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Crop Notes

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University of California, U.S. Department of Agriculture, and County of Monterey cooperating

1432 Abbott Street • Salinas, CA 93901

phone 831.759.7350
fax 831.758.3018

http://cemonterey.ucdavis.edu

NAMING OF ANOTHER NEW RACE (RACE PFS 13) OF THE SPINACH DOWNY MILDEW PATHOGEN

Jim Correll, University of Arkansas
Steven Koike, University of California Cooperative Extension

Another new race, the 13th, of the downy mildew pathogen (Peronospora farinosa f. sp. spinaciae) of spinach has been found and documented. First identified in January 2010 from spinach in Holtville, California, this race breaks the resistance of several important cultivars. The isolate was initially designated as UA0510C and was characterized with a standard set of differential varieties. Isolates apparently identical to UA0510C have been found in an increasing number of locations throughout California in 2010 and 2011. After careful evaluation of the significance of this development to the spinach industry, the International Working Group on Peronospora (IWGP) has designated this isolate as race Pfs 13. The IWGP is located in The Netherlands and is administered by Plantum NL.

Race Pfs 13 poses a threat to the spinach industry because it is particularly well-adapted to modern hybrids with resistance to races 1-12. The appearance of a new race is not unexpected because hybrids with resistance to races 1-12 have been widely planted over the past few years. Similar developments have taken place when races Pfs 5 (1996), Pfs 6 (1998), Pfs 7 (1999), Pfs 8 and 10 (2004), Pfs 11 (2009), and Pfs 12 (2009) were identified and named. The occurrence of Pfs 13 will clearly encourage the industry to develop and use new spinach cultivars having resistance to races 1-13. A history of the detection of the various spinach downy mildew races is presented in Table 1.

A collaboration of researchers with the IWGP, University of Arkansas (Correll), and University of California (Koike) is monitoring the development of new races of spinach downy mildew on a global scale by collecting and testing suspected new isolates. In this way it is hoped that research findings and conclusions will be agreed upon and better communicated between the seed industry, spinach growers, and other interested parties. For California and Arizona, the Correll-Koike team will continue to receive and test spinach downy mildew samples for growers, pest control advisors, and seed companies. Industry is encouraged to continue to submit downy mildew outbreak samples to Correll-Koike, as such samples facilitate the discovery of additional new races. The Correll-Koike research is made possible by support from the California Leafy Greens Research Board and by active participation by the agricultural industries in California and Arizona.

For more information on this subject you can contact Steven Koike (stkoike@ucdavis.edu), Jim Correll (jcorrell@uark.edu), Diederik Smilde (d.smilde@naktuinbouw.nl), or IWGP chairperson Jan de Visser (JandeVisser@popvriendseeds.nl).

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Table 1. Races of spinach downy mildew and year of detection

Year	Race
1824	1
1958	2
1976	3
1990	4
1996	5
1998	6
1999	7
2004	8
...	(9)*
2004	10
2008	11
2009	12
2010	13

*One time detection only

Downy mildew of spinach is the most important disease on this crop and results in quality and yield losses.

DRIP IRRIGATION MANAGEMENT FOR OPTIMIZING N FERTILIZER USE, YIELD, AND QUALITY OF LETTUCE

Michael Cahn, Richard Smith, Tim Hartz, Barry Farrara, Tom Bottoms, Tom Lockhart, and Marita Cantwell

Introduction

A key to optimizing yield and quality in lettuce and minimizing nitrate leaching is to match applications of fertilizer and water with the crop needs. The nitrate quick test, used with an understanding of the N uptake pattern of lettuce, can be valuable for determining an appropriate amount of N fertilizer for pre-plant and post-thinning applications. The combined use of CIMIS evaporations (ET) data and soil moisture monitoring can also guide irrigations so that lettuce growth is optimal and nitrate leaching is minimized

Lettuce, like many cool season vegetables, is sensitive to modest deficits in soil moisture. Growth usually slows when soil water tensions are above 30 to 40 centibars (cbars). A recent survey of grower practices confirmed that many managers irrigate lettuce at intervals of 6 to 8 days during the drip phase of the crop and in amounts that are often 50% greater than the ET requirement of the crop (150% of crop ET). While an 8-day irrigation interval may be appropriate just after thinning, when plants are small, larger plants would require more frequent irrigations to keep up with the ET demand of the crop. By applying water in excess of the ET requirement of the crop, growers can maintain growth at these longer intervals, but risk leaching nitrate below the root-zone.

We conducted trials in commercial lettuce fields to evaluate if using the quick nitrate test to guide fertilizer applications and applying water at intervals of 4 to 5 days in amounts equal to the ET requirement of the crop could minimize nitrate leaching while maintaining yield and quality.

Procedures

Two trials evaluating the effects of irrigation and nitrogen management on lettuce production were conducted in commercial iceberg and romaine lettuce fields. The iceberg trial was planted May 20, 2010 on a loam soil, and the romaine trial was planted July 27, 2010, on a fine sandy soil. Lettuce was germinated with overhead sprinklers, and irrigated with surface drip after thinning and cultivation. Three irrigation/nitrogen treatments were compared during the drip phase of the crop (Table 1): Treatment 1 was the grower's standard strategy for irrigation and fertilizer N applications. Treatment 2 utilized the nitrate quick test to guide nitrogen fertilizer applications, and water was applied at intervals of 4 to 5 days in amounts averaging 100% of crop ET. Treatment 3 also utilized the nitrate quick test to guide nitrogen fertilizer applications, but the crop was irrigated every 6 to 8 days in amounts averaging 140% of crop ET. Although some adjustments in the irrigation of the 4 and 7-day interval treatments were made to accommodate weather conditions and field operations, the average intervals closely approximated the treatment schedule.

Table 1. Irrigation/nitrogen management treatments.

Treatment	Nitrogen Management	Irrigation Interval	Irrigation volume
Grower	Grower Standard	Grower Standard	Grower Standard
4-day	Nitrate quick test[1]	4-5 day irrigation intervals	100% crop ET
7-day	Nitrate quick test[1]	6-8 day irrigation intervals	140% crop ET

[1] nitrogen will be applied based on the use of the nitrate quick test using 20 ppm of nitrate-N as the threshold for fertilizer application.

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Treatments were replicated four times in a randomized complete block design and individual plots were greater than 100 feet in length and 4 beds in width. The center 2 beds were used for harvest and plant evaluations. Irrigation treatments were accomplished using a manifold plumbed into the grower's mainline. Applied water of each treatment was monitored with flow meters. Fertilizer and irrigation decisions were carried out in close consultation with the grower to fit in with other field operations. All fertilizer applications conducted post-thinning were applied through the drip system at the iceberg trial. One side-dress application of N was made using a tractor in the grower treatment in the romaine trial. All subsequent fertilizer inputs were applied through the drip system.

Treatments were evaluated for soil mineral nitrogen in the top foot of soil at weekly intervals and leaf tissue nitrate-N and total N at 3 stages of development. Leachate was sampled with lysimeters after each irrigation event and analyzed for nitrate-N concentration. Soil moisture tension was monitored with watermark granular matrix sensors at 8 and 18 inch depths in 3 of the 4 replications. The iceberg field was harvested for cartons and the romaine field was harvested for hearts. Plant population, head weight, biomass, and marketable yield were evaluated at harvest. The effect of irrigation and nitrogen management on postharvest lettuce quality was evaluated in several ways. At harvest, total N, NO_3-N and dry matter concentration of head tissue was determined. Samples of midrib tissue were analyzed for phenylalanine ammonia lyase (PAL) activity; elevated PAL activity can enhance the production of phenolic compounds responsible for browning in lightly processed lettuce.

Results

The 4-day irrigation interval required less water than the 7-day and grower treatments in both the iceberg and romaine trials and maintained similar soil moisture tensions (Tables 2 and 3; Fig. 1). Applied water volumes for the 4-day irrigation interval were approximately 100% of crop ET for both trials, and approximately 140% of crop ET for the 7-day irrigation interval treatment. The applied water for grower standard practice averaged 135% of crop ET for both trials (Tables 2 & 3). The grower irrigation interval averaged 7.5 days for the iceberg trial and 4.5 days for the romaine trial.

