Investigating the Interaction of Irrigation, Surfactant and Fertilizer Rates on Nitrate and Chlorophyll Contents of Tomato Leaves

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Abstract: *Tomato is one of the most important vegetables grown in the United States. Due to continuous rise in the cost of fertilizers and irrigation water crisis, there is a need to continuously find ways for efficient use of fertilizers and irrigation water, without affecting the quality and quantity of the tomatoes. Current approaches involve utilizing products such as soil surfactants which can potentially enhance water and nutrient uptake by plants, and thereby optimize overall crop productivity. The objective of this study was to evaluate the influence of surfactant, Nitrogen (N) fertilizer and irrigation rates on the nitrate concentration and chlorophyll content of tomato leaves. The study was conducted on a sandy loam soil, as a split-split plot experiment, with irrigation (high, medium and low) as the main factor, and surfactant (with and without) and fertilizer rates (100, 150 and 200 lbs N/acre) as secondary factors. Leaf petioles were analyzed for nitrate concentrations at 1" diameter of fruit stage (first ripe stage) and at harvest, with weekly chlorophyll contents in leaves determined using a SPAD 502 Plus Chlorophyll Meter. At first ripe stage, fertilizer rates had a significant effect (P = 0.02) on leaf tissue nitrate content, with rates of 150 and 200 lbs N/acre resulting in the highest levels for all the irrigation and surfactant treatments. At harvest, mean petiole nitrate level was highest in plants receiving 200 lbs N/acre, and there was also was an interaction effect of the three treatments at the P=0.10 significance level. Overall, there was a slight decrease in the chlorophyll contents in leaves as the tomatoes progressed from immature green stage to harvest. However, at the harvest stage there was no difference in chlorophyll content for plants grown on soil treated with or without surfactants. These initial findings concur with our earlier studies with turfgrass which indicated that the addition of soil surfactants can potentially enhance vegetative plant growth*.

Keywords. *Surfactant, Water use efficiency, Nitrogen use efficiency, Nitrates in petiole, Chlorophyll, and SPAD 502 Plus meter.*

NOTE: This work represents the first year of our ongoing study to evaluate the effect of surfactant use on water and nitrogen use efficiency in vegetable production. A second trial was conducted during Summer 2012 and complete findings should be available by June 2013.

Introduction

The United States (U.S.) is the second largest producer of tomatoes worldwide and California is the leading producer of all tomatoes in the U.S. Most of the tomato production in California is located in San Joaquin Valley and Sacramento Valley. Input costs for agriculture continue to rise due to cost of fertilizers, fungicides and insecticides. Efficient use of water is important in the areas of irrigation water crisis. However, soil Water repellency causes non- uniform moisture levels in the soil due to which plants may deprive of consistent water supply and may also result in non-uniform distribution of soil applied fertilizers, fungicides and insecticides. To date, soil surfactants have been successfully used for the management of non-uniform moisture distribution in turf grasses. However, the application of surfactants to enhance vegetable production is a relatively new practice and most of positive effects reported by growers have been anecdotal, and so there is a need to scientifically assess the impact of surfactant usage in vegetables, such as tomatoes, production.

The objective of this study was to evaluate the influence of surfactant, Nitrogen (N) fertilizer and irrigation rates on the nitrate concentration and chlorophyll content of tomato leaves.

Materials and Methods

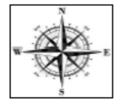
The study was conducted at California State University- Fresno (Fresno State). During summer 2011, tomatoes (*Lycopersicon esculentum* Miller) *cv* Quali-T 23 were grown on sandy loam soil, at the Center for Irrigation Technology (CIT) research plots. Quali- T 23 is a fresh market beefsteak tomato variety, which is a determinate and medium-late maturity type. Plants were hand transplanted on June 10th 2011 with a spacing of 12" between each plant. Twenty seventy tomato beds (5 feet wide x 150 feet long) were used in a split-split plot experimental design comprising of eighteen treatments replicated three times (Figure 1) as follows:

