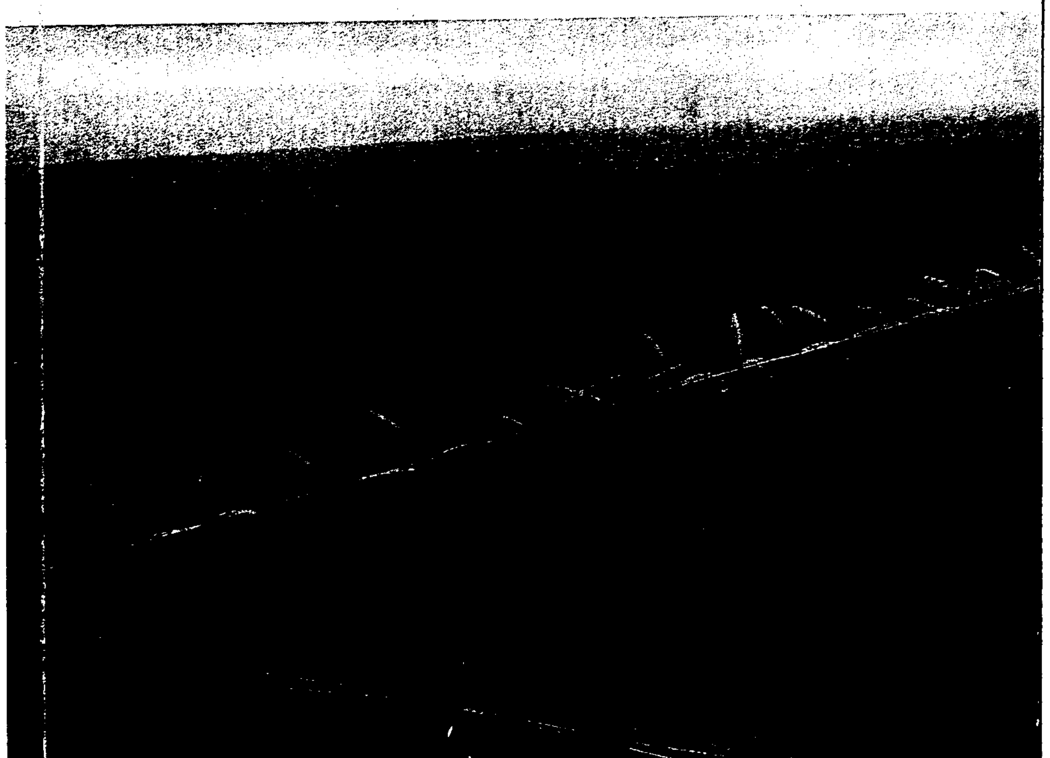
PROCEEDINGS

Of the Sixth Annual

RIO GRANDE VALLEY HORTICULTURAL INSTITUTE

Weslaco, Texas

January 16, 1952



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CONTENTS

COVER PICTURE: A Valley scene in the spring, showing sprinkler irrigation of vegetables, with citrus groves in the background.

Program of the Horticultural Institute

January 16, 1952

Citrus and Vegetable Training Center

Texas A&I College, Weslaco

MORNING SESSION, STARTING AT 8:30 A. M.

Address of Welcome: E. B. Dubuisson, President, Rio Grande Valley Horticultural Club.

The Tomato Research Program for the Rio Grande Valley: Guy Adriance, Head, Department of Horticulture, Texas A&M College.

Some Factors Relating to the Marketing of Commercial Vegetables: Porter R. Taylor, Director, Fruit and Vegetable Department, American Farm Bureau Federation, Washington, D. C.

Gummosis of Citrus: E. O. Olson, Plant Pathologist, U.S.D.A. Citrus Rootstock Investigations, Weslaco.

Activities of the Texas Citrus Commission: Stanley Crockett, Chairman, Texas Citrus Commission, Weslaco.

Panel Discussion of Citrus Varieties.

AFTERNOON SESSION, STARTING AT 2:00 P. M.

The Veterans Land Bill: Bascom Giles, Commissioner, General Land Office, Austin, Texas.

Weed Control: John Kennedy, District Manager, Houston Office, Kolker Chemical Works.

Processing and Utilization Research on Citrus Fruits: C. H. Fisher, Director, Southern Regional Research Laboratory, New Orleans.

Colored Slides of the Citrus Industry in Florida.

EVENING SESSION, STARTING AT 8:00 P. M.

