IRRIGATION MANAGEMENT IN WALNUT USING EVAPOTRANSPIRATION, SOIL AND PLANT BASED DATA.

Bruce Lampinen, Rick Buchner, Allan Fulton, Joe Grant, Nick Mills, Terry Prichard, Larry Schwankl, Ken Shackel, Cyndi Gilles, Cayle Little, Sam Metcalf and Dan Rivers

ABSTRACT

The first year results suggest that the range of target water potentials that were selected for the treatments was reasonable. The mild and moderate deficit irrigation treatments reduced shoot growth significantly, more so on Northern California Black than on Paradox rootstock. At the Tehama County site there was no significant effect of the irrigation treatments on nut size, while at San Joaquin County site there was a small but significant decrease in nut size for both deficit irrigation treatments. The difference in shoot versus nut growth in the mild and moderate stress treatments compared to the more intensively irrigated control suggests that there may be level of mild water deficit that can have a beneficial impact on minimizing shoot growth without impacting nut growth in walnut while utilizing water efficiently. The fact that neither deficit treatment had a significant impact on dry yield was expected since this is the first season that stress was imposed in these orchards. Past research in walnut and other tree crops has indicated that nut size would likely be the only yield component impacted during the first season of deficit irrigation. These preliminary results support the contention that there may be a place for deficit irrigation management in walnut. However, the carryover effects of these treatments will determine the utility of these practices for walnut irrigation management.

INTRODUCTION

Irrigation management has been implicated as a major factor in numerous walnut problems including Phytophthora root rot (Miricetich et al., 1998), walnut decline (Blanchard, 1939; Schreader, 1972) and deep bark canker (Brown, 1976; Teviotdale et. al., 1977).

Recent irrigation related problems encountered have included too much water causing Phytophthora related orchard damage, dieback (not linked to any diseases) caused by improper irrigation (usually excessive water early in the season), and later season water deficits combined with hot, dry weather causing extensive blackening of hulls and nuts in Chandler walnuts. Many farm advisors spend a large proportion of their farm call time going out to look at problems that turn out to be irrigation related.

A common perception among growers is that walnut trees need to be kept very wet to get good production. However, as described above, irrigating in excess of plant needs can lead to a number of problems. Also, because nut sizing is largely completed by June, moderate stress later in the season may not impact crop load significantly if it is not severe enough to impede nut filling. Measurements done on a variety of walnut orchards in the Sacramento and San Joaquin Valleys in 2001 suggest that substantial stress occurs in many productive walnut orchards as the summer proceeds. In most cases, the growers were unaware that the trees were under stress since visible symptoms were not obvious. In other cases, the midday leaf water potential data
suggested that the orchards might well have been over-irrigated based on the fact that the values stayed on or above the baseline all season.

The pressure chamber can be an effective tool for irrigation management. By regular measurement of midday stem water potential and withholding irrigation until a reasonable falloff from the baseline occurs, over-irrigation and resulting root damage can be avoided. Likewise, avoiding an excessive falloff from the baseline can avoid undesirable stress from deficit irrigation associated with shallow and deep bark canker and other orchard health problems. By combining the pressure chamber with use of crop evapotranspiration information or monitoring of deep moisture with Watermark sensors and/or tensiometers, a soil water balance can be maintained that allows sufficient drying between irrigation cycles to prevent over-irrigation that can lead to *Phytophthora* and dieback, while preventing deficit irrigation of a level sufficient to impact shoot growth and nut load, nut sizing or other quality characteristics.

The advantage of the pressure chamber compared to soil moisture monitoring or applying evapotranspiration estimates alone is that the pressure chamber provides a measure of crop stress that integrates root health and volume, soil-water availability, non-uniform irrigation and weather conditions. With soil moisture monitoring a very limited volume of soil around the sensor is used to indicate soil-water status in the root zone, and there is no way of knowing with certainty that the sensors have been accurately placed to represent the soil-water status of the root zone. Furthermore, if loss of root function has occurred, Goldhamer et.al. (1987) showed that the measurement of soil moisture status may not indicate a problem even though the trees are under stress. In these situations, the use of a pressure chamber is essential for irrigation management.

