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Phosphorus and Potassium Nutrition: A Summary of Two Twenty-Nine Year Experiments

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Introduction

The object of this work was to study the behaviour of the avocado Hass with potassium (K) leaf levels between 0.3% and 0.7%; also to induce phosphorus (P) deficiency in an especially poor soil.

Materials and Methods

Two Hass avocado plantings on Topa-Topa rootstock were established in April 1973. In both plots the soil was of metamorphic origin, permeable, neutral and free of carbonates. Soils and management until 1982 were described by Casado *et al.* (1984). From 1990 they were kept with a cut natural sward, green in winter and dry in summer. The wet area was kept weed free with glyphosate, oxyfluorfen, or simazine in successive periods. The irrigation water was of good quality, with electrical conductivity under 1 dS/m^{-1}, and high contents of HCO_3, Ca^{2+} and Mg^{2+}. Each autumn, leaf blades of spring grown flush were analyzed according to Lachica *et al.* (1973).

PK Experiment

In the PK experiment the soil was rocky and poor. The treatments P_0K_0, P_0K_1 P_1, K_0 and P_1 K_1 were compared. From 1973 to 1998 the P_1 treatments received an average of 78 $k/ha^{-1}/year^{-1}$ of P and the K, treatments 388 $k/ha^{-1}/year^{-1}$ of K. Between 1999 and 2001 they received 38 $k/ha^{-1}/year^{-1}$ of P and 207 $k/ha^{-1}/year^{-1}$ of K always as calcium superphosphate and potassium sulphate. The initial planting distance was 6x6 meters. The design was on randomized blocks with 4 replicates of 4 trees per treatment. The border trees were eliminated in 1986 and substituted by a vertical polyethylene film down to the rocky subsoil. The experiment was drip irrigated until 1990. Later on 2.5 spitters per tree, wetting 11% of the surface soil, were used. Foliar zinc was applied in the years 1977 to 1981, and 1999 to 2001.

Four Levels of K

The experiment comparing 4 levels of K (K_0, K_1 K_2 and K_3) had a similar soil although somewhat richer because it had been cropped with vegetables for several years.

Between the years 1973 and 1998, mean annual applications were 251 k/ha^{-1} for K_1 495 for K_2 and 642 for K_3 as potassium sulphate. In the 1999 - 2001 period the annual applications were 95, 125 and 332 k/ha^{-1} of K to the treatments K_1, K_2 and K_3 respectively. Planting distances were, initially, 4x4 meters in randomized blocks with 4 replicates and 16 trees per plot. They were thinned in 1982 to 8 x 4m and in 1990 to 8 x 8 m with 4 trees per plot and treatment. There were no border trees or root separation barriers. Trees were irrigated with 3 drippers until 1982 and 5 drippers in 1982-1985. In 1986, a micro irrigation system, wetting 40% of the surface area, was installed. Except in the two drought years (1994/1995), soil matric potentials in the wet areas were kept between 0 and -50 kPa. Zinc foliar sprays were applied every year in July and September. To prevent iron deficiency, Fe-EDDHA was applied regularly. From 1996, boron was applied in the irrigation water increasing leaf levels from 15 mg/k^{-1} in 1996 to 24-35 mg/k^{-1} in 1998.

Table 1. PK experiment. Summary of yield parameters.

Seasons	Yield k .tree^{-1}.year^{-1}		Tree efficiency g .cm^{-2} trunk area		Mean fruit weight g.		Leaf K (Ψ) %	
	Coefficient $K_0.K_1^{-1}$	Difference K_1-K_0 Level of significance	Coefficient $K_0.K_1^{-1}$	Difference K_1-K_0 Level of significance	Coefficient $K_0.K_1^{-1}$	Difference K_1-K_0 Level of significance	K_1	K_0
1978-81	1,047	N.S.	0,938	N.S.	0,943	**	0,69	0,58
1982-85	0,793	**	0,800	*	0,914	*	0,60	0,42
1986-87	0,733	**	0,723	**	0,918	N.S.	0,54	0,33
1988-89	0,877	N.S.	0,900	N.S.	0,906	*	0,67	0,36
1990-93	0,973	N.S.	0,966	N.S.	0,978	N.S.	0,78	0,52
1995-96^{s}	1,156	N.S.	1,005	N.S.	0,942	**	0,75	0,27
1997-98	1,063	N.S.	0,996	N.S.	0,933	*	0,86	0,44
1999-00	0,730	**	0,760	*	0,980	N.S.	0,87	0,49
2001-02	0,960	N.S.	0,970	N.S.	0,920	**	0,89	0,63

