.0	0.60
D-14	5.2	0.60
D-15	0.5	0.32
D-16	4.4	0.27
D-17	24.5	0.84

Figures:

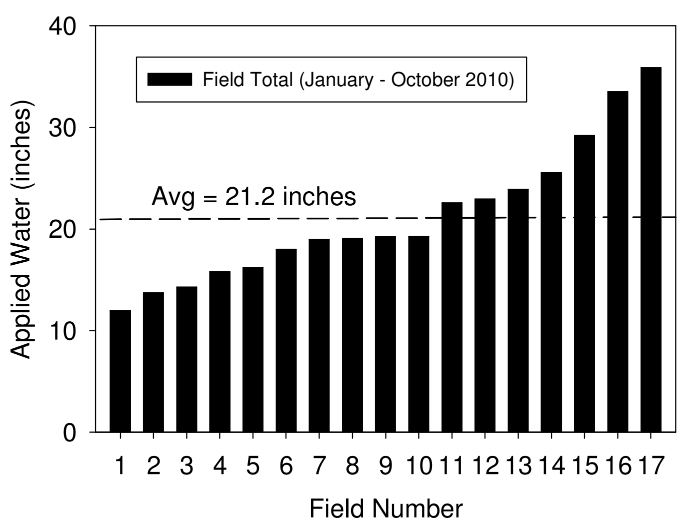

Fig. 1. Total applied water for 17 strawberry fields on the central coast between January and October 2010.

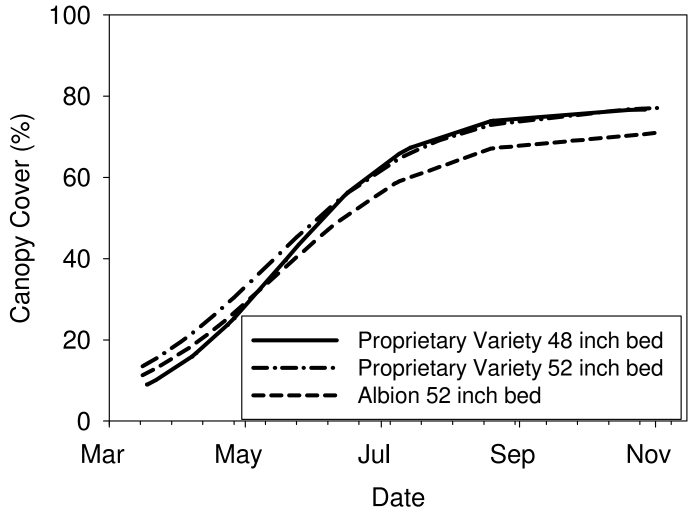

Fig.2. Canopy cover development for different strawberry varieties and bed widths.

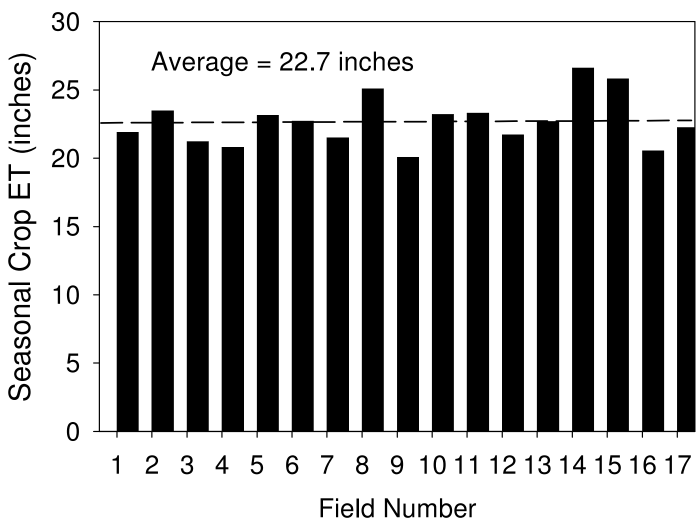

Fig. 3. Estimated crop ET of the 17 intensively monitored fields from January to October 2010.

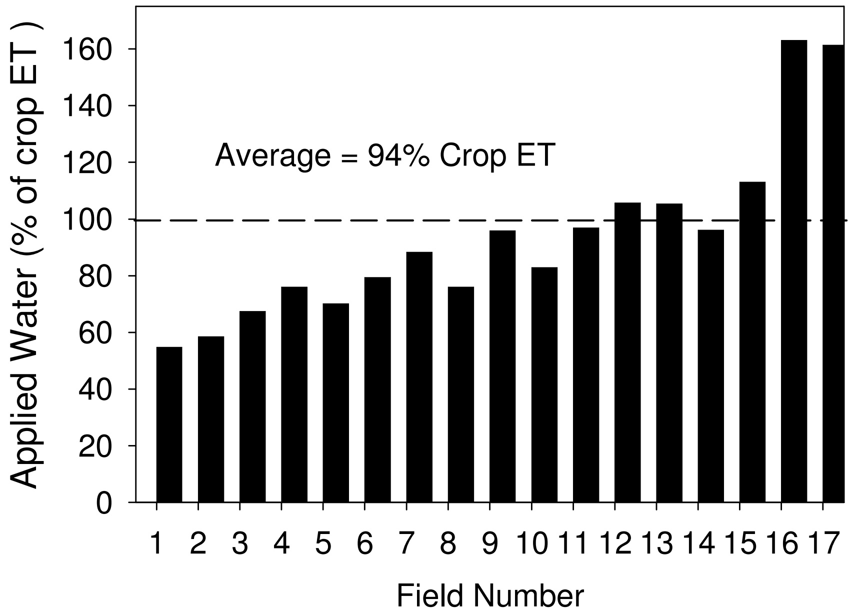

Fig. 4. Applied water expressed as a percentage of crop ET for the 17 intensively monitored fields from January to October 2010.

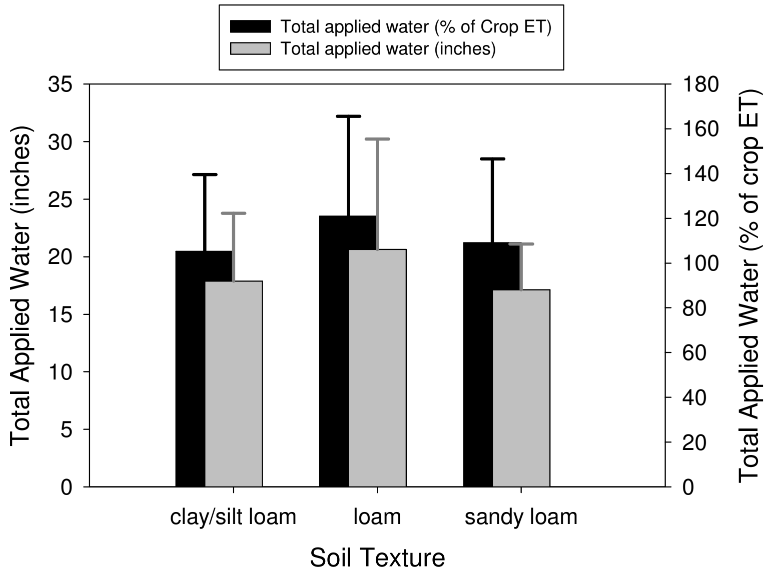

Fig. 5. Variation in seasonal applied water compared among fields with different soil textures.

