Evaluation of Plant-Water Relations Aspects of Walnut Tree Decline in the Central and Southern San Joaquin Valley

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ABSTRACT

Mature walnut tree decline, characterized by poor tree vigor, dieback, and low productivity, is present in numerous orchards in the Central and Southern San Joaquin Valley. To investigate the nature of the problem as related to soil water status (irrigation), experimental sites were established in Stanislaus, Merced, and Kings Counties in orchards that contained both "decline" and "normal" trees. Frequent measurements of soil and plant water status were made through the season.

We found that decline trees had lower midday leaf water potential and stomatal conductance values than the normal trees, which is symptomatic of plant water stress. However, available soil water levels were not appreciably different for the decline and normal tree locations. Therefore, it doesn't appear that decline symptoms are associated with current season irrigation practices. While decline trees appear to suffer from an inability to extract soil water, the nature of the resistance to flow within the soil to leaf water conducting pathway is unknown. Speculation centers on lower root densities or a loss of root function.

OBJECTIVES

1) To investigate the nature of mature walnut tree decline as related to current season soil and plant water status, and

2) To provide information to ascertain whether the decline problem is due primarily to current season irrigation management.

PROCEDURE

Experimental sites were established in 1987 with grower/cooperators in Stanislaus, Merced, and Kings Counties with Ashely, Payne, and Hartley cultivars, respectively. Orchard selection was based on the presence of both "decline" and "normal" trees in the orchard. (While no clear consensus exists as to what constitutes decline, it's characterized by poor vigor, dieback and low production).

Neutron probe access tubes were installed to a depth of 10 ft. adjacent to three or four of each tree type (decline and normal) at each location. Calibration curves were developed for each orchard and field capacity and permanent wilting point values were determined using field and laboratory techniques. Probe readings were taken weekly at 12 inch increments over the season. Irrigation scheduling was handled by each grower and flood irrigation was practiced at all locations.
Beginning no later than mid-June, plant based measurements of leaf water potential and stomatal conductance were made with a pressure chamber and steady-state porometer, respectively. For leaf water potential, three leaves on each of three or four trees were monitored. Stomatal conductance was measured on ten leaves per monitored tree. All plant based measurements were made at midday (noon to 2:00 p.m.).

Tree productivity and size were characterized only at the Kings County location. Trunk circumference, orchard floor shading by the canopy, nut yield, and nut quality were determined.

RESULTS AND DISCUSSION

Stanislaus County

Soil water levels monitored from early March through July were quite high at both the decline and normal tree sites, as shown in Figure 1. In the upper 24 inches of the profile, available water was clearly plentiful for both tree types; soil water levels didn't appear to limit extraction by the roots. Figure 2 illustrates available soil water in the upper 60 inches of the profile. Lower amounts of available water after mid-July may reflect a reduction in infiltration rates with time, which is a common occurrence. However, the neutron probe data show that abundant soil water was available, especially through mid-June.

Seasonal midday leaf water potentials presented in Figure 3 show that the decline trees had consistently lower values through mid-season. The differences narrowed after mid-August. Stomatal conductance of the decline trees was also consistently lower than the normal trees through July (Figure 4). Reduced leaf water potential and stomatal conductance indicate that extraction of soil water was diminished, which is commonly associated with inadequate soil moisture. Such was not the case in this experimental orchard. Thus, the stress symptoms were presumably due to some disruption in the water transport pathway between the soil and the leaves. This could include low root density or a loss of root function. Backhoe pits were not dug at this site but on similar-appearing decline trees located nearby, backhoe pits showed much less dense and expansive root systems.

Kings County

Available soil water levels with time in the upper 60 inches of the profile are shown in Figure 5. A water penetration problem resulted in available soil water never exceeding 80%, but relatively frequent irrigations maintained levels generally greater than 50%. Note that soil moisture was virtually identical at the decline and normal tree sites at each sampling date.

Midday leaf water potential with time (Figure 6) was consistently lower for the decline trees through the end of August. Similarly, stomatal conductance of the decline trees was less throughout the season. While midday leaf water potential fluctuated somewhat between samplings, the mean values through August were approximately -10 and -12 bars for the normal and decline trees, respectively. Although they fluctuated somewhat between samplings, the time-course behavior was relatively constant during this period. On the other hand, midday stomatal
condutance generally decreased with time (Figure 7). This decrease was not related to soil water levels and may be due to leaf ageing or some feedback inhibition of stomatal opening. This latter process may result from decreased demand for carbohydrates from the reproductive and vegetative sinks after mid-June (see report on tree response to sustained plant water stress).

To help explain the apparent presence of plant water stress in the decline trees in the absence of low soil moisture levels in the upper 60 inches of the soil profile, we examined extraction patterns of soil water in the decline trees. Figure 8 shows the distribution of soil water just after and immediately prior to successive irrigations. While the amount of extraction decreased with increasing soil depth, water uptake occurred to a depth of 7 ft. This pattern is typical for trees and is not indicative of a root system limited to the upper part of the profile. Therefore, it appears that the decline trees had expansive root systems, although their density is unknown. Another possible explanation for the lack of correlation between soil water levels and plant-based measurements of water status is poor root function.

