

California Pepper Commission – ANNUAL Report for 2010

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 Baron 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. Excessive soil residual nitrogen foiled the field conditions for the second consecutive year and we did not get a yield response to the nitrogen treatments. Postharvest evaluations of mature green fruit revealed that the lower N treatments resulted in fruit with less weight, the thinnest pericarp wall, and the highest % dry weight. Red peppers are notably less firm than mature-green peppers. There were significant differences in final red color of the peppers: peppers from the higher N treatments developed the reddest color (lower hue value). Also percent weight loss in peppers in storage was substantially lower in red peppers than in mature-green peppers. This is likely due to greater wax and cuticle development on the red peppers. Although some post harvest quality results were obtained, several key characteristics did not separate out 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 at harvest include fruit weight, color, firmness, bruise susceptibility, cracking, pericarp wall thickness, internal color, and dry weight.

Methods and Procedures for 2010

FIELD Trial: 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. 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 7 applications that were made on: June 18, July 2, July 16, July 23, July 30, Aug 6 and Aug 20.

Bell peppers (cultivar Baron) were transplanted on May 18 with a commercial transplanter set at a 10" within row spacing into 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 July 16, August 5, and August 26 and sent to the DANR Laboratory for % Total N analysis. The peppers were hand harvested on August 10 and August 31 and sorted by size, color and defects. On the last 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 Evaluations: Fruit were harvested twice as mature-green fruits (August 10 and September 1) and once as ripening fruit (September 1). The mature-green harvested on Aug 10 corresponded to an early harvest and there were no red fruit on the plants. On September 1 there was about an equal number of mature-green and ripening fruit on the plants. A minimum of 30 fruit per field replicate were harvested, placed in plastic bags that were overlapped and placed in plastic crates and transported in an air-conditioned van to the laboratory at UC Davis. Fruit were held at 45°F, covered with plastic sheets to prevent weight loss, while completing evaluations (completed within 2 days of harvest). Fruit with defects were eliminated and 12 fruit per field rep were used for quality evaluations (weight, firmness, % weight loss, color, pericarp or wall thickness and % dry weight) and another set of 12 fruit per rep were used to determine bruise and crack susceptibility.

Postharvest Evaluations (performed in order listed):

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
4. **Bruise Susceptibility.** A 2cm stainless steel (67g) was dropped through a PVC tube from 1, 2 or 3 feet. Fruit were scored 1 if there was sufficient damage to break through the skin and 0 if skin was not broken. A bruise index was calculated by summation of multiplying the result of the 3 different drops by the height dropped; a minimum score of 0 or maximum score of 6 could be obtained. Measurement was made at room temperature, but peppers were at 45F.
5. **Susceptibility to cracking.** Turgid peppers can sometimes crack or split easily when boxes are handled roughly and/or dropped. Measurement was made at room temperature, but peppers were at 45F. Individual fruit were dropped through tubes (galvanized stove pipes) onto the blossom end from heights of 1, 2 or 3 feet. Peppers that had visible cracking (either at blossom end, side or stem-end) were scored 1 and peppers with no visible cracking were scored 0. A cracking index was calculated as the sum of multiplying the result of the 3 different drops by the height dropped; a minimum score of 0 or maximum score of 6 could be obtained.
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.** 150 g cut rings were accurately weighed to nearest 0.01g and dried in a plastic tray in the freeze dryer. Calculate % dry weight.

Results and Discussion: FIELD Trial

Soil residual nitrogen: Unfortunately for two consecutive years soil residual nitrogen was too high and we did not get good separation of means for all of our field measurements. Even though we tried to deplete residual nitrogen by growing a crop of wheat followed by sudan grass there was still 25 ppm nitrate nitrogen in the top 6 inches of soil (Table 1), which is enough to support a crop for several weeks. The station field manager was in disbelief, but 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 the field you could easily pick out the low and high nitrogen plots but the middle treatments were not discernible. Low N treatments were less green and much shorter than the lush green foliage of the taller plants in the high nitrogen treatments. **No differences were observed in pepper whole leaf tissue samples, pepper biomass, or in pepper yields as a result of the nitrogen applications.**

Field Trial Table 1:

| | Preplant Soil Analysis - ppm | | | |
|-------|------------------------------|-------|---------|-----|
| | 2010 | NO3-N | Olsen-P | K |
| 0-6" | | 25.2 | 14.8 | 391 |
| 6-12" | | 15.1 | 10.5 | 320 |

