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# AVOCADO MINERAL NUTRITION
# THE WATER-NUTRIENTS RELATIONSHIP

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## SUMMARY

It has been well established that irrigation practices and mineral nutrition have a significant effect on the avocado tree growth, production and fruit quality. With the introduction of modern pressurized irrigation systems, which incorporates fertilizers into the irrigation system (Fertigation), water and nutrients should be looked as inter-related factors.

Till now, the most common way to understand the effect of water on the avocado nutrition is by the leaf mineral analysis. Correct leaf sampling is a crucial factor for the accurate nutrition assessment. Only spring flush leaves should be sampled in the autumn. The best criterion for correct sampling is the calcium level. In autumn sampling, Ca level in the spring flush leaves should be in the range of 1.7%-2.2%.

The water effect on the avocado nutrition can be summarized as follows:

The rainy season is followed by increase in N,P,K and decrease in Ca and Mg (Martinique) and heavy rainfall results in decrease in Cl level (Israel).

Irrigation method but slightly affects avocado nutrient levels. Drip irrigation increases Cl and Mn concentrations as compared to flood irrigation in Texas and Cl level as compared to microjets in Israel. One of the effects of dripping on avocado nutrition is via its effect on soil aeration .There are many instances where conversion of chlorotic avocado orchards from flood or sprinkler to drip reduced iron induced chlorosis. There is some effect of irrigation interval as frequent irrigations increase iron induced chlorosis and Cl levels in the leaves.

Water amount is the best way, except fertilization itself, to control avocado nutrition. Increased water amount increase Na, Cl and B probably due to the increased quantities of these elements applied with the water. On the other hand applying more water reduce N,P,Ca,Mg,Fe and Zn levels

in the leaves, largely a dilution effect resulting from increased growth or leaching. Controlling water amount is essential to reduce leaching and pollution of underground water.

In parallel to the world water shortage, the use of saline water for avocado irrigation is increasing from year to year. Salinity increases not only Cl and Na concentrations in the leaves but also K,Zn, and Cu and decrease N,Mn, and possibly P and Mg. Another possible future source for avocado irrigation may be reclaimed wastewater which contain high levels of salts and nutrients. The use of reclaimed wastewater result in increased levels of Cl, Na and B. In that aspect, leaf analysis serves as a monitoring tool (in preventing excess of toxic elements) rather than nutrition assessment. Water analysis before and during the irrigation season and adjustment of fertilizers accordingly, might reduce the growers expenses.

## BACKGROUND

It has been well established that irrigation practices and mineral nutrition have a significant effect on the avocado tree growth, production and fruit quality.

With the introduction of modern pressurized irrigation systems, which incorporates fertilizers into the irrigation system (Fertigation), water and nutrients should be looked as inter-related factors.

Till now, the most common way to understand the nutritional status of avocado and its nutrition is by the leaf mineral analysis. Correct leaf sampling is a crucial factor for the accurate nutrition assessment. Only spring flush leaves should be sampled in the autumn (Fig. 1). The best criterion for correct sampling is the calcium level. In autumn sampling, Ca level in the spring flush leaves should always be in the range of 1.7-2.2% (Fig.2).

