The Division of Subtropical Agriculture. The Volcani Institute of Agricultural Research 1960-1969. Section B. Avocado. Pg 23-40.

1. SELECTION OF ROOTSTOCKS AND OTHER WORK RELATED TO SALINITY AND LIME

A. Kadman* and *A. Ben-Ya'acov

a. Selection of Rootstocks for Resistance to Salinity — *A. Kadman*

The rootstocks commonly used in avocado orchards in Israel belong to the Mexican race. Types of this race are highly susceptible to saline conditions, at levels which are considered low for most other crops.

In the late 1950s, with the rise of salinity levels in many wells along the coastal plain, problems arose in many orchards. In addition, we were expecting the higher salt content of the irrigation water from the National Water Carrier, which was intended to transport water of rather high salt content from the Sea of Galilee to the central and southern districts of the country.

In some orchards in the coastal plain which received water of 150-170 mg chlorine per liter, leaf burn of various degrees appeared, caused by high chlorine intake. In some cases the damage was very serious and resulted in tree decline.

In a discussion of the problem and its solution, selection of resistant rootstocks was proposed by Ch. Oppenheimer. Other means to overcome the danger were also to be tried, especially in existing orchards.

In 1957, a preliminary trial was carried out with Mexican and West Indian seedlings at three levels of salinity of the soil. At the highest level (0.25% NaCl) all plants from both races died shortly after planting. At the medium level (0.15% NaCl) most Mexican and some of the West Indian seedlings died. At the lowest level (0.08% NaCl) all seedlings grew well.

The main selection trial was carried out in 1958-1960. In this trial 576 seedlings of eight varieties, of all three races, were used: Three Mexican varieties, three Guatemalan varieties, one Mexican-Guatemalan hybrid, and one West Indian Guatemalan hybrid. The trial was carried out in large containers, placed in the soil, and under natural climatic conditions. During the irrigation season the seedlings were irrigated with water containing 830 ppm NaCl. In winter they were exposed to the natural rainfall.

Continuous growth measurements were carried out on all plants and the degree of salt damage was recorded at short intervals. The trial included frequent analysis of leaves and finally of roots and stems. Soil analyses were carried out frequently in order to study the influence of salinity.

After the start of the treatment, all plants showed leaf burn, but to different degrees (Plate B. 1.1). Parallel to the amount of damage, a rise of chlorine level in the leaves was found. The sodium level in the leaves was low and generally remained so throughout the three-year period. Only in the population from one variety — the Mexican Northrop — were high sodium values found in the leaves, about one year after the beginning of the trial. The sodium level continued to rise for some time and remained high until the end of the trial. At the same time, typical sodium damage was seen in the leaves of this group. In the roots of all types, sodium levels were high, at a ratio of between 10:1 and 20:1 to sodium content of the leaves. Only in the Northrop seedlings was the ratio much lower, approximating 1:1.

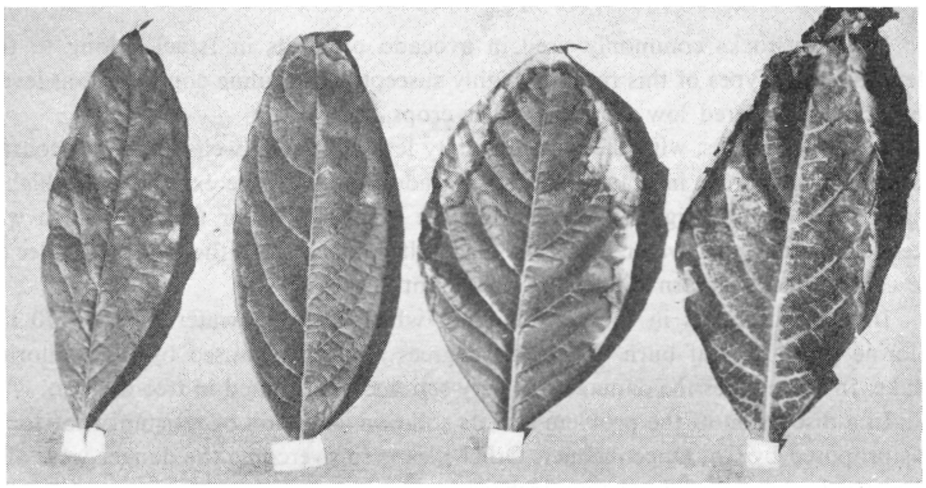

Plate B.1.1. Different degrees of tip burn in avocado leaves.

The reliability of growth indices for the evaluation of salinity resistance was tested statistically and found to be suitable. Intra-and inter-population variability could be tested by the use of additional growth and leaf damage through ranking.

At the end of the trial, nine seedlings were selected for superior behavior under the conditions of the trial: five Guatemalans, two Guatemalan-West Indian hybrids, and two from the offspring of one Mexican seedling.

It seems to us that we have to take into account two types of resistance of avocado types to salinity. The first, low uptake of chlorine by the plant is found mainly in resistant West Indian and Guatemalan types. The second, normal uptake together with high specific resistance of the tissues seems to be the norm for the resistant types found among the seedlings of one Mexican type, called Glickson-7. In the seedlings selected from this type, leaf burn was relatively low, in spite of extremely high chlorine content in the leaves. These two types of resistance of the rootstock may have very different influences on the varieties budded on them. The second type, in spite of its resistance to chlorine, may prove to be an unsuitable rootstock, allowing transport of the salt to the susceptible scion. This hypothesis still has to be tested.

Nearly all of the Northrop and most of the Mexicola seedlings died during the trial, and at its end sodium values in the leaves of the Northrop survivors were as high as 1%. In Mexicola seedlings the values were much lower but also much higher than those found in other populations.

