California Pepper Commission – ANNUAL Report for 2009

Title: The Effect of Nitrogen Fertilization on Yield and Quality of Bell Peppers

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Summary: A field study was established at the UC WSREC to investigate 5 rates of nitrogen fertilizer on the yield and postharvest quality of drip irrigated bell peppers. The variety Jupiter was transplanted and grown without plastic mulch or poles on 40-inch beds with a manifold system that allowed different nitrogen rates to be applied simultaneously through subsurface drip irrigation to different parts of the test plot. Whole leaf tissue samples collected several times over the growing season revealed increasing leaf nitrogen with increasing soil applied nitrogen. Biomass and yield results indicated that the highest yields were not obtained with the highest amount of soil applied nitrogen. Field conditions were not perfect for a fertilizer rate study that needed the crop response to nitrogen and the best quality produce to define postharvest characteristics. Overall green fruit were firmer, had thinner walls, and weighed less than red fruit. The dry weight of red fruit increased with increasing amounts of applied nitrogen, whereas in this study that trend was not seen in green fruit. Fruit with low nitrogen were less green and less red in color. Although some results were obtained, the results are not comprehensive and need further field and postharvest laboratory investigation.

Background: In the Central Valley peppers are grown for fresh and processing markets, and in some cases the same crop is used for both purposes. Some fields are grown on poles and plastic mulched beds for extended fresh market production, while others are grown without plastic mulch or support for a once (or twice) over harvest. Many bell pepper growers use drip irrigation and apply liquid nitrogen fertilizers through the drip system. Planting configurations differ by grower. Although growers learn how to grow peppers under drip irrigation on their soils, nitrogen best management practices have not been updated for many years. Yield of peppers also varies significantly depending upon pepper variety, planting method, time of planting and other cultural practices including irrigation and fertilization. There has not been a recent study that investigates the relationship between nitrogen fertilizer and pepper quality at harvest, when grown under drip irrigation. Good quality mature-green peppers for fresh market should be of a color typical of the variety, without defects (cracks, sunburn, shrivel), firm to hand pressure and retain firmness during typical commercial handling, and have no decay. Pepper firmness varies by variety, wall thickness, and weight loss during commercial handling. It is expected that peppers with a higher dry matter content will also perform better during commercial handling than those with a lower dry matter content.

Goals and Objectives
The goal of this project is to evaluate the effect of nitrogen applied to a drip irrigated crop of bell peppers throughout the season on pepper yield, horticultural attributes, and quality at harvest. Pepper quality parameters include fruit weight, color, firmness, bruise susceptibility, cracking, pericarp wall thickness, internal color, and dry weight.

Procedures and Methods for 2009
FIELD Experiment: Preseason soil samples were collected and a subsurface drip irrigation system was established in a field at the UC WSREC in Fresno County in panoche clay loam soil. A series of manifolds was built which allowed for 5 separate yet simultaneous applications of nitrogen (N) fertilizer rates to different sections of the field. A preplant application of 150 units of 11-52-0 was uniformly applied to the field prior to transplanting and an additional 30 units of N was uniformly applied to the field a month after transplanting. Five rates (75, 150, 225, 300, and 375 lbs/acre) of N in the form of CAN 17 were tested in this field experiment. Each rate was split into 5 applications that were made on: May 29, June 11, June 19, July 6, and July 17. Bell peppers (cultivar Jupiter) were transplanted on March 25, 2009 with a commercial transplanter set at a 9” within row spacing onto a 40-inch bed. Plot size was four 40-inch beds x 60’ length and replicated 4 times in the field in a Randomized Complete Block Design. Only the middle 2 beds were used for data collection and the outer 2 beds served as a buffer zone between N treatments. Weed control consisted of Dual Magnum applied at transplanting and hand cultivated for the rest of the season. No other pesticides were used in this study. Whole leaf plant tissue samples (60-80 leaves per plot) were collected on June 5, June 24, and July 17 and sent to the DANR Laboratory for % Total N analysis. The peppers were hand harvested on July 23 and sorted by size, color and defects. At harvest 5 representative plants from each treatment and all four reps (total 20 plants per treatment) were harvested at the soil line, weighed whole, then stripped of fruit, and the fruit and leaf/stems weighed separately (wet biomass).

