Walnut Marketing Board
Final Project Report
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Project Title: Irrigation Management and the Incidence of Phytophthora Root Rot in Young Walnut Trees

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Key Words: irrigation management, Phytophthora, walnut rootstocks

**ABSTRACT**

Irrigation can have a large effect on the rate of orchard establishment and longevity. Specifically, the irrigation volume and its frequency and duration can cause problems. Problems often encountered are slow growth caused by over or under irrigation. The effects of under-irrigation are simply due to inadequate water in the root zone while over irrigation can cause water logging, or the lack of air in the soil, complimented with the increase hazard of diseases such as Phytophthora. This trial was established to evaluate the effects of water volume, irrigation frequency and potential interactions with different rootstock and the presence / absence of Phytophthora. It was conducted for two years at the Davis campus LAWR Campbell Tract, on a clay loam soil.

In the first year (2001) on imposed treatments, the results were promising in terms of differences in measured tree grow parameters and soil moisture depletion levels. No differences were found in midday stem water potential between treatments. However, differences were found between rootstocks with Paradox averaging 0.7 bars more stress. Interestingly, the Paradox rootstock trees were those exhibiting the highest growth. No interaction was found with Phytophthora inoculation versus the control over the irrigation treatments.

In the second year (2002), the water applied was greater due in part to the increased tree size. Water volumes were near 3, 9 and 21 inches, which corresponds to 9, 24 and 58 percent of the applied water in a mature orchard. It was found that the lowest volume treatment provided for the least growth measured as trunk growth and tree height. Little differences were found between the other treatments in tree growth or midday stem water potential (MDSWP). MDSWP was at what is considered a well-watered level for the entire season indicating that most if not all water volumes were too high for average growth. The exception may have been the lowest water level, which experienced reduced growth. Paradox rootstock appears to grow more at the higher water volumes applied whereas Northern California Black rootstock seem to grow at a similar rate across irrigation volumes and at a lower over all rate. The method of determining the volume of water to apply based on the canopy volume seems sound and is similar to methods being developed by others in fruit trees and grape. The effect of irrigation

frequency may only be apparent when the volume of water is on the low end of the spectrum. The first year of the study shows that the more frequent the irrigation with small volumes leads to more evaporation and less soil recharge.

**PROBLEM AND ITS SIGNIFICANCE**

The loss of walnut trees following spring planting has noticeably increased over the past few years. Symptoms include poor or minimal vegetative growth to outright tree death within the first or second season. Surviving trees with minimal first season growth often continue to perform poorly in the succeeding year and eventually are replaced. Possible explanations range from wet springs that saturate the root zone to the use/misuse of new technology irrigation systems such as micro-irrigation systems (drip and micro-sprinklers). Both can encourage Phytophthora root and crown rot.

Continued observation of these problems has resulted in an emergence of two factors as important to the problem: first a desire to maximize tree growth can lead to over-irrigation and second, many growers (as well as ourselves) are uncertain about proper irrigation frequency, duration, and quantity of applied water. The presence/absence of Phytophthora inoculum can further complicate the situation. Over-irrigation can be prevented by reducing irrigation volumes to the estimated water use or by the correct use of soil-based water status devices to prevent soil saturation. However, no comprehensive guidelines for irrigating young walnuts currently exist.

This study seeks to determine the responses of English walnut (Chandler cultivar) grafted on Northern California Black and Paradox rootstocks to irrigation frequency, duration and quantity of applied irrigation water with and without soil infestation by Phytophthora. The responses evaluated will include magnitude of tree growth and incidence of Phytophthora-included disease.

**OBJECTIVES**

(1) Determine growth response of English walnut grafted to both Northern California Black and Paradox rootstocks walnut rootstocks to irrigation frequency, duration and quantity of applied water.

(2) Evaluate the response (Objective 1) with and without inoculation of Phytophthora and the possible interaction.

(3) Determine the extent of wetted soil volume and the quality (matric potential) of the wetted area) which produces optimal vegetative growth.

