The Effectiveness of Foliar Potassium Nitrate Sprays on the 'Hass' Avocado (Persea americana Mill.)

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Abstract. Potassium nitrate (KNO₃) was sprayed on the leaves of four-year-old bearing 'Hass' avocado trees at the rate of 13.6 kg (30 pounds) per 378.5 liters (100 gallons) of water. Spray application was done either at half leaf expansion, full leaf expansion or one month after full expansion. A combination of two and three of these spray treatment times was also done. Foliar applications of KNO₃ were effective in increasing the K level in the leaves of 'Hass' avocado trees. Two and three applications were effective. All treatments lowered the leaf Mg level below that of the control with three sprays lowering it significantly. All treatments significantly increased the leaf Zn level above that of the control. The three spray treatments significantly increased the Mn level above the control. Leaf levels of N, P and Na were generally higher while Ca was generally lower in treated versus control leaves. Leaf Fe and Cu levels appeared to be unaffected. The foliar sprays of KNO₃ were estimated to be more expensive than soil-applied (banded) potassium sulfate (K₂SO₄) applied every three years.

On avocados, K deficiency is characterized by lack of growth and vigor of the tree and some leaves are yellow or pale green with dry (necrotic) dead spots on the leaves (Koo, 1968). The University of California recommended concentrations of potassium in avocado leaves based upon analysis of the spring growth cycle sampled during mid-August to mid-October are as follow: less than 0.35% = deficient; 0.75 to 2% = adequate; more than 3% = excess (Goodall, 1979).

Foliar application of fertilizers has been gaining popularity in situations where soil application is found ineffective or while waiting for soil application to become effective (Embleton et al., 1964). Foliar potassium fertilization has been successful for citrus and other fruits (Uriu et al., 1980, Stebbins, 1977; Diver et al., 1985; Calvert, 1969; Page et al., 1963; Embleton and Jones, 1972).

The general purpose of this experiment was to provide potassium by foliar KNQ3 sprays on 'Hass' avocado trees. It should be noted that other trees in the orchard under study had a history of K deficiency. The analyses for the last two years for percent of K in the leaves in the trees that were used had been below optimum range but were not considered deficient (McNeil, 1989). Foliarly-applied potassium was utilized in this study in order to test it as a possibly effective and hopefully more economical application method than soil-applied potassium. The only known effective alternative means of
applying potassium would have been to band 2.27 to 4.54 kg (5-10 pounds) of K₂SO₄ under the dripline of each tree. Banding, rather than broadcasting, would be required because the serpentine derived soils in this growing area are of high magnesium content which competes with potassium uptake by the plant. The latter treatment may last for two or three years (McNeil, 1989).

The specific objectives of this study were as follows:

1. To determine the effect of foliar KNO₃ spray on the levels of macro- and microelements within the leaves.
2. To determine the growth stage at which foliar applications of KNO₃ would be most effective in maintaining an adequate leaf nutrient level of K.
3. To determine the frequency and concentration of KNO₃ application that would provide the optimum level of leaf K with minimum leaf burning.
4. To make a cost comparison of foliarly applied KNO₃ with soil applied K₂SO₄.

Materials and Methods

A rate experiment was conducted using increasing rates of KNO₃ to determine the rate at which minimum or no leaf burning would occur. For this part of the experiment, ten shoots with half-expanded leaves were tagged for each treatment and sprayed with the following rates of KNO₃: 2.4, 3.6, 4.8, 6.0, 7.2 and 8.4 kg/100 liters of water (20, 30, 40, 50, 60 and 70 pounds/100 gallons). Visual observations for leaf burning were made every day for the first three days and once a week for two weeks. Based on the findings from the rate experiment, 3.6 kg of KNO₃/100 liters (30 pounds per 100 gallons) of water was found to be the highest safe concentration where minimum to almost no leaf burning occurred.

Forty-nine four-year old bearing 'Hass' avocado trees on a Mexican rootstock grown in a Lodo clay loam soil were used for the study. The experimental design used was a randomized complete block design with single tree plots and seven treatments which were replicated seven times. Data was analyzed by analysis of co-variance. Treatment mean separation was calculated with the Bonferroni (Dunn) T test (Neter et al., 1985).