POSTHARVEST Experiment: Pepper fruit were harvested on July 23, with about 50% of the fruit red and 50% or less at the mature-green stage. A minimum of 20 fruit per field replicate (rep) of each color were harvested. Fruit without apparent defects (sunburn, decay, etc.) were harvested from 10:30am -2pm, placed in plastic trays and transported in an air-conditioned van to the MANN laboratory at Davis. Fruit were held at 45°F, covered with plastic sheets to prevent weight loss, while completing evaluations (complete within 3 days of harvest). After sorting in the lab, another 25% of the fruit had noticeable defects (shrivel in one location, blossom end rot, split end, insect, and other defects). Because of variability in numbers of fruit from each field rep, fruit from all field reps were combined and 4 laboratory replicates created: 10 fruit per rep for each of 4 reps for green fruit and the same for red fruit from each treatment; 40 green fruit and 40 red fruit per treatment total for weight, external color, firmness, cracking and bruising test. Another 32 fruit, 8 fruit x 4reps of both green and red were used to measure pericarp thickness at the equator of the fruit and a ring from each fruit was used to determine dry weight.

<u>Postharvest Evaluations (performed in order listed)</u>:

1. **Fruit weight**
2. **Color (external)** was assessed nondestructively at the midpoint of the fruit using a reflectance colorimeter. The L*a*b* values generated are reported as L* (lightness or darkness), chroma (color intensity) and hue (green color). Hue color value is reported.
3. **Firmness** (3 assessments done in the order listed)
    a. **Firmness score**, a subjective score from 5 to 1, where 5=very firm, 4=firm, 3=moderately firm, 2=moderately soft, and 1=soft
    b. **Compression test** to measure whole fruit firmness; objective measurements made by pushing a flat plate on the wall of the pepper using a computerized texture analyzer; values will be correlated with the subjective scoring of firmness
    c. **Durometer,** this hand held device provides a non-destructive assessment of firmness in a small area on the wall of the pepper; durometer values are useful for fruits but may also be useful for peppers. The durometer used was calibrated for tomato fruits and did not have sufficient range to measure pepper fruits unless they were softening.
4. **Bruise Susceptibility.** A 2cm stainless steel (67g) will be dropped 24 inches from a cylinder onto the shoulders of the fruit; 2 measurements per fruit. This simple setup has been used to access bruise susceptibility of potatoes, peaches, avocadoes, etc. Prior to harvest, we will assess representative peppers for the appropriate drop height (can be varied from 12-48 inches). Assess damage after drop and again after 5 days at 45°F using a subjective score of 1 to 5 where 1=no visible bruise, 2=slight, 3=moderate, 4=moderately severe and 5=severe. This scoring will be referenced to photos to illustrate each score. In a demonstration test, a drop from 36 inches was sufficient to cause noticeable bruise damage on turgid peppers.
5. **Susceptiblity to cracking**. Turgid peppers can sometimes crack or split easily when boxes are handled roughly and/or dropped. Individual fruit will be dropped vertically through a PVC tube from a height of 24 inches onto a hard table surface; peppers will be scored for cracking at the blossom end. Score 1=none, 2=slight, 3=moderate, 4=moderately severe and 5=severe. This scoring will be referenced to photos to illustrate each score and to lengths of cracks.
6. **Pericarp wall thickness.** A ring segment cut at the midpoint of the pepper and wall thickness measured with a digital vernier caliper on a representative side (not the thinnest nor the thickest).
7. **Dry weight.** 40 g finely chopped fresh tissue accurately weighed to nearest 0.01g and dried in a plastic tray in the freeze dryer. Calculate % dry weight.