**Fig. 1.** Spring flush leaves.

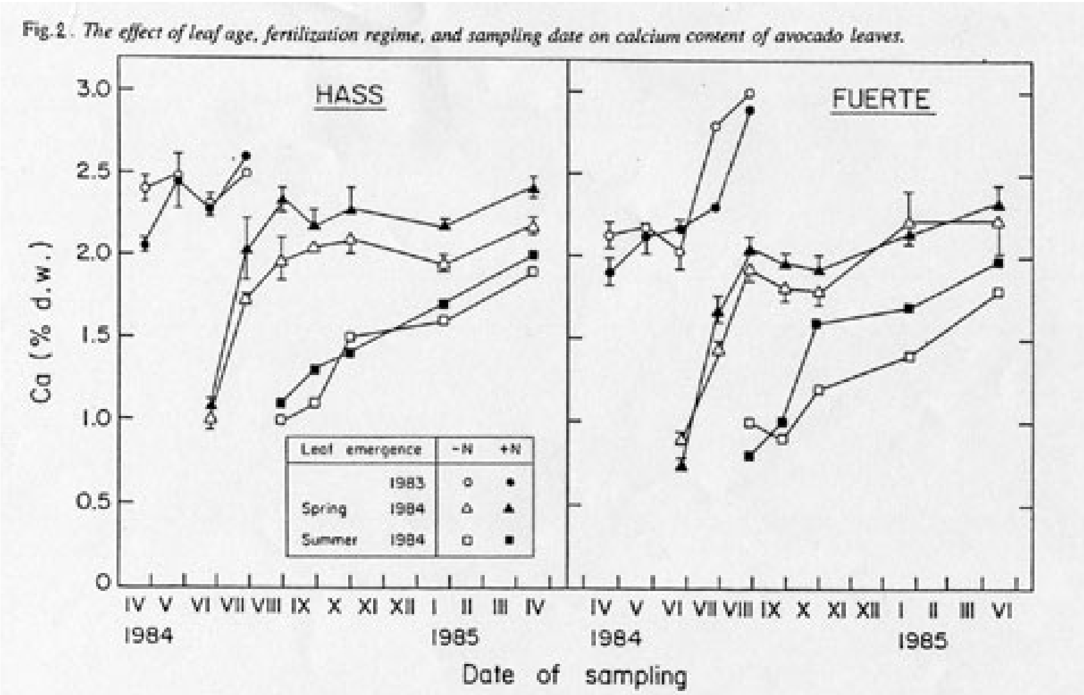


**Fig. 2.** The effect of leaf age, fertilization regime and sampling date on calcium content in avocado leaves.

The water effect on avocado nutrition as expressed by leaf mineral composition can be summarized as follows:

## WATER EFFECT

### Precipitation

The effect of the rainy season on the nutrient levels was tested on 'Lula' leaves in Martinique (Bertin et al., 1976). The dry season was accompanied by low levels of N, P and K. Calcium and Mg concentrations increased at the same time but this may be an antagonistic reaction to the low K levels.

A significant relationship was found between winter precipitation and Cl level the following autumn especially in 'Fuerte' leaves (Fig. 3). Increased rainfall resulted in increased leaching and reduced Cl in the leaves (Kalmar and Lahav, 1976).

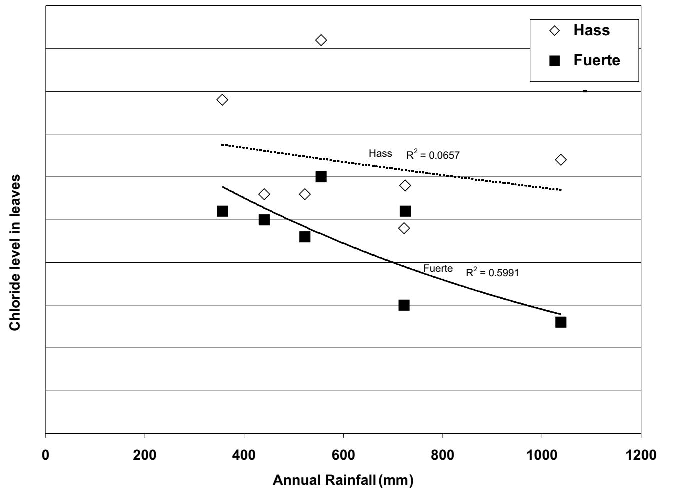


**Fig. 3.** Winter precipitation and Cl level in the following autumn.

## Irrigation Method

Irrigation method but slightly affects avocado nutrient levels. Drip irrigation as compared to flood increases Cl levels in the leaves from 0.47% to 1.35% in Texas (Wutscher and Maxwell, 1975). All other nutrients were not affected except Mn, which was 118 ppm in the drip-irrigated leaves, as compared to 90 ppm in flood-irrigated trees.

Chloride level was significantly higher in drip-irrigated trees (1.9%) as compared to trees irrigated by microjets (1.14%, Fig. 4) in Loess soil in Israel. The difference between drip and microjets is decreasing with increased water amounts (Shimshi et al., 1985).