Development of a Water Supply for the Lower Rio Grande Valley: L. M. Lawson, Commissioner, United States Section, International Boundary and Water Commission, United States and Mexico, El Paso.

Panel Discussion of New Crops for the Valley.

Address of Welcome

E. B. DUBUISSON, *President, Rio Grande Valley Horticultural Club*

It is indeed a pleasure to see you in attendance at our sixth annual Rio Grande Valley Horticultural Institute. We extend a most cordial welcome and hope that the quality and substance of our program will meet with your approval.

The successes of our past Institutes speak well of the keen interest shown in enlargement of horticultural knowledge of this area. It is our aim and purpose to continue to bring you the latest scientific and practical developments in various phases of horticulture. The continued financial support of the many sponsoring organizations, both private and public, attests to their confidence in our ability to do so.

The production of this program entails a vast amount of co-operative endeavor between various local organizations and individuals and to these, we express our appreciation. The Texas Agricultural Experiment Station, members of the Rio Grande Valley Horticultural Club, the Valley Chamber of Commerce, Valley radio stations, Texas A&I College, Valley newspapers, and our financial sponsors are among the varied group that contribute unselfishly to the success of this event.

We urge you to enter into the discussions and ask questions of the speakers, in order to get the most from this Institute.

The Difficulties of Replanting Lands to the Same Species of Orchard Trees

JAMES P. MARTIN and LEON D. BATCHELOR,
University of California Citrus Experiment Station, Riverside, Calif.

INTRODUCTION

The difficulties of replanting lands to the second or third orchard of the same species as the first one are rather widespread. This applies to replanting lands to peaches throughout much of the coastal area of the Atlantic seaboard. It applies especially to replanting orchards in the sandy soils of the Norfolk soil series from South Carolina to New Jersey. Similar troubles are also experienced in replanting lands to peaches in the central valley of California. The problem of replanting of lands to grapes in western New York along Lake Erie is also perhaps to a less degree a comparable problem.

One of the most extensive areas affected with comparable replant problems is the citrus growing districts of California. The orchardists here may wish to replant lands to the second citrus orchard for various

Figure 1. Valencia orange trees growing in Yolo loam near Santa Paula, California. The trees are approximately 14 years old. The large ones on the left followed walnuts while those on the right followed lemons.

reasons. Perhaps the first orchard is old and diseased, affected with psorosis if the trees are oranges or shell bark if they are lemons. In many other cases trees have been killed with quick decline, and it is necessary to periodically replant such individual tree spaces, or in extreme cases the entire first orchard may be destroyed and it is desired to plant a second orange orchard.

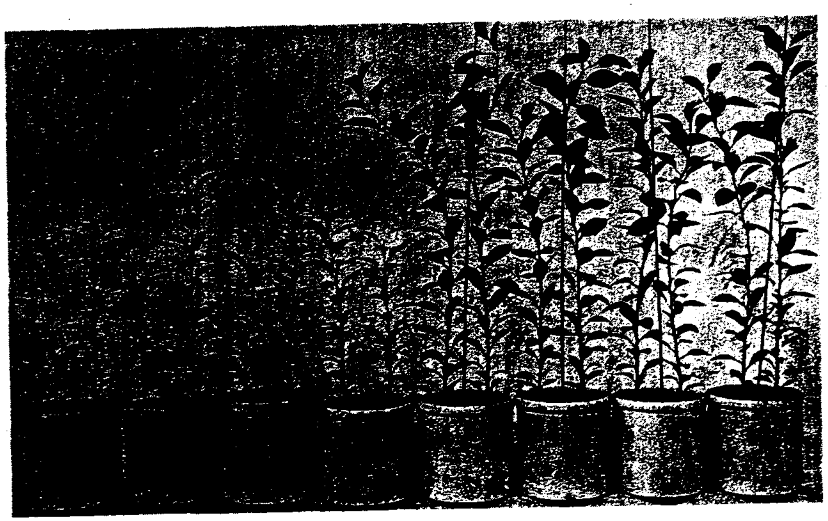
REPLANTING LANDS TO CITRUS IN CALIFORNIA

It has been the general observation in California that when the old trees are replaced with new ones, growth of the replants is slow compared to that of similar young trees planted in soil which has never before been planted to citrus. On some soils where records have been kept the average fruit yields over a period of years have been reduced by as much as 20 to 60 per cent on second or third orchards compared to comparable yields of the first plantings.