(4) Develop a method of estimating the required applied water volume in newly planted trees to maximize growth and minimize disease hazard.

**PLANS AND PROCEDURES**

*Treatments*. Irrigation treatments: 4-irrigation duration and 4 irrigation frequencies are combined to provide 6 treatments, which vary the irrigation quantity (0.3x, 1x, and 2x) (Table 1). The irrigation volume is held constant in the 1x treatments (T2, T3 T4 and T5) while varying the duration and frequency. The 1x treatments were used to determine the weekly estimate of applied water required for T2 through T5. The other treatments (T1 and T6) are scaled based on the 1x irrigation volumes. The range of moisture (6x) should provide for under- and over-watered trees.

Table 1. Typical Application Water Volumes at Peak (Mid July) 2002

| | Treatment | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Irrigation Duration (hrs) | 8 | 6 | 8 | 12 | 24 | 24 |
| ETo and Canopy Adj. | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 | 0.85 |
| Frequency (times/wk) | 1 | 4 | 3 | 2 | 1 | 2 |
| Emitter flow rate (g/hr) | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 |
| Hours/wk | 7 | 21 | 21 | 21 | 21 | 41 |
| Volume Gal/wk) | 39 | 117 | 116 | 117 | 117 | 234 |

*Irrigation Volume.* Irrigation volume delivered to each treatment was based on the irrigation duration, frequency, adjustment for climatic demand and the canopy volume. Climatic demand (Evapotranspiration, ET) reference values (ETo) available from the Davis CIMIS station were used. The expanding canopy size was estimated using a volume measurement technique. These factors along with emitter flow rate determined the volume applied to each treatment.

*Field Site*. The planting is located at Campbell Tract on the University of California Davis campus (LAWR field site). The soil is a clay loam. A single micro sprinkler per tree discharging 5.7 gallons per hour provides the irrigation. The heads are Bowsmith full circle pattern achieving a 10-foot diameter surface wetted area. The heads are atop a 9-inch stand placed 36 inches to the west from each tree. Water is supplied from the campus-pressurized source.

*Experimental Design*. The design used is a factorial with four replications. The irrigation treatments are randomized within each replication. The rootstocks (with and without inoculum) are randomized within the irrigation treatments.

4 trees per plot
Trees: 384
Area planted at 15 x 24 = 3.2 acres

**RESULTS**

2000 Activities

*Field Activities.* The field site was chiseled to 3 feet and land planed in fall 1999. All buried portions of the irrigation system were installed at that time also. The grafted trees were held in cold storage due to wet soil conditions at the site. The trees were planted into moist soil May 4, 2000. The above ground portions of the irrigation system were installed shortly after planting.

*Irrigation*. Water was applied to maintain adequate soil moisture in the root zone throughout the season based on soil monitoring. All treatments were irrigated equally to promote uniform growth. Water applied from planting through November 5$^{th}$ totaled 603 gallons per tree or 2.7 acre inches per acre.

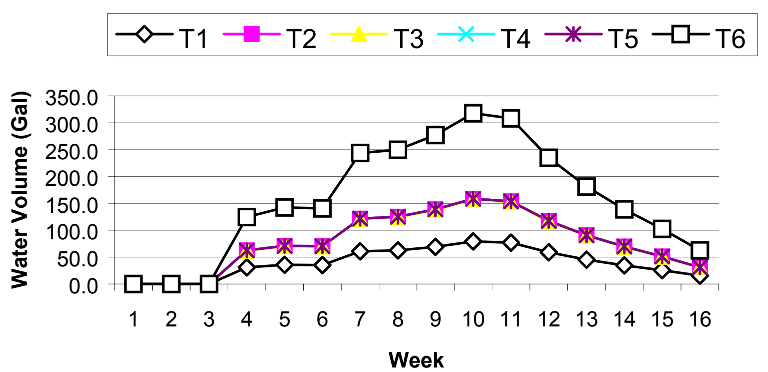
*Inoculation.* Inoculation of the soil with cultures of Phytophthora species *P. citrocola* and *P. cinnamomi* was performed September 5, 2000. The prepared cultures were placed on each side to the tree and rototilled into the soil to a depth of 4 to 5 inches. Care was taken not to contaminate adjacent non-inoculated treatments. Irrigation followed inoculation. Prior to winter rainfall, the centers were disked and harrowed. A soil berm was formed in the center of each middle and at the end of each plot between trees of adjacent plots. The purpose was to control winter water movement from inoculated and non-inoculated plots.