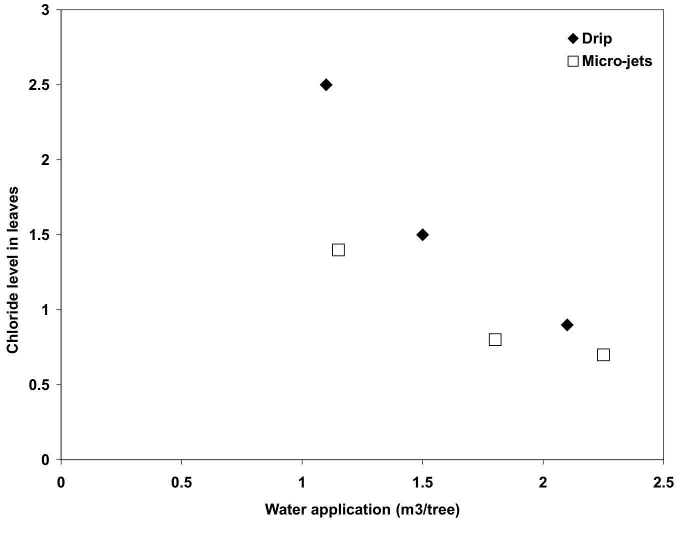


**Fig. 4.** Chloride level in leaves as a function of irrigation method.

One of the effects of dripping on avocado nutrition is via its effect on soil aeration. There are many instances where conversion of chlorotic avocado orchards from flood or sprinkler to drip reduced iron induced chlorosis.

### *Water Amount*

Water application has also an effect on leaf mineral composition. Increasing water amount in several irrigation experiments conducted in Israel during the past 40 years resulted in increased concentration of Na, Cl and B. This was probably due to the increased quantities of these elements applied with the irrigation water. On the other hand, applying more water reduced N, P, Ca, Mg and Zn levels, largely a dilution effect resulting from increased growth. Similar results for nitrogen only were received in California (Embleton *et al.*, 1958; Slowik *et al.* 1979).

In a recent experiment conducted in Israel, four relative water amounts were applied (85%, 100% - commercial amount, 115% and 130%) to 'Ettinger' and 'Hass' trees for six years. The increase in water amount up to 115% increased tree growth, fruits size and yield (Table 1). It seems that additional water amount is excessive and doesn't give any advantage. Tree and fruit growth were reduced by applying 130% water amount and 'Ettinger' yield was reduced as well. Only 'Hass' production increased somewhat.

**Table 1:** The effect of water amount on tree growth, fruit size and yield of 'Ettinger' and 'Hass' (6 years average)

| Relative water amount (%) | | 85 | 100 | 115 | 130 |
|---|---|---|---|---|---|
| Annual trunk growth (%) | Ettinger | 3.12 | 3.45 | 3.80 | 3.92 |
| | Hass | 2.92 | 4.47 | 3.77 | 3.25 |
| Fruit size (g) | Ettinger | 275.2 | 285.1 | 291.2 | 284.6 |
| | Hass | 199.9 | 201.6 | 205.7 | 205.6 |
| Yield (t/ha) | Ettinger | 15.2 | 15.7 | 15.8 | 12.0 |
| | Hass | 17.0 | 18.1 | 18.3 | 19.5 |

Irrigation treatments had a marked effect on the nutrient concentrations in the leaves. Increasing water amount increased K, Zn(antagonism to N and Mn respectively) and B and reduced N, P, Cl and Mn (Table 2). Nitrogen concentration decrease is probably due to leaching below root zone and not due to dilution in the plant tissues since measurements of tree growth (trunk growth, tree visual appearance and yield) had shown a decrease with increasing water amounts. Therefore, it may be concluded that over-irrigation (as well a s over fertilization) reduces N efficiency and increases the hazard of underground water pollution.

**Table 2:** The effect of relative water amount on the nutrient concentration in 'Hass' avocado leaves (% or mg $kg^{-1}$ d.w. during 3 years)