s : Two year dry period. *** :** Level of significance 95 % **** :** Level of significance 99 %
Ψ**:** Leaf analysis in the autumn previous to picking.

Results and Discussion

PK Experiment

• Phosphorus

Even in the P_0 treatment (without phosphorus) the leaf blade P content has kept above the critical 0.10% level (Figure 1) except for the last five years. In none of the two or four-year periods studied (Table 1) were there significant differences in yield, tree efficiency (yield/cm^{-2} trunk sectional area) or mean fruit weight between P_0 (unfertilized) and P_1 (fertilized) trees. The global means for the periods studied (not shown) were practically identical.

• Potassium

During the years 1984 to 1988 (Figure 2) the treatments without K (K_0) had leaf contents consistently under 0.4%. They were also lower in the two-year drought period, 1995-1996. Yield and tree efficiency (Table 1) were significantly lower than the

treatments with potassium (K_1) during the periods 1982-85, 1986-87 and 1999-2000. Mean fruit weight was lower in the K_0 in all the studied periods, with statistically significant differences in 8 out the 12 two-year periods.

The change from drip to spitter irrigation in May 1991, with a small increment of the wet area, increased leaf K contents in both K_0 and K_1. Drought in the biennial period 1994-95 decreased leaf levels.

Figure 1. PK experiment. Leaf lamina P levels

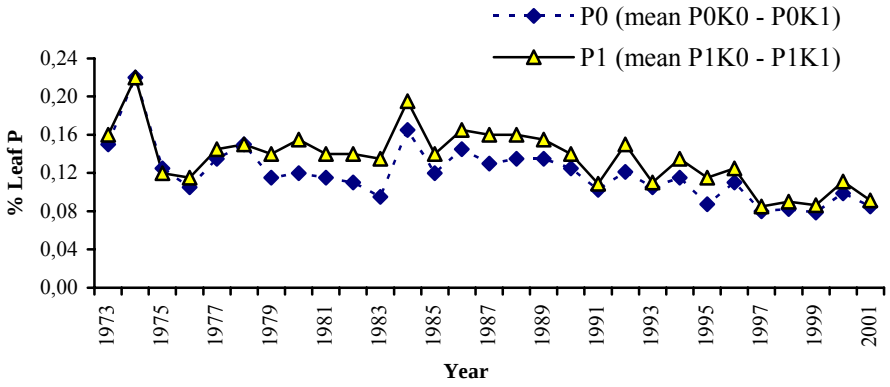
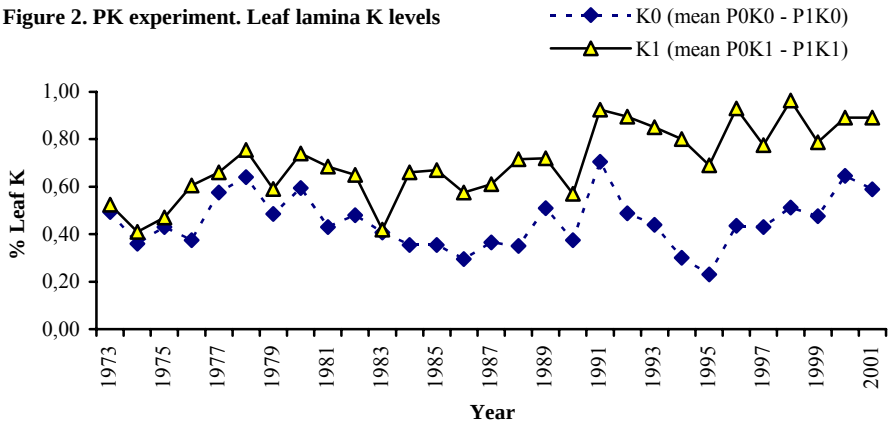