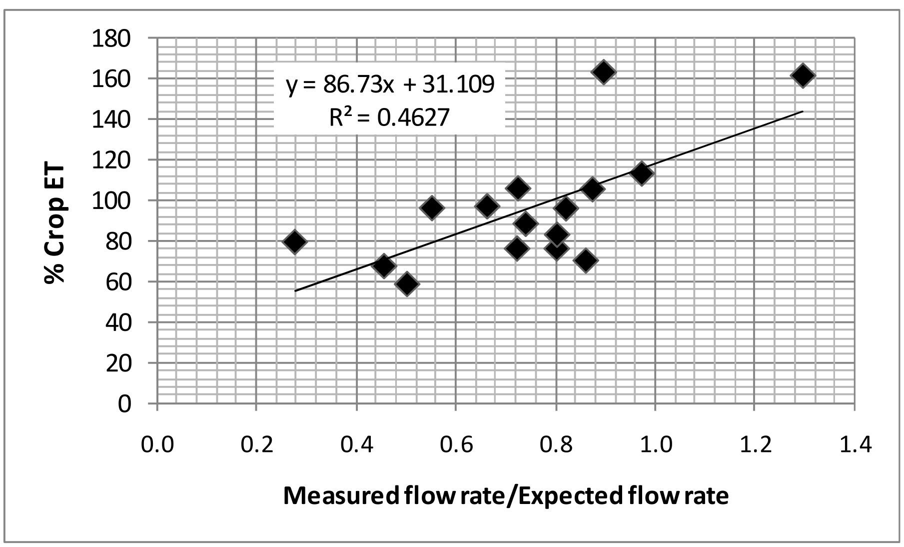

Fig. 6. Applied water expressed as a percentage of crop ET *vs* ratio of measured and expected drip system flow rates.

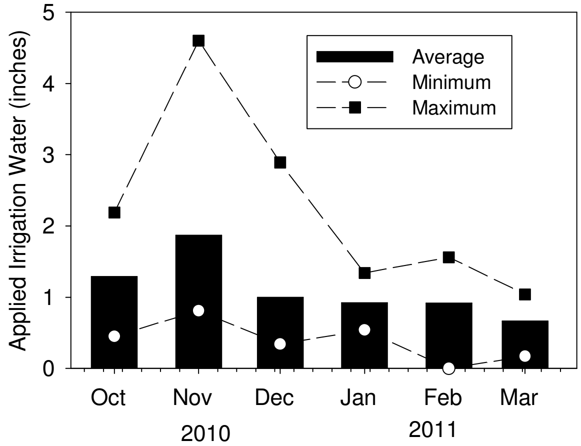

Fig. 7. Applied water for the establishment of new strawberry plantings for the 2011 season (average of 6 sites).

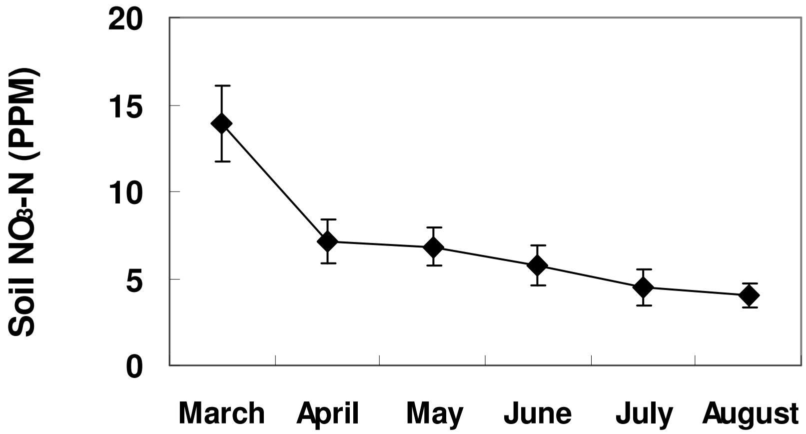

Fig. 8. Mean root zone soil NO_3-N concentration of 30 monitored fields; bars indicate standard error of measurement.

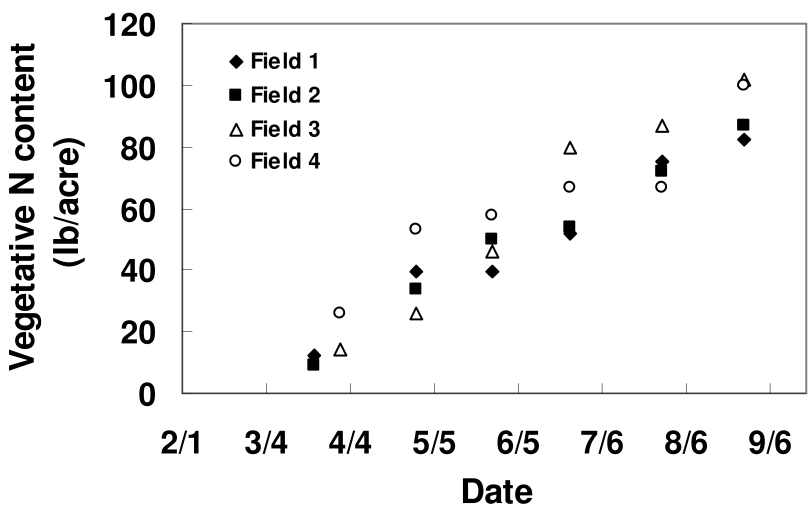

Fig. 9. N uptake in vegetative tissue; fields 1 and 2 are cultivar ‘Albion, fields 3 and 4 are a day-neutral proprietary cultivar.

Fig. 10. Seasonal N fertilization rate for the monitored fields; ‘A’ denotes a field monitored under project support of the California Strawberry Commission.