An example of the reduced growth effect of one crop of citrus on a second crop is given in figure 1 which shows Valencia orange trees approximately 14 years old. The trees on the left followed walnuts while those on the right followed lemons.

GREENHOUSE STUDIES

During the summer of 1945 greenhouse studies were initiated at the University of California Citrus Experiment Station to determine whether or not reduced growth of citrus in old citrus soils could be demonstrated



A *B* *C* *D*

Figure 2. Sweet orange seedlings growing in old citrus and non-citrus soils. *A.* Yolo loam old citrus soil. *B.* Hanford sandy loam old citrus *C.* Yolo loam walnut soil. *D.* Hanford sandy loam garden soil.

with seedlings in the greenhouse, and if so, to determine possible causes and find corrective measures. For these studies old citrus soils were obtained from orchards which had been in citrus for 25 to 50 years. For comparative purposes soils which had never been cropped to citrus were obtained from adjacent garden spots, walnut groves, etc. All tests were made in 3 gallon pots and were replicated 5 times.

The result of one of these tests is illustrated by figure 2. In general both sour and sweet orange seedlings made from 15 to 200 per cent better growth in the noncitrus soils than in the soils from the old citrus orchards. Tomatoes and barley grew just as well or better in the old citrus soils, as illustrated by figure 3.

A *B* *A* *B*

Figure 3. Sweet orange seedlings and tomato plants growing in *(A)* old citrus Hanford sandy loam soil previously cropped ot sour orange seedlings in the greenhouse for 9 months and in *(B)* adjacent noncitrus soil soil from a garden spot.

VARIOUS THEORIES TESTED

Various theories have been advanced to explain unsatisfactory growth of plants in soils previously cropped to the same species. These include: 1. The development of one or more nutrient element deficiencies. 2. The development of an unbalanced nutritional condition within the soil. 3. Deterioration of soil structure. 4. The accumulation of an organic toxic substance in the soil. 5. The development of a detrimental microbial population in the soil. All of these factors affect plant growth in general and are no doubt responsible for part of the reduced growth of citrus replants in some orchards. However, extensive greenhouse studies, and field tests and observations have indicated that two of the theories, namely, the development of a detrimental microbial soil population and the possible accumulation of a toxic organic substance in the soil are probably the primary causes of the relatively poor growth of citrus replants in California.

DETRIMENTAL MICROBIAL SOIL POPULATION

Nematodes: Various types of microorganisms have been found in citrus roots or have been found to be closely associated with them. Investigations carried on for 3 or 4 decades and by several investigators have shown that large numbers of the citrus-root nematode, *Tylenchulus semipenetrans* Cobb, are found in a majority of the citrus soils of California. Controlled experiments also have shown that these nematodes reduce the growth of citrus trees and seedlings.

Fungi: Pathogenic fungi primarily *Phytophthora* spp. have been isolated from citrus feeder roots and citrus soil. A study to determine if the growth of citrus affected the nature of the fungus population of the soil revealed that certain fungi were found in greater concentration in old citrus soils than in adjacent soils never before cropped to citrus. The most common fungus in the old citrus soils was *Fusarium solani.* Using sterile culture technique and a sand medium the effect of this fungus was studied as well as others found in the root zone of citrus trees. Observations were made on their effect on the germination of sweet orange seeds and the development of the young seedlings. *Fusarium solani, Fusarium oxysporum,* and *Cylindrocarpon radicicola,* all closely related fungi, caused decay of some of the seeds and injured the root tips of most of the seedlings which did develop. *Fusarium solani* plus a *Pyrenochaeta* sp., the second most common fungus isolated from old citrus soils, inhibited germination and caused the decay of over 98 per cent of the seeds tested. Many other fungi under similar conditions exerted no noticeable affect on the germinating seeds or the growth of young seedlings.

These studies suggest that the type of fungus population developing as a result of prolonged culture of citrus on the same soil may be partly responsible for the decay of citrus feeder roots and for the reduced growth of citrus in second or third plantings.

SOIL FUMIGATION STUDIES

If detrimental soil organisms are the cause of reduced growth of replanted citrus trees, treatments which kill these organisms without leaving a toxic residue in the soil should improve growth. Attempts to kill the organisms in the presence of the living trees have not met with success. After the old trees are pulled and before the replants are set, it is possible to kill the nematodes and other microbes by soil fumigation.