Figure 2. PK experiment. Leaf lamina K levels



K experiment

Treatment K_2 lost one plot in 1991 and it has been eliminated from the statistical analysis. Only during the two years 1983-84 the treatment without K fertilizer (K_0) had a leaf K level below 0.4% (Figure 3). During the same period treatment K_3 had significantly higher yield and tree efficiency than K_0 and K_1. No differences between treatments were recorded for yield, tree efficiency or mean fruit weight in the periods 1979-1982,1984-1985, 1987-90,1991-94,1995-96,1997-98,1999-2000 nor 2001-2002. The weighted means of all of them, including 1983-84, do not show significant differences (Table 2).

After the change in 1986 from drip to sprinkler irrigation, probably due to the 300% increase in wet area, K leaf levels increased for several years.

As it happened in the PK trial, during the two year drought (1995-1996) the trees without K (K_0) had smaller reductions of yield and tree efficiency than the fertilized ones (K_1 and

K_3) (data not shown).

Figure 3. K experiment. Leaf lamina K levels

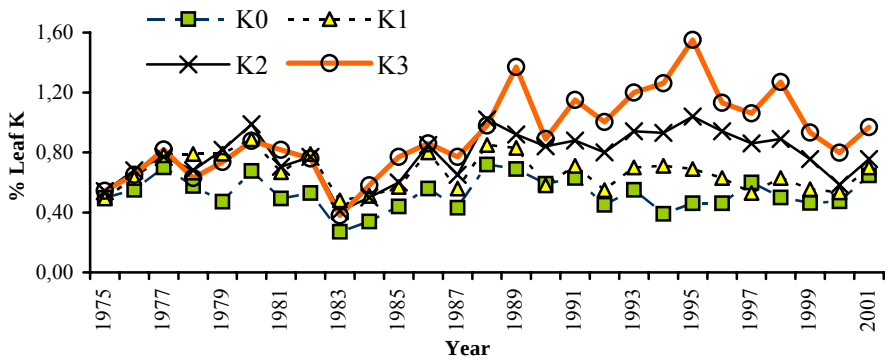


Table 2. K experiment. Summary of yield parameters

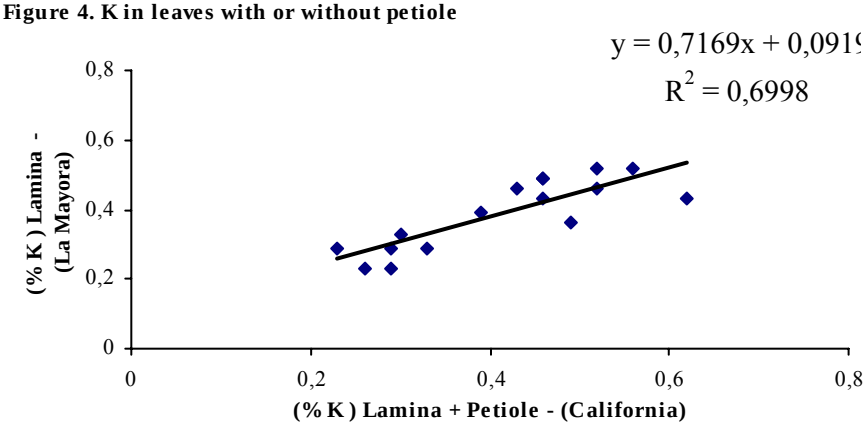
	Yield $t.ha^{-1}.year^{-1}$	Tree efficiency $g.cm^{-2}.year^{-1}$	Mean fruit weight (g)	Trunk area 2001/02 (cm^2)
K_0	14,3	115	241	1231
K_1	11,4	115	264	970
K_3	11,8	115	248	1134