Accounting for residual soil nitrate with the quick nitrate test, fertilizer N inputs were reduced by 127 and 59 lb N/acre in the iceberg and romaine trials, respectively, in the 4- and 7-day treatments relative to the grower standard (Tables 2 and 3, Figs. 2 and 3). Despite the reduction in fertilizer N, nitrate-N levels were maintained greater than 20 ppm in the top foot of soil until harvest in 4- and 7-day treatments. In both trials, the grower fertilizer practice resulted in soil nitrate-N concentrations greater than 40 ppm after the first post-thinning application (approximately 30 days after planting). The grower treatment had the highest concentration of nitrate in leachate samples collected in the iceberg trial (Table 2) and lowest concentration in leachate collected in the romaine trial (Table 3). The load of nitrate lost by leaching is assumed equal to the nitrate-N concentration in the leachate multiplied by the volume of drainage below the root zone of the crop. Estimated post-thinning drainage was several times higher for the grower and 7-day interval treatments compared to the 4-day interval for both trials. The lower amount of drainage resulted in the least amount of N leached under the 4-day interval treatment at both sites (Tables 2 and 3).

The combination of applying water equal to crop ET and using the quick nitrate test to guide fertilizer applications resulted in less risk for nitrate leaching after harvest. In the iceberg trial, the grower standard practice had the highest residual soil nitrate concentrations at all depths in comparison to the 4- and 7-day interval treatments which utilized the soil nitrate quick test to reduce N fertilizer inputs (Fig. 4). This residual soil nitrate can be lost by leaching during pre-irrigations for a subsequent crop or during fall and winter rain events.

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In the romaine trial, residual soil nitrate was lower than in the iceberg trial. The 7-day treatment which received 140% of crop ET and had the most drainage, also had the highest concentration of nitrate was at the 2 and 3 foot depths (Table 3, Fig. 4). In both trials, the pattern of residual soil nitrate measured after harvest corresponded with the estimated loads of N lost by leaching for the various irrigation/nitrogen treatments.

Marketable yields and uptake of N were not statistically different among treatments at either trial (Tables 4 and 5). However, biomass yield, trimmed and untrimmed head weights and plant population were statistically different in the romaine trial. Head weights and biomass yield were highest for the 7-day treatment and the plant population was highest in the grower treatment at the romaine trial.

Nitrogen fertilization and irrigation management had no consistent effect on postharvest lettuce quality (Table 6). In the iceberg trial, the grower treatment had somewhat greater PAL activity after 3 days of storage than the treatment utilizing a 7-day irrigation interval, but that difference was not evidenced by more browning at later evaluation dates. In fact, after 3 and 9 days of storage the browning intensity was greatest in the 7-day irrigation interval. No treatment differences in either PAL activity or tissue browning intensity were observed in the romaine trial. Visual evaluation of the romaine lettuce also showed no treatment effects (Fig. 5).

Discussion and Conclusions

Results of the 2 trials demonstrated that using the quick nitrate test with careful water management could minimize potential leaching losses of N during the crop cycle and also lower the residual level of nitrate in the soil after harvest. By shortening the irrigation interval to 4 or 5 days during the drip phase, lettuce could be irrigated at 100% of crop ET without causing excessive water stress or drainage that can carry nitrate below the root zone of the crop.

The grower treatment in the iceberg trial resulted in the highest loss of N by leaching and the most residual nitrate in the soil profile due to applying more N than was taken up by the crop, and by applying water equal to 134% of crop ET at intervals averaging 7.5 days. In contrast the grower treatment in the romaine trial resulted in relatively minimal leaching losses of nitrate-N and lower residual N levels in the soil profile compared to the 7-day treatment. In this case, the grower's irrigation interval averaged 4.5 days, almost equal to the 4.4 day interval used in the 4-day treatment. Though the grower treatment at the romaine trial also equaled 137% of crop ET, by irrigating at short intervals, the volumes of water applied for an individual irrigation were less than in the iceberg trial, thereby reducing the volume of water that percolated below the root zone (Table 2).

Although marketable yields and post harvest quality were not statistically different among treatments at both trials, the biomass yield and head weights were statistically lowest in the 4-day treatment at the romaine trial. Since similar rates of N fertilizer were applied for the 4 and 7-day treatments, one would assume that the reduced water application in the 4-day treatment resulted in lower weight heads and reduced biomass. However, we measured higher soil moisture contents in the 4-day interval than in the 7-day interval treatment at the 8 inch depth until two few days before harvest. Nevertheless, the results demonstrate that some yield risk may be associated with cutting the corners too close on water applications. For crops such as lettuce which are sensitive to moisture and N deficits, balancing irrigation and N applications to minimize nitrate leaching and maintain yields will certainly require growers to use all their tools in their tool box. Based on the results of these and previous trials, our recommendations for drip irrigated lettuce are:

For nitrogen--

1. Use the quick N test to monitor the level of mineral nitrogen in the top foot of soil, especially before planting and after thinning.
2. Avoid applying large applications of N fertilizer (> 40 lb N/acre) in a single application
3. Match fertilizer applications with crop

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uptake requirements. In other words, minimal amounts of N should be applied during the first 30 days of the crop because uptake is low. Crop N uptake after thinning averages 4.5 lbs of N/acre per day during late spring and summer.

For water—

1. Use ET data and monitor soil moisture to match water applications with crop requirements.
2. Consider shortening irrigation intervals during the last 3 to 4 weeks of the crop to avoid having to apply extra water to maintain adequate soil moisture.
3. Avoid heavy irrigations that coincide with N fertilizer applications.

Acknowledgements: We would like to thank the California Leafy Green Research Board for funding this project and the grower cooperators who participated in the commercial field trials.

Table 2. Iceberg lettuce. Applied water, applied fertilizer N, average nitrate concentration in soil and leachate, and estimated leaching losses of nitrate-N

Treatment	Applied water: Post thinning		Total	Post-thinning drainage	Applied N	Average soil nitrate-N	Average nitrate-N in leachate	Estimated N leaching
	inches	% ETc	----- inches -----		lb/acre	---------	ppm -----	lb/acre
4-day	5.5	101	9.1	0.7	127	26.0	21.0	4.6
7-day	7.7	142	11.3	2.2	127	21.4	18.9	4.7
grower	7.3	134	10.9	2.1	253	44.6	44.5	30.2

Table 3. Romaine lettuce. Applied water, applied fertilizer N, average nitrate concentration in soil and leachate, and estimated leaching losses of nitrate-N

Treatment	Applied water: Post thinning		Total	Post-thinning drainage	Applied N	Average soil nitrate-N	Average nitrate-N in leachate	Estimated leaching losses
	inches	% ETc	----- inches -----		lb/acre	---------	ppm -----	lb/acre
4-day	3.5	103	7.4	0.32	130	28.9	46.9	5.8
7-day	4.7	140	8.6	1.42	130	26.1	61.1	21.7
grower	4.6	137	8.5	1.26	189	47.9	36.2	10.5

Table 4. Iceberg lettuce. Head weight, plant population, yield, and crop uptake of N

Treatment	Head Weight: Untrimmed	Head Weight: Trimmed	Plant Population: Marketable	Plant Population: Diseased	Yield: Marketable	Yield: Biomass	Crop N uptake: Total	Crop N uptake: Harvested
	------- lb/head	--------	----- plants/acre	----	------------------	lbs/acre	-----------------	
4-day	2.493	1.72	39685	883	68350	101080	108	73
7-day	2.483	1.68	41156	441	69363	103339	116	78
grower	2.546	1.72	40241	343	69023	103231	129	86
$LSD_{0.05}$	ns	ns	ns	ns	ns	ns	ns	ns

ns means are not statistically different at $p < 0.05$ level

Table 5. Romaine lettuce. Head weight, plant population, yield, and crop uptake of N

Treatment	Head Weight: Untrimmed	Head Weight: Trimmed	Plant population: Marketable	Plant population: Diseased	Yield: Marketable	Yield: Biomass	Crop N uptake: Total	Crop N uptake: Harvested
	------- lb/head	--------	----- plants/acre	----	------------------	lbs/acre	-----------------	
4-day	1.627	0.45	34640	5200	15664	64832	129	31
7-day	1.829	0.51	32539	6688	16542	71775	135	31
grower	1.743	0.48	35809	4971	17265	71065	129	31
$LSD_{0.05}$	0.11	0.07	2265	ns	ns	4407	ns	ns

ns means are not statistically different at $p < 0.05$ level

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Table 6. Effect of N fertilization and irrigation practices on phenylalanine ammonia lyase (PAL) activity (µmol cinnamic acid h^{-1} g^{-1}) and browning intensity (absorbance at 320 nm) of minimally processed lettuce.