In 1961, after the end of the trial, all plants were left *in situ* and irrigated with normal water. Nearly all of those which had not declined too much, recovered during the summer.

During the trial, chlorine content of the soil showed large fluctuations, in accord with the quality of the water used in summer and that of the winter rains. Chlorine was easily drained out of the soil by water of low salt content. This proves that salinity damage can be reversed, whenever better water is made available, and surplus quantities used for soil-flooding.

In 1959/60, another trial was carried out with West Indian and hybrid types, using two levels of salinity, 830 ppm NaCl and 1330 ppm. Individual plants were grown in small containers in a shade house: 50 seedlings, ten each from four Guatemalan-West Indian hybrid varieties and ten from a pure West Indian type. The last type was found to be the most resistant: three out of five seedlings remained alive in the high salinity treatment and recovered after change of water, as against only two out of 20 from the hybrid varieties. During this trial, the salt level in the soil rose to nearly twice the highest level in the preliminary trial (where all plants had died quickly). This shows that avocado plants can be conditioned to rather high levels of salinity if the rise is slow, but will be killed if the rise is sudden.

At the same time, trials in culture solutions were carried out for the study of chlorine and sodium symptoms. Seedlings of the three races were put into solutions containing either additional sodium or additional chlorine. Chlorine damage to the leaves was found early, mostly in the form of burns of tip and margin. Damage spread all over the leaf, until it dropped. In these cases, new buds lower on the stem usually started growing. There was some root decline but new roots continued to be produced. Sodium damage in the leaves appeared much later but was ultimately much greater. About two months from the start, necrotic spots were seen on the leaves, in concentric circles. Rather quickly, this damage spread to the whole leaf and led to its drop. With sodium damage practically no new growth was started from buds on the stem, and most of them degenerated. In the sodium treatment, roots were severely damaged and practically no new roots grew. During 4-5 months most seedlings died. In both treatments, Guatemalan and West Indian seedlings were more resistant than Mexican.

b. Stock-scion Relations under Saline Conditions — *A. Ben-Ya'acov*

After the first stage of rootstock selection, salinity trials with seedlings of the three races as rootstocks and scions of standard varieties were carried out in 1962-1966, in soil, culture solutions and orchards. The relationship between stocks and scions and the behavior of different stock-scion combinations were investigated, as to the chemical composition of plant parts and its relation to their behavior.

Salinity damage (growth retardation and leaf burn) was found to be especially marked on Mexican types, and was the most severe on un-budded Mexican seedlings. Guatemalan seedlings (of the Nabal variety) also showed considerable damage. West Indian seedlings showed the least damage. Budded plants on West Indian and Nabal stock showed equal and relatively light damage (Table B. 1.1). The differences between the seedlings and budlings of the same race were not due to the fact of budding, as was found from autoplastic grafts.

Amount of damage was closely correlated with chlorine content of the leaves, but Mexican and Guatemalan seedlings suffered more and West Indian seedlings less, than would have been anticipated from their relative leaf content. This seems to point to different specific susceptibility of the tissues of the different races.

TABLE B. 1.1

LEAF BURN (scale of 0 = no burn, to 5 = very severe burn) IN AVOCADO PLANTS AT THE END OF THE SECOND YEAR OF THE SALINITY TRIAL (mean values of 24 plants)

Stock	*Non-grafted*	*Scion*	
		Fuerte	Nabal
Mexicola	3.7	3.0	2.7
Nabal	2.5	1.9	1.7
West Indian	1.0	1.8	1.4

The stock and scion influence and interaction were highly significant.

Both West Indian and Nabal stocks retained chlorine and sodium in the roots and prevented their transfer to the leaves. In addition, both rootstocks and especially the West Indians, showed higher uptake of nutrients than the Mexican, and rising uptake under saline conditions.

It seems probable that this rise in uptake is caused by better development of the root system of the West Indian stocks and its additional development under saline conditions (Plate B. 1.2). This was probably also helpful in the higher uptake of water.

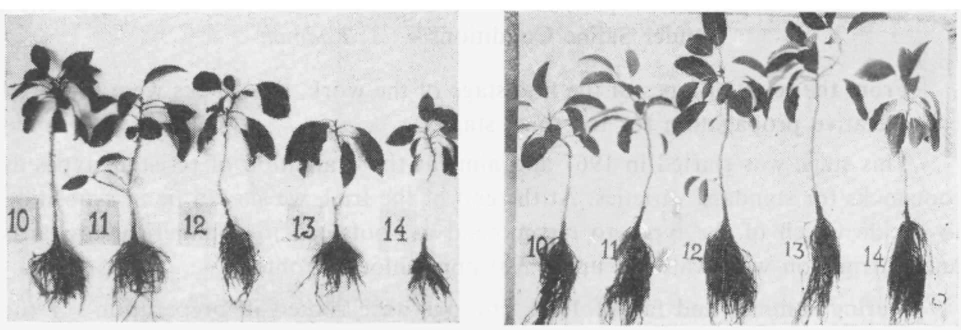

Plate B.1.2. Fuerte grafts grown in saline nutrient solution: *10*, 70; *11*, 210; *12*, 350; *13*, 496; and *14*, 630 ppm chlorine. Left, on Mexicola stock; right, on West Indian stock.

The higher uptake of nutrients by the roots under saline conditions was found to be selective, especially that of calcium. On the other hand, Mexican rootstocks reacted to salinity by higher uptake of potassium. It seems that resistant rootstocks transfer chlorine to the leaves as calcium chloride, and susceptible ones transfer it as potassium chloride, and that this difference has considerable influence on the toxicity of the chlorine.