<u>Main plot treatment</u>: Three <u>irrigation rates</u> based on meeting 100% (I1), 80% (I2), 60% (I3) of total crop evapotranspiration (ETc). A manifold with three irrigation lines for the three irrigation rates controlled by electronic valves with an automated data logger system was used. An electronic meter was used to calculate the amount of water added to each irrigation treatment. Water was applied via a subsurface drip irrigation system buried at a depth of 6 inches;

<u>Sub-plot treatment</u>: Plots were treated either with or without <u>surfactant,</u> with S1 and S2 representing whether plots received no surfactant and surfactant at 1 gallons/acre, respectively. For the S2 treated beds, the surfactant was applied three times during the growing season at rates of 0.5 gallons/acre prior to planting, and then two more 0.25 gallons/acre applications at one and two weeks after transplanting. The surfactant was applied using a portable CO_2 spray system by mixing the product with two gallons of water per each half of the bed (75 feet). For the S1 treatment beds, two gallons of water without surfactant was sprayed whenever the S2 treated beds received the surfactant (Figure 2);

<u>Sub-sub plot treatment</u>: Urea Ammonium Nitrate (UAN 32) <u>fertilizer</u> was applied six times over the growing season to achieve total N rates of 100 lbs N/acre (F1), 150 lbs N/acre (F2) and 200 lbs N /acre (F3).

Plot Layout for Aquatrols 2011 Project at CIT



<<-----Barstow avenue------->>

Block 3			Block 2			Block1		
I2	I3	I1	I1	I3	I2	I3	I2	I1
(49) S1F2	(43) S2F1	(37) S1F2	(31) S2F1	(25) S2F1	(19) S2F2	(13) S2F1	(7) S1F2	(1)S1F1
(50) S1F3	(44) S2F3	(38) S1F1	(32) S2F2	(26) S2F3	(20) S2F3	(14) S2F2	(8) S1F1	(2) S1F2
(51) S1F1	(45) S2F2	(39) S1F3	(33) S2F3	(27) S2F2	(21) S2F1	(15) S2F3	(9) S1F3	(3) S1F3
(52) S2F3	(46) S1F1	(40) S2F3	(34) S1F3	(28) S1F2	(22) S1F3	(16) S1F3	(10) S2F2	(4) S2F1
(53) S2F1	(47) S1F2	(41) S2F1	(35) S1F2	(29) S1F3	(23) S1F1	(17) S1F2	(11) S2F1	(5) S2F2
(54) S2F2	(48) S1F3	(42) S2F2	(36) S1F1	(30) S1F1	(24) S1F2	(18) S1F1	(12) S2F3	(6) S2F3
Beds 25-27	Beds 22-24	Beds 19-21	Beds 16-18	Beds 13-15	Beds 10-12	Beds 7-9	Beds 4-6	Beds 1-3

LEGEND	Irrigation	% ET		Surfactant	gal/acre		Fertilizer	lbs N/acre
	I1	100		S1	0		F1	100
	I2	80		S2	1		F2	150
	I3	60					F3	200

Numbers 1 to 54 in ( ) represent the sub plots, which are 3 beds x 25 feet long = 3 beds x 5'/bed x 25' = 375 sq. ft .

Figure 1: Experimental design showing irrigation (I1, I2 and I3), surfactant (S1, S2) and fertilizer rates (F1, F2 and F3).

Figure 2: Photos showing the surfactant application (*left*), transplanting tomatoes (*middle)* and fertilizer application (*right*).

Leaf tissue analysis for nitrate was done at 1" diameter of fruit (first ripe stage) and at final harvest stage (red ripe stage). A Konica Minolta SPAD-502® leaf chlorophyll meter was used five times during the growing season to assess the chlorophyll content in the leaves. Four different leaves were used to get an average SPAD reading in each plot during each event.

Data collected was subjected to analyses of variance using the general linear model option in the SPSS® software (SPSS, 2010).