In field and greenhouse studies the following have been tested: "D-D" (dichloropropane and dichloropropylene mixture), ethylene dichloride, ethylene dibromide, methyl bromide, carbon disulfide, chloropicrin, propylene oxide, ethylene oxide, and other fumigants. Fumigation of the old citrus soil prior to replanting to citrus has usually resulted in marked improvement in growth as shown by figures 4 and 5.

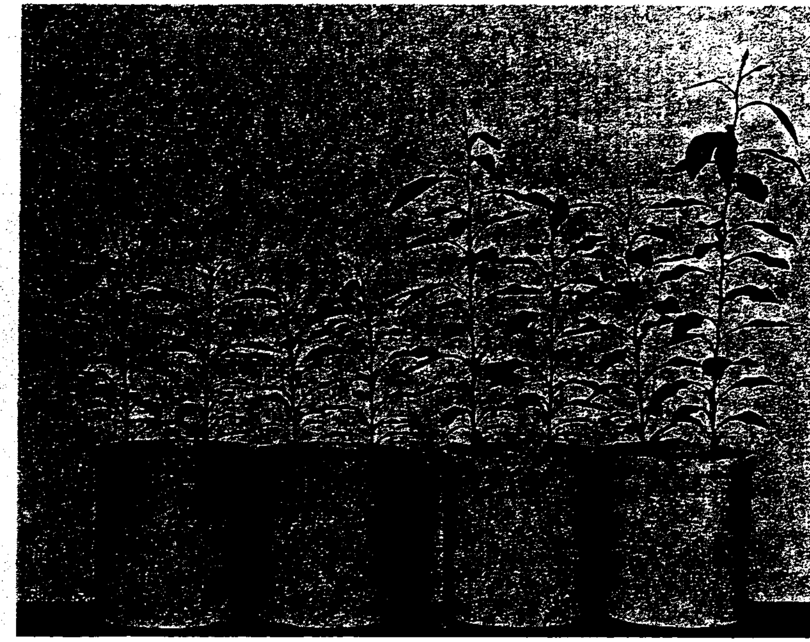


Figure 4. Effect of soil fumigation on growth of sour orange seedlings in old citrus Hanford sandy loam soil. The two pots on the left were fertilized only while those on the right were fumigated with 4000 lbs. per acre of carbon disulfide in addition to receiving fertilizer.

In order to obtain favorable results with fumigation it is necessary to follow the proper procedure. At the time of fumigation the soil should be at a moisture content considered ideal for plowing, that is, not too dry and not too wet. If too dry the organisms are more resistent to the toxic action of the fumigant, and if too wet, the fumigant does not diffuse readily throughout the soil mass. After using most fumigants the surface of the soil should be sprinkled with water. This forms a temporary water seal and prevents the gas from escaping into the air rapidly.

The dosages of fumigants necessary for good stimulation of citrus replants are much higher than those required to kill nematodes for vegetable crops, beans, tomatoes, etc. Good results with citrus have been obtained with from 600 to 3000 pounds per acre of "D-D." About twice as much ethylene dichloride or carbon disulfide and half to two-thirds as much chloropicrin is required. The lower dosages are sufficient for sandy soils or soils with a low exchange capacity, and the higher values for loams and clay loams or soils with a relatively high exchange capacity. Studies have indicated that it is sufficient to inject all the fumigant at one

Figure 5. Effect of soil fumigation on growth of lemon replants. The top tree is representative of those in a row planted approximately 6 months after the old trees were removed. The bottom tree is representative of those in an adjacent row in which the soil was fumigated with approximately 3000 lbs. per acre of D-D about 5 months before planting. The trees were approximately 2 years old.

depth. This should be from 12 to 15 inches. In sandy soils injection spacings of eighteen inches have given good results. In the finer textured soils 12-inch spacings have been more satisfactory. At the dosages used most or all of the nematodes and soil fungi and many of the bacteria and actinomycetes have been killed. Because of the high dosages required the cost might be prohibitive if the entire soil surface is fumigated. For this reason it is common practice to fumigate a 6 by 6 or 9 by 9 foot square where the replant is to be set.

In greenhouse tests a variety of fumigants have given good results, including "D-D," chloropicrin, carbon disulfide, ethylene dichloride, propylene oxide and ethylene oxide. Fumigants containing bromine, such as ethylene dibromide and methylbromide have been less satisfactory. In field tests "D-D" has given the best and most consistent results. With this material a water seal has not been necessary but it would not be a mistake to apply one if the proper facilities are available. The fumigant, especially if "D-D" is used, should be applied to the soil 5 or 6 months before plant-

ing in heavy soils in the cooler sections. In the hot inland areas planting can safely follow fumigation after six weeks. This shorter interval is safest on the sandy soils where only a moderate amount of the fumigant has been used. This is to allow time for the fumigant to diffuse into the air and throughout the soil mass and for the adsorbed portion in the soil to be decomposed by soil organisms which become active soon after the initial fumigation treatment.