Table 3. Leaf mineral levels (%)

	Lamina	Lamina + petiole	Petiole
N	1,99	1,80	0,78
P	0,13	0,13	0,14
K	0,38	0,41	0,65
Ca	2,09	2,21	2,56

To compare the results shown here of leaf lamina analysis with work done in other countries (i.e. California) where lamina and petioles were analyzed together, 16 comparative analysis were made (Table 3). There were no differences for phosphorus. Potassium showed a significant linear regression, lamina contents being much lower than petiole's (Figure 4). The contrary happened with nitrogen.

Figure 4. K in leaves with or without petiole

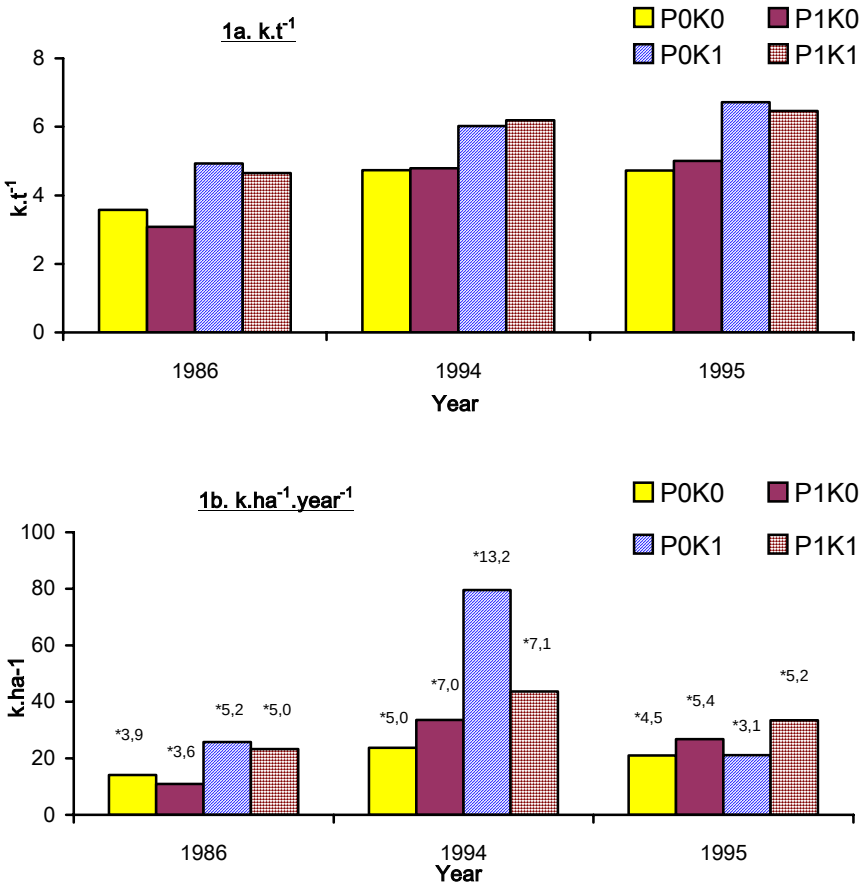


In May 2000, near the end of the picking period, postharvest fruit rotting was studied after ripening at room temperature. Fruits were big (mean fruit weight 252 g.) due to the heavy hedgerow pruning. Treatments K_2 and K_3, with 0.85% leaf K in the previous autumn, had approximately double percentage of fruits heavily rotted by *Colletotrichum*

gloeosporioides (body rot) and stem end rot. Also half the percentages of fruits totally rot free than K_0 and K_1 with 0.52% leaf K. Only the differences in stem end rot were statistically significant (data not presented).

After 13, 20, and 22 years from the start of the experiment K extraction by fruits from both experiments were studied (Figures 5 and 6). K fertilization levels were closely correlated with leaf and fruit contents. In the K trial, with high K fertilization, "luxury" exports were registered not associated with increased tree efficiency.

