Potassium Nutrition of Pistachio: Development of Potassium Diagnostic Procedures and Fertilizer Recommendations (First Year Report)

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Summary

During the first year of this project, 3 field trials were established to study the effects of K applications at 4 rates (0, 100, 200 and 300 lbs K/acre), with 3 K fertilizers (K_2SO_4, KCl and KNO_3) and 2 application methods (micro-sprinkling and soil banding) on leaf K status, nut yield and quality in pistachio. In addition, gypsum was applied (650 lbs/acre) in Madera and Yolo orchards with 200 lbs K/acre to determine its effects on soil K availability and plant K uptake. Our preliminary data indicate that K application increased leaf K concentration, nut yield and quality. However, K effects varied with K application rates, K fertilizers, K application methods and Soil K status. Further investigations are necessary to determine the proper K application rate and method and the relative suitability of K fertilizers for pistachio production.

Introduction

Potassium (K) is an essential plant nutrient and is involved in most plant functions. Little is known, however, about K nutrition in pistachio trees. Recent studies indicate that nutrient uptake by pistachio is driven by sink demand (Brown et al., 1995) and alternate bearing strongly regulates nutrient uptake and distribution in pistachio trees (Rosecrance, 1996; Weinbaum et al., 1994).

Pistachio trees have a high K demand and the annual K removal by fruits and leaves approaches N removal (166 lbs K vs. 188 lbs N per acre) (Rosecrance et al., 1996). Currently, however, K fertilization is not commonly practiced in California pistachio orchards. Consequently, K deficiency has been identified in limited areas and will likely increase in severity in the future. We anticipate that K deficiency in pistachio occurs primarily due to:

a) depletion of soil K after long term cultivation with limited use of K fertilizers;
b) increased crop yield, giving rise to high K removal and demand by pistachio tree;
c) strong K-fixation capacity of soils in some orchards, reducing soil K availability and the efficiency of applied K.

Table 1. The treatments used in the pistachio experiment (1996).

Treatments	K Rates (lbs K/acre)	Actual Fertilizer Materials* (lbs/acre)			
		K_2SO_4	KCl	KNO_3	Gypsum
1. Control (K_0)	0	0	-	-	-
2. K_1-K_2SO_4 - Micro-sprinkling	100	238	-	-	-
3. K_2-K_2SO_4 - Micro-sprinkling	200	476	-	-	-
4. K_3-K_2SO_4 - Micro-sprinkling	300	714	-	-	-
5. K_2 - KCl - Micro-sprinkling	200	-	400	-	-
6. K_2- KNO_3 - Micro-sprinkling	200	-	-	555	-
7. K_2-K_2SO_4-Soil banding	200	476	-	-	-
8. K_2-K_2SO_4-Micro-sprinkling + Gypsum#	200	476	-	-	650

* Rate of each K fertilizer is calculated based on their K analysis: K_2SO_4 = 42% K; KCl = 50% K; KNO_3 = 36%.
\# Treatment 8 (K + gypsum) was applied to Yolo and Madera orchards only, not to Orland orchard.

Potash fertilization can correct K deficiency and may improve nut yield and quality in pistachio. Little is known, however, about the K fertilization requirements of pistachio and its effects on tree growth, nut yield, and quality in pistachio. No yield-based K diagnostic criteria have been developed to determine K deficiency or sufficiency in pistachio trees. Furthermore, the relative suitability and effectiveness of different K fertilizers for pistachio production have not been adequately determined.

Understanding K nutrition in pistachio trees and the suitability of K fertilizers is critical for developing sound fertilizer programs for pistachio. The primary objectives of this study are to: a) determine the effects of K fertilization on tree nutrient status and fruit production; b) identify K fertilizers, K application rates and K application methods that are optimal for pistachio trees; and c) develop diagnostic criteria for K deficiency and sufficiency in pistachio.

Procedures

Field trials with mature 'Kerman' trees were established in 3 commercial orchards, i.e., Agri World in Madera, Triple P Ranch in Yolo, and American Almond Orchard in Orland during the first year of this project. These orchards are micro-sprinkler irrigated and soils are sandy to loamy with organic matter content in the range of 0.36-1.15%, pH 6.5-7.3, and CEC 8.5-11.5 meq/100 g. Exchangeable K was 156, 78 and 117 ppm in Yolo, Madera and Orland orchards, respectively.