Results and Discussion: FIELD Experiment

Soil residual nitrogen: According to UC Vegetable Crops Specialist Tim Hartz, “In California vegetable rotations soil residual nitrate-nitrogen (NO3-N) can range from virtually none to enough to completely supply the next crop. In general NO3-N concentration less than 10 PPM suggests limited residual soil N, and normal fertilization practices are appropriate.” In 2009 there was only one field available to conduct a pepper experiment on the WSREC. Since the field had been cropped with unfertilized wheat to obtain field uniformity for the next research project, it was hoped that this field would be low enough in residual N to obtain a yield response in a subsequent pepper crop with increasing rates of N. The preplant soil test laboratory results revealed an average of 26 ppm nitrate nitrogen in the top six inches and 20 ppm in the top 6-12 inches of soil (**Table1**). These concentrations are adequate to support crop growth for at least several weeks and sometimes the entire season (Hartz, 2007).

Unfortunately the pepper trial had already been planted before we got the soil test results and the soil residual nitrogen did interfere with a pepper yield response to additional nitrogen fertilizer. As the crop was growing only the lowest fertilizer rate was discernible in the field and all other treatments appeared very similar.

A couple of other field problems arose. The field experiment was initiated a few weeks earlier than originally planned (the third week of March instead of mid April) and was ready to harvest sooner than anticipated. Harvest was postponed for two weeks for several reasons and the crop condition at harvest was sub-optimal for a postharvest study. It was exacerbated by a fair amount of Tomato Spotted Wilt Virus, a fruit disfiguring disease in peppers and a problem that has been worsening in the San Joaquin Valley since 2003, but one that had not previously been such a problem at the WSREC.

Pepper whole leaf tissue samples: Results clearly indicate that plots receiving higher amounts of fertilizer nitrogen had higher amounts of % total N in their leaves (**Table 2**). This trend was consistent at all three sample dates (June 5, June 24, and July 17). The June 5 and June 24 samples were collected 7 days after a nitrogen fertigation and the July 17 samples were collected 11 days after a fertigation. The second sample date had the highest concentration of nitrogen in the leaves.

Pepper biomass: The middle rate of applied N fertilizer (225 lbs) produced the most biomass in the whole plant, the fruit, and the leaf/stem tissues (**Table 2**). The highest rate of applied N fertilizer (375 lbs) had a damaging affect on total plant and fruit biomass. The lowest rate of applied N fertilizer (75 lbs) was not that low compared to the other treatments and is one indicator that residual soil nitrogen may have been a factor in supplementing the growth of the plant.

Pepper yield: Total yield for each applied nitrogen treatment was about 20 tons per acre and treatments were not significantly different from each other (**Table 3**). There were no differences in the production of different fruit sizes or in crop maturity (red and green fruit) as a result of N treatments. There were more cull fruit in the low N treatments as a result of more sunburned fruit. Plots with low nitrogen were visibly shorter in the field and the fruit was more exposed. There was a trend of increasing market yield with increasing amounts of applied nitrogen, but this was only significant at the 90% confidence level (LSD 0.10). If true, this result indicates that 375 lbs N/Acre might be too much N and have a negative impact on market yield.

Results: POSTHARVEST Evaluations are reported for fruit weight, color, firmness score, firmness measurement on the texture analyzer, pericarp wall thickness and % dry weight. No data is reported on the effect of nitrogen treatments on bruising and cracking susceptibility because the fruit from the experiment was too variable. The data was not consistently different among treatments, even when the drop height was increased to 36 inches in the cracking test.

Average **% dry weight** was 7.75% for mature-green fruit and 9.20% for red fruit (**Table 1**). For green fruit, there were no significant differences in % dry weight due to Nitrogen treatment. The

% dry weight of red peppers was significantly higher in fruits from the 225, 300 and 375 lb N treatment than the 75 and 150 N treatments.

Wall thickness of the red peppers averaged 5.84 mm and was significantly different from wall thickness of mature-green fruit which averaged 4.62 mm (Table 1). For a given color stage, there were no consistent differences in wall thickness due to N treatment.