CHEMICAL AND PHYSICAL EFFECTS OF SOIL FUMIGANTS

Soil fumigation, as well as killing organisms, exerts other effects on the soil. In order to determine whether or not all the beneficial effects of soil fumigation on growth of citrus replants is due to the killing of detrimental organisms or other causes, a study of its effect on various chemical and physical properties of the soil and on the chemical composition of the plant was made. This work revealed that soil fumigation had little or no effect on soil aggregation or structure, that it temporarily increased the soluble or available calcium, magnesium, potassium, and manganese in the soil, and that it occasionally increased the percentage of calcium, magnesium, and/or potassium and slightly reduced the phosphorus and sulfur in the plant. The magnitude of these changes, however, was not such that the supply was changed from a deficiency to a sufficiency level either in the soil or in the plant. Therefore it would appear that the increased growth of citrus replants after fumigation can best be explained on the basis of the destruction of a detrimental microbial population.

LEACHING STUDIES

Although fumigation usually improved the growth of citrus replants in greenhouse pot experiments, it did not restore growth to the status of that in soils not previously cropped to citrus. If old citrus soils from the orchards were additionally cropped to orange seedlings in the greenhouse, fumigation gave much less favorable results than using the soil directly from the orchards.

On the theory that in addition to harmful organisms some type of organic toxic material might be accumulating in the soil it was decided to try some rather drastic leaching treatments. Accordingly, different lots of old citrus soil in 3-gallon pots were given the following leaching treatments: 1. Distilled water. 2. Alcohol. 3. Ammonium chloride solution. 4. Two per cent sulfuric acid, and 5. Two per cent potassium hydroxide. After leaching with the last mentioned three materials it was necessary to saturate the soil colloids with a favorable ratio of calcium, magnesium, and potassium and to leach out the excess salts with distilled water.

Leaching with rather large amounts of distilled water before planting the second lot of seedlings did not significantly improve growth of sour or sweet orange seedlings in old citrus soils compared with seedlings grown on unleached soils. Similar leaching with distilled water of sand previously cropped to citrus seedlings improved growth of orange seedlings slightly. Leaching of old citrus soil with ethyl alcohol or a 1 normal solution of ammonium chloride at pH4, followed by saturation of the soil colloids with a favorable ratio of calcium, magnesium, and potassium, increased growth of the seedlings but did not enable them to grow so well as those in noncitrus soil. Leaching with two per cent sulfuric acid or with two per cent potassium hydroxide, followed by saturation of the colloids with a favorable action ratio, completely overcame the growth retarding factors enabling the seedlings to grow as well as in noncitrus soil.

In one test an old citrus soil was made extremely toxic to citrus by cropping it to sour orange seedlings in the greenhouse. Although tomatoes grew just as well in this soil as in non-citrus soil, orange seedlings grew very poorly. Leaching this soil with two per cent sulfuric acid followed by saturation of the colloids with calcium, magnesium, and potassium completely overcame the toxic effect. The increased growth of seedlings following this treatment was approximately 500 per cent. Fumigation of this same soil increased growth only 40 per cent.

These results support the hypothesis that, in addition to detrimental organisms, a toxic material gradually accumulates in soil which is continuously cropped to citrus for long periods of time. This hypothetical material in the amounts present is toxic to citrus but not to other plants such as avocados, tomatoes, barley, and in fact any annual crop we have seen tried. This material is either only slightly soluble in water or is absorbed by the soil colloids and held against leaching with distilled water, and is apparently destroyed by, or is soluble in, relatively strong acid or base solutions.

CITRUS PLANTING IN FLORIDA

Citrus growers of Florida are quite generally of the opinion that they do not have any replant problem. For this reason it was decided that it would be of interest to grow citrus seedlings in old citrus and noncitrus soil from Florida along with old citrus and noncitrus soils from California. Accordingly soil samples were obtained from one location in Florida; for comparison with two locations in California, sweet orange seedlings were grown in the soils in 3-gallon pots for 9 months. The results of the test are

Table 1. Growth of sweet orange seedlings in old citrus and noncitrus soils from California and Florida.