Harvest results and tree size data are given in Table 1. Not only were the normal trees larger but their harvest index was greater (.184 and .124 lbs. dry nuts/ft$^2$ shaded area). The smaller nut size and somewhat lower nut quality of the decline trees reflect the symptoms of stress previously discussed.

Table 1. Harvest and tree size data from the Kings County site.

<table>
<thead>
<tr>
<th>Tree Type</th>
<th>Trunk X.S. area (ft$^2$)</th>
<th>Shaded area (lbs/tree)</th>
<th>Dry in-shell yield (lbs/ft$^2$)</th>
<th>Harvest index</th>
<th>Jumbo (%)</th>
<th>Large (%)</th>
<th>Medium (%)</th>
<th>Baby (%)</th>
<th>Peewee (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decline</td>
<td>1.31 881</td>
<td>109.3</td>
<td>109.3/1.24</td>
<td>80.6 10.5 4.2</td>
<td>1.4 3.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>1.62 1429</td>
<td>262.5</td>
<td>262.5/1.84</td>
<td>93.2 3.8 2.3</td>
<td>0.2 0.6</td>
<td></td>
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</tbody>
</table>

1/ 8% water content on dry weight basis.

Merced County

Soil water levels over the season in the top 60 inches of the profile are shown in Figure 9. They remained invariant with time and were essentially equal at both the decline and normal tree sites. Available soil water never exceeded 20%, indicating that over the period of monitoring (June 30 to September 24), the upper 60 inches of the profile were quite dry and influenced only marginally by the summer irrigations.

Midday leaf water potential (Figure 10) averaged approximately -10.5 and -11.7 bars over the season for the normal and decline trees, respectively. For the
normal trees, leaf water potential was relatively constant with time and if any
trend is present, it's one of slightly less negative values as the season
progressed, except just prior to harvest. The decline trees showed more
variation. However, the midday leaf water potential values recorded at both
tree type sites do not reflect the dry soil water conditions monitored.

Stomatal conductance with time is shown in Figure 11. Again, the decline trees
had consistently lower stomatal conductance. For the monitored period, stomatal
conductance averaged 0.50 and 0.81 cm/sec for the decline and normal trees,
respectively. The latter value does not indicate that irrigation-related plant
water stress existed, which is not consistent with the soil water data from the
upper 60 inches of the profile. Apparently, a water table existed at a depth
below 10 ft; the deepest neutron probe measurement. Figure 12 presents the
available soil water content profiles monitored on July 24 which are indicative
of the situation throughout the season. It's clear that the bulk of the
available soil water is below the 8 ft. depth. Additionally, it appears that
differences between the two tree type sites existed below this depth with
generally higher values found with the decline trees. Presumably, the water
table supplied the normal trees with most of their crop water requirement but
the decline trees failed to use water at their potential rate.

CONCLUSIONS

Trees characterized as in decline based on vigor, dieback, and productivity had
seasonal leaf water potential and stomatal behavior symptomatic of plant water
stress. However, available soil water levels were not appreciably different
that those found with "normal" trees at each location. Therefore, it doesn't
appear that decline symptoms are associated with the current irrigation
practices. Decline trees appear to suffer from an inability to extract water,
which indicates an increased resistance to flow in the conducting pathway
between the soil and the leaves.

The nature of this resistance is beyond the scope of this study. Based on
extraction patterns, decline and normal tree rootzones appear to explore to
similar depths. However, the density of roots of the different tree types may
be different. Another possible explanation involves the loss of root function.

In view of the lack of correlation between soil water levels and decline
symptoms, it appears that current season grower irrigation management, by
itself, will not correct the problem. This is not to say that the decline is
not directly or indirectly related to past irrigation practices or that longterm
proper irrigation cannot help in the recovery of the trees.
Figure 1. Available soil water in the upper 24 inches of the profile with time over the season in the Stanislaus County orchard.

Figure 2. Available soil water in the upper 60 inches of the profile with time over the season at the Stanislaus County site.
Figure 3. Time-course midday leaf water potential values at the Stanislaus County site.

Figure 4. Midday stomatal conductance with time at the Stanislaus County location.
Figure 5. Available soil water with time in the top 60 inches of the profile at the Kings County site.

Figure 6. Midday leaf water potential with time at the Kings County location.
Figure 7. Stomatal conductance measured at midday in the Kings County orchard.

Figure 8. Soil water content profiles between two successive irrigations at the Kings County site.
Figure 9. Soil water content with time in the upper 60 inches of the profile at the Merced County site.

Figure 10. Leaf water potential measured at midday over the season at the Merced County site.
Figure 11. Midday stomatal conductance with time in the Merced County orchard.

Figure 12. Available soil water content profiles measured on a single day at the Merced site.