Despite all the irrigation related problems that occur regularly in walnut, there have been relatively few resources devoted to understanding the fundamentals of walnut water relations as they relate to tree longevity, disease and productivity. Good water management is essential for growers. Orchards that are adequately irrigated without over irrigating will provide the best returns overall. Orchards that are over irrigated are prone to many problems include *Phytophthora* root rot, decline etc. Orchards that go into a state of decline lead to increased costs since they need to be removed and replanted, but as the trees mature following replanting, they often go through the same cycle of decline once again if management practices have not been altered. An additional benefit of better water management might be a balance between enough shoot growth to sustain crop bearing wood and resulting nut load and less vegetative growth. In a mature orchard where the trees have filled in their allotted space, this could provide an effective management strategy. Finally, there is some preliminary evidence that moderately stressed walnut trees can potentially show a reduction in codling moth susceptibility (Mills et. al. 2001) and mold problems (Prichard et.al, 2001).

**OBJECTIVES**

1) Develop water management strategies for walnut using a combination of evapotranspiration, soil and plant based measurements.

2) Develop basic data on the relationship between midday stem water potential and walnut productivity.
The data that comes out of this project should give growers the tools to effectively manage water to maximize productivity while minimizing excessive vegetative growth and potential environmental problems.

PLANS AND PROCEDURES

Experimental design
All experimental design and procedures are duplicated at two sites, one in San Joaquin County and one in Tehama County.

San Joaquin County Site- The San Joaquin County site is a ‘Chandler’ orchard planted on Paradox rootstock at a 32’ by 32’ equilateral triangle arrangement (49 trees/acre). The soil is a Cogna loam which is a deep well drained alluvial derived soil. The orchard is irrigated with one Nelson R10 sprinkler per tree. Variation in irrigation treatments was achieved using different size nozzles with the high, medium and low irrigation treatments applying 0.066, 0.056, 0.047 inches per hour. There are four replications of each irrigation treatment with 3 rows per replication. A replication consists of 18 trees receiving the same irrigation treatment.

Tehama County Site- The orchard was planted in 1994 on a 30’ by 18’ spacing (81 trees/acre). The soil is a Maywood sandy loam series, consisting of stratified soils. Sandy loam textures are predominant from about 0 to 30 inches, gravelly sandy loam soils are common from about 30-54 inches, and loams and clay loams are found below 54 inches. The variety is ‘Chandler’ alternating on Northern California Black and Paradox rootstocks. Replants have been on Paradox rootstock. The orchard is irrigated with one Nelson R-5 micro-sprinkler per tree. Variation in irrigation treatments was achieved using different size nozzles with the high, medium and low irrigation treatments applying 0.055, 0.046, 0.038 inches per hour. The water application in the mild and moderate stress treatments represents a 16 and 30 percent reduction in the hourly water application rate, respectively. The surrounding orchard outside of the experimental plots was irrigated at the same frequency as the low stress experimental treatment. Typically during the summer, the low stress irrigation treatment was irrigated every third day for 18 hours. Manual shut-off valves were placed on each irrigation line in order to allow turning the water on and off to these plots as needed to achieve target stress levels. There are four replications of each of the three irrigation treatments with 3 rows per replication and 12-13 trees per row as well as guard rows between plots. Flow meters were installed in-line for each row of trees where crop response data were taken to provide an accurate record of applied water.

Midday stem water potential monitoring
The goal of this project is to maintain target water potentials for the three different irrigation regimes at each site throughout the season (Fig. 1).