Forty spring-cycled leaves from non-fruiting, non-flowering and disease-free terminal growth (10 randomly selected) were sampled per tree before (in fall 1988) and after (in fall 1989) treatment applications to determine the nutrient (N, P, K, Ca, Mg, Zn, Mn, Fe, Cu and Na) status of the trees. The post-treatment sampling was taken from each tree of the previously tagged and treated branches (10 shoots per tree). Potassium nitrate was sprayed on the leaves at the rate of 3.6 kg per 100 liters (30 pounds per 100 gallons) of water. Spray application was done once at half leaf expansion, full leaf expansion and one month after full expansion. Combinations of two and three of these spray treatment times was also done to determine the frequency of KNO₃ application that would be effective in supplying potassium to the leaves. Two double spray applications were done. One was done at half leaf expansion followed by a second spray at full leaf expansion. Another spray once at half leaf expansion was followed by a
second spray one month after full leaf expansion. A triple treatment application was
done once at half leaf expansion followed by a second spray at full leaf expansion and a
third spray one month after full leaf expansion.

The leaves were wetted to a point where the spray solution started dripping from them.
Approximately 11.35 liters (3 gallons) of spray solution per tree, about 2442.1 liters per
hectare (261 gallons/acre) were applied. Spring flush leaves were half expanded on the
first spraying date on May 12, 1989, and the leaves were fully expanded by the second
spraying on July 20, 1989. The final spray application (one month after full leaf
expansion) was made on August 18, 1989.

Results and Discussion

The effect of foliar sprays on the N, P, K, Ca and Mg contents of leaves is reported in
Table 1. Although there were no significant differences in levels of N, P, Ca and Na in
the leaves due to the KNO₃ application over the control, the leaf concentration of N, P,
and Na in the sprayed trees were generally higher than the control, while the Ca levels
were generally lower than the control.

A basic and widely observed interaction of N and K is the necessity of adequate levels
of K for increased yields and possibly for an increase in the leaf concentration as N
rates are increased. Potassium is recognized as being important for efficient N
utilization, and generally, as K is taken up in larger amounts, the N is taken up and used
in larger amounts if available at adequate levels in the growth medium. If N uptake
increases, then K uptake will also increase. In contrast to N, there is no major observed
physiological connection between P and K inside the plant, except for the possible
effect of K on the P-Zn interaction (Dibb and Thompson, 1985). Investigations of the
effects of K fertilization by means of leaf analysis have shown that K and P levels may
depend more on the associated N fertilization than directly on the added K or P
(Cabianchi and Morro, 1966).

The K application had no significant effect on the Ca content of the leaves. However,
the control trees had the highest level of leaf Ca among all the treatments as opposed
to K content where the control trees had the lowest level of K in the leaves. The same
observation were found for Mg, except that there was a significant difference between
the treatments with three spray applications as compared to the control. Na, however,
was lower in control leaves than those of all other treatments. These data showed the
possible antagonistic interaction among K, Mg, Ca, and possibly Na. Previous workers
have found decreases in leaf Ca (Embleton and Jones, 1972; Kilmer, 1968) and Mg
(Embleton and Jones, 1966) associated with increased K levels. The fact that Ca did
not have significant differences among treatments compared to the Mg content in the
leaves could be due to the difference in the replacing or competing abilities of these two
cations. Itallie and Van (1938), in a study on Italian rye grass, found that the competition
between the various cations are in the order (from strongest to weakest competition): K
> Na > Mg > Ca.
The effect of K application on the Mn, Zn, Na, Fe and Cu contents of the leaves is reported in Table 2. Except for Mn and Zn levels, there were no significant differences observed in the Na, Fe and Cu contents. Mn levels were significantly higher in trees sprayed three times with KNO₃ compared to the rest of the sprayed trees and the control. This indicated a potential interaction between K and Mn. Potassium, Ca and Mg play a significant role in the regulation of Mn absorption in plants. The cations either promote Mn absorption when Mn is present in low amounts or effectively decrease Mn uptake when Mn is present in high amounts that might be toxic (Ramani and Kannan, 1974).