2001 Activities

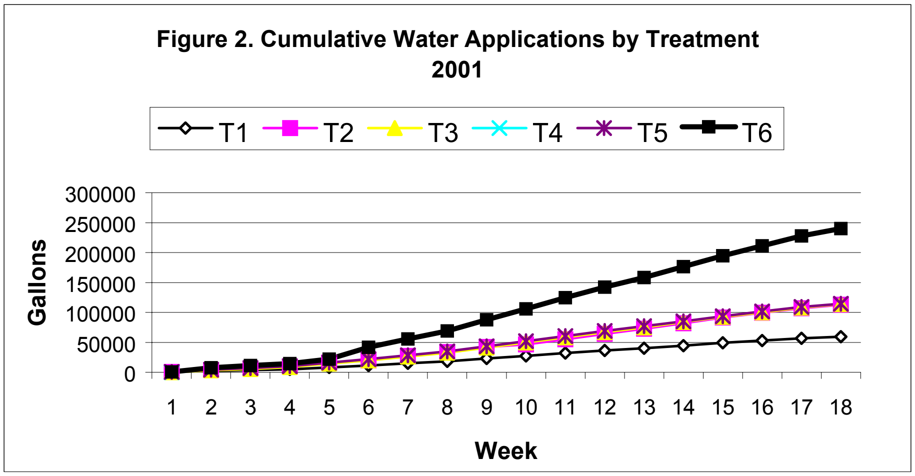
*Field Activities.* All of the trees were pruned back to 3-4 buds above the graft union on April 9.

*Irrigation*. Irrigation was performed as per the treatment schedule from May through September. Figure 1 shows the original target irrigation volumes. Note that the Treatments 2 through 5 are the same volume (although different duration and frequency) making them indistinguishable on the figure. The use of climatic ETo values and canopy factor are responsible for the low applied volumes early in the season. After the peak use period, the ETo is responsible for the decline in volumes even though the canopy was still increasing in size. This methodology will provide the basis for scheduling irrigations for developing orchards.

**Figure 1. Weekly Water Volume by Treatment**

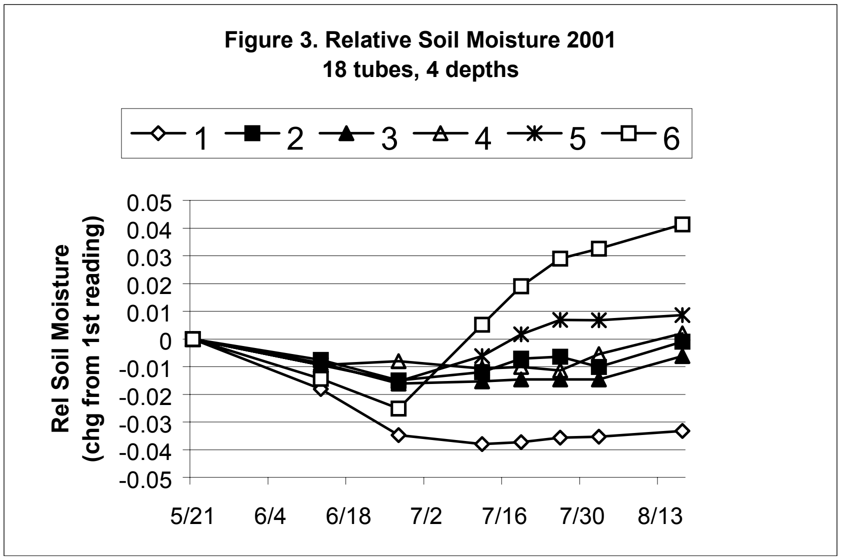



After the initiation of the irrigation season, soil moisture monitoring indicated the highest irrigation level (T6) was not as wet as anticipated. This was primarily due to the evaporation loss during irrigation and evaporation from the soil surface after irrigation from the 10-foot diameter wetted area. It was decided to increase the volume across all treatments. Figure 2 indicates the cumulative irrigation water applied over the season. This action amounted to about a 40 percent increase.