San Joaquin County Site- The middle four trees in each plot were used for detailed water potential, nut and shoot growth measurements. Midday stem water potential was measured approximately every 7-10 days (generally near the end of an irrigation cycle) on 4 trees per plot (a total of 12 trees per treatment). Leaves in low, shaded positions near the base of the tree were bagged at least 15 minutes before sampling and placed immediately in the pressure chamber (still enclosed in the bag). Any needed adjustments to the sprinkler head sizing or turning on/off
Irrigation treatments will be done promptly to assure meeting treatment target midday stem water potentials.

Tehama County Site- Due to the high frequency and low volume irrigation, midday stem water potential was measured approximately every 3-4 days on 6 trees per plot (total of 24 trees per treatment) using methods similar to those described above for the San Joaquin County site. Midday stem water potential was measured just prior to irrigation to the extent possible. Although rootstocks originally alternated between Northern California Black and Paradox rootstocks, replanting was done with Paradox. This study ended up with a total of 14 Paradox and 10 Northern California Black rooted trees being monitored for midday stem water potential in each treatment.

Soil moisture monitoring
Soil moisture was monitored with neutron probes as well as Watermark soil resistance blocks. At the San Joaquin location, a neutron probe was placed in one replication in each treatment. In addition, Watermark sensors attached to small dataloggers were placed at 18” and 36” in one replication in each treatment. At the Tehama County site, a neutron probe access tube was placed in each replication of all treatments to a minimum depth of five feet. Watermark sensors, attached to small dataloggers, were placed at 8”, 18” and 30” in one replication for each treatment. Watermark sensors were set to continuously log at 15-30 minute intervals. Neutron probe measurements were taken every 3 or 4 days beginning in mid-May through mid September on the same days that midday stem water potential measurements were taken.

Canopy light interception measurements
Canopy light interception was measured approximately every three weeks using a Decagon Ceptometer (80 cm bar with light sensors mounted on it). Measurements were taken within 1 hour of the time the sun is directly overhead by making 100 measurements in a grid pattern covering a consistent area in each replication. Small differences in light penetration can be difficult to detect with this method. Therefore, an additional 30 measurements were taken directly underneath the tree canopy in each replication to look for potential differences in canopy light penetration within the tree canopy.

Shoot and nut growth measurements
San Joaquin County site- Nut diameter was measured approximately every three weeks with a digital micrometer on 10 nuts per tree on the same 12 trees per treatment on which stem water potential was measured. Shoot growth was measured on 3 shoots per tree for a total of 36 shoots per treatment on the same trees as nuts were measured. Because little growth was occurring, selected shoots were hand pruned and shoot growth was measured on the re-growth on these shoots.

Tehama County site- Nut growth measurements were made every 7-10 days on 10 nuts per tree on the same 24 trees per treatment on which stem water potential was measured. Shoot growth was measured on approximately 2 unpruned and 2 pruned shoots on each of the same trees.
Codling moth susceptibility sampling
Nuts were sampled from around the canopy on the monitored trees at the San Joaquin County site on one occasion. The nut samples were then used for codling moth susceptibility assays in the lab. Samples were not collected from the Tehama County site since an insecticide spray had been applied several days before the planned sampling date.

Harvest
Yields were monitored by harvesting the individual monitored trees at both sites. After each individual tree was shaken, the nuts were swept into windrows and harvested with a small manually pulled cup-type harvester at the Tehama County site and the growers’ harvester at the San Joaquin County site. Sub-samples were taken for drying, size and quality analysis.

Mold
Samples taken from each water potential monitored tree will be used for analysis of the relationship between water status and mold. These data will be described in Terry Prichard’s mold project report.

RESULTS

Applied water- Cumulative applied water for the control, mild and moderate stress irrigation treatments at the Tehama County site averaged 43.8, 31.2 and 25.8 inches, respectively. Cumulative real time crop evapotranspiration for walnut at the site was estimated to be 41.7 inches. This represents total applied water exceeding total crop evapotranspiration by 5 percent in the control treatment and a deficit of 25 and 38 percent for the mild and moderate stress treatments, respectively.

