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Vegetative Responses of the Elberta Peach on Love11 -and Shalil Rootstocks to High Chloride and Sulfate Solutions

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FIELD observations have indicated that some rootstocks are superior to others in promoting good growth of the scion. Hutchins (3) found that the Shalil peach rootstock promoted vigorous growth, the trees (Early Hiley) on that rootstock being "among the most vigorous and productive in the orchard" where nine different rootstocks were under test. He also found complete resistance to root-knot, and Tufts and Day (2, 4, *5)* obtained similar results on nematode resistance with Shalil in California. Chandler (1) has noted the tolerance of peaches on Davidiana rootstock to saline conditions, but that variety has not been a desirable one because of lack of vigor.

Owing to the extensive use of the Lovell variety as a rootstock and the favorable characteristics reported for the Shalil, they were selected to test the effects of chloride and sulfate salts on peaches. The Elberta variety was used as the scion.

MATERIALS AND METHODS

Elberta peach trees on Love11 and Shalil rootstocks have been grown in sand culture under differential salt treatments since the spring of 1940. Seventy-two yearling trees were planted in 4-gallon glazed earthenware containers which were sunk in the soil to avoid the inhibiting effect of high temperature on the root systems. The trees were randomized in blocks of four and maintained in this design until February, 1941, when they were transplanted to sand tanks which were large enough (5 feet by 10 feet by 6 feet) to accommodate four trees without excessive crowding (Fig. 1) •

The large sand culture tanks are arranged in a block of three rows, six per row. The experimental design was so planned that each row of tanks contained all six treatments with the treatments randomized in the rows. Two trees on each rootstock were arranged in each tank so that a Shalil and a Lovell rootstock occupied opposite corners with the others in the intermediate positions. At the conclusion of the 1941 growing season, the intermediate trees were harvested and data obtained with respect to their vegetative responses. The remaining trees are being carried on so that studies of fruiting responses can be made.

Each tank has its own reservoir with a capacity of 4,500 liters of solution which is circulated to the sand cultures by electrically driven pumps controlled by a time clock. The pumps deliver sufficient water at one irrigation to completely flood the surface thus preventing any unequal accumulation of salts in the upper layers of sand. The frequency of irrigation was determined by the weather and the vegetative status of the trees. During mid-summer, the irrigations were at 3 hour intervals from 6 a.m. to 6 p.m. with one at midnight.

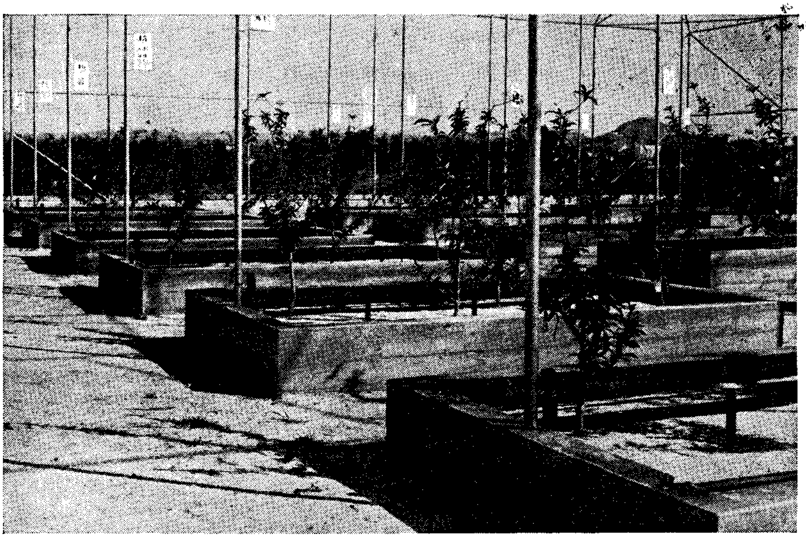

FIG. 1. General view of the sand culture tanks showing the arrangement of the trees and their growth status on April 8, 1941.

Six solutions were used : 1, the control or basic nutrient solution ; 2, 3, and 4, the basic nutrient solution plus 10, 40, and 80 milliequivalents of chloride per liter; and 5, and 6, the basic nutrient solution plus 80 and 160 milliequivalents of sulfate per liter. The cations of the added salts were supplied as Na, 65 per cent; Mg, 25 per cent ; and Ca, 10 per cent. Solutions were brought up to volume twice weekly and the pH adjusted to 6.5 using HNO_3.