The roots of West Indian types had a higher cation-exchange capacity than those of Mexican types (35.7 millieq per 100 g dry weight of roots in the Mexican, against 42.9 millieq in the West Indian). This explains the higher ratio of divalent cations to monovalent.

For most elements, including chlorine, the variability between individual analyses was very great. Among them, phosphorus proved relatively stable. High P values in the roots seem to be correlated with resistance. The variability in chlorine values of the same sapling between years was reflected in variability of resistance.

Other relationships found were: Good correlation between growth of diameter of stock and scion, between growth increment and chlorine content of leaves and calcium + magnesium content of roots, and between calcium and magnesium content of leaves.

The behavior of different combinations of stock and scion was found to be similar in both soil and water culture.

Practical results: Character correlations were found which can be of help in selection. Ways were initiated for the strengthening of resistance and lessening of damage in orchards. New stocks were selected from budlings. Twelve trees (3 Mexican, 5 Guatemalans and 4 West Indians) were found to be clearly superior to their neighbors in the same orchards and their rootstocks were recovered and propagated.

c. Trial with Vegetatively Propagated Rootstocks Budded with Standard Varieties, under Saline Conditions — *A. Kadman*

From the selected types of the first stage of the work, rootstocks were prepared by vegetative propagation for the third stage.

This stage was started in 1967 and aims at the evaluation of resistant types as rootstocks for standard varieties. At the end of the trial, we should be in a position to decide which of the types to recommend as rootstock in commercial orchards under irrigation with water of up to 350 ppm chlorine content.

During summer and fall of 1966, cuttings were rooted in preparation for the trial. There were five resistant types and one susceptible, as control. Three of the former came from the large selection trial and two others that seemed promising, from additional work. Two of the types are West Indian hybrids (Fuchs-20, Lula-3), two are Guatemalans (Anaheim-3, Benik 31/6) and two are Mexicans (Gvaram-13, Northrop 28/5). The last one is used as control.

The trial was laid out in spring 1967 in four blocks of 12 plots each. Each plot is 4 m^2 and is separated by asbestos sheets on all four sides, down to 120 cm into the soil. The bottom was left open so as not to impede drainage. The six rootstock types are each grafted with either Fuerte or Hass, for 12 combinations. There are four replications, one in each block, of four plants each.

During 1968, the plants grew well and it was possible to start with saline water irrigation on nearly all plots. In July, records of height, diameter of stem below and above bud union, leaf burn and general condition, were made for all plants. Leaves were taken for analysis, four leaves from each plant, and analyzed for 15 elements. Soil samples were taken at three depths to 90 cm and were analyzed for moisture content, conductivity, chlorine, sodium and potassium.

Early in August, irrigation was started with water artificially salt-enriched up to 350 ppm chlorine, two-thirds from sodium chloride and one-third from magnesium chloride. Two hundred liters of irrigation water was given to each plot at the first irrigation. Afterwards, plots were irrigated about once a week, until the onset of the rainy season.

Every three months, all plants were scored and leaves taken for analysis. During the winter, all plots received rain water only and this resulted in considerable leaching of salts, especially chlorine. In spring 1969, the second season of saline irrigation was started. In June, tensiometers were placed in some of the plots so as to make possible irrigation in accordance with the water requirement of the different plots. Early in 1969, it was found necessary to reduce the number of plants in each plot from four to two, the plants having grown so much that they became crowded.

