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

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Abstract. **Potassium nitrate (KNO_3) 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 KNO_3 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 KNO_3 were estimated to be more expensive than soil-applied (banded) potassium sulfate (K_2SO_4) 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 K_2 804 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 KNO_3spray on the levels of macro- and microelements within the leaves.
2. To determine the growth stage at which foliar applications of KNO_3 would be most effective in maintaining an adequate leaf nutrient level of K.
3. To determine the frequency and concentration of KNO_3 application that would provide the optimum level of leaf K with minimum leaf burning.
4. To make a cost comparison of foliarly applied KNO_3 with soil applied K_2SO_4.

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 KNO_3: 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 KNO_3/100 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 KNO_3 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 KNO_3application 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 KNO_3compared 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 KNO_3sprays 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 KNO_3 (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 $ZnS0_4$/3785 liters (1 pound/100 gallons) on August 25, 1989, one week after the last KNO_3 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 KNO_3 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 KNO_3 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 K_2 SO_4 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 KNO_3 and soil-applied K_2 SO_4 is reported in Table 3. Considering the cost of fertilizer and labor, three annual sprays of KNO_3 would be more expensive than soil-applied (banded) $K_2\ SO_4$ at both rates applied every three years.

Conclusions

The following conclusions can be drawn from this study:

1. Foliar applications of KNO_3 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 KNO_3 were estimated to be more expensive than soil-applied (banded) K_2SO_4.

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

	Macronutrient				
	N	P	K	Ca	Mg
Treatments	Percent dry weight[z]				
Half (H) [y]	2.175 a	0.308 a	0.568 ab	0.606 a	0.576 ab
Full (F) [x]	2.146 a	0.322 a	0.581 ab	0.642 a	0.653 a
H + F	2.028 a	0.334 a	0.614 abc	0.578 a	0.590 ab
H+F+1MAF	2.095 a	0.299 a	0.678 c	0.544 a	0.545 b
1 MAF[W]	2.091 a	0.312 a	0.615 abc	0.564 a	0.594ab
H + 1 MAP	2.168 a	0.319 a	0.642 be	0.602 a	0.618 ab
Control [v]	2.073 a	0.301 a	0.534 a	0.652 a	0.668 a

[z] 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 2. Effect of potassium nitrate foliar treatments on the micronutrient contents of 'Hass' avocado leaves.

	Macronutrient				
	Mn	Zn	Cu	Fe	Na
Treatments	Percent dry weight[z]				
Half (H) [y]	147.10 a	28.83 a	6.88 a	85.43 a	50.00 a
Full (F) [x]	152.44 a	30.06 a	7.31 a	83.24 a	65.00 a
H + F	164.91 a	30.51 a	7.36 a	84.36 a	64.00 a
H+F+1MAF	200.34 b	48.27 b	7.45 a	90.98 a	70.00 a
1 MAF[W]	159.54 a	32.96 a	7.08 a	72.86 a	73.00 a
H + 1 MAP	157.57 a	40.85 c	8.14a	87.14 a	55.00 a
Control [v]	166. 64 a	21.83 d	7.08 a	81.86 a	48.00 a

[z] 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 KNO_3 and soil applied (banded) K_2SO_4.

	KNO_3[a]			K_2SO_4[b]	
	Single spray	Double spray	Triple spray	2.27 kg per tree	4.54 kg per tree
Labor cost per ha [c]	$12.35	$24.70	$37.05	$18.50	$37.00
Fertilizer amount per ha (kg)	87.6	175.2	262.8	488.0	976.0
Fertilizer cost per ha [e-d]	$54.32	$108.64	$162.96	$180.56	$361.12
Total cost per ha	$66.67	$133.34	$200.01	$199.06	$398.12
Total annual cost per ha[f]	$66.67	$133.343	$200.01	$66.35	$132.71

[a] Based on 13.6 kg $KN0_3$ 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 K_2S0_4 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 KNO_3 application requiring 2.47 h per ha and the K_2SO_4 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: KNO_3 = §0.62 per kg, K_2SO_4 = $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 K_2SO_4 is effective for three years.