Figure 5. PK experiment. K losses in fruit.



Conclusions

In the PK experiment, with a poor soil and small wet area, K deficiency in the cv. Hass appeared with leaf lamina K below 0.5%.This did not happen in the K experiment, with a richer soil, where a 0.5% content kept, in these trials, yield and growth similar to higher contents. Fruit weight was more sensitive than yield and tree efficiency to low leaf lamina K levels. When the wet soil volume was increased, K absorption was improved in both experiments. In the dry two-year period (1995-96) the treatments with K had a slightly bigger decrease of yield and tree efficiency than control trees without K even though they had leaf contents below 0.3% in the PK experiment. A negative osmotic

effect of the K fertilizer at the root level can not be discarded at low soil matric potentials.

There were no differences between the P treatments with leaf foliar levels extending over the 0.08% to 0.17% range.

It appears that with big shoot growth and fruit size, high K leaf contents may increase fruit susceptibility to fungal attack.

References

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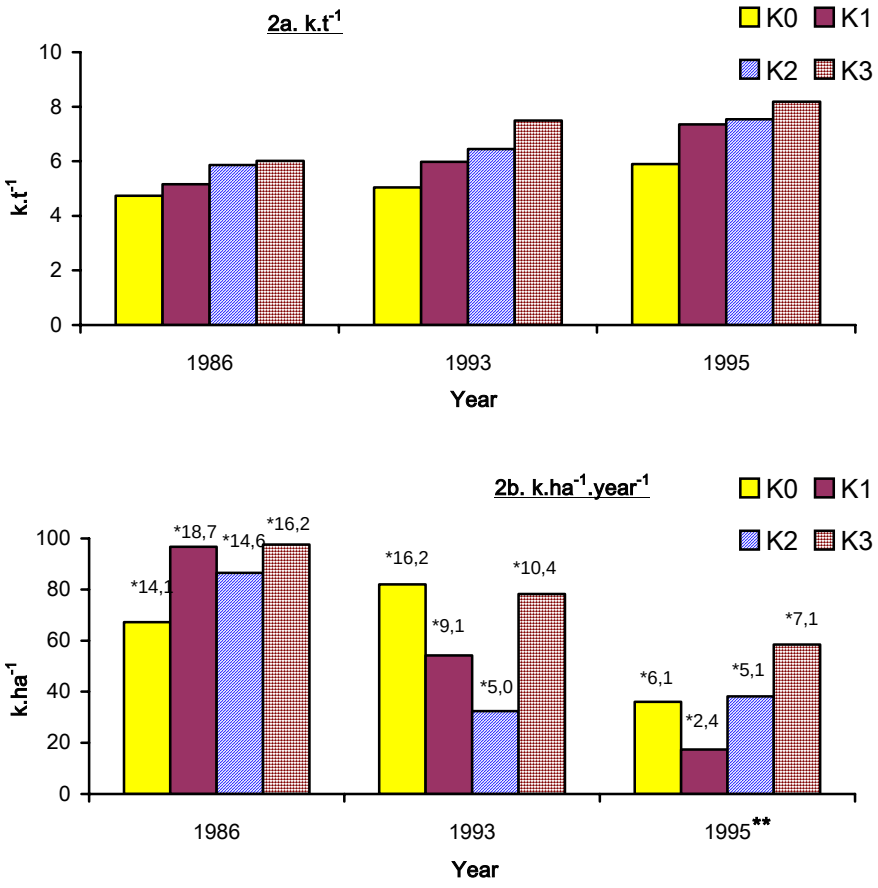
Lachica M, Aguilar A, Yáñez J (1973). Análisis foliar. Métodos utilizados en la Estación Experimental del Zaidín. (II) Anal. Edaf. Y Agrobiol. XXXII, N° 11-12:1033-1047.



***** Yield (t.ha^{-1}).

** 1995 was a drought year.