*Soil Water Measurement*. Neutron probe wells were installed in a grid fashion in each of the treatments to assess soil moisture wetted area and volume. Eighteen access wells were installed per monitored tree. The grid allows one to view water recharge and use in the entire area of the micro-sprinkler area of influence. The soil water as an average of all 18 wells over the 4 depths measured indicates an overall average moisture status. It is plotted on a relative to the May 21$^{st}$ reading to assess moisture change in Figure 3.

From May through most of June, the relative decline represents the soil drying down combined with tree use and water applications. Beginning June 27$^{th}$ when irrigation water volumes increased, treatment differential becomes apparent. Treatment 1, which receives the least water, remained essentially flat in terms of water content. The irrigation water volume balanced the tree water use. When looking at the individual depth moisture content, only the 0-9 inch depth was recharging as a result of irrigation. Treatment 6, which received the most water, shows the greatest increase in soil water content. The remainder of the treatments received the same volume of water just at different duration and frequency of irrigation. Treatment 5 with the least frequency and greatest duration resulted in the most effective recharge as a result of less evaporatorative loss from the soil surface. The remaining treatments were less differential; however Treatment 3 had significantly less recharge the others receiving the same irrigation volume. Again, this is attributed to a higher frequency (4 irrigations/week) that resulted in more evaporation from the wetted soil.




*Tree Growth Measurements*. Tree height was measured July 13, August 20, and September 20, 2001. The growth from July 13 to August 20 was significantly different between treatments (Table 2). The treatments that at this time had higher moisture content were generally higher in growth (T5 and T4) (Figure 4.). In the later growth period from August 20 to September 20, there were not any significantly treatments; however there was a trend (p = 0.0641) (Table 2). Both the lowest moisture (T1) and the highest (T6) attained the least growth, indicating the treatment water volumes were appropriate to cause a reduction from too little and too much water (Figure 5).

Figure 4.

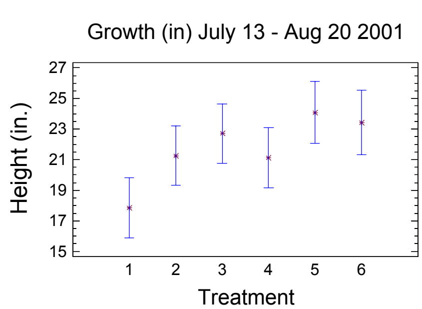



Figure 5.