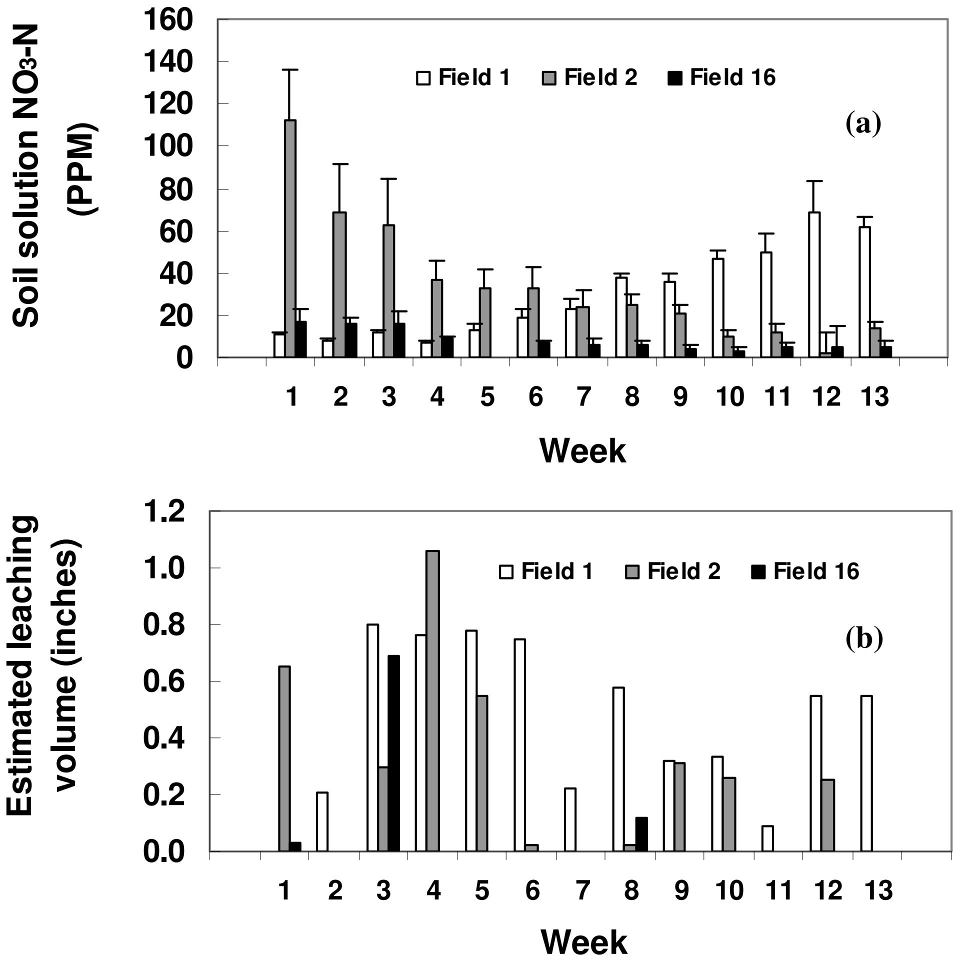

Fig. 11. Mean soil solution NO_3-N concentration at 24" depth (a) and estimated leaching volume (b) by week over the period June 1 - August 30; bars on graph (a) indicate standard error of measurement.

Appendix 1. Newsletter articles:

Strawberry water use on the Central Coast

Michael Cahn, Barry Farrara, Tim Hartz, Tom Bottoms, and Mark Bolda

With few options for importing water from other areas of the state, water supplies on the Central Coast will remain limited for the foreseeable future. Since the agriculture sector accounts for more than 80% of all pumping of ground water on the Central Coast, growers are increasingly under pressure to use water efficiently, especially for cool season vegetables and berries, which need ample soil moisture to achieve commercially viable yields and quality. Additionally, careful water management is required to curtail losses of nutrients from agricultural fields and prevent nitrate from contaminating ground water supplies.

Many growers have taken steps to improve water use efficiency of their crops by employing drip irrigation, reducing water use during crop establishment, and using equipment to monitor soil moisture so that they can better match irrigations with crop water demands. Acreage of strawberries, a crop of major economic importance to the Central Coast, has steadily increased in the Pajaro and the Salinas Valleys during the last 10 years, and has received a fair amount of criticism for its high water-use requirements. However, little information is available on the water management practices that growers use in the production of strawberries grown in this region that would substantiate claims that this crop uses high volumes of water. We surveyed water use of 34 commercial strawberry fields on the Central Coast during the 2010 production season to assess seasonal water use and to identify irrigation practices that may improve water use efficiency. Specifically, we investigated if water applied to strawberries matched crop evapotranspiration requirements, and evaluated effects of variety, weather, salinity, soil type, on water use.

Procedures Flow meters were installed in approximately 0.5 to 1-acre sections of 34 commercial strawberry fields located in the Salinas-Watsonville production region during January and February of 2010. Fields with a proprietary variety and UC Albion were included in the study. Planting configurations ranged from 48-inch and 52-inch wide beds with 2 plant rows, and 64-inch wide beds with 4 plant rows. Drip tape discharge rates in fields ranged from low flow (0.34 gpm/100 ft) to high flow (0.67 gpm/100 ft) and drip systems varied between either 1 or 2 drip lines per bed. Soil texture among sites varied from clay to loamy sand and the salinity of the irrigation water ranged from 0.3 to 1.4 dS/m

Applied water was monitored until the end of the crop in October 2010 using 2 and 3-inch diameter flow meters. In 17 of the 34 fields, flow meters were connected to dataloggers to record the irrigation scheduling pattern and granular matrix blocks or tensiometers were installed to monitor soil moisture tension. Periodic infra-red photos of the canopy were taken at monthly intervals and used to estimate crop coefficients of strawberry and to estimate crop evapotranspiration (ETc) from reference evapotranspiration data available from the California Irrigation Management and Information System (CIMIS) for each of the 17 field sites. Samples of irrigation water were collected for analysis of nitrate and salinity content. Undisturbed cores of soil were collected for determining the water retention pattern for each soil type. Soil samples were also collected for texture analysis. Collected data was analyzed to determine if water-use was consistent with the water requirements of the crops. Seasonal fruit yield data was collected at 14 sites with the proprietary variety.

Results

Applied water: Total applied water for 34 sites between January and October 2010 is summarized in Figure 1. The total volume applied ranged from a low of 10.7 inches to a high of 34.4 inches during the production season (January – October). The average amount of applied water was 21.0 inches and the median amount was 20.8 inches. The subset of intensively monitored 17 fields also had a similar range and average volumes of seasonal applied water as the full group of fields (Figure 2). More than 90% of rainfall occurred between January and April and ranged from 11.9 to 17.6 inches, and averaged 14.2 inches across all sites. Although the amount of water applied to the crops varying significantly among sites, the variation could not be explained by differences in variety, bed width, soil type, or weather.

Crop ET: Evapotranspiration requirements of berry and vegetable crops are most dependent on the canopy cover and weather conditions. We determined that crop canopy of strawberries increased during the season from a minimum of 10% in early March to a maximum of 70% to 80% in August and September (Figure 3). Canopy development was similar for the proprietary variety grown on both 48- and 52-inch wide beds. Albion had similar early season canopy growth as the proprietary variety but reached a slightly lower maximum value by August (Figure 3). The similar canopy development measured among different varieties and bed widths would suggest that mainly variation in weather among fields would affect crop water use. Although crop ET did vary among sites (Figure 4), the range between the highest and the lowest crop ET values was 5.0 inches, and therefore did not account for the more than 20 inches of variation in applied water among fields. Applied water expressed as a percentage of crop ET averaged 94%, but ranged from 55% to 161% of crop ET (Figure 5), and had no significant effect on seasonal fruit yield at sites with the proprietary variety (data not presented).

Soil type: Soil texture differences also did not explain the variation in applied water amounts. Although the average volume of water applied per season varied somewhat among soil of different textures, the differences were small compared to variation in volumes measured within a soil type (Figure 6).

System uniformity: Distribution uniformity of the irrigation systems may also account for variation in applied water among sites. Growers need to apply more water when irrigation systems distribute water non-uniformly to assure that the driest areas receive sufficient moisture to match crop ET requirements. We measured an average uniformity of 84% (100% is perfect uniformity) ranging from 80% to 88% in 4 fields evaluated (Table 1). A distribution uniformity of 85% is average for commercial drip fields; therefore the observed variation in uniformity among fields was relatively small and unlikely to explain the differences in applied water amounts. In contrast, average pressure of the drip systems among these 4 sites evaluated varied more than ± 40% (Table 1).

System flow rate: Because the discharge rate of drip tape varies with pressure, fluctuations in pressure can affect the flow rate of the drip systems. Data collected at 17 of the fields confirmed that system flow rates varied an average of 17% during the season. The lowest seasonal variation in flow rate at an individual site was 7% and the highest was 29%. All sites used manually adjusted gate valves to regulate pressure to irrigation blocks rather than pressure regulating valves.
System flow rates not only fluctuated during the season but also were lower than the expected flow rate calculated from the manufacturer's discharge rate of the drip tape. For all but 2 fields, measured flow rates were less than estimated rates, suggesting that pressures in the drip lines were less than values recommended by the manufacturer or significant clogging of the emitters occurred. The average seasonal flow rate was 76% of the expected rate for all 17 fields and the lowest measured flow rate was 27% of the expected flow rate. Our data confirmed that the fields with the lowest flow rates were usually where less water than crop ET was applied (Figure 7).