The foliar KNO₃ sprays had a significant effect on the leaf Zn content. Based on these results, all treatments had greater Zn content than did the control. Moreover, three applications of KNO₃ (at half leaf expansion, full leaf expansion and one month after full leaf expansion) gave the highest levels of Zn in the leaves, whereas two applications (at half leaf expansion and one month after full leaf expansion) gave the next highest Zn level.

It should be noted that since zinc is usually deficient in this area, all trees received a standard foliar spray of 0.45 kg ZnSO₄/3785 liters (1 pound/100 gallons) on August 25, 1989, one week after the last KNO₃ spraying date (McNeil, 1989).

The leaf K content of 'Hass' avocados as influenced by the frequency of application and growth stage when K was applied is shown in Table 1. For single spraying of K, the % leaf K increased as spraying was done later in the season when the leaf surface area was expanding. Similarly, with the double foliar K spray, the treatment with the second spray applied 1 month after full leaf expansion had a higher % leaf K than when the second spray was applied at full leaf expansion. Finally, three foliar KNO₃ sprays (at half leaf expansion, full leaf expansion and one month after full leaf expansion) gave the highest leaf K content.

The results of this study showed that foliar KNO₃ sprays were effective in increasing the K level in the leaves of 'Hass' avocados. Two or three spray applications were most effective. The fact that there was an increase in the leaf K concentration when the last spraying was done one month after full leaf expansion, may suggest that this stage of vegetative growth was the period when the leaves were approaching a foliar K-absorption maximum.

An effective soil potassium fertilizer treatment for this particular growing area is K₂SO₄ applied at the rate of 2.27 to 4.54 kg (5-10 pounds) per mature tree banded under the dripline. This treatment is usually repeated every 2 to 3 years. Band rather than broadcast application is required since the soils in this growing area are of high magnesium level which would compete with the potassium (McNeil, 1989).

The cost comparison between foliar-applied KNO₃ and soil-applied K₂SO₄ is reported in Table 3. Considering the cost of fertilizer and labor, three annual sprays of KNO₃ would
be more expensive than soil-applied (banded) K₂SO₄ at both rates applied every three years.

Conclusions

The following conclusions can be drawn from this study:

1. Foliar applications of KNO₃ were effective in increasing the K level in the leaves of 'Hass' avocado trees.
2. Several interactions appeared to exist among the macro- and micronutrient content of 'Hass' avocado leaves as induced by the K applications.
3. Foliar sprays of KNO₃ were estimated to be more expensive than soil-applied (banded) K₂SO₄.

Literature Cited


Table 1. Effect of potassium nitrate foliar treatments on the macronutrient contents of 'Hass' avocado leaves.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Half (H)</td>
<td>2.175 a</td>
<td>0.308 a</td>
<td>0.568 ab</td>
<td>0.606 a</td>
<td>0.576 ab</td>
</tr>
<tr>
<td>Full (F)</td>
<td>2.146 a</td>
<td>0.322 a</td>
<td>0.581 ab</td>
<td>0.642 a</td>
<td>0.653 a</td>
</tr>
<tr>
<td>H + F</td>
<td>2.028 a</td>
<td>0.334 a</td>
<td>0.614 abc</td>
<td>0.578 a</td>
<td>0.590 ab</td>
</tr>
<tr>
<td>H+F+1MAF</td>
<td>2.095 a</td>
<td>0.299 a</td>
<td>0.678 c</td>
<td>0.544 a</td>
<td>0.545 b</td>
</tr>
<tr>
<td>1 MAFw</td>
<td>2.091 a</td>
<td>0.312 a</td>
<td>0.615 abc</td>
<td>0.564 a</td>
<td>0.594ab</td>
</tr>
<tr>
<td>H + 1 MAP</td>
<td>2.168 a</td>
<td>0.319 a</td>
<td>0.642 be</td>
<td>0.602 a</td>
<td>0.618 ab</td>
</tr>
<tr>
<td>Controlv</td>
<td>2.073 a</td>
<td>0.301 a</td>
<td>0.534 a</td>
<td>0.652 a</td>
<td>0.668 a</td>
</tr>
</tbody>
</table>