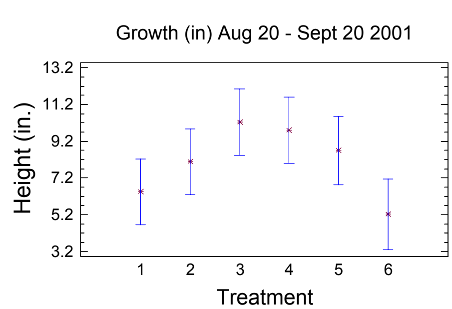


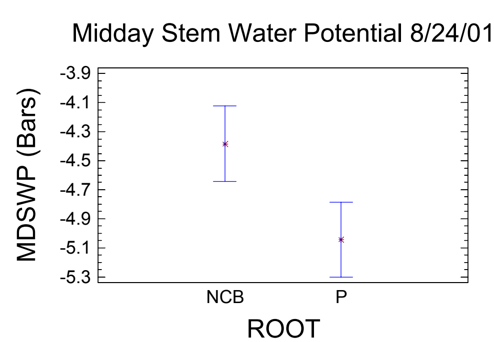
Table 2. Tree Growth at Two Periods

| Treatment | July 13 – Aug. 20 | Aug. 20 – Sept. 20 |
|---|---|---|
| 1 | 17.8 ab | 6.4 ab |
| 2 | 21.2 ab | 8.0 ab |
| 3 | 22.7 a | 10.2 a |
| 4 | 21.1 b | 9.8 a |
| 5 | 24.0 a | 8.7 ab |
| 6 | 23.4 a | 5.2 b |
| P = | 0.0354 | 0.0641 |

| | July 13 – Aug. 20 | Aug. 20 – Sept. 20 |
|---|---|---|
| Rootstock | | |
| NC Black | 20.6 | 8.5 |
| Paradox | 22.8 | 7.7 |
| P = | 0.0616 | 0.4181 |
| | | |
| Inoculation | | |
| Control | 22.2 | 8.6 |
| Inoculation | 21.2 | 7.5 |
| P = | 0.4139 | 0.3161 |

*Water Potential*. Numerous measurements were made of midday stem water potential; however the only significant differences were between the rootstocks. Figure 6 shows a relationship between Paradox and Northern California Black that was consistent throughout the season. Paradox was about 0.7 bars more negative than NC Black.

Figure 6.




2002 Activities

Trees in all treatments were pruned to a 5-foot main trunk with all laterals removed. Neck buds were removed. Weeds were controlled using residual herbicides as well as spot spraying. Mites were controlled twice during the season. Trees were fertilized in late May.

*Irrigation.* Irrigation was performed as per the treatment schedule from May through September. Figure 7 shows the original target irrigation volumes. Note that the Treatments 2 through 5 are the same volume (although different duration and frequency) making them indistinguishable on the figure. The use of climatic ETo values and canopy factor are responsible for the low applied volumes early in the season. After the peak use period, the ETo is responsible for the decline in volumes even though the canopy was still increasing in size. This methodology will provide the basis for scheduling irrigations for developing orchards. Figure 8 shows the actual applied water volumes during the 2002 season. Differences exist from the planned volumes due to minor irrigation controller/loss of water pressure complications however planned and actual volumes are close. The volume of irrigation water delivered on a seasonal basis was between 3.2 and 21.0 inches depending upon treatment (Table 3).