Salinity: One concern about applying less water than crop ET is that the volume applied was insufficient to leach salts from the root zone of the crops. Salinity levels of the saturated paste extracted from soil sampled from the surface to a 1 ft depth increased by an average of 0.64 dS/m during the production season (Figures 8 and 9). Highest levels of salts measured were 2.3 dS/m at the end of the season. Salt concentrations above 1.0 dS/m in soil have been shown to cause yield loss in strawberry. Fruit yield data indicated that salts may have reduced yield in this study. Though not statistically significant, fields with high soil or water EC values tended to produce less fruit yield than fields with lower EC values (Figure 10). The combination of a low leaching fraction and high salinity levels in the irrigation water can significantly increase soil salinity levels during the production season.

Conclusions: Overall water use in strawberries on the Central Coast was close to estimated crop ET; however, the amount of water applied varied greatly among sites, with many locations applying significantly less water than the estimated crop water use requirement. The variation in water use among sites could not be explained by differences in varieties, weather conditions, or soil types, but rather a lack of control of system pressure and flow rates. Most sites had significant increases in soil salinity during the season that may have resulted from using water with EC values above 1.0 dS/m and providing insufficient water to leach salts. Total fruit yield of the proprietary variety was not significantly affected by the amount of water applied to the crop but may have been impacted by the salinity of the irrigation water and soil.

Table 1. Distribution uniformity and average drip tape pressure for 4 strawberry sites evaluated during the 2010 production season.

	Distribution Uniformity	Tape Pressure
	%	psi
site 1	88	14.2
site 2	84	9.2
site 3	80	7.1
site 4	82	10.0
AVG	**84**	**10.1**

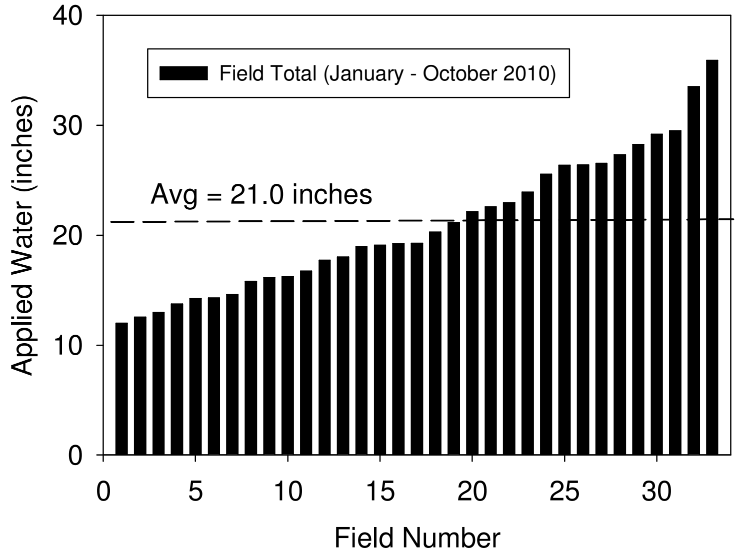

Figure 1. Total applied water during the production season for 34 strawberry fields located in the Pajaro and Salinas Valleys.

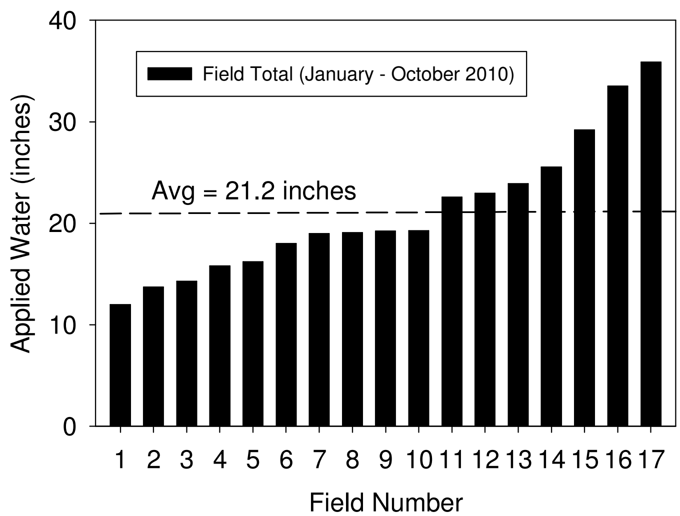

Figure 2. Total applied water during the production season for a subset of 17 of the 34 strawberry fields that were intensively monitored.

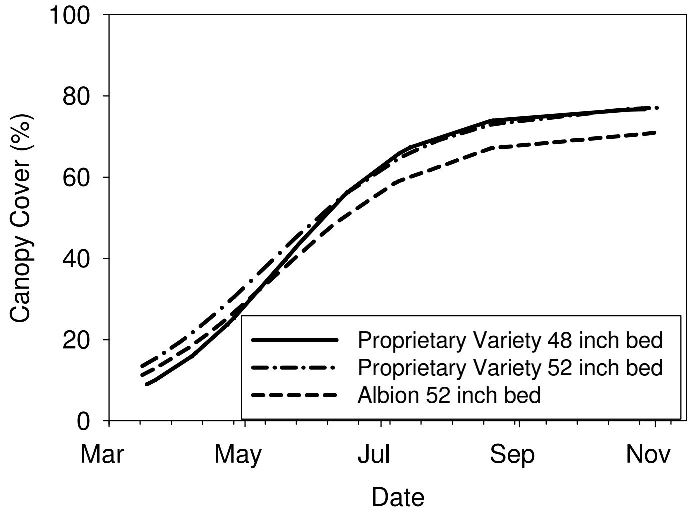

Figure 3. Strawberry canopy cover for 2 varieties and 48 and 52 inch wide beds measured during 2010.

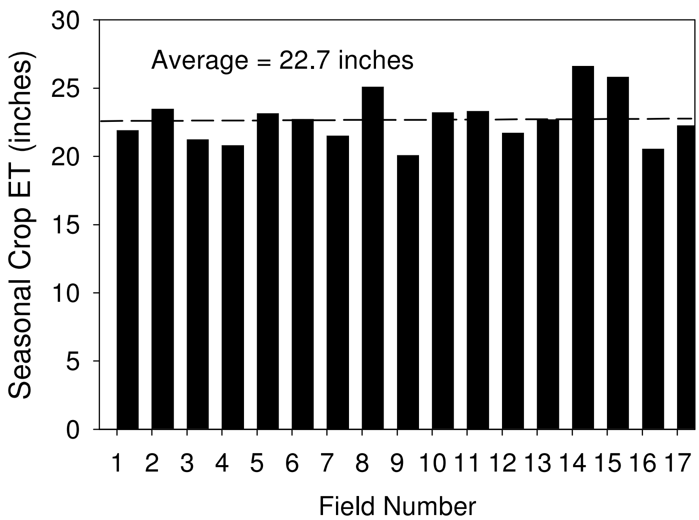

Figure 4. Estimated crop ET of the 17 intensively monitored fields from January to October 2010.