Identical treatments were applied in all 3 orchards. Seven treatments were initiated (Table 1): 4 K application rates (0, 100, 200 and 300 lbs K/acre), 3 K fertilizers (K_2SO_4, KCl and KNO_3) and 2 K application methods (micro-sprinkling vs. soil banding). Equal doses of nutrients other than K were applied to all treatments. At Yolo and Madera orchards, one satellite treatment, in which 650 lbs gypsum per acre was supplemented with 200 lbs K/acre as K_2SO_4, was set up to look at the effects of gypsum on soil K availability and plant K uptake in pistachio.

Treatment fertilizers were applied in 4 equal splits at one month intervals during May to August, 1996. Except for Treatment 7 in which K as K_2SO_4 was banded to soil surface, fertilizers were applied via a specially designed fertigation system which allowed for the injection of fertilizer solutions into each individual plot, using the Solution Master fertilizer injection tank provided by the Soil Solutions Corporation (Visalia, CA).

Treatments were applied to plots which consisted of 4 (Orland and Yolo orchards) or 5 (Madera orchard) adjacent trees on the same row and replicated 5 times. The plots were arranged in complete randomized block design. To avoid inter-treatment nutrient uptake by penetrating roots, treatment plots were isolated from each other by border trees and rows. Representative soil and plant tissue samples were collected. Soils were sampled from 0 to 40 cm depth in the root zone prior to the trials and leaves were sampled at random around the tree on a monthly basis

during May to September. Trees were harvested on September 13, 14 and, 24 in Yolo, Orland and Madera orchards respectively and yield were determined by plot.

Results and Discussion

I. Effects of K fertilization on leaf K status in pistachio.

Our preliminary data indicate that K application increased leaf K concentration over the control treatment in all 3 orchards (Fig. 1 and 2). However, the magnitude of increase varied with phenological stages, K application rates, K fertilizers, K application methods, and soil types. Among the different K treatments, there was a trend for higher leaf K concentration using K_2SO_4 than KCl or KNO_3 (Fig. 3). Potassium application via micro-sprinklers resulted in higher leaf K concentration than banding to soil surface (Fig. 4). However, these trends need to be further studied. Variations in leaf K response to K application among these orchards may be associated with soil properties, particularly soil K availability and K-fixation capacity. These are critical for improving the K fertilizer efficiency and will be investigated next year.

One factor limiting the widespread use of KCl is that Cl may become toxic to Cl-sensitive plants (Marschner, 1995). Our preliminary data (Fig. 5) indicate no significant difference in leaf Cl concentration among KCl, K_2SO_4, KNO_3 and the control treatment, with all values falling within the optimal Cl range suggested by Brown (1995). However, these data are not sufficient to suggest whether pistachio trees are sensitive to Cl or not. Scorching of bearing 'Kerman' leaves with high Cl accumulation was observed in California (Ashworth et al., 1985), even though pistachio was considered to be salt-tolerant (Sepaskhah and Maftoun, 1981). Further studies on the sensitivity of pistachio to Cl are necessary to determine the suitability of KCl for pistachio.

II. Pistachio nut yield and quality as affected by K application.

Our preliminary data (Table 2) indicate that K application increased nut yield over the control treatment in all 3 orchards. In the Madera orchard where the soil was the most deficient in K (78 ppm K), the trees applied with 100 or 200 lbs K/acre as K_2SO_4 yielded significantly higher than did those without K. Whereas in Yolo and Orland orchards where the soil K was relatively abundant (156 and 117 ppm K), no significant differences were found between trees

Figure 1. Seasonal variation in leaf K of pistachio. K was applied as K_2SO_4 at the rate of 200 lbs K/acre via micro-sprinkler. Each value is the mean ± standard error of 2 replicates in May and June and of 5 replicates in July to September.