**Figure 7. Planned Weekly Applied Water Walnut Davis, 2002**

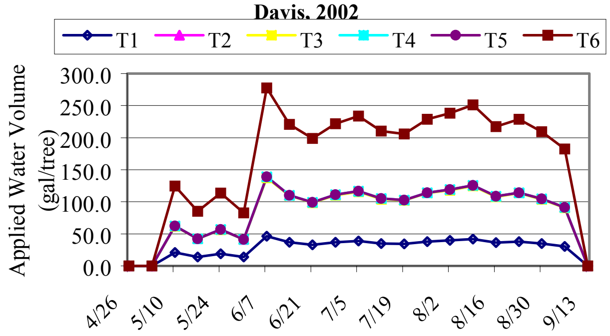



**Figure 8. Irrigation Voume, Davis Walnut, 2002**

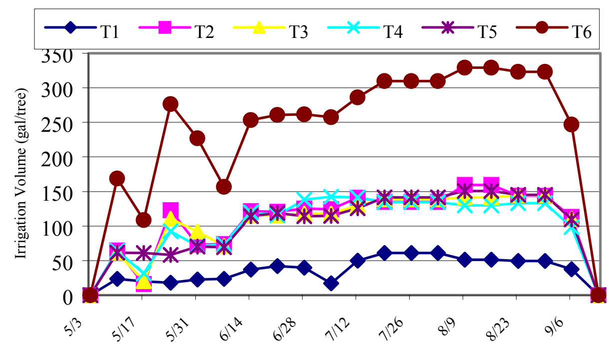
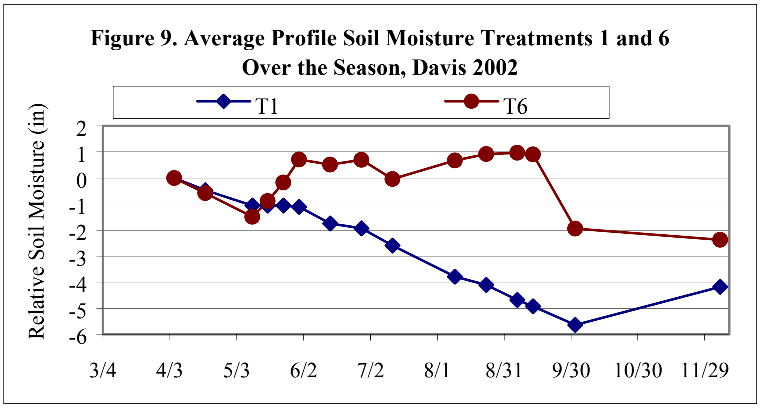


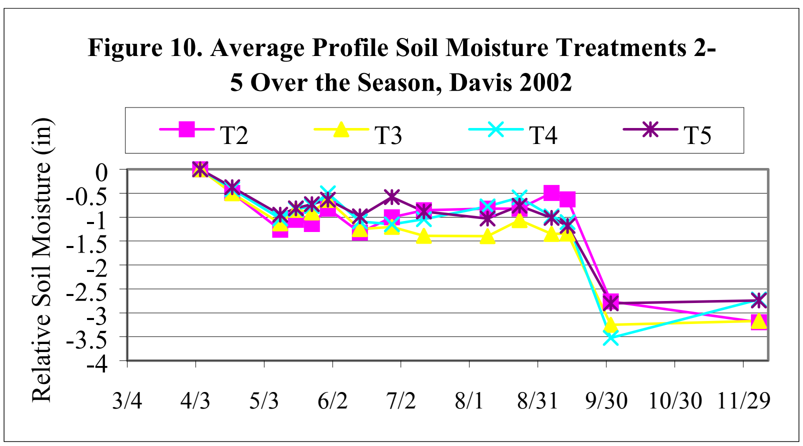

Table 3. Tree Water Use by Treatment, Davis 2002

| | Treatment | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Gallons per tree | 717 | 2110 | 2050 | 2020 | 2033 | 4737 |
| Acre inches/season | 3.2 | 9.4 | 9.1 | 9.0 | 9.0 | 21.0 |
| Mature ETAW (inches) | 36 | | | | | |
| % of Mature ETAW | 8.8 | 26.0 | 25.3 | 24.9 | 25.1 | 58.4 |

*Soil Water Measurement*: Neutron probe wells were installed in a grid fashion in each of the treatments to assess soil moisture wetted area and volume. Eighteen access wells were installed per monitored tree. The grid allows one to view water recharge and use in the entire area of the micro-sprinkler area of influence. The soil water as an average of all 18 wells over the 4 depths measured indicates an overall average moisture status. The highest water volume Treatment 6 achieved a higher than the beginning soil moisture measured in April 5$^{th}$ until irrigation cutoff on September 6$^{th}$ (Figure 9). The lowest water Treatment 1 continually lost soil moisture to tree use for the entire season until rainfall increased soil moisture in late October.




Unlike 2001, the treatments which received the same water volumes and varied in frequency and duration were found to be quite similar declining only about 0.5 to 1.5 inches for the irrigation season (Figure 10). This is an indication the volume of water supplied was near the trees requirement. If slightly less water would have been applied differences could have been greater (like 2001 shown in Figure 3).




*Water Potential*. Numerous measurements were made of midday stem water potential. Table 4 shows both the irrigation, rootstock and inoculation treatment averages and also the probability of interactions. The only significant differences were between the rootstocks. Figure 11 shows a relationship between Paradox and Northern California Black that was consistent throughout the season. Paradox was about 0.7 bars more negative than NC Black, which was nearly the same as in 2001 (see Figure 11).