Midday stem water potential- There was some difficulty in maintaining the target midday stem water potentials (MSWP) at both sites in 2002. In interpreting these data, it is important to realize that the MSWP measurements at the San Joaquin Valley site were generally done near the end of the 14 day irrigation cycle so they represent the most stressed conditions that the trees experienced. The treatment average MSWP would have been somewhat less negative. The MSWP for the treatments tended to bounce above and below the target levels during May-June, then tended to be below target values during July until the middle of August followed by a recovery above target levels from mid-August through mid-September (Fig. 2). At the Tehama County site, there was also considerable variation of the MSWP around the target values but the fluctuations tended to be over a shorter time period (Fig. 3). This may have been due the frequent low volume irrigation combined with limited root development below three feet in the stratified soils.

Soil moisture monitoring- San Joaquin County site- Soil moisture data had not been processed at the time of report writing at the San Joaquin County trial but will be reported in next years report.

Tehama County site- Average soil-water depletion determined by neutron probe measurement are illustrated for the Tehama County Experiment in Figure 4. Soil water depletion in the top five feet of soil did not exceed 40 percent at any point in the season in the low stress treatment. Soil
water depletion slowly cumulated from mid May through October, being highest, near 40 percent, at the end of the season in October. In the mild stress irrigation regime, soil water depletion was maintained below 40 percent through mid June and approached 50 percent depletion by mid July and exceeded 50 percent depletion routinely in July, August, and September. The highest level of soil-water depletion averaged 60 percent in mid August in the mild stress irrigation treatment. The moderate stress irrigation treatment exceeded 40 percent depletion by late May and exceeded 50 percent depletion in mid June. Soil water depletion remained between 50 and 60 percent depletion from mid June until the end of the season.

**Canopy light interception**- San Joaquin site- Canopy light interception for the mild stress treatment was significantly higher than that for the control treatment for much of the season (Fig. 5a). This difference was most likely due to orchard variability since it began early in the springtime before treatments were imposed. There were no significant treatment differences between the control and moderate stress treatments at any time during the season. Light interception measured at the San Joaquin site beneath the tree canopy was generally at the mid ninety percent level and there were no significant treatment effects at any time during the season (Fig. 5b). This suggests that leaf yellowing and drop that occurred in both deficit treatments late in the season was not severe enough to impact overall canopy light interception (Fig. 5a) or light interception beneath the tree canopy itself (Fig. 5b).

Tehama County site- There were no significant treatment differences in overall canopy light interception at any time during the season at the Tehama County site (Fig. 6a). Overall canopy light interception was generally about 10% lower at the Tehama (Fig. 6a) compared to the San Joaquin site (Fig. 5a). There were no significant treatment differences in light interception beneath the tree canopy at the Tehama County site in 2002 (Fig. 6b). There was some leaf yellowing and drop in the deficit treatments at this site in 2002, but again, these data suggest that the drop was not enough to significantly influence canopy light interception as measured by the two methods we used.

**Shoot growth**- San Joaquin County site- The shoot growth rate was significantly lower in the moderate stress treatment compared to the control from May into early July (Fig. 7). For the mild stress treatment the shoot growth rate was only significantly lower than the control on the May and mid-June sampling dates (Fig. 7). These differences in shoot growth rates resulted in significantly shorter shoots that were 66 and 55% of the control length for the mild and moderate stress treatments respectively (Fig. 7).

Tehama County site- There was a significant effect of treatment on shoot growth on both pruned (Fig. 8a) and unpruned (Fig. 8b) shoots on Northern California Black rootstock. However, the effect on pruned shoots was much greater. Final shoot length for the mild and moderate stress treatments was approximately 72% and 44% for the mild and moderate stress treatments on a pruned shoot versus 87% and 76% for the same treatments on unpruned shoots. This suggests that pruning may be used in conjunction with deficit irrigation to limit tree size in walnut. The result for shoot growth on Paradox rootstock were similar to those on Northern California Black rootstock except there was not a difference between the control and mild stress treatments for the pruned shoots (Fig. 8c, d). These differences in response may have been due to crop load differences which will be discussed later.
**Nut growth**- San Joaquin site- Significant differences in nut diameter were found between treatments when readings of nut diameter began in early June (Fig 9). The differences became larger as the season progressed. The control treatment averaged the largest diameter by late September while the mild and moderate stress treatments resulted in decreases in average nut diameter of 2 and 5% respectively.