Trial	Measurement	Storage duration (days)	Treatment: Grower Standard	4 day	7 day
Iceberg	PAL activity	0	0.03a*	0.04a	0.02a
		3	0.06b	0.04ab	0.03a
		6	0.03a	0.03a	0.03a
		9	0.03a	0.03a	0.03a
Romaine		0	0.03a	0.07a	0.05a
		3	0.15a	0.15a	0.14a
		6	0.09a	0.08a	0.09a
		9	0.04a	0.06a	0.05a
Iceberg	Browning Intensity	0	0.27a	0.27a	0.29a
		3	0.38a	0.45b	0.49b
		6	0.54a	0.67a	0.68a
		9	0.63a	0.70a	0.81b
Romaine		0	0.40a	0.38a	0.34a
		3	0.42a	0.46a	0.43a
		6	0.47a	0.52a	0.48a
		9	0.56a	0.59a	0.60a

* within rows, means followed by the same letter not significantly different at p = 0.05, by Tukey's mean separation test.

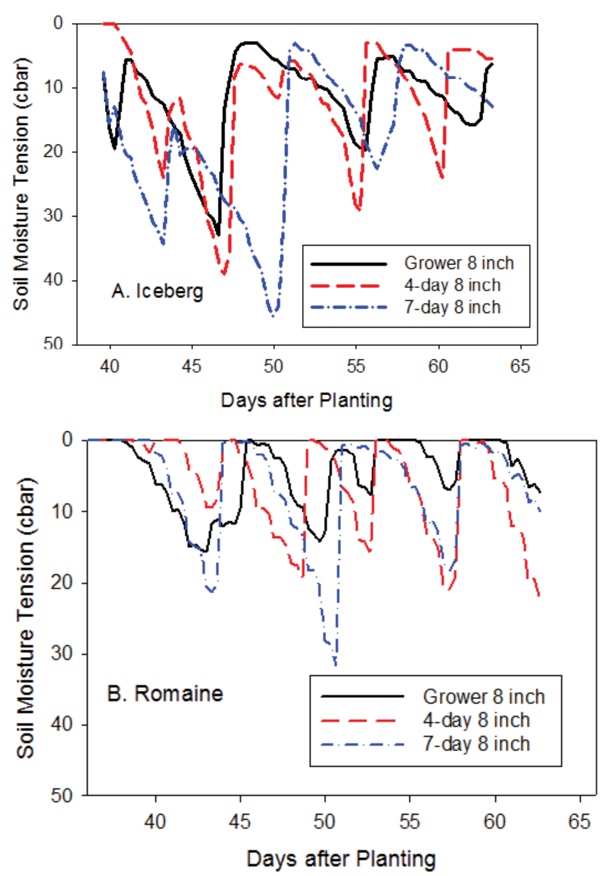

Fig. 1. Soil moisture tension at 8-inch depth for iceberg and romaine trials. High tensions indicate drier soil.

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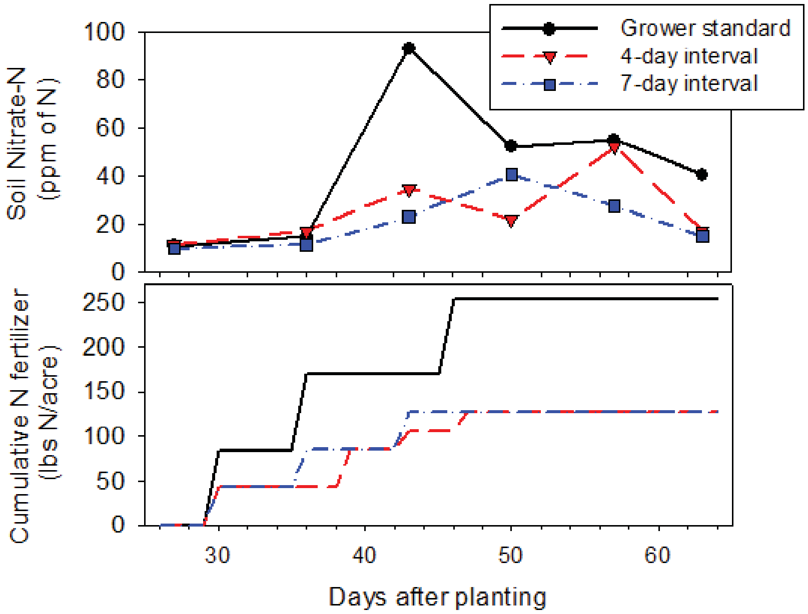

Fig. 2. Cumulative N fertilizer applied to treatments at iceberg trial and soil nitrate concentration in top foot of soil.

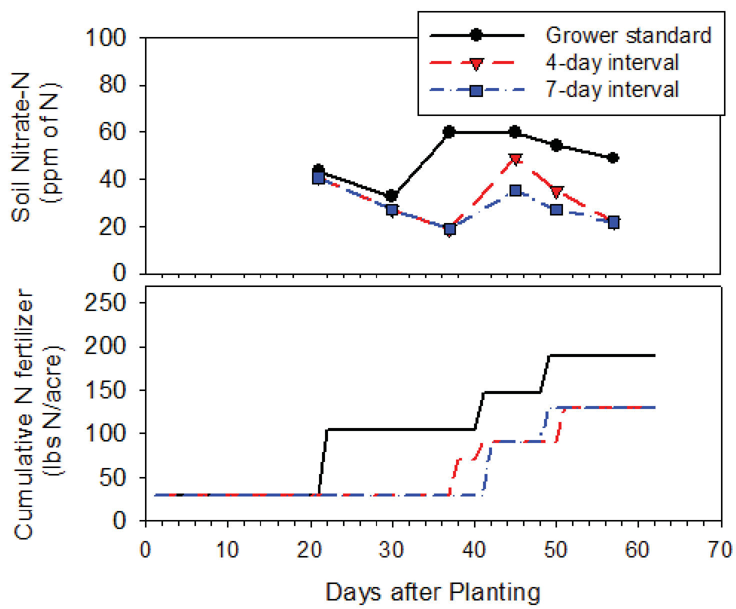

Fig. 3. Cumulative N fertilizer applied to treatments at romaine trial and soil nitrate concentration in top foot of soil.

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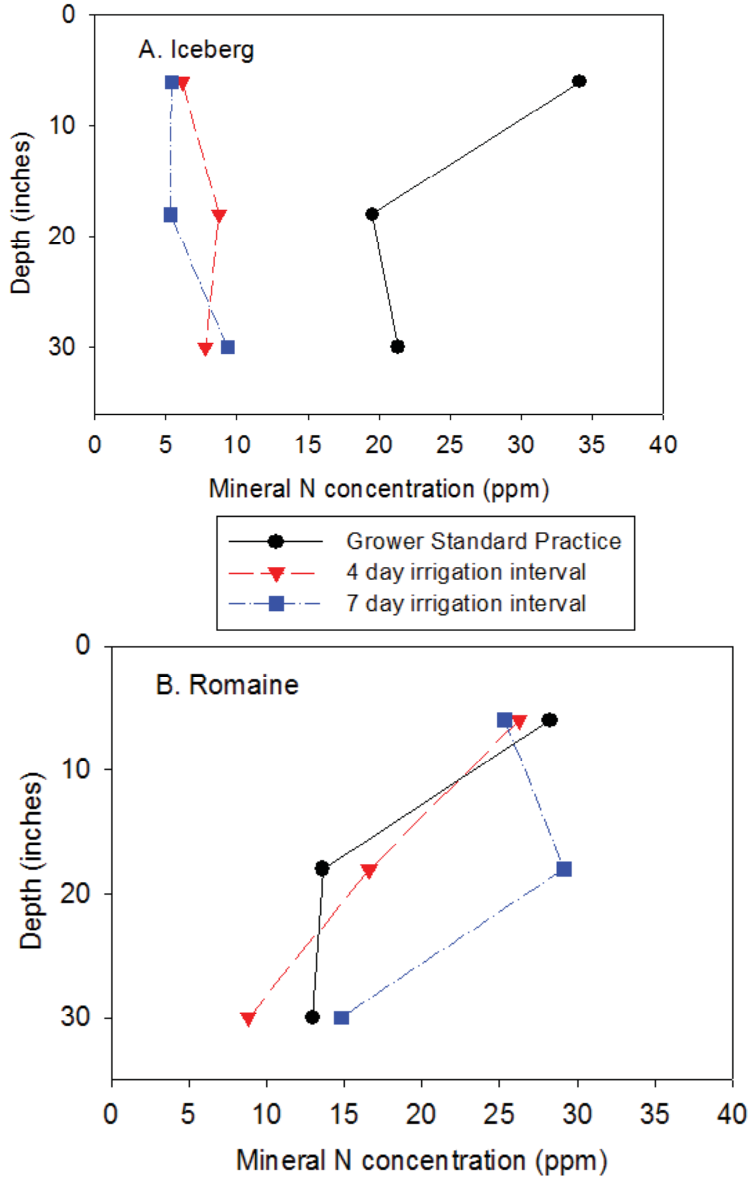

Fig. 4. Post-harvest mineral N in soil profile for iceberg and romaine.