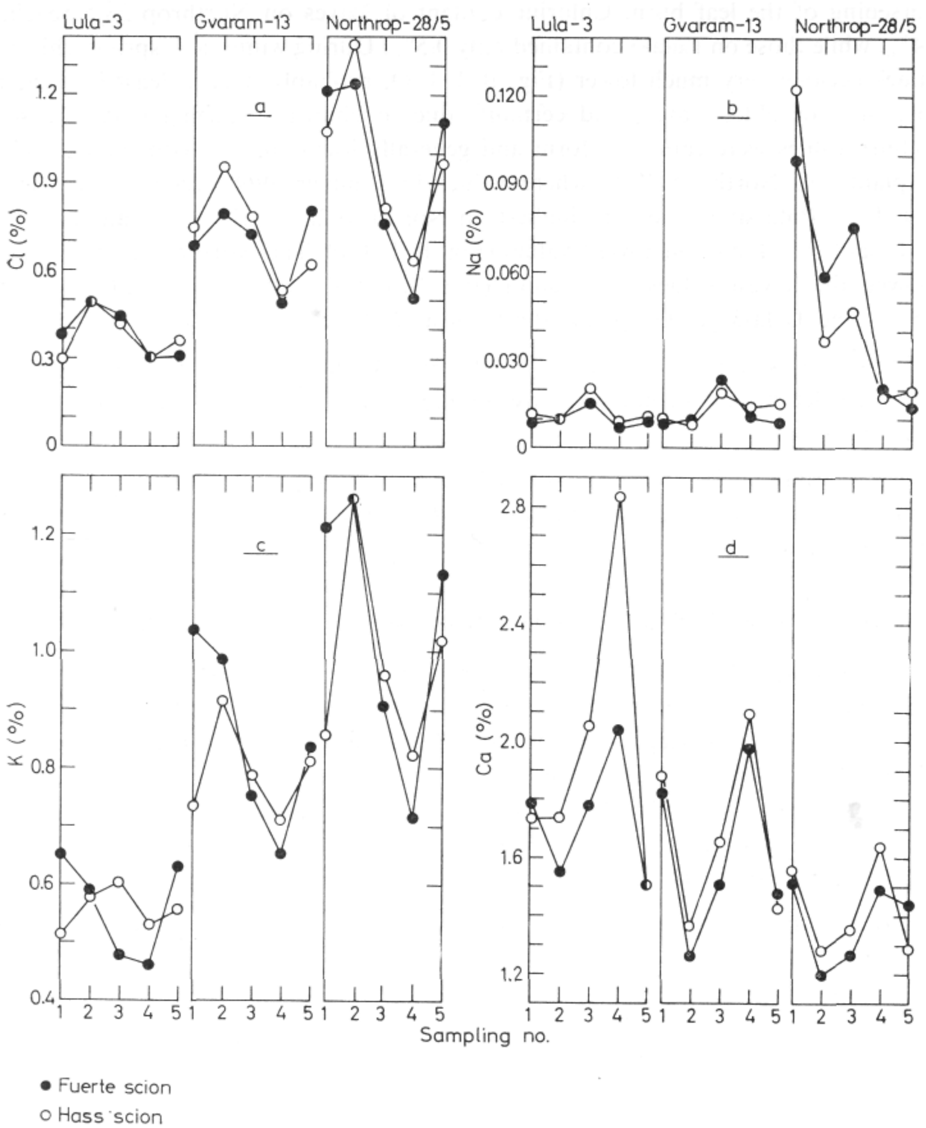

Fig. B.1.1. Leaf mineral content of different combinations of rootstocks (vegetative) and scions. Dates of sampling: *1*, 1.VIII.68; *2*, 1.XI.68; *3*. 1.II.69; *4*, 1.V.69; and *5*, 1.VIII.69.

The trial is not yet concluded but it is possible to give some preliminary results from ranking as to damage, from growth measurements and from leaf analyses. Plants on rootstocks Lula-3 and Anaheim-3 seem, so far, to be the most tolerant, followed by Fuchs-20, Gvaram-13 and Benik 31/6. Northrop 28/5, the control, shows least resistance. There is not much difference between the two varieties. Growth increment does not show, at this stage, a good correlation with leaf burn.

Leaf analyses show considerable seasonal fluctuations of the scions on all rootstock types. Chlorine values were highest in fall, as was to be expected from the worsening of the leaf burn. Chlorine content of leaves on Northrop 28/5 reached 1.4%, while those on Lula-3 contained only 0.5%. During winter and spring, chlorine values became very much lower (Fig. B. 1.1.a), probably due, at least in part, to abscission of older leaves, and certainly due to chlorine leaching from the soil. Sodium values were rather uniform and generally low (0.02%), with the exception of plants on Northrop 28/5, where values in summer 1968 reached 0.6% (Fig. B. 1.1.b). Potassium, too, was highest on Northrop 28/5; 1.25% (in fall) *vs.* 0.6% on Lula-3, which had the lowest values (Fig. B. 1.1.c). The Northrop grafted plants showed the lowest values for calcium (Fig. B. 1.1.d) and magnesium (1.25% and 0.5%), and Lula-3 grafted plants the highest (1.65% and 0.65%).

These results show no antagonism between sodium and potassium, but bivalent cations, calcium and magnesium, are antagonistic to monovalent cations, sodium and potassium.

This trial will be continued for at least two more years and it is too early to make a final evaluation, especially as growth rate does not seem to be correlated with leaf damage.

d. Orchard Trials to Reduce Damage from Saline Conditions — *A. Ben-Ya'acov*

During the years 1962-1966, a number of trials were carried out in different orchards in order to see what can be done to reduce or alleviate the damage to avocado trees on susceptible rootstocks by irrigation with water of high salt content. In the orchard where most of the work was done, there appeared to be two forms of damage — leaf burn and tree decline. No correlation was found between them. Tree decline started with chlorosis and worsened through leaf drop and drying of branches, until death of the tree.

TABLE B. 1.2

GRADE OF LEAF BURN IN AVOCADO PLANTS IN THE FALL, IN ORCHARDS UNDER SALINE CONDITIONS

Variety	1962	1963	1964
Fuerte	2.1	3.4	1.2
Ettinger	4.1 ⎤	3.6 ⎤	1.7
Anaheim	3.6 ⎢	3.6 ⎦	1.4 ⎤
Benik	4.4 ⎢	3.1	⎢
Nabal	5.1 ⎦	4.1	1.4 ⎦

Influence of variety highly significant. Non-significant differences are shown linked.

Leaf burn was more pronounced in Ettinger and Nabal and less in Fuerte (Table B. 1.2).

Analysis of soil, water and leaves showed chlorine to be responsible for the leaf burn. The water contained more than 210 ppm chlorine. Soil analysis showed a rise from 1-2 millieq Cl (per liter extract of saturated soil paste) in spring to 8-10 millieq in August. In the leaves, chlorine values were between 0.5% and 1%.

Tree decline and chlorosis were especially severe in trees of the Fuerte variety. They seem to be due to a general disturbance in nutrition. With the worsening of tree conditions, leaf values for almost all elements declined, with only sodium values rising. High sodium values were also found in the roots of declining trees. Sodium very probably contributed to the decline, but the main reason was faulty soil structure. Digging revealed a reddish layer of soil lacking structure at different depths into which roots did not penetrate. The nearer to the surface this layer was, the earlier decline occurred. In these cases, chelate 138 did not improve the condition of the chlorotic trees.

Between 1962 and 1964, leaf burn diminished (as seen in Table B. 1.2). This is probably due to improved cultural practices, such as non-tillage, cutting of weeds, night irrigation at low volume, irrigation beneath the trees, more frequent irrigations, leaching irrigations, and better regimes of manuring and fertilizing. Some of these measures will be discussed. Tree decline became more serious during these years, probably because more trees reached the impenetrable soil layer.