| Nutrient | Year | Relative water amount (%) | | | | S.E. | Sig. |
|---|---|---|---|---|---|---|---|
| | | 85 | 100 | 115 | 130 | | |
| N (%) | **1998** | 1.85 a | 1.82 ab | 1.72 b | 1.60 c | 0.024 | 0.000 |
| | 2000 | 1.78 a | 1.73 a | 1.55 b | 1.46 b | 0.031 | 0.000 |
| | 2001 | 1.86 a | 1.92 a | 1.71 ab | 1.54 b | 0.071 | 0.005 |
| P(%) | **1998** | 0.129 a | 0.132 a | 0.115 b | 0.110 b | 0.0034 | 0.000 |
| | 2000 | 0.136 a | 0.129 a | 0.108 b | 0.103 b | 0.0028 | 0.000 |
| | 2001 | 0.128 a | 0.122 a | 0.101 b | 0.086 c | 0.0049 | 0.000 |
| K (%) | **1998** | 0.75 | 0.76 | 0.78 | 0.92 | 0.048 | n.s. |
| | 2000 | 0.79 b | 0.74 b | 0.76 b | 0.96 a | 0.040 | 0.004 |
| | 2001 | 0.54 | 0.53 | 0.58 | 0.63 | 0.041 | n.s. |
| Cl (%) | **1998** | 0.149 | 0.155 | 0.155 | 0.125 | 0.014 | n.s. |
| | 2000 | 0.150 | 0.150 | 0.140 | 0.110 | 0.017 | n.s. |
| | 2001 | 0.228 a | 0.165 b | 0.169 b | 0.165 b | 0.017 | 0.049 |
| Zn (mg kg-1) | **1998** | 22.8 b | 23.2 b | 25.3 b | 31.0 a | 1.60 | 0.006 |
| | 2000 | 15.1 c | 16.3 c | 20.6 b | 29.8 a | 1.25 | 0.000 |
| | **2001** | 16.8 b | 16.7 b | 21.7 b | 36.6 a | 2.08 | 0.000 |
| Mn (mg kg-1) | **1998** | 108.2 a | 101.5 a | 95.9 a | 72.1 b | 4.17 | 0.000 |
| | 2000 | 165.5 a | 159.0 a | 112.6 b | 94.4 c | 6.18 | 0.000 |
| | **2001** | 162.7 a | 122.5 ab | 119.9 ab | 108.0 b | 12.67 | 0.033 |
| B (mg kg-1) | **1998** | 35.9 b | 38.6 b | 50.9 a | 53.1 a | 3.96 | 0.011 |
| | 2000 | 21.9 c | 25.8 b | 32.3 a | 34.6 a | 1.21 | 0.000 |
| | **2001** | 23.2 c | 27.9 bc | 35.0 ab | 42.2 a | 2.63 | 0.002 |

**Water Quality**

In parallel to the water shortage, the use of saline water for avocado irrigation is increasing from year to year. A long-term salinity experiment was conducted in an avocado plantation in the Western Galilee, Israel (Steinhardt *et al*., 1989).The treatments, in a factorial design, comprised of three levels of Cl ion (90, 250 and 400 mg/$L^{-1}$) in the irrigation water. In another treatment, increased N application (100 mg$L^{-1}$ as $NH_4NO_3$) was applied to the medium salinity level. Salts were applied as NaCl and $CaCl_2$. All treatments included continuous nitrogen fertilization as $(NH_4)_2SO_4$ and $K_2SO_4$ at a rate of 25 mg $L^{-1}$. Nutritional status was assessed annually by leaf sampling.

As expected Cl and sometimes also Na levels increased in the leaves with increasing salinity (Table 3). The Cl level in the West-Indian salt resistant rootstocks was almost one third of that in the Mexican rootstock. It is interesting to note that the Cl level in the low salinity Mexican rootstock leaves is equal to the level in the high salinity West Indian leaves. Additional applied N did not affect N levels but significantly reduced Cl concentration in the leaves.

**Table 3:** The effect of salinity and supplementary nitrogen on the nutrient concentrations (% d.w.) of 'Hass' avocado leaves

| Nutrient | Rootstock | Chloride concentrations mg/L$^{-1}$ | | | | S.E. |
|---|---|---|---|---|---|---|
| | | 90 | 250 | 20+N | 400 | |
| Cl | West-Indian | 0.12 b | 0.38 a | 0.19 b | 0.41 a | 0.03 |
| | **Mexican** | 0.45 d | 1.05 b | 0.74 c | 1.27 a | |
| Na | West-Indian | 0.0058 b | 0.0123 a | 0.0120 a | 0.0099 a | 0.001 |
| | **Mexican** | 0.0124 | 0.0126 | 0.0110 | 0.0125 | |
| N | West-Indian | 1.67 a | 1.58 ab | 1.62 ab | 1.57 b | 0.03 |
| | **Mexican** | 1.67 a | 1.60 ab | 1.62 ab | 1.49 b | |
| P | West-Indian | 0.095 a | 0.094 ab | 0.090 ab | 0.085 b | 0.002 |
| | **Mexican** | 0.093 a | 0.089 ab | 0.087 ab | 0.084 b | |
| K | All | 0.69 b | 0.75 a | 0.76 a | 0.75 a | 0.02 |

Generally, N and P concentrations were reduced in parallel with the increased salinity. This might be related to some damage caused to the roots, which affected their development and uptake ability.

Potassium levels were also affected by salinity; increased salinity caused increased K content. These effects may indicate a specific physiological defensive barrier against salinity as found by Ben-Hayyim (1987), who reported that citrus cells resistant to salinity contained more K than regular cells.