Of the fruit selected for study, the **fruit weight** of mature-green fruits averaged 166 g per fruit compared with average fruit weight of peppers at the red stage of 189g. In green peppers, fruit from 75 and 150N had significantly lower weight than fruit from the other 3 treatments (**Table 2**). In the red fruit (**Table 3**), there were no consistent trends in fruit weight due to N treatment, although fruit from the 75 lb N treatment were smaller than fruit from 3 of the remaining 4 N treatments.

Objective color values indicated that green fruit from the 75N treatment were slightly less green than fruit from other treatments; these fruit were perceived as being slightly more yellow-green, but differences were not consistently noticeable although color value differences are significant (Table 2). As fruit ripen color changes from green to red and that is represented by color values around a value of 35-40 hue; the lower the value, the redder the fruit. Fruit from the 75 and 150 lb N treatments were slightly less red than fruit from the other nitrogen treatments. These differences, although significant, are not perceptible to the eye (Table 3).

Firmness scores and firmness measurements both indicate that the green fruit were much firmer than the fruit harvested red. There were no consistent trends in firmness scores among the nitrogen treatments for either green (Table 2) or red fruit (Table 3).

Similarly texture analyzer measurements showed no significant differences in firmness for green fruit from the 5 N treatments. In red fruit, the peppers from the 75 and 375 N treatments were less firm than fruits from the other treatments. **Figure 1** shows the relationship between the subjective firmness scores in this test in relation to the texture analyzer measurements. Fruit at a given firmness score may have a large range of objective firmness values.

Concluding remarks: Every attempt was made to design and conduct a fair experiment to determine nitrogen effects on pepper fruit quality, but the researchers were unable to achieve the necessary response to nitrogen in the field. In 2009 the field available for this study at the research station had residual soil nitrogen that interfered with the N-rate field experiment. However much was accomplished in 2009. The investment into the drip components, specifically the manifold with pressure regulators, meters, fertilizer pumps and mainline tubing was built and is still very useful. Familiarization with the trial protocol and development of drip and fertigation management expertise has increased. Anticipating another opportunity to reach the primary goals of the research, we have already started to prepare a field on the research station for the 2010 season by growing an additional crop of sudangrass following a wheat crop with no additional fertilizer. The residual soil N should be very low, which would make for a very good test site in 2010.

Field Experiment Table 1:

	Preplant Soil Analysis - ppm		
	NO3-N	Olsen-P	K
0-6"	25.7	30	370
6-12"	20.3	11.6	341

Field Experiment Table 2: The Effect of Nitrogen Rates on Pepper Leaf Tissue Samples and Plant Biomass

	% Total N Whole Leaf Samples						Biomass at Harvest (wet weights) Average of 5 plants (lbs)					
N lbs/A	**5-Jun**		**24-Jun**		**17-Jul**		**Total Plant**		**Fruit**		**Leaf/Stem**	
75	4.23	c	5.02	c	4.20	c	3.60	bc	2.63	bc	0.94	c
150	4.51	bc	5.55	b	4.68	b	3.92	abc	2.77	ab	1.12	bc
225	4.72	ab	5.63	b	5.21	a	4.50	a	3.15	a	1.34	a
300	4.94	a	5.85	ab	5.32	a	4.24	abc	2.88	ab	1.32	ab
375	4.94	a	6.01	a	5.60	a	3.45	c	2.25	c	1.15	abc
Pr>Treat	0.808		0.131		0.599		0.048		0.048		0.008	
Pr>Block	0.007		0.001		0.001		0.006		0.002		0.193	
CV%	5.3		4.2		5.2		12.2		14.2		11.6	
LSD (0.05)	**0.38**		**0.37**		**0.40**		**0.74**		**0.60**		**0.21**	

Field Experiment Table 3: The Effect of N-Rates on Pepper Yield, Fruit Size, Maturity, and Culls.