\[\text{Mean values not followed by the same letter are significantly different at the 1 \% level, Bonferroni (Dunn) T test.}\]
\[\text{\textsuperscript{y} Sprayed at half leaf expansion.}\]
\[\text{\textsuperscript{x} Sprayed at full leaf expansion.}\]
\[\text{\textsuperscript{w} Sprayed one month after full leaf expansion.}\]
\[\text{\textsuperscript{v} No foliar potassium nitrate spray.}\]
### Table 2. Effect of potassium nitrate foliar treatments on the micronutrient contents of 'Hass' avocado leaves.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Mn</th>
<th>Zn</th>
<th>Cu</th>
<th>Fe</th>
<th>Na</th>
</tr>
</thead>
<tbody>
<tr>
<td>Half (H)</td>
<td>147.10 a</td>
<td>28.83 a</td>
<td>6.88 a</td>
<td>85.43 a</td>
<td>50.00 a</td>
</tr>
<tr>
<td>Full (F)</td>
<td>152.44 a</td>
<td>30.06 a</td>
<td>7.31 a</td>
<td>83.24 a</td>
<td>65.00 a</td>
</tr>
<tr>
<td>H + F</td>
<td>164.91 a</td>
<td>30.51 a</td>
<td>7.36 a</td>
<td>84.36 a</td>
<td>64.00 a</td>
</tr>
<tr>
<td>H + F + 1 MAF</td>
<td>200.34 b</td>
<td>48.27 b</td>
<td>7.45 a</td>
<td>90.98 a</td>
<td>70.00 a</td>
</tr>
<tr>
<td>1 MAF w</td>
<td>159.54 a</td>
<td>32.96 a</td>
<td>7.08 a</td>
<td>87.14 a</td>
<td>55.00 a</td>
</tr>
<tr>
<td>H + 1 MAP</td>
<td>157.57 a</td>
<td>40.85 c</td>
<td>8.14 a</td>
<td>90.98 a</td>
<td>55.00 a</td>
</tr>
<tr>
<td>Control v</td>
<td>166.64 a</td>
<td>21.83 d</td>
<td>7.08 a</td>
<td>81.86 a</td>
<td>48.00 a</td>
</tr>
</tbody>
</table>

Percent dry weight. Mean values not followed by the same letter are significantly different at the 1% level, Bonferroni (Dunn) T test.

y Sprayed at half leaf expansion.
x Sprayed at full leaf expansion.
w Sprayed one month after full leaf expansion.
v No foliar potassium nitrate spray.

### Table 3. Cost comparison between foliar-applied KNO₃ and soil applied (banded) K₂SO₄.

<table>
<thead>
<tr>
<th></th>
<th>KNO₃ a</th>
<th>K₂SO₄ b</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Single spray</td>
<td>Double spray</td>
</tr>
<tr>
<td>Labor cost per ha</td>
<td>$12.35</td>
<td>$24.70</td>
</tr>
<tr>
<td>Fertilizer amount per ha (kg)</td>
<td>87.6</td>
<td>175.2</td>
</tr>
<tr>
<td>Fertilizer cost per ha e, d</td>
<td>$54.32</td>
<td>$108.64</td>
</tr>
<tr>
<td>Total cost per ha</td>
<td>$66.67</td>
<td>$133.34</td>
</tr>
<tr>
<td>Total annual cost per ha f</td>
<td>$66.67</td>
<td>$133.343</td>
</tr>
</tbody>
</table>

a Based on 13.6 kg KNO₃ in 100 L of water applied foliarly; or 35.38 kg in 987.88 L of water per hectare.
b Based on 2.27 to 4.54 kg K₂SO₄ per tree applied to the soil (banded); or 488.0 and 976.0 kg per hectare, respectively.
c Based on $5.00 per hour with the KNO₃ application requiring 2.47 h per ha and the K₂SO₄ application requiring 3.70 h per ha for the 2.27 kg treatment and 7.40 h per ha for the 4.54 kg treatment.
d March 1990 prices: KNO₃ = $0.62 per kg, K₂SO₄ = $0.37 per kg.
e There were 215 trees per ha at a 6.1 x 7.6 meter spacing.
f Based on the assumption that K₂SO₄ is effective for three years.