Leaching: The accumulation of salts in the soil makes leaching mandatory from July on. To bring about effective leaching from the upper 60 cm of the soil, copious irrigations, with at least 50% more water than usual, must be given about every third irrigation. Leaching is essential and must be used whenever salt levels in the soil reach values above those in the irrigation water; however, it only alleviates damage and cannot prevent it. In trials where salinity of the soil was kept at the level of that of the irrigation water, avocado trees were damaged. This is due to their very efficient intake of chlorine.

Mulching: Three treatments were used: Straw mulch, compost mulch, and control without mulch. Each treatment was given to 90 one-tree plots, of the same variety and general condition. The compost mulch ammeliorated chlorosis and tree decline, but led to more leaf burn and higher chlorine values in the leaves. The straw mulch improved the leaf burn condition and led to lower chlorine values in the leaves.

e. Selection of Mexican Types in a Mature Orchard, Based on Condition and Yield of the Budded Tree — *A. Ben-Ya'acov*[*]

During the years 1962 to 1966, annual surveys were carried out in the orchard discussed in the preceding section. They included ranking for chlorosis, tree decline, leaf burn, and yield. While most trees in the orchard were in very bad condition in most of the years, a very few showed a consistently superior performance.

In 1967, before the orchard was to be abandoned, we were able to cut back these

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[*] In cooperation with H. Ullmann of Kibbutz Na'an

interesting trees and to obtain new growth from the stocks. Material was taken from them for vegetative propagation (see chapter B. 4). With the trees grown from this material as rootstocks, four trial plots were planted.

f. Chlorosis — *A. Kadman*

Selection of resistant rootstocks

One of the problems of the avocado grower in Israel is chlorosis, which is common mostly on soils of high lime content and is caused by lack of available iron in soil and tree.

Observations in the Jordan Valley and other regions of the country have shown differences in susceptibility to chlorosis between different trees in the same orchard. There have been many cases where some trees have shown severe chlorosis and decline while neighboring ones have remained healthy.

In the preliminary trial for salt tolerance it was found that all Mexican seedlings, in soil of high lime content (from the Jordan Valley) without added salts, showed more or less severe chlorotic conditions soon after the start of the trial, while West Indian seedlings remained unaffected.

In some regions of the country, climatic conditions are suitable for avocado growing, but soils have very high lime content. The differences in reaction to such soils between the different races and also between trees of the same race, made it seem probable that this problem, too, could be solved by the selection of resistant rootstocks. Selection was started in 1958.

Containers were filled with soil from the Bet She'an region containing 54% lime. Ninety-six plants from eight populations were planted into these containers — 3 Mexican (Northrop, Mexicola, Glickson-7), 3 Guatemalans (Anaheim, Benik, Nabal), 2 hybrids: one Mex./Guat. (Fuerte) and one Guatemalan-West Indian (Lula). In that year we could not obtain seeds from pure West Indian types.

At the start of the trial (July 1958), height and diameter of the plants were measured. Every two months during the two-year trial, measurements were made, the plants were graded as to chlorosis, and leaves were taken for analysis.

Chlorosis appeared in the Mexican types two months after the start of the trial and worsened during the summer. In light cases only young leaves yellowed and the veins remained green. In medium cases leaves turned pale and tips and margins showed burns. In the worst cases many leaves dried up and fell and plants were greatly retarded in growth. In spring 1959, more or less normal leaves were produced by most plants, but chlorotic symptoms appeared again in summer on the same plants that had shown them the year before. Mexican types showed least resistance, and Guatemalan and West Indian types were better, in both leaf symptoms and growth rate.

Leaf analysis showed that in most cases total iron values were higher in chlorotic than in green leaves. This fact makes it probable that some, and probably most, of the total iron content of the leaf is not available to the plant for chlorophyll synthesis. Because analysis for iron content does not give reliable values for the detection of chlorosis, we have begun to look for other indicators among the relevant enzymatic systems, such as peroxidase, which was found usable for citrus.

Chlorosis has been observed also in orchards on soil of low lime content. This happens rather frequently on heavy soils with impaired drainage. Under these conditions, Guatemalan types are more severely affected than Mexican types. In both conditions, West Indian rootstocks have given the best results. It seems, therefore, that until better selections are available, West Indian types may be used wherever there is serious danger of chlorotic conditions.

Trials to cure chlorosis

At the same time as selection for resistant stocks started, trials were also begun to see what can be done to cure chlorotic trees without changing their rootstocks. Various iron-containing substances were tried, both in container trials and in the orchards. Among many substances, Fe-sequestrene 138 was found to be by far the best. This material, applied in the soil, normally brings about greening of the avocado plant within 10-14 days. Most other substances failed.

Excellent results were obtained with this substance in many orchards and this treatment has become normal practice for all avocado orchards in the country whenever chlorosis appears. The only drawback of the chelate 138 is its very high price. Therefore, trials have been carried out (by E. Lahav) to find a cheaper and no less effective remedy. The trials were carried out in 1968 in the Western Galilee.

a. The Spanish chelate type 56 was injected into the soil in mid-July, 30 g for each two-year-old tree. After one month the trees greened, while controls remained chlorotic. The influence of the treatment lasted one year.

b. Feron F was injected into the soil in July, 50 g for each three-year-old tree. In August all trees, including the controls, were found to have greened — but the treated trees had a peculiar bluish-green color.

c. Mature Ettinger, Fuerte and Nabal trees in severe condition, were sprayed with Riplex and Fetrilon 0.1%. On every tree four branches were sprayed with each material and others left for control. After one month the leaves sprayed with Riplex showed only green dots; Fetrilon-treated branches showed weak reactions. In another orchard, treatment produced green leaves and healthy new growth. Inarching with resistant rootstocks gave promising results. The work was carried out by A. Ben Ya'acov and will be described in chapter B. 3.

g. Factors Influencing Intake and Accumulation of Chlorine and Sodium in Avocado Plants — *A. Kadman*

Trials were carried out on the influence of various factors on the intensity of transpiration of avocado plants, and on intake, transport and accumulation of chlorine and sodium.