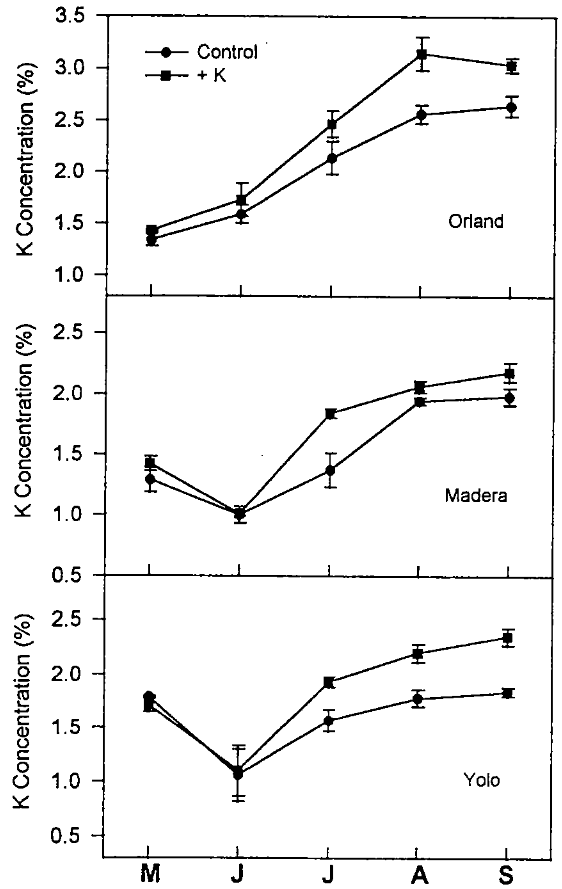

Figure 2. Leaf K changes with K applicaton rates in pistachio (August). The K source was K_2SO_4 applied via micro-sprinklers. Each value is the mean of 5 replicates ± standard errors.

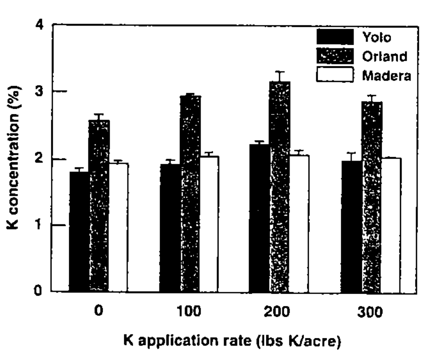

Figure 3. Leaf K as affected by different K fertilizers in pistachio (August). K was applied at the rate of 200 lbs K/acre via micro-sprinklers. Each value is the mean of 5 replicates ± standard errors.

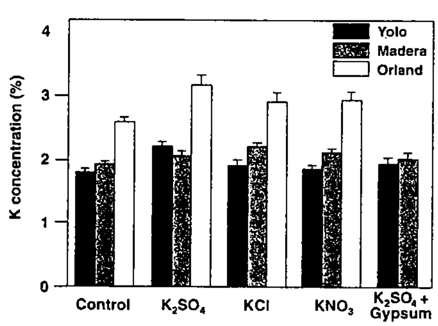

Figure 4. Leaf K as affected by different K application methods in pistachio (August). K was applied as K_2SO_4 at the rate of 200 lbs K/acre. Each value is the mean of 5 replicates ± standard errors.

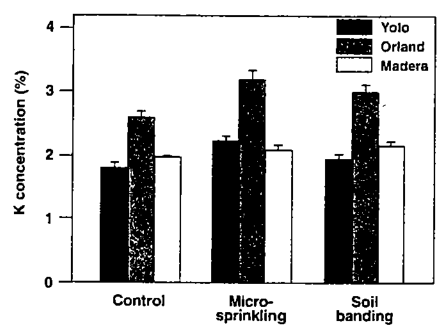

Figure 5. Leaf Cl as affected by different K fertilizers in pistachio (September). K was applied at the rate of 200 lbs K/acre via micro-sprinklers. Each value is the mean of 5 replicates ± standard errors.

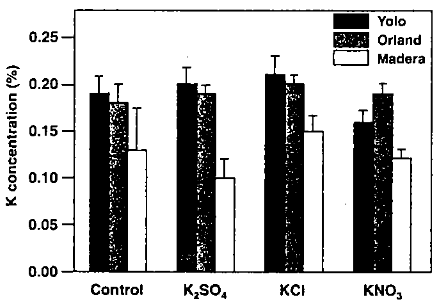

Table 2. Pistachio nut yield as affected by K application (1996).

Treatments	Nut Yield* (lbs/acre)		
	Yolo	Madera	Orland
1. Control (K_0)	1259 a	820 c	2718 a
2. K_1 - K_2SO_4 - Micro-sprinkling	1419 a	2182 b	3521 a
3. K_2 - K_2SO_4 - Micro-sprinkling	1673 a	1796 b	3547 a
4. K_3 - K_2SO_4 - Micro-sprinkling	1430 a	689#c	3069 a
5. K_2 - KCl - Micro-sprinkling	1225 a	3389 a	2921 a
6. K_2 - KNO_3 - Micro-sprinkling	1511 a	1606 bc	3014 a
7. K_2 - K_2SO_4 - Soil banding	1605 a	1516 bc	3016 a
8. K_2 - K_2SO_4 - Micro-sprinkling + Gypsum	1572 a	1255 bc	

* Each value is the mean of 5 replicates. Values with different letters are significantly different at $P=0.05$ level according to Fisher's Protected LSD test.