Tehama County site- Although there was a slight tendency towards smaller nuts with the deficit treatments, the differences were not significant at any point during the season on either the Northern California Black (Fig. 10a) or the Paradox (Fig. 10b) rootstocks.

**Harvest**- San Joaquin County site- There were no significant treatment impacts on overall yield for either fresh weight as measured at harvest or for weights after being adjusted to a constant dry weight (Table 1). There were significantly fewer large nuts in the moderate stress treatment compared to the control (Table 4). There were no significant treatment impacts on mold, insect damage, shrivel, or adhering hulls at the San Joaquin site (Table 4). There was a significantly lower RLI in the moderate stress treatment compared to the control (Table 4).

Tehama County site- The crop was good at the Tehama County site with the fresh weights significantly higher for the control versus the moderate stress treatment (Table 1). However, when the crop was dried to constant moisture content, there were no significant treatment effects on yield (Table 1). There were significantly fewer large nuts in the moderate deficit treatment compared to the control (Table 5). There was also significantly more mold and shrivel in both of the deficit treatments compared to the control although the levels for both were only about 1-2 percent higher than for the control (Table 5). There were significantly more adhering hulls in the control treatment compared to the moderate stress treatment. There were no significant effects on nut color as measured by RLI (Table 5).

**DISCUSSION**

The first year results suggest that the range of target water potentials that were selected for the treatments was reasonable. The difference in shoot versus nut growth in the mild and moderate stress treatments compared to the more intensively irrigated control suggests that there may be level of mild water deficit that can have a beneficial impact on minimizing shoot growth without impacting nut growth in walnut while utilizing water efficiently. The fact that neither deficit treatment had a significant impact on dry yield was expected since this is the first season that stress was imposed in these orchards. Past research in walnut and other tree crops has indicated that nut size would likely be the only yield component impacted during the first season of deficit irrigation. The mild and moderate deficit irrigation treatments did reduce shoot growth, more so on Northern California Black than on Paradox rootstock. These preliminary results support the contention that there may be a place for deficit irrigation management in walnut. However, the carryover effects of these treatments are important and will determine the utility of these practices for walnut irrigation management.
TABLES

Table 1. Fresh weight yield by treatment for the San Joaquin site as measured in the field and dry weight adjusted yield based on adjusting fresh weight based on a dry sub-sample. Different letters indicate significant difference at 5% level.

San Joaquin yield by treatment

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Fresh weight yield (tons/acre)</th>
<th>Dry weight yield (tons/acre)</th>
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</thead>
<tbody>
<tr>
<td>Control</td>
<td>4.86 a</td>
<td>3.55 a</td>
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<tr>
<td>Mild stress</td>
<td>4.53 a</td>
<td>3.26 a</td>
</tr>
<tr>
<td>Moderate stress</td>
<td>4.66 a</td>
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<tr>
<td>LSD</td>
<td>0.98</td>
<td>0.68</td>
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</tbody>
</table>

Table 2. Fresh weight yield by treatment for the Tehama site as measured in the field and dry weight adjusted yield based on adjusting fresh weight based on a dry sub-sample. Different letters indicate significant difference at 5% level.

Tehama yield by treatment

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Fresh weight yield (tons/acre)</th>
<th>Dry weight yield (tons/acre)</th>
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<tbody>
<tr>
<td>Control</td>
<td>3.98 a</td>
<td>1.98 a</td>
</tr>
<tr>
<td>Mild stress</td>
<td>3.40 ab</td>
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<td>Moderate stress</td>
<td>3.02 b</td>
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<td>LSD</td>
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Table 3. Dry weight yields for ‘Chandler’ on Northern California Black and Paradox rootstocks by treatment for the Tehama site. Different letters indicate significant difference at 5% level.