Soil*	Dry weight per 3 gal. pot			Increase, noncitrus over old citrus soil
	Tops	Roots	Total	
	gm	gm	gm	per cent
Norfolk sand from Florida,				
Old citrus soil	34	19**	53	—
Adjacent virgin soil	37	26**	63	19
Hanford sandy loam from California,				
Old citrus soil	21	9	30	—
Adjacent noncitrus soil	44	24	68	127
Yolo loam from California,				
Old citrus soil	23	10	33	—
Adjacent walnut soil	54	26	80	142

*All pots received nitrogen, phosphorus, potassium, manganese, zinc, and copper fertilizer

**Roots of seedlings in the old citrus soil from Florida showed considerable decay, while those in the noncitrus soils were very healthy in appearance.

recorded in table 1. The depressing effect of the old citrus soils from California on the growth of the seedlings was much greater than that of the old citrus soil from Florida. This result is in harmony with the general observations of those concerned with citrus growing in Florida.

The difference in the replant problem in California and Florida* is probably explainable when one considers the soil and climatic differences in the two areas. Florida citrus soils are over 95 per cent sand, are naturally acid, and are thoroughly leached several times each year by heavy rains. As mentioned previously sand culture experiments in California showed that leaching of old cultures with distilled water improved the growth of seedlings and leaching with two per cent acid *completely* overcame the reduced growth effect. The natural leaching and with the acid condition of Florida soils may be the reasons why the replant problem is not serious there. However neither leaching with water or acidification, alone or combined, has been beneficial to date under field conditions in California.

SELECTION OF ROOTSTOCKS AND VIGOROUS TOPS FOR REPLANTING OLD CITRUS LAND

Another aspect of our work has been the selection of especially vigorous rootstocks to combine with tops from very vigorous growing trees. Some of these combinations are promising as a practical means of overcoming this replant difficulty. With oranges the combination which is growing especially well is the Troyer citrange root with a Campbell Valencia or with some nucellar Valencia top. Fig. 6 shows a four year old Campbell Valencia on Troyer citrange rootstock and an ordinary four year old Valencia on grapefruit rootstock. These trees were planted near each other where old trees had been taken out because of quick decline. The soil was not fumigated. It is not possible from this particular comparison to tell which is the most important in producing a satisfactory tree, the vigorous Campbell Valencia top or the vigor of the Troyer citrange rootstock. We know from other experiments however that both of them are important. There are other combinations with lemons which seem to be equally as promising.

SUMMARY

The difficulties of replanting lands to citrus in California, and to peaches in California and in the Atlantic seaboard states is a serious problem.

The failure of such second citrus orchards in California is believed to be due to the development of a detrimental microbial soil population, and the apparent accumulation of a toxic organic substance in such citrus soils, which specifically affect citrus.

All other tree or annual crops which have been tried have grown equally as good on old citrus orchard soil as on noncitrus soil.

*Florida soil samples were obtained through the cooperation of Dr. Walter Reuther.

Figure 6. Four year old Valencia trees planted where old orange trees have been removed; soil not fumigated. Left, Campbell Valencia tree on Troyer citrange rootstock. Right, ordinary Valencia tree on grapefruit rootstock.

Fumigation of the soil under field conditions and also under controlled greenhouse cultures has only partially restored soil to its original productivity for citrus.

With pot cultures growing under greenhouse conditions, old citrus orchard soil can be fully restored to its productivity for citrus by leaching the soil with two per cent sulfuric acid or two per cent potassium hydroxide. It was necessary to saturate the colloids with a favorable ratio of calcium, magnesium, and potassium and to leach out the excess salts with distilled water. No field procedure of leaching has thus far been found practical.

The replanting difficulty can apparently be rather successfully overcome by two procedures. First the land should be fumigated with any one of several soil fumigants, using a relative heavy dosage. Second by using especially vigorous rootstocks which have been budded to particularly vigorous or nucellar strains of such common citrus varieties as Valencia oranges, Lisbon lemons, or Eureka lemons, etc.

Pruning Tests With Citrus Trees Damaged by Freezes in the Lower Rio Grande Valley

NORMAN P. MAXWELL, *Texas Agricultural Experiment Station, Weslaco*

The Rio Grande Valley citrus industry suffered three severe setbacks from the freezes of January 1949, December 1950 and February 1951. The fruit production has been reduced from a peak of about 28 million boxes in 1948 to an estimated 500,000 to 1 million boxes for the 1951-52 season. The latter estimates are by the U.S.D.A. and the Texas Citrus Commission.