Figure 11.

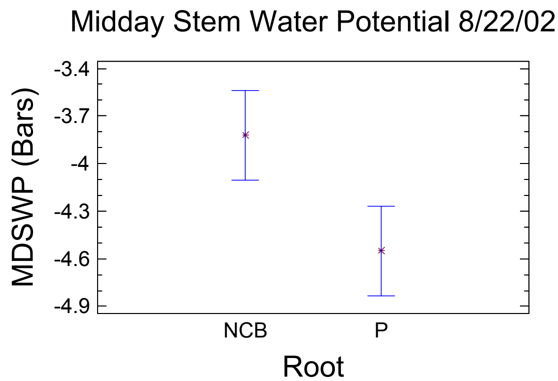



Table 6. Average Midday Stem Water Potential Walnut, Davis, 2002

| Treatment | MDSW | P = |
|---|---|---|
| 1 | -4.2 | 0.8594 |
| 2 | -4.1 | 0.2000 |
| 3 | -3.6 | 0.5669 |
| 4 | -4.5 | 0.5142 |
| 5 | -4.1 | |
| 6 | -4.6 | |
| P = | 0.3363 | |
| Rootstock | | |
| NCB | -4.1 | |
| Paradox | -4.6 | |
| P = | 0.0125 | |
| Inoculation | | |
| Control | -4.4 | |
| Inoculation | -4.0 | |
| P = | 0.1390 | |
| Interactions | | |
| Rootstock X Treatment | | |
| Rootstock X Inoculation | | |
| Treatment X Inoculation | | |
| Rootstock X Inoculation | | |

*Tree Growth Measurements*. The weight of prunings was collected for each tree in February 2002. Differences are a result of last season's treatments. Treatment 3 was highest at 2.0 kg while Treatment 1 was the lowest at 0.89 kg (Table 5). Treatment 1 was significantly less than Treatments 3 and 6. The Paradox rootstocks averaged 1.65 kg, which was significantly more than the Northern California Black rootstock at 0.79 kg. There were no significant differences in pruning weights between the inoculated and control treatments. A significant interaction occurred between the irrigation treatments and rootstock (Table 5). The pruning weights of the Northern California Black rootstock are relatively flat over the irrigation treatments while the Paradox rootstock is lower in the least water treatment and higher in the greatest water treatment (Figure 12).

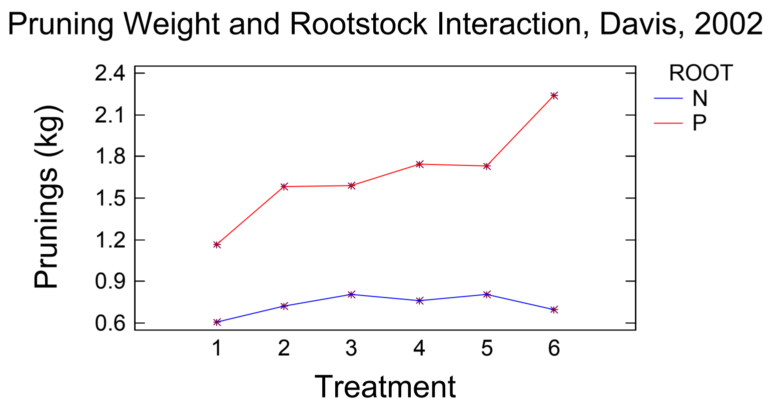
Tree height was measured December 2002. Treatment 1 (least water) was significantly lower in height than all other treatments (Table 5). The Paradox rootstocks averaged a significant 12 inches more height than the Northern California Black rootstock. Again, no significant differences were found between the control and inoculated treatments. A significant interaction occurred between the irrigation treatments and rootstock (Table 5).