During the first two years, this research was financed by a grant from the Ford Foundation. In all these trials we used radioactive isotopes, chlorine-36 and sodium-22. In this way we could observe these elements from the time of intake to their accumulation in different parts of the plant, without impairing the functioning of the living plant. Geiger counter measurements were used for chlorine-36 and scintillation counter measurements for sodium-22. From auto-radiographs it was possible to obtain clear pictures of the localization of both elements in different parts of the plant.

The work was carried out in three stages. In the first stage, preliminary work was carried out to establish methods: *(a)* rapid calculation of leaf surface by an easy method, for the calculation of transpiration rate per unit of leaf surface; *(b)* localization of stomata on the leaf surface and study of their behavior under different conditions; (c) materials which lower transpiration rate; and *(d)* materials which lower intake of ions. In the second stage, the intake of chlorine-36 and sodium-22 by different avocado races was studied under various conditions of temperature, light and relative humidity. The third stage, which is still in progress, is devoted to finding ways to mitigate salinity damage under controlled or semi-controlled conditions. Various anti-transpirant have been used with this aim — both those producing a thin film on the leaves, and systemic materials which are given through the roots and produce partial closing of the stomata. Other materials were tried which may produce higher resistance of the plants to salinity. Trials were carried out either in small containers in the glasshouse or incubator, or in large containers in the open. If ways are found to alleviate salinity damage, we shall later try them in the orchard.

For the calculation of leaf surface, a good correlation was found between planimeter readings and values obtained by multiplying maximal length and width and a factor which has been calculated for the different avocado types.

Stomata can be easily counted after printing with rubber-silicon and obtaining a copy in transparent cellulose acetate solution. Under the microscope this gives a very good picture of the leaf surface, including the stomata. Stomata were found only on the underside of the leaves. Differences in number and size of stomata were found between types of the Mexican and West Indian races. Plants placed in the dark and treated with the systemic 8-hydroxy-quinoline-sulphate closed their stomata partially, with a resultant reduction in transpiration.

For the trials on the influence of external factors on intake and accumulation of chlorine, susceptible Mexican seedlings and resistant West Indian seedlings, both 6-8 months old, were used. Plants were grown in sealed containers with half-Hoagland solution to which was added, at the right time, the desired concentration of salt and some chlorine-36. After this, each group of plants was subjected to one of the three factors — changes in temperature, humidity or light intensity. Radioactivity was measured in the leaves daily and the plants were weighed to determine the loss of water. After 7-10 days of the trial, plants were exposed for 24 hours to X-ray films. After development, very good pictures of chlorine distribution were obtained.

Temperature and light intensity showed good positive correlations to transpiration and chlorine intake, and humidity a good negative correlation. Mexican plants showed higher accumulation of chlorine than West Indian plants. This showed that *(a)* accumulation of chlorine in leaves is highly dependent on transpiration and on all the factors which influence it; and *(b)* under identical conditions of transpiration West Indian types are more successful in avoiding transportation of chlorine from roots to leaves.

In another series it was found that under controlled conditions an increase in the concentration of chlorine in the nutrient solution led to a several-fold increase in the concentration of chlorine in the leaf (Fig. B. 1.2). These trials are being continued with the aim of determining whether there is a critical concentration which will produce a steep rise in the accumulation curve of the leaf.

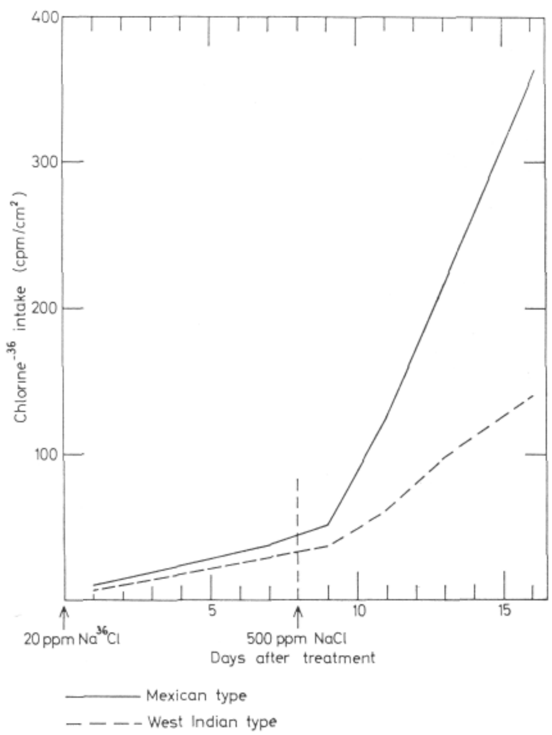

Fig. B.1.2. Influence of stock type and concentration of solution on intake of chlorine-36 in leaves of Fuerte avocado.

Other trials have been carried out with sodium-22 to determine the influence of various factors on root intake and transport to other parts of the plant. For this series we used Northrop seedlings, which were found in earlier trials to be extremely sensitive to sodium and the only ones which accumulated much sodium in the leaves.