The composition of the four-salt nutrient solution, expressed in millimoles per liter, was $Ca(NO_3)_2$, 1.0; KNO_3, 2.0; $MgSO_4$, 1.2; and KH_2PO_4, 0.2. The essential micro-elements were added, and iron was supplied as magnetite, 0.3 per cent by weight, mixed with the sand. Table I shows the Cl or SO_4 content of the solutions expressed in milliequivalents and parts per million, and the average osmotic concentration of each.

CARE OF TREES

During the dormant season, and prior to transplanting into the

TABLE I-COMPOSITION OF SOLUTIONS USED

Solution	Total Cl or SO_4		Osmotic Concentration Atm.*
	Me/l	Ppm	
Control	1 Cl 3 SO_4	36 142	0.40
Low Cl	10 Cl	355	0.73
Intermediate Cl	40 Cl	1418	1.95
High Cl	80 Cl	2836	3.36
Intermediate SO_4	80 SO_4	3842	2.21
High SO_4	160 SO_4	7684	3.61

*Average of 15 determinations.

large sand tanks, all of the trees were uniformly pruned so as to leave four scaffold branches with two or three laterals on each one. Measurements were taken of the height and diameter of the main axis and the total length of the branches to serve as a basis for the determination of total growth during the 1941 season.

In March, about 10 days ahead of the expected opening of the buds, all trees were sprayed with dinitrophenol using a power spray rig. No difficulty was experienced with delayed foliation ; but, owing to the fact that no extra trees were available to serve as controls, it is not possible to state to what extent this was due to the application of the spray. It seems probable that the season was a favorable one for Elberta peaches as there was relatively little trouble encountered in the southern California area with this variety or with Sims, while considerable delayed foliation occurred with the Lovell, Hale and Tuscan varieties. No spray was applied during the spring of 1942. There was some delayed foliation which was most pronounced on the trees under the high sulfate treatments.

GROWTH DATA

Following transplanting in February 1941, the vegetative buds began to expand and show color the first week in March, and subsequent growth and development was rapid. Owing to the procedure of adjusting the pH with HNO_3, the average concentration of NO_3 in the solutions was approximately 5.5 milliequivalents per liter (341 parts per million) during the growing season of 1941. On this luxury consumption basis with respect to nitrate, the trees made better than normal growth under the control treatment.

The diameter of each tree was measured at regular intervals to determine the rate of secondary thickening. There were highly significant differences in cambial activity between the trees under the high chloride and sulfate treatments and those in control tanks. Table II

TABLE II—GROWTH RESPONSES OF ELBERTA PEACH ON LOVELL AND SHALIL ROOTSTOCKS

Treatment	Diameter (Centimeters)		Linear Growth (Meters)		Weight (Kilograms)		Volume (Liters)	
	Lovell	Shalil	Lovell	Shalil	Lovell	Shalil	Lovell	Shalil
Control	6.0	6.5	197	220	8.24	10.00	8.45	10.12
10 m.e. Cl^-/1	5.9	6.7	222	228	8.54	11.00	8.85	10.91
40 m.e. Cl^-/1	6.0	5.7	206	166	8.19	7.04	8.12	6.99
80 m.e. Cl^-/1	4.6	4.9	125	103	4.74	4.26	4.84	4.48
80 m.e. SO_4^{--}/1	5.9	6.2	214	218	8.48	8.69	8.56	8.78
160 m.e. SO_4^{--}/1	4.3	4.4	107	106	3.85	3.97	3.87	3.90

shows the average diameter of the trees when harvested at the conclusion of the 1941 growing season. As indicated in this table, high concentrations of either chloride or sulfate salts result in a marked reduction in the diameter of the stem. With respect to the differential response of the rootstocks, the Shalil promoted greater secondary thickening under the control, low chloride, and intermediate sulfate treatments while trees on the Lovell rootstock developed more rapidly under the intermediate chloride treatment. No difference due to rootstock was observed at the high chloride level.