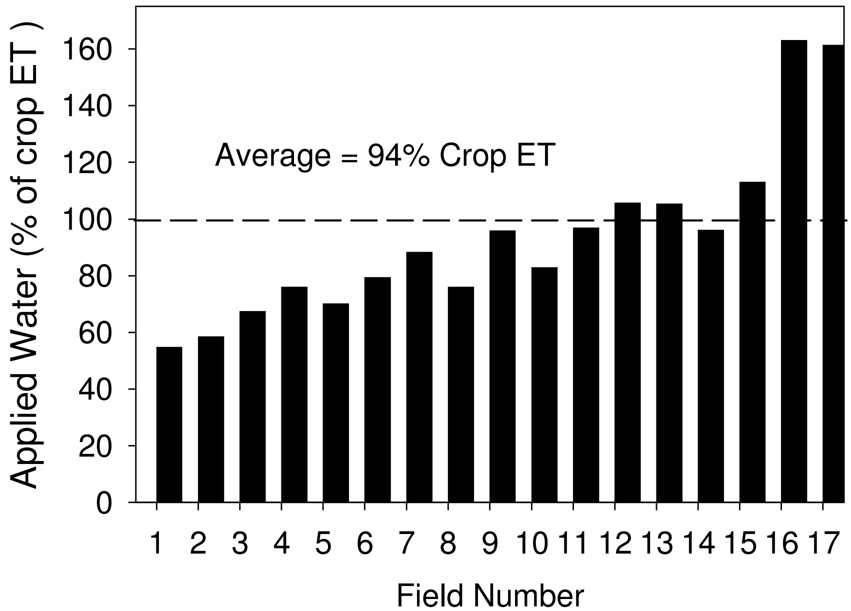

Figure 5. Applied water expressed as a percentage of crop ET for the 17 intensively monitored fields from January to October 2010.

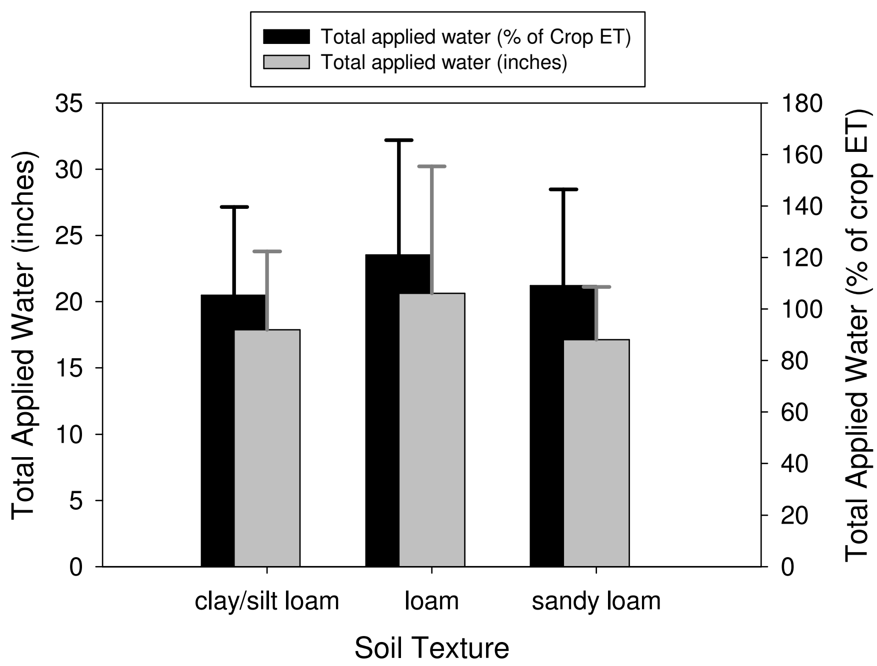

Figure 6. Variation in seasonal applied water compared among fields with different soil textures.

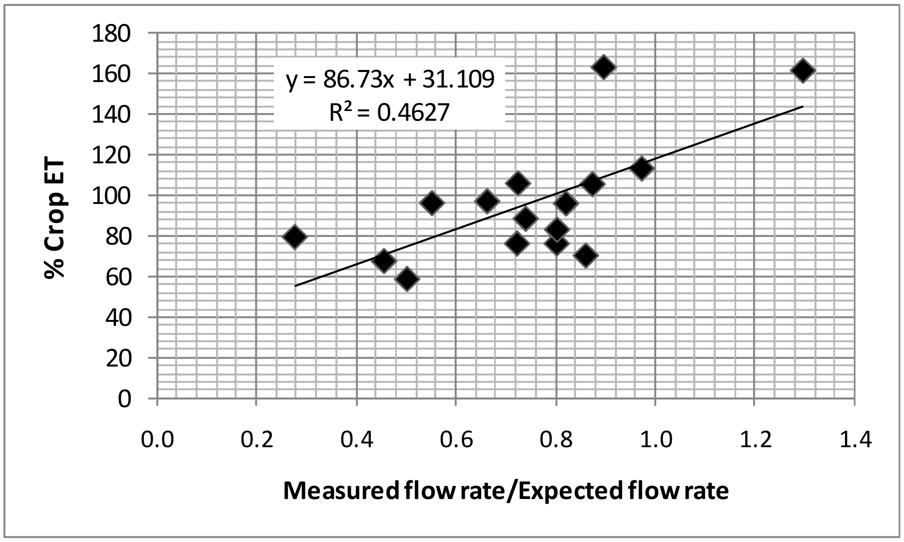

Figure 7. Applied water expressed as a percentage of crop ET *vs* ratio of measured and expected drip system flow rates.

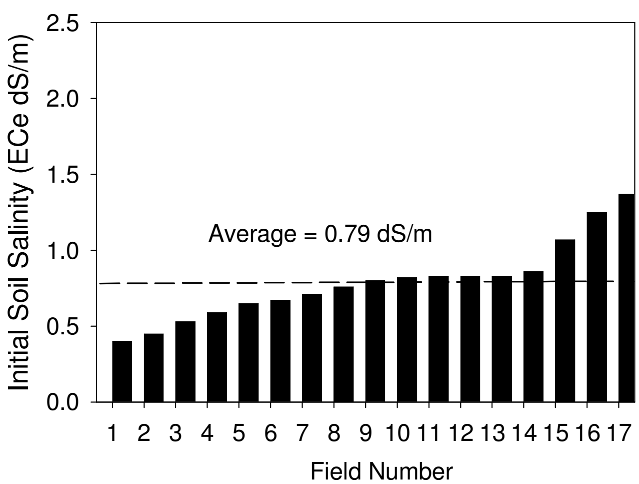

Figure 8. Salinity values measured in the upper foot of soil at the 17 strawberry fields at the beginning of the 2010 production season.

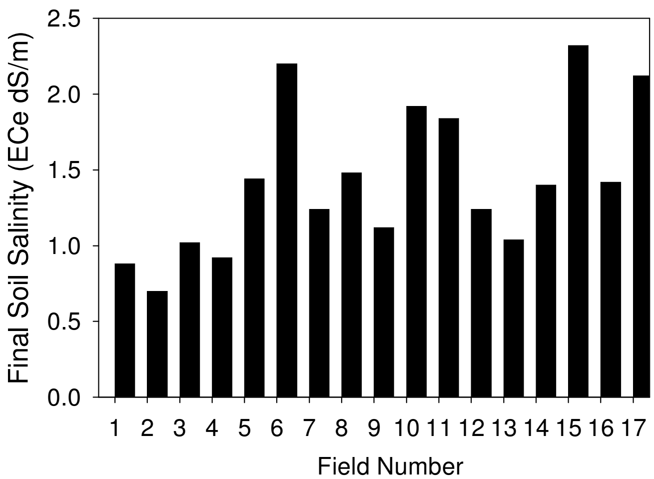

Figure 8. Salinity values measured in the upper foot of soil at the 17 strawberry fields at the end of the 2010 production season.