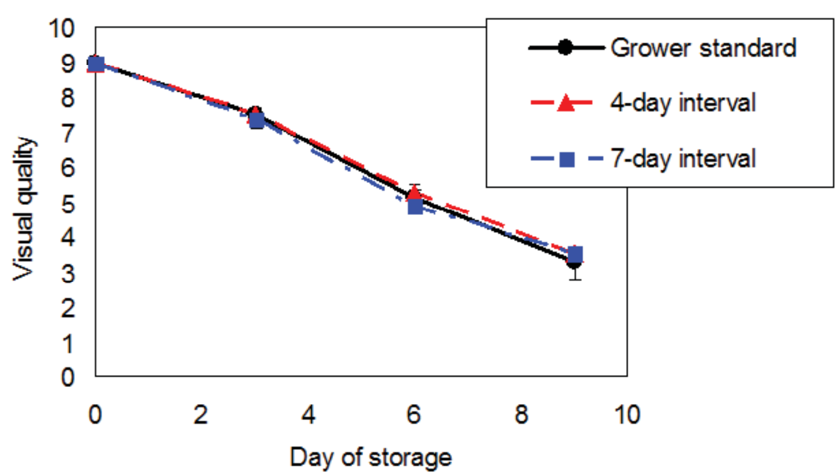

Fig. 5. Visual quality of minimally processed romaine lettuce stored at 5 °C. Each data point is the average of 4 replications; bars indicate standard error of the mean.

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OVERVIEW OF TIPBURN OF LETTUCE

Richard Smith, Tim Hartz and Ryan Hayes
Vegetable Crops and Weed Science Farm Advisor, Extension Vegetable Specialist and USDA Lettuce Breeder, respectively.

Tipburn of lettuce is a calcium-related disorder which causes the development of necrotic areas on the inner leaves of romaine and other leaf lettuce and on enclosed leaves of head lettuce (Photo 1). The necrotic areas likely develop due to a localized calcium deficiency that causes tissue collapse of the affected cells. There are two key factors that affect the development of localized calcium deficiency: 1) uptake of adequate calcium from the soil, and 2) calcium transport through the plant.

In a study conducted from 2005-2006 Tim Hartz, Michael Cahn and I showed that soil calcium levels in the lettuce growing areas of the Central Coast were optimal for plant growth. Soil calcium levels as measured in saturate paste extract was found to be the best indication of available soil calcium to the plant. The reason for this is that soil calcium levels from saturated paste extracts can be easily converted to concentration of calcium in the soil water, as well as pounds of calcium per acre in the soil water. In the two-year survey of a number of soils in the Salinas and Central Valleys, calcium concentrations in the soil water were found to average about 680 ppm; this value exceeds the calcium levels that are used in hydroponic vegetable production systems (100 – 200 ppm). Only one sandy soil in the survey had calcium levels below 200 ppm.

In the study, the effect of supplementing soil calcium with calcium thiosulfate, calcium nitrate and calcium chloride through the drip system was evaluated. Calcium from these materials was applied at the rate of 10-15 pounds per acre. No impact on tipburn symptoms was observed in these trials. To understand why this occurred, it is important to compare the amount of calcium that was applied to what was already in the soil. Calcium levels in the soil water can be converted to pounds of available calcium on a per acre basis; the amount of available calcium in the soil water in these evaluations was approximately 200 pounds/A, so the fertigated calcium supplied only a small fraction of what already existed in the soil.

Another factor in calcium nutrition of lettuce is the effectiveness of calcium transport through the plant. Calcium moves in the xylem by transpirational flow and is delivered to all parts of the plant this way. Factors that reduce transpiration also reduce calcium availability to leaf tissue and may lead to tipburn symptoms. Leaves enclosed in head lettuce and inner leaves of romaine are susceptible to tipburn because they are not transpiring as readily as leaves in the open which can transpire freely. In addition, root growth of lettuce decreases approximately two weeks prior to maturity which can further limit the supply to calcium to the transpirational stream. Various aspects of the growth pattern and physiology of lettuce varieties affect their susceptibility to tipburn (Tables 1-3). In a study conducted in 2005 and 2006, Sylvie Jenni and Ryan Hayes, showed that, in general, head lettuce types are less sensitive to tipburn than romaine types. This is primarily due to greater breeding efforts on tipburn resistance dedicated to date for head lettuce types.

An additional factor that influences the development of tipburn on lettuce is the weather. Foggy weather that reduces transpiration in the last 6-10 days before harvest is conducive to the development of tipburn in susceptible varieties.

One practice that may have a place in reducing tipburn is the use of foliar applications of calcium prior to and/or during the critical period of lettuce development. I currently have four trials out evaluating this technique. At the recommended application rates of the materials being tested,

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weekly applications of 0.15 to 0.20 lbs of calcium are applied. The trials are currently underway, but the question will be, can we get enough calcium into the plant at the right time? In addition, can the spray reach the tissue that may develop the symptoms, given that calcium does not readily move in the phloem of the plant?

Conclusions: Lettuce production soils of the Central Coast generally have high levels of readily available calcium. Most coastal soils have well over 200 ppm of calcium in the soil water which is adequate for optimal plant growth. The greater issue for the development of tipburn in lettuce is the variety. In addition, persistent foggy conditions that reduce transpirational flow of calcium to all parts of the leaves in the last 6-10 days prior to harvest will trigger this disorder in sensitive varieties.

Photo 1. Tipburn symptoms along the edge of an inner leaf or romaine lettuce.

Table 1. Head Lettuce: percent of plants with tipburn tested in Salinas, California and Yuma, Arizona (adapted from Jenni and Hayes, 2010).

Variety	California			Arizona			
	Salinas			Yuma			
	2005	2006		2005	2006		Mean
Calicel	99.0	78.0		99.0	100.0		88.7
Calmar	16.7	40.0		89.3	60.0		51.5
Cochise 47	43.3	13.3		79.3	66.7		50.7
Desert Spring	40.0	76.7		89.7	80.0		71.6
Diamond	1.0	36.7		86.0	13.3		34.3
Gabilan	53.3	20.0		46.7	0.0		30.0
GLMesa659	37.0	40.0		99.0	33.3		52.3
Head Master	10.3	39.6		76.3	33.3		39.9
Navajo	16.7	66.7		73.0	20.0		44.1
Pacific	1.0	8.1		49.7	40.0		24.7
Salinas	14.0	46.7		76.3	13.3		37.6
Silverado	7.0	26.7		66.3	0.0		25.0
Sniper	26.7	26.7		76.3	26.7		39.1
Sundance	30.3	80.0		69.7	20.0		50.0
Tiber	1.0	53.3		69.7	13.3		34.3
Van 75	40.3	60.0		36.7	60.0		49.3
Vanmax	43.3	90.0		79.3	26.7		59.8
Mean	28.3	47.2		74.3	35.7		46.1

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Table 2. Romaine: percent of plants with tipburn tested in Salinas, California and Yuma, Arizona (adapted from Jenni and Hayes, 2010).