In these trials the combined influence of transpiration intensity and a metabolic inhibitor on the transport of sodium from roots to leaves, was investigated. Plants were kept in conditions leading either to high transpiration (30°C, 7000 ft. c., 40% R.H.) or to low transpiration (20°C, darkness, 90% R.H.). 830 ppm sodium chloride and a small quantity of sodium-22 were added to the nutrient solution. Some of the plants in each group received, in addition, potassium cyanide, a metabolic inhibitor of respiration. The plants were weighed every 24 h to establish transpiration loss, and radioactivity was measured. After the end of the trial the plants were autoradiographed on X-ray film. It was found that high transpiration intensity led to high accumulation of sodium in the leaves; and KCN treatment led to higher accumulation with both high and low transpiration.

Other trials with sodium-22 were carried out on West Indian seedlings, under different rates of transpiration. In these trials radioactivity was never found in the leaves but only in the roots, and always at high intensity.

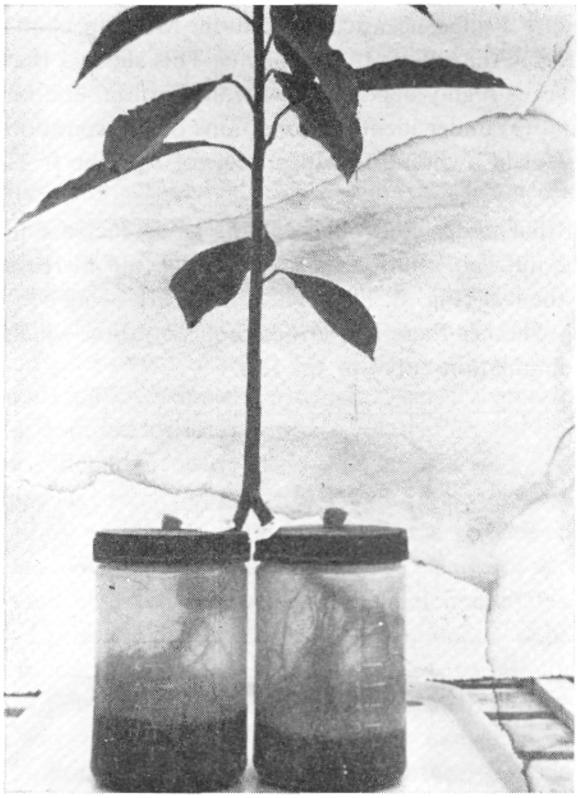

Plate B.1.3. Double-rooted avocado plant: Left, whole Mexican plant; right, roots of secondary West Indian stock.

This seems to show that there exists between roots and stem some kind of block through which, under normal conditions, sodium is not transported. In order to find out more about the localization of this block, trials were carried out[*]* with pairs of resistant and susceptible types grafted to each other by inarching, just above the root-collar. This means that each pair had two root systems, one susceptible and one resistant, but only one top (Plate B. 1.3). Each root system was placed into a separate container with Hoagland solution and sodium chloride. A small quantity of sodium-22 was added to only one of the two containers in each pair. Radioactivity was measured every 24 h and after the end of the trials, all plants were autoradiographed on X-ray film (Plates B. 1.4, 5). Other plant stems were cut into 25-mm sections, the phloem and xylem were separated, and sections were dried and put into a Well counter for measuring radioactivity. Thus, we could obtain measurements of radioactivity per mg of dried material for each segment.

Results from this trial show that in resistant avocado types there is indeed a block for the transport of sodium from roots to the trunk and that it is possible to circumvent this block by inarching a susceptible type above the root-collar of the resistant type. In this way, the sodium which has been given to the roots of the susceptible stock is transported without blocking into the stem of the resistant type. In the opposite case,

[*] In cooperation with A. Ben-Ya'acov and C.D. Gustafson.

sodium which is supplied to the roots of a resistant type will not enter the susceptible type (Fig. B. 1.3).

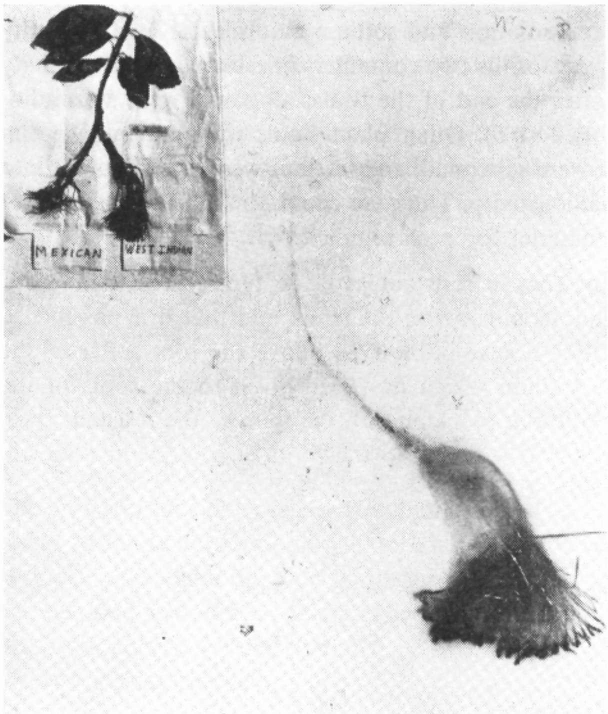

Plate B.1.4. Autoradiograph. Sodium–22 did not penetrate from the secondary West Indian root stock to the Mexican plant. (Inset: Double rootstock — left, Mexican; right, secondary West Indian).