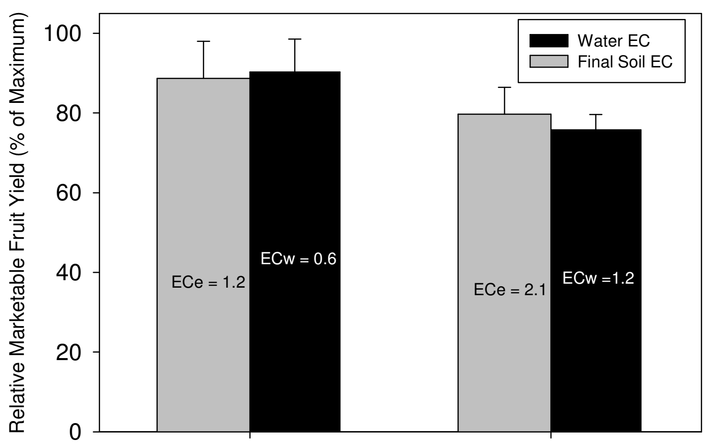

Figure 9. Comparison of average yields from fields with water salinities below and above 1.0 dS/m and soil salinity values below and above 1.5 dS/m. EC values on bars are the average salinity values of fields.

Nitrogen management in strawberry production

Tom Bottoms, Tim Hartz and Mike Cahn

The impending renewal of the 'Ag waiver' has focused regulatory scrutiny on the irrigation and fertilization management practices of vegetable and strawberry growers in the Central Coast region. In 2010 we conducted a monitoring survey of 30 commercial strawberry fields in the Watsonville-Salinas area to evaluate current nitrogen fertilization practices, and to identify ways to improve fertilization efficiency. The fields were planted with either 'Albion' or a common proprietary day-neutral variety. Cooperating growers were asked to provide detailed information on their fertilization practices. In all fields root zone soil nitrate-N (NO_3-N) concentration was sampled monthly from March through August. In four of these fields (two of each variety), 12 randomly selected whole plants per field were collected at monthly intervals. Fruit were removed, and the dry weight of leaves and crowns and their total N content were determined. Fruit samples were also dried for measurement of their N content; total N uptake in fruit was estimated from grower-reported marketable yields.

To evaluate the amount of NO_3-N lost through leaching, suction lysimeters (6 per field, 24" depth) were installed in three of the fields. Once per week from early June through August, a vacuum was applied to these lysimeters throughout an irrigation event, and the soil solution drawn into the lysimeters was analyzed for NO_3-N concentration. Water meters monitored irrigation input; infrared photography was used to determine the degree of canopy development, from which crop evapotranspiration (ET_c) was calculated. In each field leachate NO_3-N concentration was multiplied by the calculated weekly leaching volume to estimate the load of NO_3-N lost through leaching.

Results:

Across fields there was a trend toward declining root zone soil NO_3-N as the season progressed (Fig. 1). From April through August average root zone NO_3-N was maintained around 5 PPM. Among fields there were substantial differences in N management, with some fields remaining below 2 PPM NO_3-N for extended periods, while in other fields N fertigations caused spikes in soil NO_3-N above 10 PPM. There was no clear difference in crop vigor between fields with low or high soil NO_3-N.

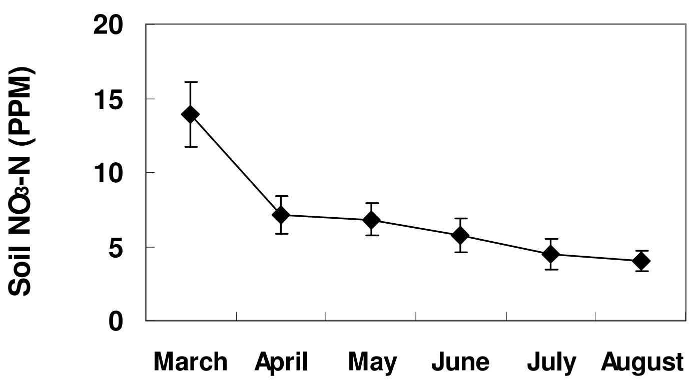

Fig. 1. Mean root zone soil NO_3-N concentration of the monitored fields; bars indicate standard error of measurement.

Crop N content in vegetative tissue increased linearly throughout the season (Fig. 2). Averaged across fields, the N content of vegetative tissue (crowns and leaves) increased by just over 0.5 lb per acre per day, and totaled 83 - 102 lb/acre by the end of August (Table 1). The N uptake of the two varieties was similar. Across fields, fruit N concentration averaged between 1.2 - 1.5 % on a dry weight basis, with fruit averaging approximately 9% dry matter. Based on the grower-reported seasonal yield, the total N content of marketable fruit varied among fields from 64 - 99 lb/acre. Therefore, estimated seasonal N content in above-ground biomass ranged from 147 - 199 lb/acre.

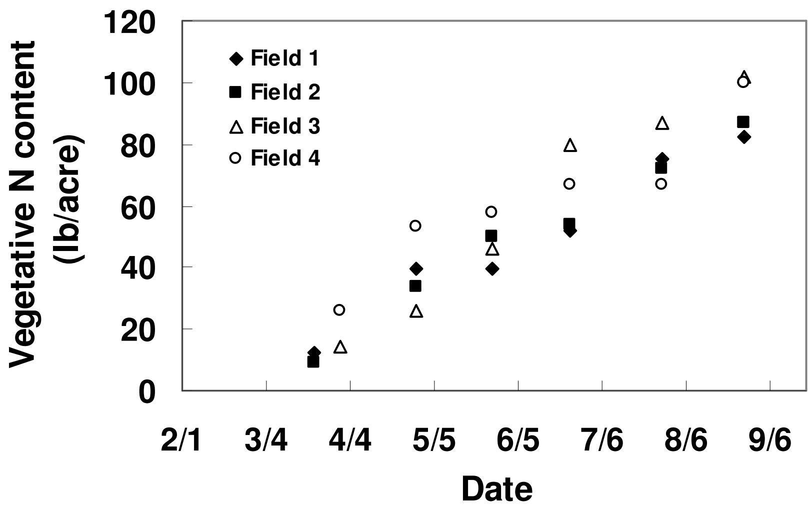

Fig. 2. N uptake in vegetative tissue (leaves and crowns); fields 1 and 2 were 'Albion', fields 3 and 4 were a day-neutral proprietary variety.

Table 1. Above-ground plant nitrogen uptake; estimates include vegetative N uptake through August, fruit yield through September.