Variety	California			Arizona			
	Salinas			Yuma			
	2005	2006		2005	2006		Mean
Avalanche	88.9	86.7		99.0	46.7		77.7
Beretta	53.3	80.0		79.7	93.3		76.6
Brave heart	70.0	86.7		76.3	33.3		66.6
Caesar	49.7	80.5		73.0	9.1		57.2
Clemente	37.0	50.0		59.7	33.3		45.0
Conquistador	93.0	78.3		82.7	33.3		71.8
Darkland	53.3	80.0		86.3	66.7		71.6
Fresh Heart	99.0	46.7		76.3	66.7		72.2
Gladiator	36.7	96.7		99.0	33.3		66.4
Gorilla	53.3	90.0		86.3	40.0		67.4
Green Towers	40.0	60.0		89.3	53.3		60.7
Heart's Delight	56.3	50.0		92.7	13.3		53.1
King Henry	63.3	80.0		33.3	26.7		50.8
Lobjoits	73.0	86.7		92.7	20.0		68.1
PIC 454	40.0	84.7		86.3	26.7		59.4
Paris Island Cos	66.3	70.2		73.2	73.3		71.4
Ruebens Red	93.0	82.9		99.0	73.3		86.6
Siskyou	16.7	66.7		66.3	0.0		37.4
Sunbelt	10.3	90.0		96.0	33.3		57.4
Triton	66.3	81.1		76.3	33.3		64.3
Valmaine	76.7	70.0		80.0	53.3		70.0
Mean	58.9	76.1		81.1	41.1		64.4

Table 3. Leaf Lettuce: percent of plants with tipburn tested in Salinas, California and Yuma, Arizona (adapted from Jenni and Hayes, 2010).

Variety	California			Arizona			
	Salinas			Yuma			
	2005	2006		2005	2006		Mean
Green Leaf							
Big Star	1.0	13.3		82.7	40.0		34.3
Eny	73.0	33.3		76.7	26.7		52.4
Genecorps Green	56.7	50.0		92.7	93.3		73.2
Grand Rapids	99.0	60.0		96.0	73.3		82.1
Green Vision	36.7	66.7		89.3	80.0		68.2
Ocean Green	43.3	40.0		79.7	53.3		54.1
Shining Star	13.7	33.3		86.3	53.3		46.7
Tehama	51.1	53.3		99.0	33.3		59.2
Two Star	60.0	36.7		96.0	66.7		64.8
Xena	60.0	75.0		63.3	6.7		58.0
Mean	49.5	46.2		86.2	52.7		59.3
Red Leaf							
Aragon Red	63.3	100.0		99.0	93.3		88.9
Deep Red	69.7	23.3		99.0	93.3		71.3
New Red	59.7	36.7		79.7	86.7		65.7
Red Fox	1.0	93.3		69.7	13.3		44.3
Red Line	63.0	93.3		89.7	86.7		83.2
Red Tide	20.3	40.0		92.7	33.3		46.6
Mean	46.2	64.4		88.3	67.8		66.7

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, and 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 day neutral 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. Infra-red photos of the canopy were taken at each of the 17 field sites 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). 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 planted with the proprietary variety.

Results

Applied water: Total applied water for 34 sites between January and October 2010 is summarized in Fig 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 (Fig 2). More than 90% of rainfall occurred between January and April and ranged from 11.9 to

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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 (Fig 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 (Fig 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 (Fig 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 (Fig 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 (Fig 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 the 4 fields that we 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 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 and application rate of a drip system. 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. The drip system adjusted to a high pressure (14 psi) applied more water per period of time than the system adjusted to the low pressure (7 psi).

System flow rates not only fluctuated during the season but also were lower than the expected flow rate, which was calculated from the drip tape manufacturer's discharge rate. 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 that some of the emitters were clogged. 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 (Fig 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

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dS/m during the production season (Fig 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 (Fig 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 applying 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**

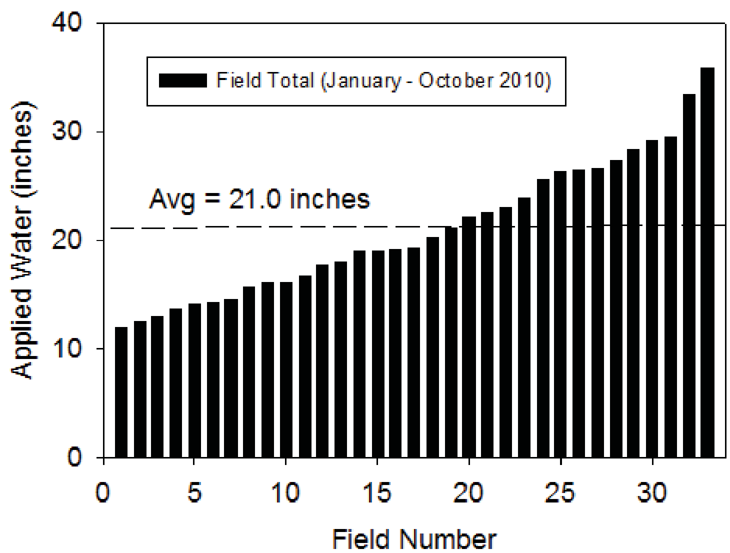

Fig. 1. Total applied water during the production season for 34 strawberry fields located in the Pajaro and Salinas Valleys.

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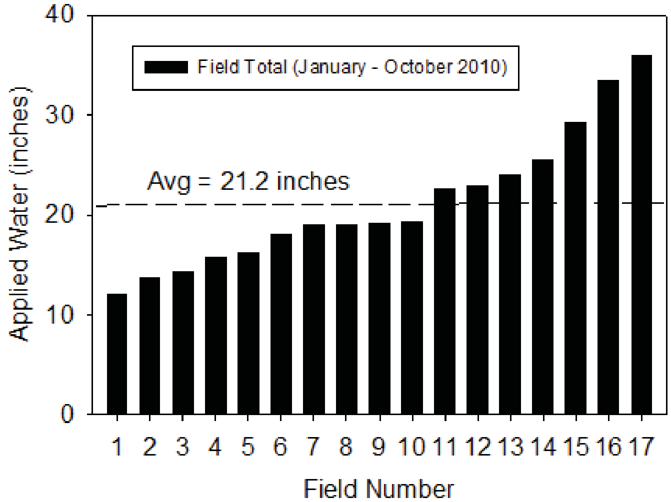

Fig. 2. Total applied water during the production season for a subset of 17 of the 34 strawberry fields that were intensively monitored.

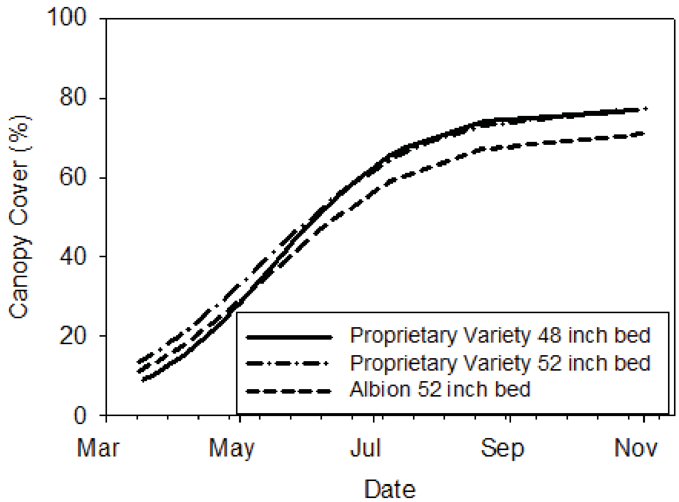

Fig. 3. Strawberry canopy cover for 2 varieties and 48 and 52 inch wide beds measured during 2010.

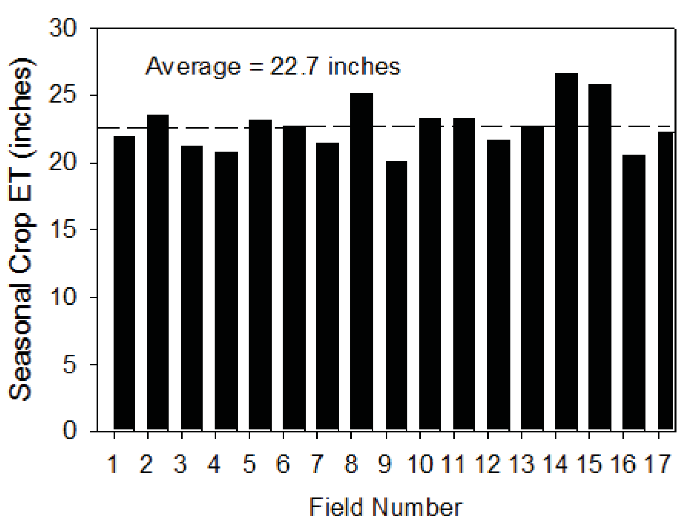

Fig. 4. Estimated crop ET of the 17 intensively monitored fields from January to October 2010.