Field Trial Table 2: The Effect of N-Rates on Pepper Leaf Tissue Samples and Plant Biomass

| N lbs/A | % Total N Whole Leaf Samples (2010) | | | Biomass at Harvest (wet weights) Average of 5 plants (lbs) | | |
|------------|--|-----------|-----------|---|-----------|-----------|
| | July 16 | Aug 5 | Aug 26 | Total Plant | Fruit | Leaf/Stem |
| 75 | 6.2 | 6.0 | 5.4 | 18.3 | 10.6 | 7.0 |
| 150 | 6.4 | 6.0 | 5.7 | 18.5 | 10.4 | 7.8 |
| 225 | 6.0 | 6.2 | 5.9 | 17.9 | 10.0 | 7.6 |
| 300 | 6.4 | 6.4 | 5.7 | 17.2 | 9.3 | 7.6 |
| 375 | 6.3 | 6.1 | 5.8 | 20.0 | 11.8 | 7.8 |
| Pr>Treat | 0.55 | 0.88 | 0.98 | 0.74 | 0.47 | 0.91 |
| Pr>Block | 0.75 | 0.88 | 0.96 | 0.78 | 0.69 | 0.63 |
| CV% | 6.9 | 9.2 | 14.1 | 15.5 | 17.8 | 16.7 |
| LSD (0.05) | NS | NS | NS | NS | NS | NS |

Field Trial Table 3: Effect of N-Rates on Pepper Yield, Fruit Size, Maturity, Culls**BOTH PICKS**

| N lbs/A | Bell Pepper Yield Tons/Acre | | | | | Harvest date = August 10 & 31, 2010 | | | |
|------------|-----------------------------|-----------|-----------|-----------|-----------|-------------------------------------|------------|-----------|------------|
| | SMALL | MED | LARGE | X-L | Culls | Total Yield | ALL Greens | All Reds | Mkt Yield* |
| 75 | 1.6 | 4.6 | 9.2 | 1.5 | 4.4 | 26.2 | 16.9 | 4.9 | 21.8 |
| 150 | 1.0 | 2.9 | 10.5 | 2.7 | 3.4 | 25.9 | 17.2 | 5.3 | 22.5 |
| 225 | 1.3 | 4.1 | 10.0 | 2.1 | 3.4 | 26.4 | 17.5 | 5.6 | 23.1 |
| 300 | 1.8 | 4.1 | 8.6 | 3.0 | 4.0 | 27.3 | 17.5 | 5.9 | 23.4 |
| 375 | 1.7 | 4.9 | 9.6 | 2.1 | 3.0 | 27.0 | 18.2 | 5.3 | 23.6 |
| Pr>Treat | 0.62 | 0.18 | 0.79 | 0.84 | 0.50 | 0.22 | 0.99 | 0.77 | 0.95 |
| Pr>Block | 0.71 | 0.83 | 0.21 | 0.45 | 0.45 | 0.99 | 0.21 | 0.04 | 0.08 |
| CV% | 52.1 | 26.1 | 23.3 | 84.9 | 32.2 | 16.0 | 20.0 | 21.4 | 16.5 |
| LSD (0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS |

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

Results and Discussion: POSTHARVEST Evaluations
HARVEST 1 MATURE GREEN FRUIT

For Harvest 1, the nitrogen applied by the time of the harvest was 61, 111, 162, 210 and 261 lb N/acre for the 75, 150, 225, 300 and 375 lb N/acre treatments, respectively. There were small but significant differences in pepper fruit weight at harvest (**Table 1**). The lower N treatments resulted in fruit with less weight. Average % dry weight was 6.81% (Table 1). The highest % dry weight was obtained in peppers from the lowest N treatment, and there were no significant differences in % dry weight among the other 4 N treatments. Pericarp or wall thickness averaged 4.94 mm and was slightly greater in fruit from the highest N treatment. Pepper firmness scores and objective determination of pepper firmness showed there were no differences among the treatments. Similarly hue (green) color values did not differ among N treatments.

Weight loss in peppers stored at 7.5°C (45°F) on open trays averaged 1.07% over a 5 day period and did not differ in peppers from different N treatments (**Table 2**). The bruise and crack susceptibility indices indicated that there were no or only minor differences in peppers among the 5 N treatments.

Postharvest Table 1. Fruit weight, pericarp thickness, % dry weight, firmness and color of Harvest 1 mature-green peppers in relation to N fertilization. Data are average of 12 fruit x 4 field reps per treatment.

| N treatment lbs/A | N applied by this harvest lbs/A | Fruit wt. grams | Dry weight % | Pericarp thickness mm | Firmness score 5=hard, 1=soft | Firmness measurement Newtons | Color Hue value |
|-------------------|---------------------------------|-----------------|--------------|-----------------------|-------------------------------|------------------------------|-----------------|
| 75 | 61 | 149.0 b | 7.15 a | 4.82 b | 4.85 | 27.6 | 120.6 |
| 150 | 111 | 149.2 b | 6.68 b | 4.84 b | 4.79 | 28.2 | 120.5 |
| 225 | 162 | 154.9 ab | 6.71 b | 5.01 ab | 4.94 | 29.5 | 120.4 |
| 300 | 210 | 161.8 a | 6.66 b | 4.87 b | 4.86 | 29.9 | 120.6 |
| 375 | 261 | 161.5 a | 6.86 b | 5.14 a | 4.88 | 30.4 | 120.3 |
| Average | | 155.3 | 6.81 | 4.94 | 4.87 | 29.1 | 120.5 |
| LSD.05 | | 9.9 | 0.25 | 0.24 | ns | ns | ns |

Dry weight data are from duplicates from a composite sample from 12 fruit per rep.