The vegetative response in terms of the total linear growth of the tops is shown in Table II. This shows that the high concentrations of salt have resulted in a very marked reduction in linear growth, and that this inhibition is approximately the same at the high chloride and sulfate levels. The reduction under the intermediate sulfate treatment was not as marked as at the intermediate chloride level and there was slightly more linear growth at the low chloride level than under the control treatment. The Shalil rootstock promoted slightly superior growth than the Love11 at the control, low chloride and intermediate sulfate levels. At the intermediate and high chloride levels, the Love11 rootstock produced considerably more growth. There was no significant difference between rootstocks at the high sulfate level.

The data for weight and volume of tops, shown in Table II present the same picture with respect to the vegetative responses. On the basis of diameter, linear growth, weight, and volume of tops, the data indicate that the high chloride and sulfate treatments result in essentially the same amount of growth depression ; that there is somewhat less depression at the intermediate sulfate level than at the intermediate chloride level; and that the growth at the lowest chloride level is slightly more than that of control trees. On the basis of influence of the rootstock, it would appear that the Shalil promotes better vegetative development at low salt concentrations; but that with the high chloride treatments a better response is made by trees on the Love11 rootstock.

FOLIAR DEVELOPMENT

Delayed foliation occurs frequently in the peach districts of Southern California owing presumably to the mild winters and high light intensity. As noted above, no serious prolonged dormancy was encountered at the beginning of the 1941 season while it was fairly pronounced in 1932. The application of dinitrophenol spray may have promoted normal foliation in 1941, but there was little difficulty on that score with Elberta in the Los Angeles area regardless of spray treatment ; whereas in 1942 some delayed foliation occurred. It is not unlikely that light as well as temperature affects foliar development ; but, with respect to the former, it is not clear to what extent a so-called light effect may be a temperature relation. Without attempting to draw any conclusion, and bearing in mind the application of the dinitrophenol spray in 1941, it may be recorded that at Riverside, California there were 461 hours below 45 degrees F in 1941 and 724 hours in 1942. The total hours of sunshine September 15, 1940, to March 31, 1941 was 1,342, and 1,442 for the same period in 1941-42. The total daily radiation for these periods was 59,659 gram calories per square centimeter in 1940-41 and 66,128 in 1941-42.

In the spring of 1941, the vegetative buds developed earliest under the chloride treatments, but this initial difference was equalized within a week after the first buds showed color ; and, subsequently, there was a better development of buds at the control and low chloride levels.

In all treatments, the vegetative buds of trees on Shalil rootstocks opened earlier than those on Lovell. There was a lag of 4 to 5 days on the part of the latter which was evident over a period of 2 weeks. In 1942, the vegetative buds appeared earliest on trees having the high chloride treatment, followed by the intermediate chloride and then the high sulfate treatment. The lag of the low salt and control trees was much more pronounced than in 1941, as was the earlier response of the trees on Shalil rootstock.

SYMPTOMS OF SALT INJURY

Following the emergence of the leaves in March 1941, definite symptoms of leaf injury were soon evident in the high and intermediate chloride treatments. By April, the leaves of trees under the high chloride treatment were showing marked chlorosis, tip and marginal burning, many leaves were dying, and there was considerable abscission. There was some die-back of small branches on the high sulfate and chloride trees, this being more pronounced in the former in the 1941 season. Leaves of trees having the intermediate chloride treatment showed some tip burn. At both high and intermediate chloride levels, the symptoms of leaf injury were more pronounced on trees grown on the Shalil rootstock.

Similar but more severe leaf symptoms were observed in the spring of 1942 resulting in complete defoliation of the high chloride trees, and marked chlorosis and burning of the leaves of the intermediate chloride trees. The leaves of the high sulfate trees on Shalil rootstock also developed extensive marginal burning and there was pronounced defoliation. Die-back was very severe at the high chloride levels with practically all small branches showing severe injury extending for several inches from the tip. To a lesser degree, similar injury was observed with the intermediate chloride treatment. The severity of symptoms was more pronounced with the trees on Shalil than on Lovell rootstock in all cases. In both 1941 and 1942, the severity of the leaf symptoms was more pronounced at the beginning of the growing season than later on. As the season progressed, the new leaves were less chlorotic and there was a reduction in the amount of tip and marginal burning. By mid-season of 1941, it was difficult to find leaves with severe symptoms.