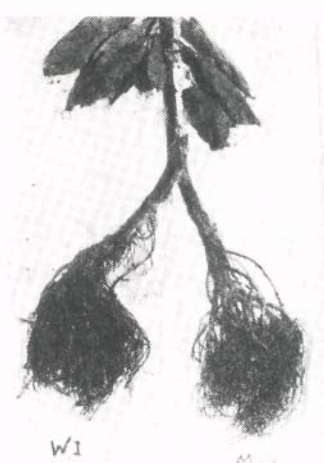

Plate B.1.5. Autoradiograph. Sodium-22 is translocated from secondary Mexican stock into West Indian plant. (Inset: Double rootstock — left, West Indian; right, Mexican).

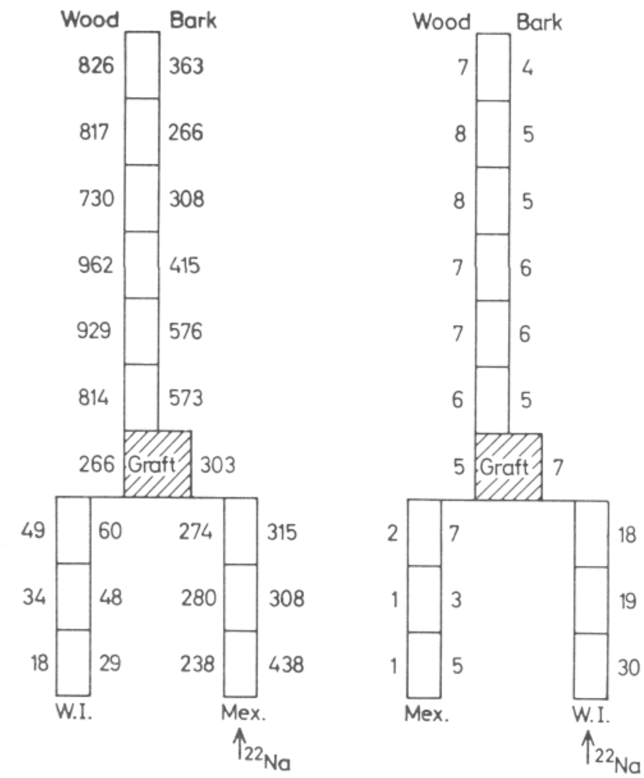

Fig. B.1.3. Intake and translocation of sodium-22 in different combinations of inarched West Indian (W.I.) and Mexican (Mex.) seedlings, in counts per minute per mg dry weight in sections of 25 mm. Left, supported; right, supporting.

The blocking must, in some way, be part of the metabolic activity of the plant, as it can be weakened or canceled by metabolic inhibitors. Research into this question continues.

Among the anti-transpirant which were tried out two — Paz-wax and O.E.D. — were found effective. Among growth retardants which were tried in order to see if they would mitigate salinity damage, such as CCC, Phosphon and B-995, none was found to be effective.

Trials on penetration of chlorine and sodium into avocado leaves

With sprinkler irrigation and the use of water with high salt content, the question of whether the salts penetrate into the leaves, and if so, under what conditions, is of great importance. To find the answer to these questions we used salt solutions with small quantities of chlorine-36 and sodium-22.

In preliminary trials, drops of a solution containing chlorine-36 were placed on the upper surface of leaves on the plant, with or without pricking them with a needle. After 24 hours autoradiographs were made. In the non-wounded leaves only a small dot was seen where the drop had been placed, but in the pricked leaves chlorine had entered and spread acropetally. The reaction to sodium-22 in the non-wounded leaf was similar, but in the wounded leaf, sodium-22 spread far less than chlorine-36 and only near the veins.

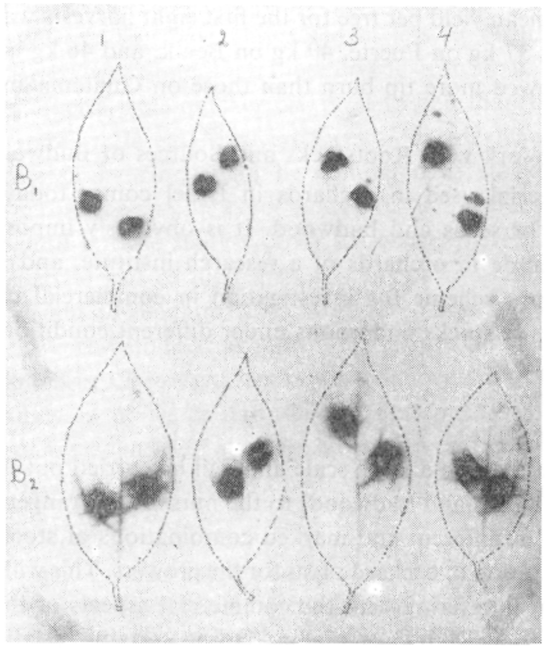

Plate B.1.6. Penetration of chlorine–36 into avocado leaves. B_1, upper side; B_2, lower side. 500 ppm NaCl (1) with spreader, (2) without spreader; 100 ppm NaCl (3) with spreader, (4) without spreader.

After this, in 1968 and 1969, a series of trials was carried out under various controlled conditions. As stated above, stomata were found on avocado leaves only on the lower surface. For this reason, treatments were given in this trial to both sides of the leaf. Some of the intact leaves were placed on calcar plates with their underside on top, and drops of a solution containing chlorine-36 were put on them. Different concentrations and additions of detergent spreader were tried. In auto-radiographs it was seen that whenever the drops were placed on the underside of the leaf, there was penetration and some spread of chlorine in the leaf. A concentration of 500 ppm as against 100 ppm did not change the picture, but the addition of the spreader somewhat improved penetration (Plate B. 1.6). Penetration was also found in the dark, with the stomata not closing fully. It seems that if penetration occurs through the stomata, a small opening is sufficient.