	Above-ground plant biomass N (lb/acre)			
	Field 1	Field 2	Field 3	Field 4
Vegetative tissue	83	87	102	100
Fruit	64	82	81	99
Total	147	169	183	199

It should be noted that these estimates are lower than total crop N uptake, for several reasons. Cull fruit was not included, and some early leaves undoubtedly dried down and were lost before late season plant sampling. Assuming that cull fruit represent approximately 15% of the total produced, and loss of leaf tissue before the final plant sampling date represented 10% of the total produced during the season, total plant N uptake into above-ground biomass may have approached 220 lb N/acre. Another important consideration is plant population. All four of these fields were planted in a two-row configuration at a plant population of approximately 21,000/acre. Some fields in the Watsonville-Salinas region, and most fields in the Santa Maria area, are planted on a 4-row configuration at plant populations as high as 30,000/acre on beds. Preliminary data from 4-row fields in Santa Maria indicated that vegetative N uptake was at least 20% higher than in the 2-row fields reported here. We found that plant population did not affect fruit N concentration, so fruit N content should be proportional to fruit yield, regardless of plant population.

The bottom line is that total strawberry crop annual N uptake probably averages at least 200 lb/acre, and fields with high plant population, above average yield, or an extended production season may take up substantially more N. N uptake is approximately linear from early spring through at least August, with an average uptake of 1-1.5 lb N per acre per day.

The three fields in which leachate samples were collected by lysimeter showed varying trends in soil solution NO_3-N concentration (Fig. 3). Field 2 began with relatively high soil solution NO_3-N, and values trended lower through the season as root zone NO_3-N declined. In field 1, relatively low soil solution NO_3-N early in the season increased as the grower increased N fertigation later in the season. Field 16 was maintained at low root zone NO_3-N throughout the season, and soil solution NO_3-N remained low as well.

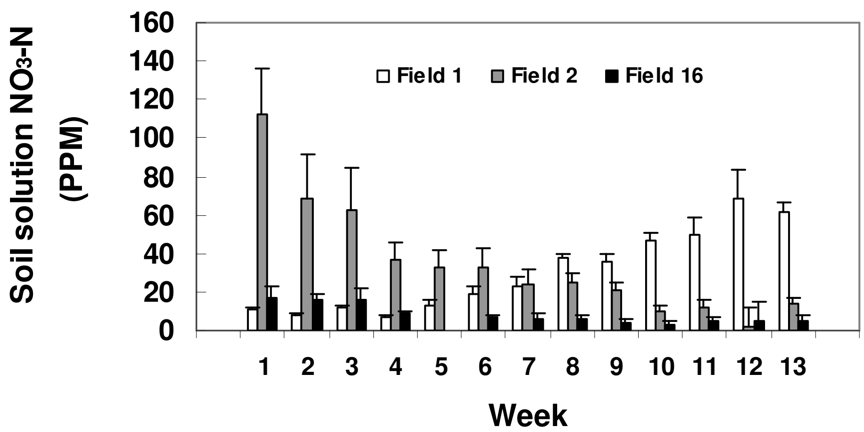

Fig. 3. Mean soil solution NO_3-N concentration at 24" depth by week over the period June 1 - August 30, 2010; bars indicate standard error of measurement.

Estimates of weekly leaching volume were calculated as the difference between ET_c and irrigation applied. In field 16, irrigation was marginally less than ET_c for most of the sampling period, with a significant leaching volume occurring only in week 3. In fields 1 and 2, irrigation exceeded ET_c over the sampling period by 5.1 and 2.5 inches, respectively. Multiplying weekly soil solution NO_3-N at 24" depth by the calculated weekly leaching volume gave a rough estimate of the NO_3-N leaching load. Over this 13 week period (early June through August), the estimated NO_3-N leaching load was 25, 24 and 2 lb N/acre in fields 1, 2 and 16, respectively.

Complete fertilization records were obtained for 17 of the 30 fields monitored (Fig. 4); other growers were reluctant to share that information, or kept incomplete records. While fertilization practices varied widely among growers, the mean seasonal N application was 187 lb N/acre, nearly evenly split between preplant and fertigated N (an average of 96 and 92 lb N/acre, respectively). These estimates do not include NO_3-N contained in irrigation water. Irrigation water NO_3-N concentration was greater than 10 PPM in 4 of these fields, and greater than 20 PPM in 2 fields. There was no correlation between seasonal N fertilizer rate and marketable yield.

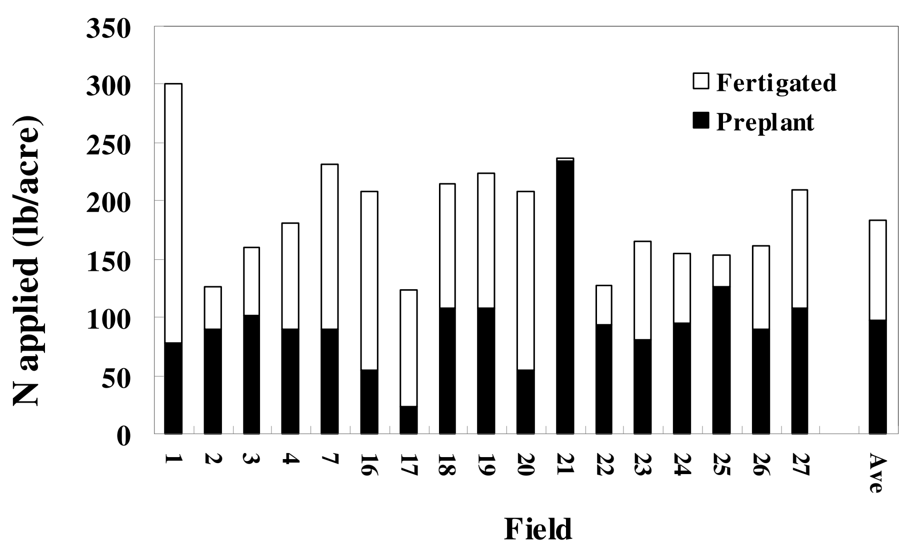

Fig. 4. Seasonal N fertilization rate applied.

From this initial year of study we draw the following conclusions regarding nitrogen management in strawberry production:

1) strawberry N uptake rate is relatively slow, much lower than vegetable crops. As a comparison, lettuce N uptake rate can reach 4 lb N per acre per day in the weeks before harvest, more than twice that of strawberries.
2) Given this low N uptake rate, strawberries can thrive with relatively low soil nitrate reserves; a number of highly productive fields in this survey were maintained around 5 PPM root zone soil NO_3-N during the summer months.
3) With careful irrigation, nitrate leaching losses from strawberry fields can be relatively low. However, a combination of high N fertilization rates and inefficient irrigation could still represent a nitrate leaching hazard.

This monitoring study focused solely on the spring though summer portion of the production cycle. Beginning in fall, 2010, we began monitoring the N dynamics of strawberry production beginning with preplant bed preparation. Those results will be the subject of a future newsletter article.