Tehama yield by rootstock and treatment

<table>
<thead>
<tr>
<th>Rootstock</th>
<th>Dry weight yield (tons/acre)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
</tr>
<tr>
<td>Northern California Black</td>
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</tr>
<tr>
<td>Paradox</td>
<td>2.24 a</td>
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<tr>
<td>LSD</td>
<td>0.45</td>
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</table>
Table 4. Quality data for the San Joaquin County site from Diamond Walnut. Harvest samples were obtained from each individual tree that was monitored for water potential. Different letters indicate significant difference at 5% level.

**San Joaquin Diamond Quality data 2002**

<table>
<thead>
<tr>
<th>Treatm</th>
<th>%large</th>
<th>%mold</th>
<th>%insect</th>
<th>%shrive</th>
<th>%adhering hull</th>
<th>RLI</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>88.3a</td>
<td>2.62a</td>
<td>0.31a</td>
<td>0.75a</td>
<td>0.12a</td>
<td>52.2ab</td>
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<td>2</td>
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<td>6.8</td>
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</table>

Table 5. Quality data for the Tehama County site from Diamond Walnut. Harvest samples were obtained from each individual tree that was monitored for water potential. Different letters indicate significant difference at 5% level.

**Tehama Diamond Quality data 2002**

<table>
<thead>
<tr>
<th>Treatm</th>
<th>%large</th>
<th>%mold</th>
<th>%insect</th>
<th>%shrive</th>
<th>%adhering hull</th>
<th>RLI</th>
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</thead>
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<td>0.17</td>
<td>0.93</td>
<td>0.67</td>
<td>1.6</td>
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</table>
FIGURES

Figure 1. Target water potentials for irrigation treatments at both sites.

Figure 2. Midday stem water potential by irrigation treatment for San Joaquin County site for 2002 season. The control, mild and moderate stress are demarcated with solid circles, open squares and open triangles respectively. Error bars indicate plus or minus two standard errors.
Figure 3. Midday stem water potential for Tehama County site for 2002 season. The control, mild and moderate stress are demarcated with solid circles, open squares and open triangles respectively. Error bars indicate plus or minus two standard errors.

Date, 2002

Figure 4. Average percent depletion of soil moisture by treatment in the five foot root zone at the Tehama County site in 2002.
Figure 5. Canopy light interception at the San Joaquin County site as measured underneath (a) entire tree and row canopy and (b) underneath tree canopy only. Asterisk indicates significant difference from control. There were no significant treatment differences in canopy light interception under tree canopy.

Figure 6. Canopy light interception at the Tehama County site as measured underneath (a) entire tree and row canopy and (b) underneath tree canopy only. There were no significant treatment differences in canopy light interception as measured by either method at the Tehama site in 2002.
Figure 7. Shoot growth rate and total shoot growth over season by irrigation treatment for San Joaquin County site. Asterisk indicates significant difference from control at 5% level.

San Joaquin County

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Total growth (cm)</th>
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<tr>
<td>Control</td>
<td>51.5 a</td>
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<tr>
<td>Mild stress</td>
<td>34.1 b</td>
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<tr>
<td>Moderate stress</td>
<td>28.2 b</td>
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</table>

Date, 2002

Figure 8. Cumulative shoot growth for ‘Chandler’ walnuts a) pruned on Northern California Black rootstock b) unpruned on Northern California Black rootstock c) pruned on Paradox rootstock and d) unpruned on Paradox rootstock.
Figure 9. Cumulative growth of ‘Chandler’ walnuts at the San Joaquin County site for the 2002 season. Asterisks indicate significant different from control at 5% level.

Figure 10. Cumulative growth of ‘Chandler’ walnuts at the Tehama County site for the 2002 season on a) Northern California Black and b) Paradox rootstocks.
LITERATURE CITED