Table 5. Pruning Weights and Maximum Tree Height Davis, 2002

| Treatment | 3/1/02 Pruning Wts (kg) | 2002 Maximum Height (in) |
|---|---|---|
| 1 | 0.89 b | 123 b |
| 2 | 1.15 ab | 133 a |
| 3 | 2.00 a | 137 a |
| 4 | 1.27 ab | 136 a |
| 5 | 1.20 ab | 132 a |
| 6 | 1.50 a | 134 a |
| P = | 0.0233 | 0.0000 |
| Rootstock | | |
| NCB | 0.79 b | 127 b |
| Paradox | 1.65 a | 139 a |
| P = | 0.0000 | 0.0000 |
| Inoculation | | |
| Control | 1.17 | 132 |
| Inoculated | 1.22 | 133 |
| P = | 0.5963 | 0.6583 |
| Significant Interactions | | |
| Treatment X Rootstock | P= 0.0195 | None |

Common letters among means within columns denote no significant difference at P ≤ 5% using Duncan's mean separation

**Figure 12.**




Trunk diameter was calculated by measuring the trunk diameter 10 cm below the graft union three times during the season—January, July and December. In general, Treatment 1 was significantly smaller across all measurements (Table 6). Trunk growth was then calculated for the time between the each measurement. The seasonal trunk growth of Treatment 3 was significantly larger than all other treatments at 4.38 cm. It is a middle water volume treatment with a 3 times a week frequency. Treatment 1 was significantly smaller than all other treatments at only 3.6 cm of seasonal trunk growth.

Table 6. Trunk Diameter and Trunk Growth Davis 2002

| | Trunk Diameter (cm) | | | Trunk Growth (cm) | | |
|---|---|---|---|---|---|---|
| Treatment | 1/17/02 | 7/18/02 | 12/26/02 | Jan. – July | July – Dec. | Jan. – Dec. |
| 1 | 6.33 b | 7.42 b | 9.68 c | 1.09 b | 2.23 | 3.36 c |
| 2 | 6.77 ab | 7.96 a | 10.59 b | 1.19 ab | 2.63 | 3.82 b |
| 3 | 6.97 a | 8.37 a | 11.35 a | 1.39 a | 2.98 | 4.38 a |
| 4 | 7.02 a | 8.21 a | 11.04 ab | 1.20 ab | 2.82 | 4.02 b |
| 5 | 7.07 a | 8.23 a | 10.96 ab | 1.31 ab | 2.73 | 4.07 b |
| 6 | 7.06 a | 8.32 a | 11.01 ab | 1.26 ab | 2.69 | 3.95 b |
| P = | 0.0118 | 0.0118 | 0.0000 | 0.0577 | 0.0022 | 0.0000 |
| Rootstock | | | | | | |
| NCB | 6.47 b | 7.86 b | 10.26 b | 1.44 a | 2.40 b | 3.85 |
| Paradox | 7.27 a | 8.31 a | 11.29 a | 1.04 b | 2.98 a | 4.02 |
| P = | 0.0000 | 0.0021 | 0.0000 | 0.0000 | 0.0000 | 0.0799 |
| Inoculation | | | | | | |
| Control | 6.82 | 8.06 | 10.74 | 1.29 | 2.68 | 3.98 |
| Inoculation | 6.91 | 8.11 | 10.80 | 1.19 | 2.70 | 3.89 |
| P = | 0.4955 | 0.7647 | 0.7290 | 0.1029 | 0.8326 | 0.3572 |

Common letters among means within columns denote no significant difference at P ≤ 5% using Duncan's mean separation.

**DISCUSSION**

Irrigation can have a large effect on the rate of orchard establishment and longevity. Specifically, the irrigation volume and its frequency and duration can cause problems. Problems often encountered are slow growth caused by over or under irrigation. The effects of under-irrigation are simply due to inadequate water in the root zone while over irrigation can cause water logging, or the lack of air in the soil, complimented with the increase hazard of diseases such as Phytophthora. This trial was established to evaluate the effects of water volume, irrigation frequency and potential interactions with different rootstock and the presence / absence of Phytophthora. It was conducted for two years at the Davis campus LAWR Campbell Tract, on a clay loam soil.

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12/02