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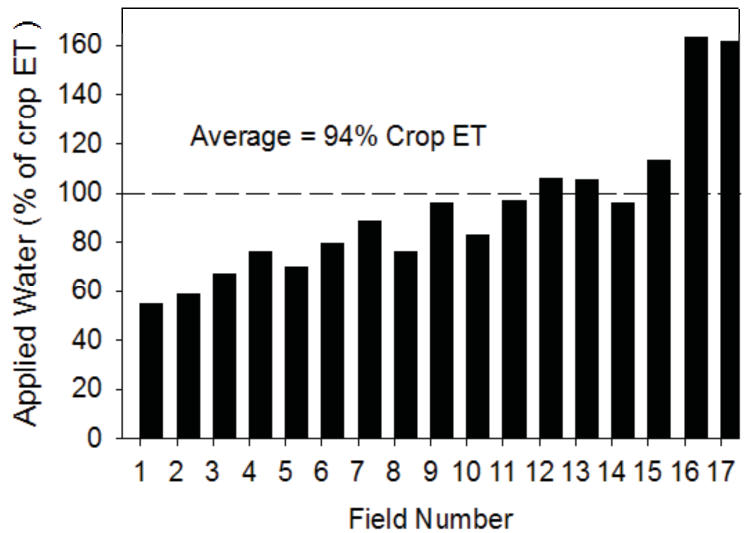

Fig. 5. Applied water expressed as a percentage of crop ET for the 17 intensively monitored fields from January to October 2010.

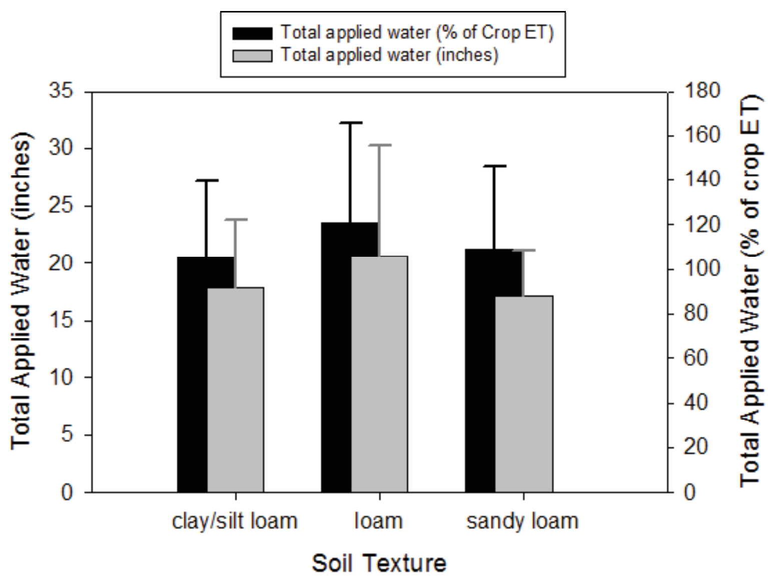

Fig. 6. Seasonal applied water compared among fields with different soil textures

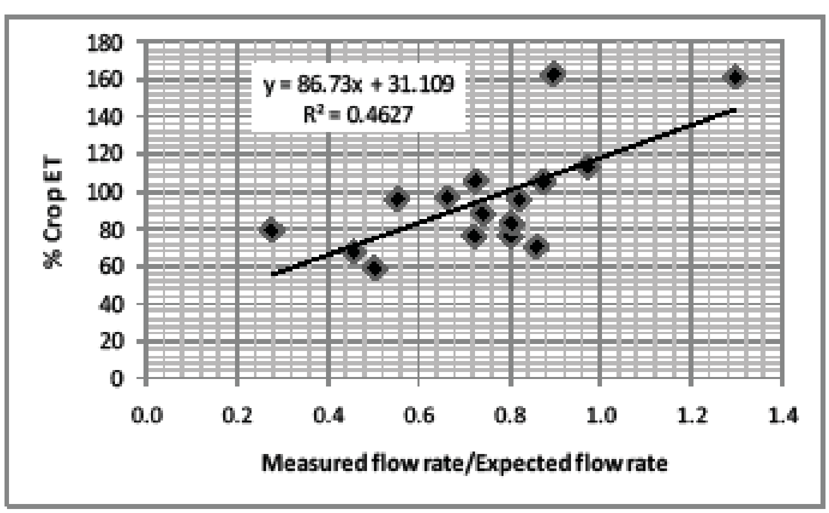

Fig. 7. Applied water expressed as a percentage of crop ET vs ratio of measured and expected drip system flow rates.

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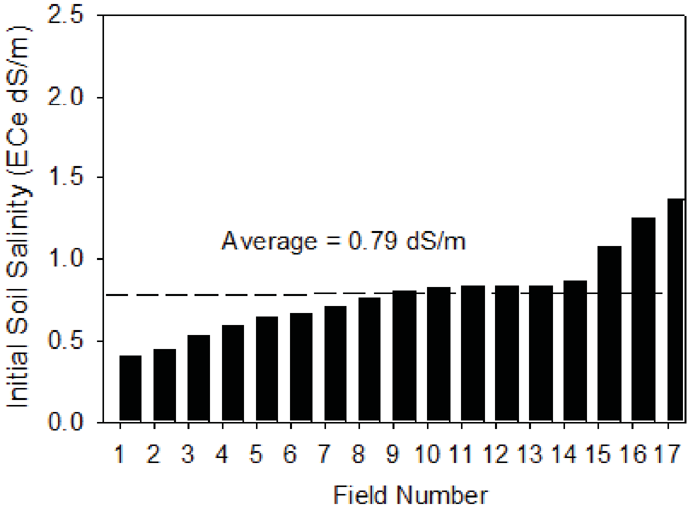

Fig. 8. Salinity values measured in the upper foot of soil at the 17 strawberry fields at the beginning of the 2010 production season.

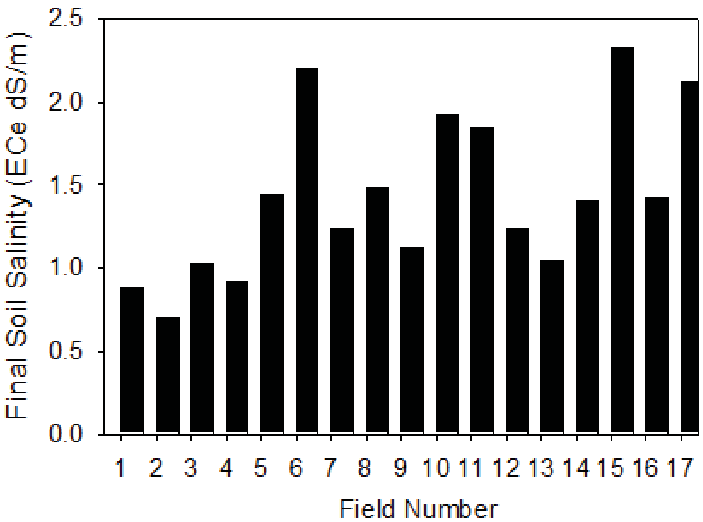

Fig. 8. Salinity values measured in the upper foot of soil at the 17 strawberry fields at the end of the 2010 production season.