In some cases, irrigation water itself contain certain concentration of elements that can either serve as a nutrient (Ca, Mg, N, S), or can be toxic in case of high concentration (Cl, B, Na). A nitrogenous field experiment in Israel (Oppenheimer, 1974)which tested from 0 to 5 kg N/tree, showed but slight effect on N content in the leaves (Table 4) and failed to show any significant effect on the avocado tree growth and production. Only water analyses indicated that the unfertilized control trees received 1.75 kg N/tree which was sufficient for normal N concentration in the leaves and optimal production. Each fertilizer application in this orchard was leached by irrigation and rainfall and just contributed to the pollution of underground water.

**Table 4:** The effect of nitrogen application on production and nutrient levels in the leaves (average for 4 cultivars and 6 experimental years).

| | | | | | |
|---|---|---|---|---|---|
| **N kg/tree/year** | 0 | 1.25 | 2.5 | 3.75 | 5.0 |
| **- as planned in practice** | 1.75 | 3 | 4.25 | 5.5 | 6.75 |
| **Average yield (kg/tree)** | 72.6 | 71.7 | 67.7 | 77.1 | 71.7 |
| **Leaf analysis (% d.w.)** | | | | | |
| **N** | 1.81 | 1.84 | 1.95 | 1.97 | 1.98 |
| **Ca** | 1.89 | 1.88 | 1.98 | 2.03 | 2.13 |
| **K** | 1.26 | 1.12 | 1.17 | 1.11 | 1.11 |

Therefore, in order to optimize the fertilization (or fertigation) program, it is advisable to analyze water before and during the irrigation season and to adjust fertilization accordingly. It is also advisable to calibrate fertilizer applications to the nutrient demand and seasonal growth patterns in the avocado as suggested by Whiley *et al*. (1988). However, very little data and experimental results exists in this direction.

### Irrigation Method And Irrigation Intervals

In a research in the Western Galilee, which has started in 1998 and is till being carried, a comparison between drip and micro sprinklers (20 and 70 l/h discharge and 1.5 and 3.0 mm/h application rate respectively), irrigation intervals is being done. The experiment is carried on 'Hass', 'Ettinger' and 'Ardit' cultivars, grown on a clay soil, in a randomized blocks design, in five replications. Statistical analyses had been done both in one-way analysis (for all treatments) and two-way analysis (for the micro sprinklers treatments only).

When comparing all the treatments (one-way analysis), a trend of higher leaf potassium were measured in the 70 l/h micro-sprinklers, irrigated once a week (not significant in all years and cultivars), while in most samples, lower levels were measured in the drip-irrigated treatments (Table 5).

**Table 5.** Potassium concentration in avocado leaves (% of dry matter) of 'Ettinger' (E), 'Hass' (H) and 'Ardit' (A) – one-way analysis (all treatments). Akko 1998-2002.

| Year/ Variety | Drip/ Daily | Drip/ Twice a week | Micro 20/ Daily | Micro 20/ Once a week | Micro 70/ Daily | Micro 70/ Twice a week | S.E. | Sig. |
|---|---|---|---|---|---|---|---|---|
| 1998 E | 0.825 b | 0.725 b | 0.795 b | 0.810 b | 0.955 a | 1.040 a | 0.039 | 0.001 |
| 1999 E | 0.810 ab | 0.732 b | 0.824 ab | 0.890 a | 0.895 a | 0.810 ab | 0.034 | 0.044 |
| 2000 H | 0.704 | 0.818 | 0.657 | 0.738 | 0.753 | 0.818 | 0.056 | n.s. |
| 2001 E | 0.668 | 0.680 | 0.697 | 0.750 | 0.755 | 0.685 | 0.078 | n.s. |
| 2001 A | 0.733 | 0.832 | 0.720 | 0.622 | 0.795 | 0.620 | 0.095 | n.s. |
| 2001 H | 0.592 | 0.765 | 0.720 | 0.622 | 0.795 | 0.620 | 0.087 | n.s. |
| 2002 E | 0.946 | 0.798 | 0.888 | 0.797 | 0.974 | 0.916 | 0.062 | n.s. |
| 2002 A | 0.964 | 1.009 | 1.288 | 1.148 | 1.227 | 0.992 | 0.091 | n.s. |
| 2002 H | 0.907 | 1.069 | 1.269 | 1.007 | 1.095 | 0.959 | 0.087 | n.s. |

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