Values within a column followed by different letters are significantly different at $P \leq 0.05$ by Tukey method.

Postharvest Table 2. Percent weight loss, bruise index and crack susceptibility index of peppers Harvest 1 mature-green stage. Data are average of 12 fruit x 4 field reps per treatment.

| N treatment, lbs/A | N applied by this harvest, lbs/A | % weight loss (5 days at 7.5°C) | Bruise Index | Crack Susceptibility Index* |
|--------------------|----------------------------------|---------------------------------|--------------|-----------------------------|
| 75 | 61 | 1.08 | 2.79 | 4.46 ab |
| 150 | 111 | 1.08 | 2.79 | 4.58 a |
| 225 | 162 | 1.06 | 2.65 | 4.45 ab |
| 300 | 210 | 1.08 | 2.56 | 4.14 b |
| 375 | 261 | 1.04 | 2.77 | 4.31 ab |
| Average | | 1.07 | 2.71 | 4.39 |
| LSD.05 | | ns | ns | 0.37 |

*Values followed by different letters are significantly different at $P \leq 0.05$ by Tukey method.

HARVEST 2 MATURE GREEN FRUIT

By Harvest 2, the peppers had received the full complement of nitrogen corresponding to each treatment (75, 150, 225, 300 or 375 lb N/acre). There were no significant differences in pepper fruit weight at harvest (**Table 3**). Average % dry weight was 7.66%, higher than the average from Harvest 1. Although there were small significant differences, these differences were not consistent with N treatment. Pericarp wall thickness averaged 4.62 mm, which was lower than the average from Harvest 1. The lowest N treatment resulted in the thinnest pericarp wall. Pepper firmness measurements (subjective and objective) and objective color measurements did not indicate any significant differences among the N treatments.

The % weight loss in peppers stored at 7.5°C (45°F) on open trays averaged 0.82% over a 5 day period (**Table 4**). This was substantially lower than that of peppers from Harvest 1. Although differences were small, % weight loss was less in the peppers from higher N treatments. The bruise and crack susceptibility indices indicated that there were no significant differences due to nitrogen treatment.

Postharvest Table 3. Fruit weight, pericarp thickness, % dry weight, firmness and color of Harvest 2 mature-green peppers in relation to N fertilization. Data are average of 12 fruit x 4 field reps per treatment.

| N treatment lbs/A | Fruit weight grams | Dry weight % | Pericarp thickness mm | Firmness score 5=hard 1=soft | Firmness measurement Newtons | Color Hue value |
|----------------------|-----------------------|-----------------|-----------------------------|------------------------------------|------------------------------------|--------------------|
| 75 | 139.2 | 7.81 a | 4.47 b | 4.7 | 28.96 | 118.9 |
| 150 | 144.9 | 7.54 b | 4.71 a | 4.7 | 31.55 | 119.8 |
| 225 | 141.2 | 7.64 ab | 4.58 ab | 4.6 | 28.04 | 120.2 |
| 300 | 150.2 | 7.49 b | 4.78 a | 4.7 | 31.45 | 119.7 |
| 375 | 138.5 | 7.84 a | 4.59 ab | 4.6 | 27.99 | 120.0 |
| | | | | | | |
| Average | 142.8 | 7.66 | 4.62 | 4.7 | 29.6 | 119.7 |
| LSD.05 | ns | 0.27 | 0.22 | ns | ns | ns |

Dry weight data are from duplicates from a composite sample from 12 fruit per rep.

Values within a column followed by different letters are significantly different at $P \leq 0.05$ by Tukey method.

Postharvest Table 4. Percent weight loss, bruise index and crack susceptibility index of peppers Harvest 2 mature-green stage. Data are average of 12 fruit x 4 field reps per treatment.

| N treatment, lbs/A | % weight loss (5 days at 7.5°C) | Bruise Index | Crack Susceptibility Index |
|-----------------------|------------------------------------|--------------|-------------------------------|
| 75 | 0.87 a | 2.7 | 4.5 |
| 150 | 0.82 ab | 3.2 | 4.5 |
| 225 | 0.86 a | 3.1 | 4.4 |
| 300 | 0.75 b | 2.8 | 4.3 |
| 375 | 0.77 b | 2.6 | 4.5 |
| | | | |
| Average | 0.82 | 2.9 | 4.4 |
| LSD.05 | 0.08 | ns | ns |

Values within a column followed by different letters are significantly different at $P \leq 0.05$ by Tukey method.