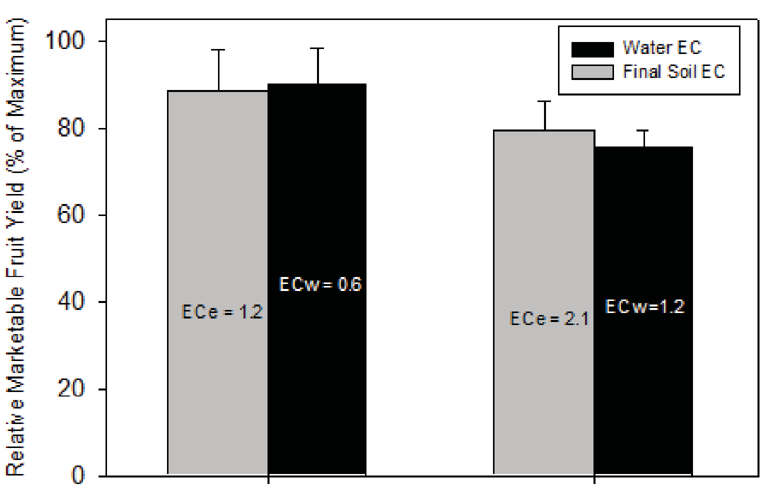

Fig. 9. Comparison of average yields from fields with water salinities below and above 1.0 dS/m and soil salinity values below and above 1.5 dS/m. EC values on bars are the average salinity values of fields.

SUSCEPTIBILITY OF WESTERN FLOWER THRIPS TO RADIANT INSECTICIDE ON STRAWBERRIES IN AN INTENSIVE CROP PRODUCTION AREA

Yi Yu, Jianlong Bi, Frank Zalom and Mark Bolda
University of California

Western flower thrips, *Frankliniella occidentalis*, are widespread pests throughout North America. Female flower thrips lay eggs inside leaves, flower buds and petals. After egg hatch, the first and second instar larvae feed on flower buds or terminal foliage. Toward the end of the second instar, the thrips stop feeding and drop to the soil or leaf litter where they become prepupae followed by pupae. Winged adults then emerge from the pupae. Developmental times depend on ambient temperature and host plant species. At 59F, the life cycle is completed in about two weeks, while at 86F, the life cycle can be finished in 4.3 days. In spring, the thrip populations build up on nearby flowering weeds. When these weeds are cut, stop flowering or dry up, they migrate to strawberries.

Thrips use their mouth parts to pierce plant cells and suck out their contents. The damaged plant cells collapse. Damage in strawberries is described as fruit bronzing, a tan or brown discoloration, sometimes leading to desiccation and cracking of the fruit surface. Control of these pests has been largely dependent upon chemical insecticides. Dow AgroScience, the manufacturer of spinosad, has recently claimed wide-spread resistance of thrips to this insecticide class in Central Coast strawberries and modified the label for reduced applications to these strawberries. Here we report susceptibility of the thrips to Radiant, a second generation of spinosad, in an intensive crop production area near Watsonville.

Materials and Methods

A 10-acre strawberry field in an intensive crop production area near the Beach Road, Watsonville, was selected for this study. Large strawberry and lettuce fields were in close proximity to this experimental field. Radiant (spinetoram) was applied twice at the top label rate to the experimental strawberries prior to our first sampling on June 17. This insecticide was applied again between the second (July 17) and the third (August 27) sampling dates. The last sampling was processed on October 1. On each of the sampling dates, western flower thrips with strawberry flowers were collected, and the collected samples were immediately shipped to the lab for bioassay experiments.

Strawberry seedlings were planted in pots filled with soil mixture in a greenhouse/shadehouse as a source for leaflets on which to conduct the bioassays. Plants used in the experiments were at the three to six trifoliate stages when leaflets were removed for the bioassays, and were never treated. Radiant was diluted in distilled water and at least 6 concentrations were used to produce a range of 5-90% mortality. The most recently fully-expanded strawberry leaflets were dipped for 10 s into a solution containing specific amount of Radiant. Control leaflets were dipped in distilled water only. After the leaf surface was dried, 25-35 adult thrips were transferred with an aspirator from the field collected flowers to the upper surface of a treated leaflet encased in a Munger cell apparatus with a layer of wet paper facing the lower surface of the leaflet. After the initial exposure, adult mortality was determined at 24, 48 and 72 h, respectively. Thrips that were unable to walk at least a distance equivalent to their body length were considered dead.

The resulting data were corrected for control mortality and analyzed by probit analysis. LC_{50} and LC_{90} for spinetoram were determined for each 24 h interval (24, 48 and 72 h) after the treatment. Differences in LC_{50s} and LC_{90s} were considered not significant if their respective 95% CI overlapped.

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Results and Discussion

Striking differences in susceptibility of the western flower thrip to spinetoram were observed at 24, 48 and 72 h after the initial exposure (Table 1). Across all sampling dates, LC_{50s} of spinetoram for adult thrips were 2.47 (August 27) to 3.61 (October 1) times greater at 24 h compared to those at 48 h and 3.21 (October 1) to 12.06 (July 17) times greater than those at 72 h. LC_{90s} were 2.27 to 4.13 and 5.35 to 10.40 times higher at 24 h in comparison with those at 48 and 72 h, respectively. These results indicate that up to 72 h post treatment is required in order to determine the resistance or susceptibility in bioassay experiments. However, Dow AgroScience used only the 24 h exposure results to identify resistance.

Between the June 17 and August 27 sampling dates, LC_{50} of spinetoram for adult thrips at 48 h increased from 80 to 344 µg ai/ml, and then (on October 1) decreased to 93 µg ai/ml (Table 1). Similarly, the LC_{90} increased from 549 to 4043 µg ai/ml from June 17 to August 27 and then decreased to 1315 µg ai/ml on October 1. The decreased susceptibility from June 17 to August 27 may be attributed to the application of Radiant and the migration of resistant thrips from nearby fields to the experimental field. The increased susceptibility from August 27 to October 1 may have been caused by the migration of susceptible thrips from the nearby fields to the experimental field.

Conclusion

In an intensive crop production area with strawberries and lettuce, susceptibility of western flower thrips in strawberries to Radiant insecticide steadily decreased to resistant levels from mid-June to late August. However, the resistance appeared to be unstable. As the season proceeded, it decreased to susceptible levels. Therefore, three applications of Radiant during the mid-season did not create a resistant population of thrips late in the season.

Margin Marks:
Western flower thrips, *Frankliniella occidentalis*, are widespread pests throughout North America.

Three applications of Radiant during mid-season on strawberries did not create a resistant population of thrips late in the season.

Table 1. Susceptibility of western flower thrips in strawberries to Radiant insecticide in an intensive crop production area in Watsonville

Sampling date	n	Exposure duration (h)	Slope ± SE	LC_{50}, µg ai/ml (95% CI)	LC_{90}, µg ai/ml (95% CI)
Jun. 17	708	24	1.454 ± 0.109	289.632 (222.953—387.499)	2204.323 (1345.502— 4702.988)
		48	1.534 ± 0.109	80.228 (60.069—102.790)	549.174(390.398—885.530)
		72	1.614 ± 0.141	45.545 (31.895—59.707)	283.523 (211.519—423.693)
Jul. 17	770	24	1.237 ± 0.112	533.712 (390.645—797.613)	5734.776 (2831.458—21374.048)
		48	1.419 ± 0.134	206.773 (153.115—262.367)	1655.331 (1116.039—3090.723)
		72	1.067 ± 0.105	44.257 (25.743—64.406)	703.644 (503.792—1121.875)
Aug. 27	883	24	0.992 ± 0.074	851.263 (640.411—1179.864)	16688.054 (8791.382—40473.892)
		48	1.198 ± 0.109	344.027 (255.815—443.848)	4043.364 (2567.751—8043.123)
		72	1.543 ± 0.171	236.922 (175.503—295.857)	1604.074 (1210.233—2419.597)
Oct. 1	1207	24	1.246 ± 0.099	279.498 (210.693—355.859)	2987.601 (2027.455—5186.879)
		48	1.112 ± 0.080	92.516 (59.785—130.184)	1314.572 (864.070—2367.524)
		72	1.542 ± 0.139	86.830 (53.186—121.767)	558.616 (430.971—905.667)

94 µg ai/ml = a spray volume of 100 gallons per acre at full label rate of Radiant (10 oz/acre)
187 µg ai/ml = a spray volume of 50 gallons per acre at full label rate of Radiant (10 oz/acre)

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.