Appendix 2. Educational meeting agendas

P.O. Box 269 • Watsonville, CA 95077-0269 • P: 831.724.1301 • F: 831.724.5973 • www.calstrawberry.com

Water Quality Round Table

California Strawberry Commission
Montrio Bistro
414 Calle Principal, Monterey, CA
Phone 831-648-8881

Wednesday, September 22, 2010
2:00 to 5:30 Presentations and Discussion
5:30 to 6:30 Reception
6:30 to 8:30 Dinner

2:00 p.m. Introduction, Dan Legard, California Strawberry Commission

2:10 p.m. Presentations (10 minutes each)

Draft Ag Waiver - Dan Legard, CSC

Nitrogen Utilization and Loss in Coastal Strawberry Fields - Tim Hartz, University of California

Water management BMPs for strawberries - Michael Cahn, UCCE

Water and Salinity Management during Plant Establishment - James Dubois, Reiter Affiliated Companies

Fertilizer and Groundwater Nitrate - Thomas Harter, University of California

Regulator's Perspective on BMP Enforcement and Assessing Effectiveness - John Sanders, Cal DPR

3:15 p.m. General Discussion
5:00 p.m. Research Needs
5:30 p.m. Adjourn to Reception (Montrio's)
6:30 p.m. Dinner (Montrio's)

Reiter 2010 Northern District Strawberry
Full-Cycle Review
Location: Pajaro Dunes – Watsonville, CA
Time: 9:00am-3:00pm

Updated Meeting Agenda:

9:00-9:30 **Coffee**

9:30-10:30 **2009 Financials–Northern District**
- Conventional
- Organic

10:30 -11:45: **2010 Mechanization**
- Mercado Machines

11:45am – 12:00pm **Break**

12:00m – 11:00pm: **2010 Production**
- Variety Performance
- Plant Population Comparison
- Fumigation and Alternatives
- 2010 Block Reports

1:00pm-2:00pm **Lunch and Garland to Speak**

2:00pm-3:00pm: **THEME TOPICS 2010**

1. **Fertility (30 minutes)**

- 2010 Strawberry Nutrient Management

2. **Irrigation (30 minutes)**

- 2010 Irrigation Monitoring and Scheduling

3:00pm Questions and Adjourn

Driscoll's Strawberry Kickoff Meeting
Watsonville Civic Plaza
April 15, 2011 8 AM – 1 PM

8:00-8:10	Research Process Changes (Rob Webb)
8:10-8:30	Methyl Bromide Regulatory Update (Doug Buessing)
8:30-9:00	Strawberry Water Usage Report (Michael Cahn)
9:00-9:15	Ag Waiver Update (Dennis Lebow)
9:15-10:00	Market Plan (Chase Renois)
10:00-10:15	Cooler Logistics (Tom Huffman)
10:15-10:45	Diversion Allocation (Tom Spaulding)
10:45-11:30	Quality Programs (Saumya Lanka/Tom Taggart)-incl. brix analysis
11:30-12:00	Export Programs (David Medina/Kenny Kusamoto)
12:00-1:00	Lunch and Export Acreage Raffle

IMPORTANT NOTE: The Export Program presentation will include the raffle of a 15-20 ac. block for the Green Fruit program. Priority will be given to growers not already in the program, and participants must be willing to commit at least 5 ac. to Taiwan MRL's. Interested growers **must** contact Tom Spaulding no later than Mar. 18th to have their names included in the raffle—participation is not automatic!!

UNIVERSITY *of* CALIFORNIA

Agriculture & Natural Resources

COOPERATIVE EXTENSION • SANTA CRUZ COUNTY
1432 Freedom Boulevard • Watsonville, CA 95076
Tel (831) 763-8040 Fax (831) 763-8006 E-Mail cesantacruz@ucdavis.edu

2011 Annual Central Coast Strawberry Meeting
February 1, 2011
Organized by University of California Cooperative Extension, Santa Cruz County
Elks Lodge, 121 Martinelli Street
Watsonville, CA, 95076

6:45-7:15	**Registration and Sign In. No Fee.**
7:15-7:45	**Laws and Regulations Update, 2011** **Ken Allen, Monterey County Agriculture Commissioner**
7:45-8:05	**Central California Breeding and Cultural Practices Update 2011** **Doug Shaw, University of California, Davis**
8:05-8:25	**Mineral Nutrition in Strawberry** **Mark Bolda, UC Cooperative Extension, Santa Cruz County**
8:25-8:45	**Sustainable Strawberry Production** **Steve Fennimore, UC Cooperative Extension, Salinas**
8:45-9:05	**Research and Regulatory Update** **Dan Legard, California Strawberry Commission**
9:05-9:25	**Water Management of Strawberries.** **Mike Cahn, UC Cooperative Extension, Salinas**
9:25-10:00	**Break**
10:00-10:20	**Anaerobic Soil Disinfestation.** **Joji Muramoto and Carol Shennan, University of California, Santa Cruz**
10:20-10:40	**Macrophomina: One of the New Soilborne Threats in Strawberry** **Steve Koike, UC Cooperative Extension, Monterey County**
10:40-11:00	**Nutrient Management in Strawberries** **Tim Hartz, UC Davis**
11:00-11:20	**Mating Disruption of Light Brown Apple Moth in Strawberries.** **Hillary Thomas, Science and Technology Policy Fellow,** **Office of Assemblywoman Fiona Ma**
11:20-11:40	**Southern California Strawberry Research Update** **Kirk Larson, University of California South Coast Research & Extension Center**
11:40-noon	**Recent Studies of Chemical Controls for Lygus, Worms and Thrips** **Frank Zalom, University of California, Davis**

All meeting participants are invited to stay for lunch, which will be served following the last presentation.
For more information, contact Mark Bolda (831)-763-8040; 1432 Freedom Blvd., Watsonville, CA, 95076
Continuing education credits will be applied for. Please call ahead for arrangements of special needs; every effort will be made to accommodate full participation.
Spanish translation will be available.

2011 Reunión de la Producción de Fresa

1ro de febrero, 2011
Extensión Cooperativa de Universidad de California del Condado de Santa Cruz
Elks Lodge, 121 Martinelli Street
Watsonville, CA, 95076

6:45-7:15	**Inscripción. Gratis.**
7:15-7:45	**Repaso de Leyes y Reglas, 2011.** **Ken Allen, Monterey County Agricultural Commissioner**
7:45-8:05	**Mejoramiento de Plantas de Fresa de California Central y Actualidades de las Prácticas Culturales 2011** **Doug Shaw, University of California, Davis**
8:05-8:25	**Unas palabras sobre nutrición minereal de la fresa** **Mark Bolda, UC Cooperative Extension, Watsonville**
8:25-8:45	**Producción de fresa sostenible** **Steve Fennimore, UC Cooperative Extension, Salinas**
8:45-9:05	**Novedades de Comisión de Fresa de California** **Dan Legard, Comisión de Fresa de California**
9:05-9:25	**Manejo de agua en la fresa** **Michael Cahn, UC Cooperative Extension, Salinas**
9:25-10:00	**Descanso**
10:00-10:20	**Desinfestación anaeróbica del suelo** **Joji Muramoto y Carol Shennan, University of California, Santa Cruz**
10:20-10:40	**Macrophomina: Unas de las amenazas de los patógenos del suelo de la fresa** **Steve Koike, UC Cooperative Extension, Monterey County**
10:40-11:00	**Manejo de nutrición en la fresa** **Tim Hartz, University of California, Davis**
11:00-11:20	**Confusión de apareamiento de palomilla marrón de manzana en la fresa** **Hillary Thomas, Science and Technology Policy Fellow** **Office of Assemblywoman Fiona Ma**
11:20-11:40	**Novedades investigaciones de fresas en el Sur de California.** **Kirk Larson, University of California South Coast Research & Extension Center**
11:40-11:45	**Estudios recientes de la chinche lygus, gusanillos y trips.** **Frank Zalom, UC Davis**

Traducción en español será disponible.
Todos los participantes son invitados para el almuerzo, lo cual será servido después de la última presentación.
Para más información, llamar a Mark Bolda en (831)-763-8040, 1432 Freedom Blvd., Watsonville, CA, 95076.
Los créditos de la formación permanente serán solicitados. Llame por favor a continuación para los arreglos de necesidades especiales; cada esfuerzo será hecho de acomodar la participación completa.