The intensity and duration of the cold varied to a slight extent in different areas of the Valley in the three freezes. The minimum temperatures recorded in the Lower Rio Grande Valley as given by the Brownsville weather station are: January 29, 30 and 31, 1949, 18° at Rio Grande City and 20° in the citrus area; December 7, 1950, 22° at one locality in the Valley but generally about 24° or 25°; January 29-February 3, 1951 nearly 65 hours below freezing with a low of 18°.

The amount of wood damage suffered by the citrus groves varied according to the age and stage of growth of the trees, and topography of the land. Those groves which were injured in the December 1950 freeze, either by defoliation or wood damage, were in a flush growth when the February 1951 freeze occurred. In most cases the trees in such groves were killed or severely damaged.

Little research had been conducted in Texas on the proper method and time of pruning freeze damaged citrus trees before the 1949 freeze.

Pruning experiments were initiated in 1949 on 5-year-old Redblush grapefruit trees on the Experiment Station at Weslaco and on a 6-year-old Valencia orange grove on Rio Farms at Monte Alto. Trees in both groves were in a flush of growth at the time of the freeze. Damage consisted of bark split on the trunks and framework branches, with destruction of all wood under one inch in diameter. The damage to the main crotch and framework limbs of some trees at Rio Farms was so severe that it was necessary to remove the entire framework heads. Since the amount and degree of injury varied with different trees, it was necessary to classify each tree as to the degree of injury and the treatment which could be applied.

The pruning treatments applied at the two locations are shown in table 1. These treatments were designed to afford a comparison of early, midseason and late pruning, in so far as timeliness of operations were concerned, as well as a comparison of methods for rebuilding heads where damage required their removal. In pruning branches and framework limbs, all cuts were made into sound green wood below serious bark wounds involving one-third or more of the circumference. Where it was possible, these cuts were made just above a shoot or branch to encourage callus growth to cover the pruning wound and to lessen the possibility of further dying back. In applying treatments where heads were to be reformed, cuts were made to the trunks and near the bud union in April 1949, and new shoots were allowed to grow. After these shoots were well-hardened, they were thinned to either a single shoot or to three to five well-placed shoots, depending on the type of head to be reformed at the time of thinning. The old trunk was repruned with a cut sloping downward from the base of the uppermost shoot into sound wood. All wounds and major bark splits were painted with a pruning compound immediately following the treatment.

Periodic observations were made on the growth and rate of recovery following pruning. Tables 2 and 3 give the detailed observations recorded September 28, 1950.

The time of pruning significantly affected the rate and degree of recovery of the trees. In treatments where it was not necessary to remove the head of the tree, the most satisfactory recovery was made where pruning was delayed until at least the first flush of growth was hardened. A good recovery was also made by the trees pruned after the second flush of growth had hardened. Slight sunburn damage was noted with treatment 4, on the Rio Farms test where the removal of a large amount of wood had exposed the center of the tree.

Dieback, which made another major pruning operation imperative, occurred when the trees were pruned within one month after the freeze. Such early pruning also seemed to result in a temporary stunting of the tree.

Tree recovery was not hastened by delaying pruning for a full year after the freeze. At that time it was very difficult to prune the trees properly due to interference of new growth with the pruning operation.

It is felt that trees pruned a year after a freeze will make good trees. For a few years production will probably be slightly below those trees pruned after the first and second flushes; the removal of weak branches with new growth generally reduces the size of the tree, compared to those pruned after the first and second flushes.

Treatment number 6, in which multiple shoots were left, appeared to be the most satisfactory treatment where it was necessary to rebuild a new head. However, this observation cannot be considered as conclusive because several years would be required to evaluate the condition of trees fully restored by various methods of rebuilding the head.

It will not be possible to obtain production and long time tree records because the trees in the pruning tests were destroyed by the February 1951 freeze. However, another series of pruning tests were initiated after the 1951 freeze repeating the treatments in Table 1 on trees in two different age groups: 5-10 years old and over 10 years of age.

At the present time results of the 1951 pruning tests corroborate the findings of the 1949 tests in that pruning should not be done until the first flush of growth has hardened.

It is planned to continue these tests for several years, in order to obtain further records on fruit production and tree recovery.

Table 1. Treatments of freeze-damaged citrus tree pruning test.