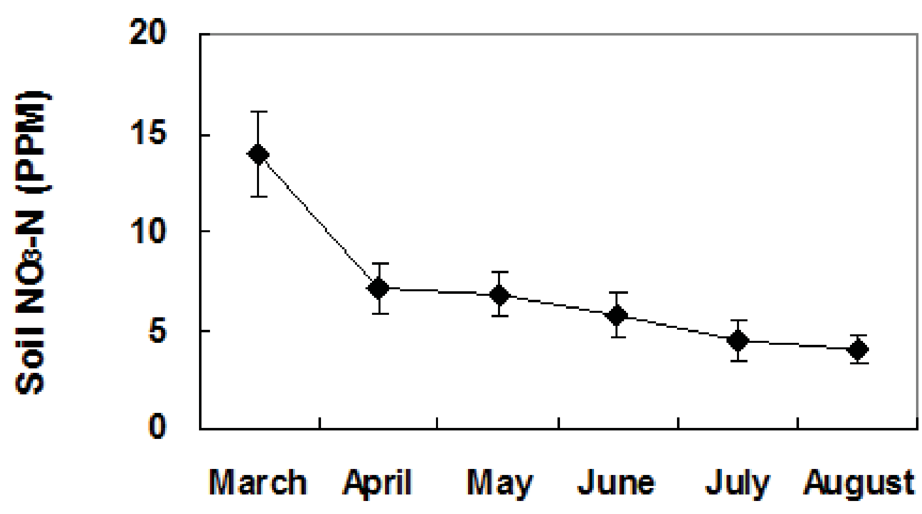

Fig. 1. Mean root zone soil NO_3-N concentration of the monitored fields; bars indicate standard error of measurement.

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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 Table 1.

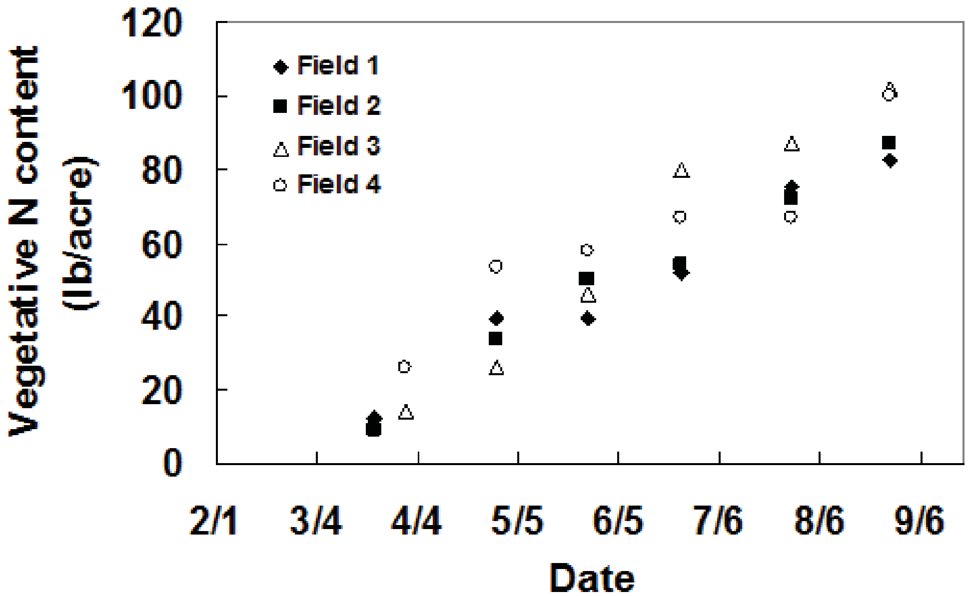

Fig. 2. N uptake in vegetative tissue (leaves and crowns); fields 1 and 2 were 'Albion', fields 3 and 4 were a day-neutral proprietary variety.

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

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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.

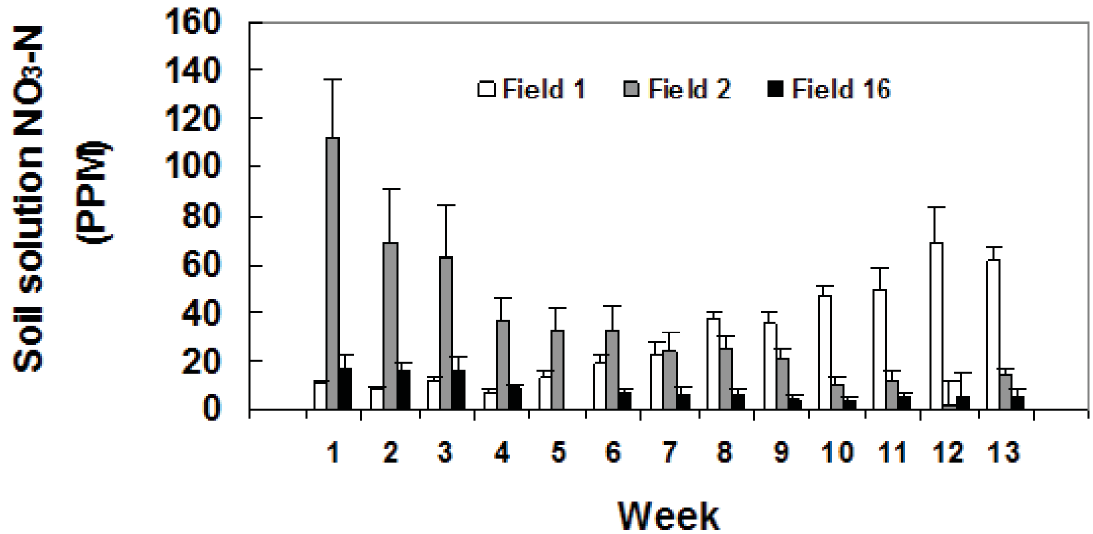

Fig. 3. Mean soil solution NO3-N concentration at 24" depth by week over the period June 1 - August 30, 2010; bars indicate standard error of measurement.

Estimates of weekly leaching volume were calculated as the difference between ETc and irrigation applied. In field 16, irrigation was marginally less than ETc for most of the sampling period, with a significant leaching volume occurring only in week 3. In fields 1 and 2, irrigation exceeded ETc 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 39, 36 and 3 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.

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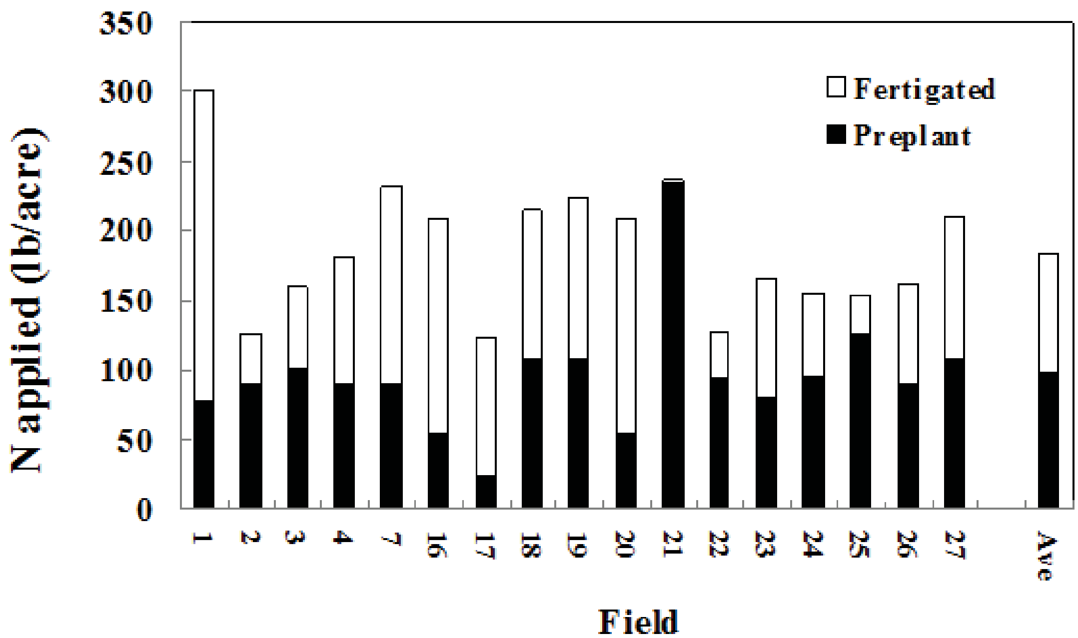

Fig. 4. Seasonal N fertilization rate applied.

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.