	Bell Pepper Yield Tons/Acre						Harvest date = July 23, 2009				
N lbs/A	**SMALL**	**MED**	**LARGE**	**X-LARGE**	**Culls**		**Total Yield**	**ALL Greens**	**All Reds**	**Mkt Yield***	
75	1.8	3.0	5.8	4.7	5.1	a	19.7	5.6	9.1	12.8	c
150	1.4	5.5	6.7	5.0	4.0	ab	21.6	7.9	9.7	16.2	ab
225	1.1	4.2	7.7	6.2	2.4	c	21.3	8.0	11.0	17.9	a
300	1.4	5.4	5.9	4.9	2.9	bc	20.5	7.8	9.8	16.2	ab
375	1.4	3.9	6.7	6.1	3.3	bc	18.9	5.9	9.7	14.2	bc
Pr>Treat	0.472	0.132	0.343	0.329	0.013		0.579	0.153	0.478	0.090	
Pr>Block	0.010	0.885	0.008	0.014	0.184		0.001	0.000	0.029	0.001	
CV%	35.4	32.5	20.3	23.6	26.6		12.6	24.1	14.7	15.7	
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**1.4**		**NS**	**NS**	**NS**		
LSD (0.10)*										**3.3**	

* Market Yield = Med, Large, X-Large Fruit

Postharvest Table 1. Pericarp thickenss and % dry weight of green and red peppers in relation to N fertilization. Pericarp data are averages of 8 fruit x 4 reps; dry weight data from composite sample from 8 fruit per rep.

Color stage	Nitrogen applied, lbs	% dry weight	Pericarp thickness, mm
GREEN	75	7.81	4.74
	150	7.88	4.45
	225	7.80	4.73
	300	7.71	4.52
	375	7.55	4.63
RED	75	8.89	6.00
	150	8.86	5.55
	225	9.47	5.96
	300	9.52	5.74
	375	9.25	5.96
	Ave Green	7.75	4.62
	Ave Red	9.20	5.84
	LSD.05	0.44	0.27

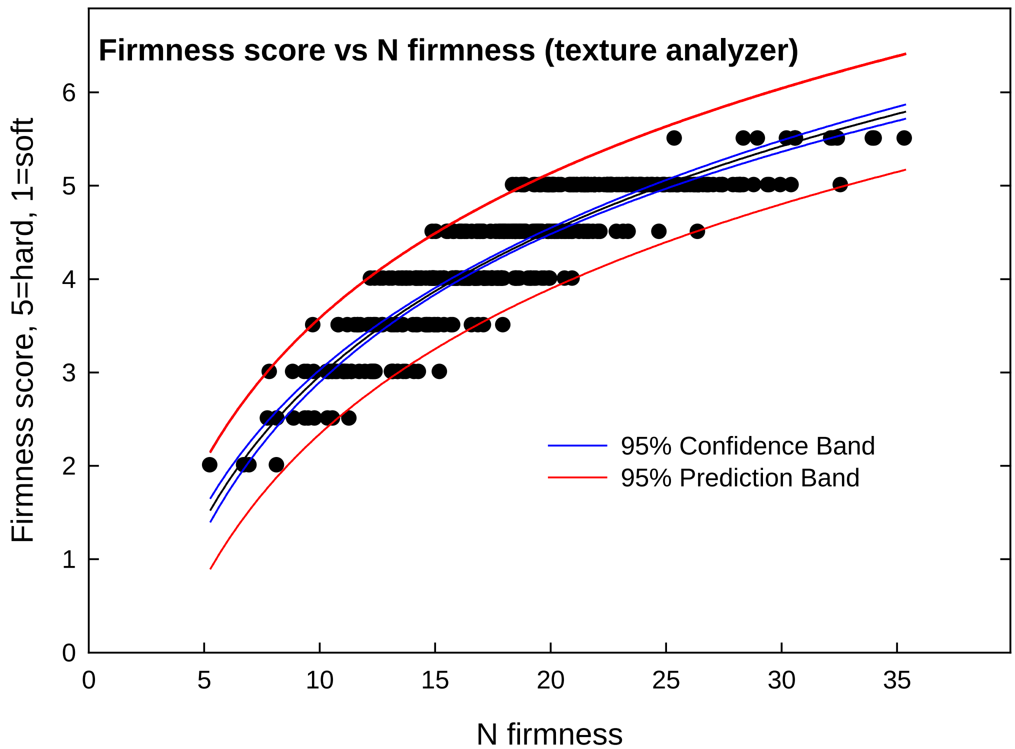
Postharvest Table 2. Fruit weight, firmness score, firmness measurement, and color of peppers harvested at the **Mature-Green** stage. Data are average of 10 fruit x 4 reps per treatment.