Preliminary Results

Figures 3 to 8 depict the effect of fertilizer and surfactants on the leaf nitrate levels for tomatoes irrigated at the three rates to satisfy 100% (I1), 80% (I2) and 60% (I3) of ETc. The interactive impact of surfactant and fertilizer on these nitrate levels are shown in Figures 9 and 10. Generally, at first ripe stage, fertilizer rates had a significant effect (P=0.02) on leaf tissue NO_3-N concentration, with the leaves from tomatoes receiving 150 and 200 lbs N/acre having the highest NO_3-N levels. At harvest, mean petiole NO_3- N level was highest in plants receiving 200 lbs N/acre. At the 10% probability level (P=0.10), there was a significant interaction, with plants receiving surfactants, and fertilized with 150 & 200 lbs N/acre and irrigated at the 80% and 100% ET having relatively higher nitrate levels than those at 60% ET irrigation rates.

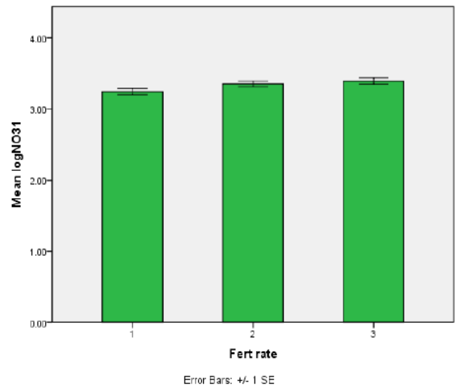


Figure 3: Fertilizer effect at first ripe stage.

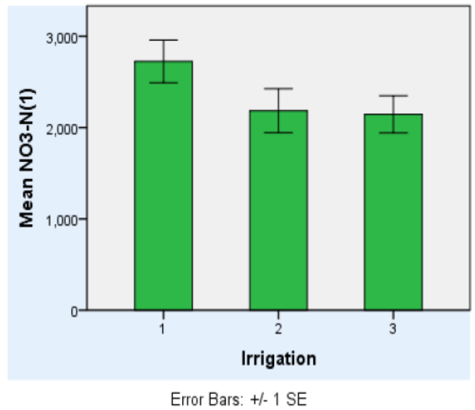


Figure 4: Irrigation effect at first ripe stage.

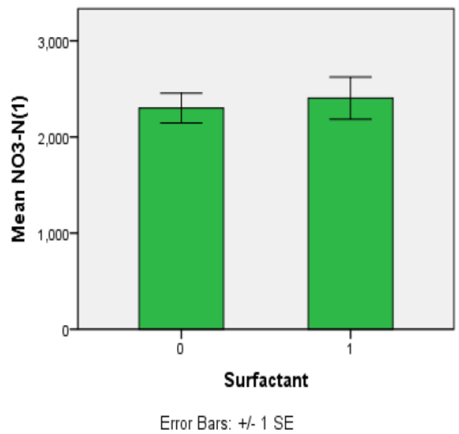


Figure 5: Surfactant effect at first ripe stage.

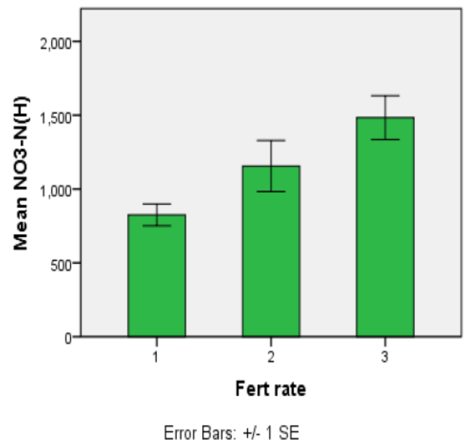


Figure 6: Fertilizer effect at final harvest stage.

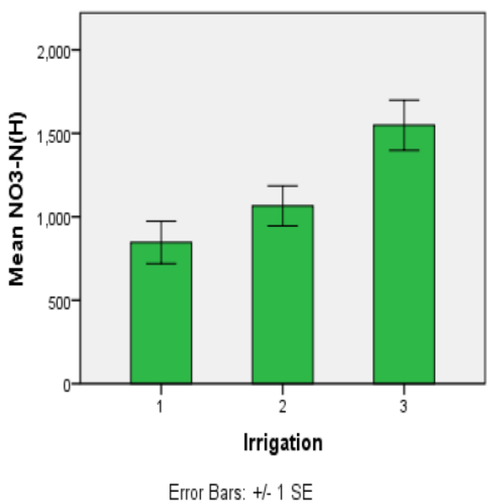


Figure 7: Irrigation effect at final harvest stage.