HARVEST 2 RED FRUIT

On the second harvest date (Sept 1), fruit that were ripening (mostly red) were also harvested from the 5 nitrogen treatments (75, 150, 225, 300 or 375 lb N/acre). There were minor differences in pepper fruit weight at harvest (**Table 5**). Average fruit weight was similar to average fruit weight of the mature-green fruit in Harvest 1 (Table 1). Average % dry weight was 9.53%, but did not differ consistently with N treatment. Pericarp wall thickness averaged 4.66 mm, with thinnest walls obtained with lowest N fertilization. There were no differences in subjective firmness evaluations and only minor differences in pepper firmness measured objectively (Table 5). The red peppers are notably less firm than the mature-green peppers (Table 2, Table 4). There were significant differences in final red color of the peppers with the peppers from higher N treatments developing the most red color (lower hue value).

The % weight loss in peppers stored at 7.5°C (45°F) on open trays averaged 0.52% over a 5 day period (**Table 5**). This was substantially lower than the % weight loss of mature-green peppers and is likely due to greater wax and cuticle development on the red peppers. The lowest % weight loss occurred in the peppers from the lowest N treatment and similarly the highest rate of weight loss occurred with the peppers from the highest N treatment (Table 5). No measurements of bruise and crack susceptibility were made with red peppers.

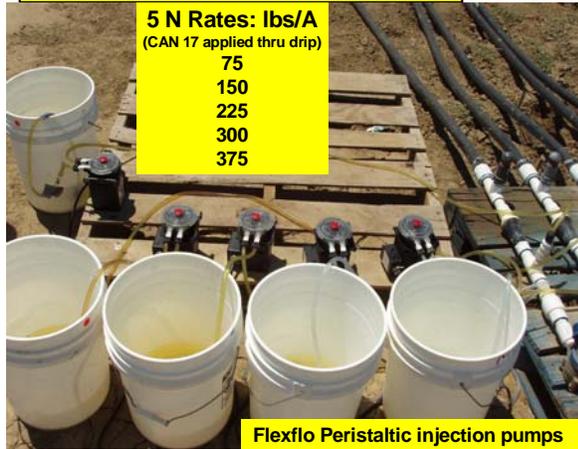
Postharvest Table 5. Quality characteristics of peppers harvested at the Red stage. Data are average of 12 fruit x 4 reps per treatment.

| Nitrogen applied, lbs/A | Fruit weight grams | Dry weight % | Pericarp thickness mm | Weight loss (5D 7.5°C) % | Firmness score 5=hard, 1=soft | Firmness measurement Newtons | Color Hue value |
|-------------------------|--------------------|--------------|-----------------------|--------------------------|-------------------------------|------------------------------|-----------------|
| 75 | 142.3 b | 9.57 ab | 4.52 b | 0.39 c | 3.6 | 19.2 b | 39.6 a |
| 150 | 155.2 ab | 9.32 b | 4.66 ab | 0.49 b | 3.9 | 22.2 a | 38.1 ab |
| 225 | 156.0 a | 9.50 ab | 4.69 ab | 0.51 b | 3.7 | 20.0 ab | 36.7 bc |
| 300 | 160.8 a | 9.42 b | 4.81 a | 0.52 b | 3.7 | 20.7 ab | 35.3 c |
| 375 | 151.2 ab | 9.83 a | 4.61 ab | 0.67 a | 3.7 | 19.3 b | 34.8 c |
| Average | 153.1 | 9.53 | 4.66 | 0.52 | 3.7 | 20.3 | 36.9 |
| LSD.05 | 13.3 | 0.34 | 0.22 | 0.04 | ns | 2.4 | 2.7 |

Values within a column followed by different letters are significantly different at $P \leq 0.05$ by Tukey method.

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. We took extra steps to try to locate a Nitrogen depleted field on the research station. We followed a crop of wheat with a crop of sudan grass. Even though that crop showed signs of fertility stress apparently not enough nitrogen depletion was achieved. For 2011 we have grown the sudan grass for a longer time period before harvesting it and we are growing another crop before we transplant the peppers in the spring. Still work was accomplished in 2010. 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. We request one more chance to reach the primary goals of the research. In 2011 we also plan to include a no nitrogen treatment (0 applied nitrogen).*

N-Rate Study - 2010



MEASUREMENTS



MEASUREMENTS



Postharvest Evaluations

Firmness measurements

Firmness using texture analyzer (control speed of compression)
For peppers use 25mm flat disc as shown in photo and compress peppers 5mm



Postharvest Evaluations

Cracking Susceptibility



Dried ground sample can be used for sugars or other components