Nitrogen applied, lbs	Fruit wt. g	Firmness score 5=hard, 1=soft	Firmness measurement, N	Color, Hue value
75	144.4	4.7	21.1	119.9
150	146.2	4.9	22.6	122.7
225	161.0	4.4	21.0	121.1
300	204.1	4.7	22.5	121.3
375	174.4	4.6	21.2	122.4
Average	166.0	4.7	21.7	121.5
LSD.05	14.4	0.2	ns	1.5

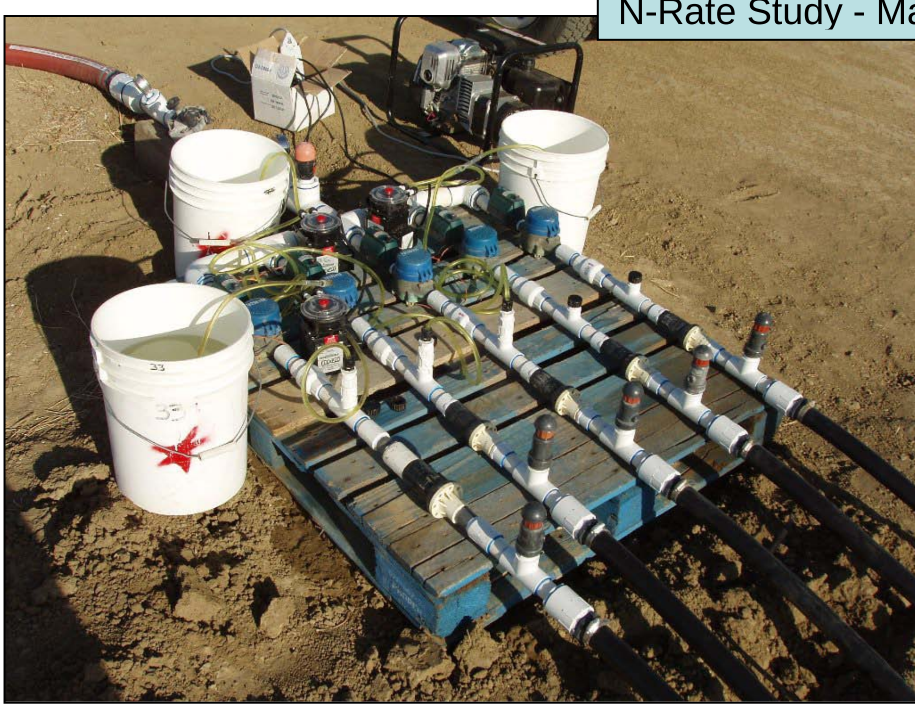
Postharvest Table 3. Fruit weight, firmness score, firmness measurement, and color of peppers harvested at the **Red** stage. Data are average of 10 fruit x 4 reps per treatment.

Nitrogen applied, lbs	Fruit wt. g	Firmness score 5=hard, 1=soft	Firmness measurement, N	Color, Hue value
75	177.2	3.4	13.4	36.9
150	198.6	4.1	17.1	37.0
225	194.1	3.8	16.0	35.1
300	163.4	4.2	16.4	35.7
375	209.8	3.7	14.4	34.3
Average	188.8	3.8	15.5	35.8
LSD.05	15.6	0.3	1.6	1.8

Postharvest Figure 1. Relationship between Firmness score and objective firmness measurements on texture analyzer. Data based on 400 fruit measurements.



N-Rate Study - Manifold & mini pumps



N-Rate Study - May 15, 2009

N-Rate Study - July 21, 2009