MORTALITY

On the basis of preliminary trials with Love11 and Shalil seedlings, it was expected that the high chloride and sulfate treatments would induce pronounced growth depression accompanied by severe symptoms, and that some of the trees would ultimately die. No mortality was experienced during the 1940 season, while the young trees were in pots; but the trees were only under full salt treatment from July 12 on, having been supplied with the basic nutrient solution prior to that date. Early in the 1941 season, it became evident that the development of the trees was severely inhibited by the high chloride treatment. By the latter part of May, 8 of the 12 trees under this treatment were dead. Four of these were Shalil and four Lovell so that there was no indication of the relative tolerance of the two rootstocks. It was possible to replace two of the dead trees with others that had been under similar treatment in pots. These six trees survived the 1941 season, but all died following resumption of active growth in the spring of 1942.

The decline of the trees preceding death involved reduction in growth rate, increase in the amount of leaf burn and chlorosis, severe and progressive die-back of the smaller branches, and ultimate complete defoliation of the trees. The root systems of the high-salt trees were much less extensive than those of the controls, and roots examined prior to the death of the trees had few white root tips and exhibited a tendency to form in very fine fibrous masses.

DISCUSSION

The vegetative responses observed when peach trees are grown in sand cultures supplied with solutions containing high concentrations of chloride and sulfate salts, indicate that total concentration of salt is a major factor in the resultant general growth depression. Regardless of the salt used, the ability of the plant to grow appears to be conditioned by the total concentration of the solution. Thus, as indicated in Table II, the greatest growth depression occurred under the high sulfate treatment which had the highest osmotic concentration, 3.6 atmospheres, of the six solutions used; and the high chloride solution with an osmotic concentration of 3.4 atmospheres produced almost as severe growth inhibition. The intermediate chloride and sulfate treatments, with osmotic concentrations of 2.0 and 2.2 atmospheres respectively, induced somewhat similar vegetative responses, but, in general, there was more growth inhibition under the chloride treatment. The slightly more favorable growth obtained at the low chloride level as compared with the control trees is not conclusive, and additional data are needed to determine this point.

Although total concentration of salt appears to be the most important factor in inducing growth inhibition, it is also clear that there are specific ionic effects that must be taken into account. High concentration of the chloride ion caused marked leaf symptoms that did not occur with high sulfate concentration, and other differences in response to the two ions were observed, notably with respect to die-back. The high death rate under the high chloride treatment affords added evidence that the chloride ion is more toxic than the sulfate ion at isosmotic concentrations.

The effect of the rootstock on the vegetative response of the Elberta peach under salt treatment is apparently correlated with the relative vigor of the two root systems. At the control and low chloride levels, the trees on Shalil rootstock exhibited better growth than those on Love11 when compared with respect to secondary thickening, linear growth, weight and volume. No significant difference between rootstocks was evident under the sulfate treatments. The Love11 rootstock promoted definitely better growth than the Shalil at the intermediate chloride level; and slightly better growth at the high chloride level. A possible explanation may be advanced on the basis of the relative vegetative vigor of the two rootstocks. The very vigorous Shalil root system is able to absorb more nutritive ions and water than the Lovell. This is advantageous at the low salt levels and results in greater growth of the scion; but may be injurious where a toxic ion, such as chloride, is present in high concentration since it results in greater intake and accumulation of the ion and consequent injury or growth depression. Chemical analyses of the leaves tend to support this theory as they show that those from the Elberta-Shalil trees accumulated more chloride than those from the Elberta-Love11 combination under the high and intermediate chloride treatments in which the former exhibit greater growth depression. This may also explain the greater salt tolerance of peaches on the less vigorous Davidiana rootstock which was observed by Chandler (1).

The possibility of progressive cumulative effects from continued salt treatment should not be overlooked in considering the growth responses of perennial plants. The behavior of the trees at the high chloride level suggests that this may be the case, and the more pronounced chloride injury to the intermediate chloride trees at the beginning of the 1942 season as compared with that of 1941 is also significant. For this reason, no final conclusions as to the maximum concentration of salts that can be tolerated or their toxic effects at a given concentration should be drawn until the trees have grown under the specified conditions for a sufficiently long time to determine whether or not maximum responses to continued treatment have been obtained.

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