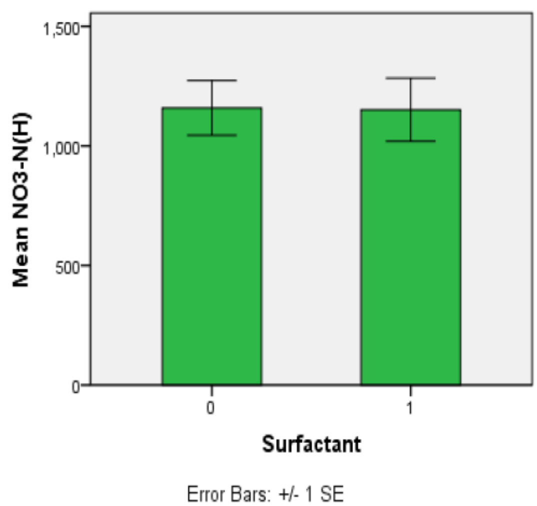


Figure 8: Surfactant effect at final harvest stage.

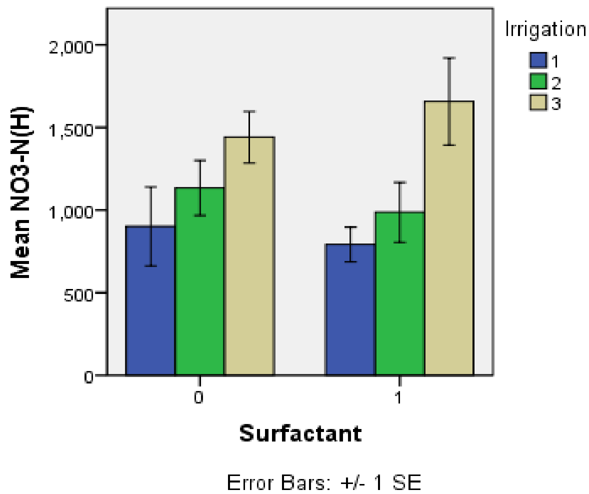


Figure 9: Surfactant and Irrigation interaction at final harvest stage.

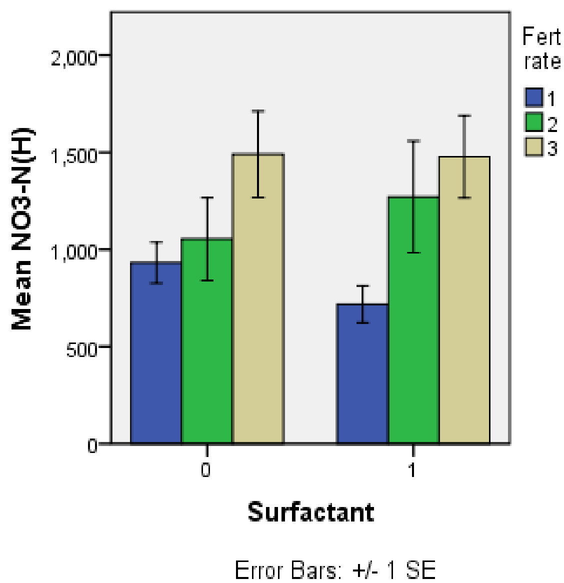


Figure 10: Surfactant and Fertilizer interaction at final harvest stage.