\# Several of the treatment trees in this treatment produced few nuts this year.

Table 3. Effects of K application on nut quality in pistachio (1996).

	% Split		% Blank		% Stained		100-nut weight (g)	
Trt.	Orland	Madera	Orland	Madera	Orland	Madera	Orland	Madera
1	55.8 b	58.6 c	16.0 b	23.4 a	6.6 a	11.8 a	98 b	104 b
2	63.4 ab	69.6 b	11.4 bc	8.4 b	3.4 ab	3.8 c	105 ab	119 ac
3	71.8 a	76.8 ab	11.8 bc	9.4 b	4.0 ab	3.8 c	101 ab	118 ac
4	60.6 ab	73.2 ab	9.8 c	8.8 b	0.6 b	2.0 c	102 ab	117 ac
5	59.2 b	79.2 a	17.6 a	9.0 b	1.8 b	1.4 c	102 ab	116 ac
6	59.0 b	75.2 ab	13.0 abc	6.2 b	3.0 ab	1.8 c	106 a	121 a
7	64.2 ab	77.6 ab	12.0 bc	11.4 b	3.4 ab	4.4 abc	99 ab	119 ac
8		71.6 ab		11.2 b		7.0 b		111 ab

Fruits samples were collected at harvest. Each value is the mean of 5 replicates. Values with different letters are significantly different at $P=0.05$ level according to Fisher's Protected LSD test.

with and without K. There was also no significant differences in nut yield between micro-sprinkling and soil banding. These results are expected in the first year because of the high K storage in pistachio tree (Brown et. al., 1995). We anticipate more significant response to K application when the stored K is consumed next year.

Potassium can improve crop quality (Usherwood, 1985) and decrease susceptibility to diseases (Huber and Arny, 1985) in plants. Our preliminary data (Table 3) indicate higher percent split nuts and 100-nut weight, but lower percent blank and stained nuts due to K application in Madera orchard. Nut staining is often considered to be caused by *Botryosphaeria dothidea* or *Alternaria alternata* (Michailides, 1995). The potential of K to improve the quality of pistachio nuts requires further testing.

III. Response of pistachio to gypsum application.

Gypsum ($CaSO_4$) is commonly used to improve soil infiltration in California. The K availability increased both vertically and horizontally in soil when treated with gypsum. Gypsum acts as a displacing agent when applied in prune (Carlson et al., 1974) and wine grapes (Mathews, 1995). Our preliminary data in the first year indicate no significant differences in nut yield (Table 2), nut quality (Table 3), and leaf K, Ca and Mg concentrations (Table 4) between trees with and without gypsum. The effects of gypsum on soil K availability and plant K uptake in pistachio will be further evaluated next year.

Conclusions

Our data from the first year of this project indicate that K application increased leaf K concentration, nut yield and quality in pistachio. However, the magnitude of pistachio responses to K was complicated and was affected by K application rates, K fertilizers, K application methods and soil K status. Effects of gypsum were not significant in the first year. Since pistachio trees contain significant stores of K, we expect treatment differences to be more pronounced in year 2 and 3. Further work on the establishment of K fertilization practice will be conducted in the coming years of this project. Preliminary results, however, are promising. Further optimization of K fertilization programs for pistachio will require consideration of the mechanisms of K uptake by the plant and soil K availability. These issues will be considered in 1997 and 1998.

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Table 4. Leaf cation concentrations (%) as affected by gypsum application in pistachio (September 1996).

	K		Ca		Mg	
Treatments	**Madera**	**Yolo**	**Madera**	**Yolo**	**Madera**	**Yolo**
Control	1.98 a	1.84 b	2.06 b	2.97 a	0.45 a	0.86 a
200 lbs K/acre	2.17 a	2.34 a	2.13 b	2.99 a	0.46 a	0.85 a
200 lbs K/acre + 650 lbs gypsum/acre	2.12 a	2.27 a	2.53 b	3.02 a	0.37 a	0.81 a

The K was applied as K_2SO_4 via the micro-sprinklers. Each value is the mean of 5 replicates. Values with different letters are significantly different at $P=0.05$ level according to Fisher's Protected LSD test.

their orchards and their invaluable cooperation throughout the year.

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