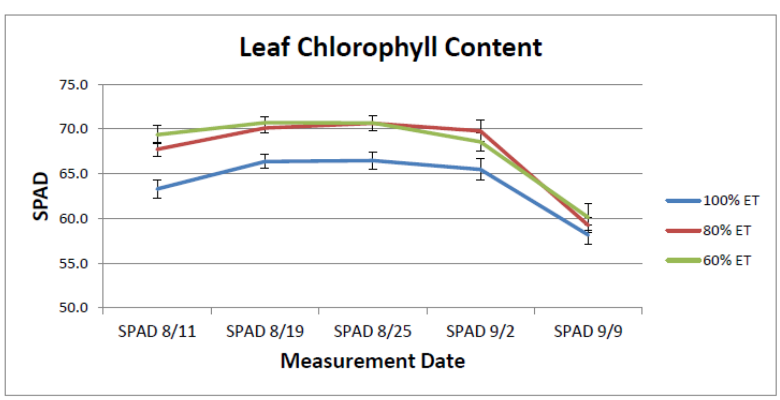


Figure 11: Average SPAD reading for three irrigation rates for five weeks prior to harvest date.

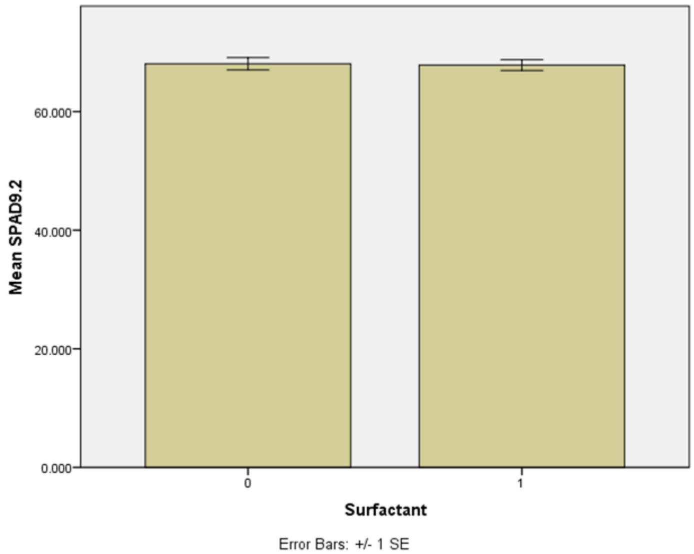


Figure 12: Average SPAD reading at harvest for plots treated with and without surfactants.

Trends in leaf chlorophyll contents measured with th SPAD meter are depicted in Figures 11 and 12. Overall, there was a slight decrease in the chlorophyll contents in leaves as the tomatoes progressed from immature green to full red stage (harvest). At first ripe stage, irrigation rates had a significant effect (P = 0.06) on leaf chlorophyll content. At harvest, there was no significant difference in the chlorophyll content due any of the three factors investigated in this study.

Concluding Remarks

The findings summarized below represent those obtained from the first year of our ongoing study to evaluate effect of surfactant use on water and nitrogen use efficiency in vegetable production. A second trial was conducted during Summer 2012 and complete findings should be available by June 2013.

- At first ripe stage, fertilizer rates had a significant effect (P = 0.02) on leaf tissue nitrate content, with rates of 150 and 200 lbs N/acre resulting in the highest levels for all the irrigation and surfactant treatments.
- At harvest, mean petiole nitrate level was highest in plants receiving 200 lbs N/acre and there was an interaction effect of the three treatments, at the 90% probability level (P=0.10), which resulted in plants grown in soils receiving surfactants, fertilized with 150 and 200 lbs N/ acre, and irrigated at the medium and high rates, having relatively higher nitrate levels than those at the lowest (60% ET) irrigation rates.
- Overall, there was a slight decrease in the chlorophyll contents in leaves as the tomatoes progressed from immature green to full red stage (harvest).
- At first ripe stage, irrigation rates had a significant effect, at the P = 0.06 level, on leaf chlorophyll content. However, at harvest, there was no significant difference in the chlorophyll content due any of the three factors investigated in this study.
- It is noteworthy that unlike other studies reported in the literature, the chlorophyll contents measured with the SPAD meter in this study did not show any positive correlation with the nitrate concentrations determined in leaf petioles.

- These initial findings concur with our earlier studies with turfgrass which indicated that the addition of soil surfactants can potentially enhance vegetative plant growth.
- In future studies, we intend to investigate the correlation between chlorophyll readings and total nitrogen content of the leaves.
- Data from a second round of the experiment conducted in summer 2012 is currently being analyzed.

Acknowledgements

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