Treatment No.	*Treatment*
	Rio Farms. Six-year-old Valencia orange trees
1	Check (No pruning)
2	Prune back to live wood in April 1950
3	Prune back to live wood after first flush (April 1949)
4	Prune back to live wood after second flush (July 1949)
5	Remove top below framework limbs and train to one shoot
6	Remove top below framework limbs and train to multiple shoots
7	Remove top near the bud union and train to one shoot
8	Remove top near the bud union and train to multiple shoots
	Experiment Station. Five-year-old Redblush grapefruit trees
1	Prune back to framework limbs within one month after the freeze
2	Prune all visible dead wood within one month after the freeze
3	Prune back to live wood after first flush (April 1949)
4	Prune back to live wood after second flush (July 1949)
5	Prune back to live wood in April 1950 (Check)

Table 2. Observations of freeze-damaged citrus tree pruning plots at Rio Farms.

Treatment No.	Treatment	Notes recorded September 28, 1950
1	Check (No pruning)	The foliage color was dark green. It will be difficult to prune the dead wood due to the large amounts of new growth. Many weak limbs will have to be removed. Most freeze wounds were healing well and some fruit was set on part of the trees.
2	Prune back to live wood, in April 1950.	Foliage color was dark green. The trees were rather open due to removal of large amounts of wood in April 1950. Some repruning will be necessary because of dying of weak limbs. Freeze and pruning wounds healing well in most cases. A few fruit were set on part of the trees.
3	Prune back to live wood after first flush, April 1949.	Foliage color was dark green. More new wood present than in treatment 2. Some repruning will be necessary due to further dying of weak limbs. Freeze and pruning wounds healing well. A few fruit were set on part of the trees.
4	Prune back to live wood after second flush, July 1949.	Foliage color was dark green. More new wood present than in treatment 2. Some repruning will be necessary due to further dying of weak limbs. Freeze and pruning wounds healing well. A few fruit were set on part of the trees.
5	Remove top below framework limbs and train to one shoot.	Foliage color was dark green. No repruning will be necessary. The wound was healing well where the old top was removed. No fruit set on any trees.
6	Remove top below framework limbs and train to multiple shoots.	Foliage color was dark green. No repruning will be necessary. Considerably more top present than in treatment 5. The wound was healing well where the old top was removed. No fruit set on any trees.
7	Remove top near the bud union and train to one shoot	Foliage color was dark green. No repruning will be necessary. The wound was healing where the old top was removed. No fruit set on any trees. It was difficult to select a shoot and make a slanting cut on the trunk that will heal because of the short trunk left to work with.
8	Remove top near the bud union and train to multiple shoots.	Foliage color was dark green. No repruning will be necessary. Considerably more top present than in treatment 7. The wound was healing where the old top was removed. No fruit set on any trees. It was very difficult to select multiple shoots and make a slanting cut on the trunk that will heal because of the short trunk left to work with.

Table 3. Observations of freeze-damaged citrus tree pruning plots on the Lower Rio Grande Valley Experiment Station.

Treatment No.	Treatment	Notes recorded September 28, 1950
1	Prune back to framework limbs within one month after the freeze.	Foliage color dark green. Considerable repruning necessary due to dieback of limbs early in 1949 after the trees were pruned. A lot of new wood growth was present. Freeze wounds were healing well. A few fruit set on some of the trees.
2	Prune all visible dead wood within one month after the freeze.	Foliage color dark green. Considerable repruning was necessary due to dieback of limbs early in 1949 after trees were pruned. A lot of new wood growth was present. Freeze wounds were healing well. A few fruit set on some of the trees.
3	Prune back to live wood after first flush, April 1949.	Foliage color dark green. Very little repruning was necessary. A few small twigs had died back. A lot of new wood growth was present. Freeze and pruning wounds were healing well. A light crop of fruit was set on some trees. Tops were larger than those given treatments 1 and 2.
4	Prune back to live wood after second flush, July 1949.	Foliage color dark green. Very little repruning was necessary. A few small twigs had died back. A lot of new wood growth was present. Freeze and pruning wounds were healing well. A light crop of fruit was set on some trees. Tops were larger than those given treatments 1 and 2.
5	Prune back to live wood in April 1950, check.	Foliage color dark green. Trees were more open than those given treatments 3 and 4. This was probably due to hte large amount of wood removed in the spring of 1950. Very little repruning was necessary. A few twigs had died back. Freeze and pruning wounds were healing well. A few fruit were set on some of the trees. Tops were larger than those given treatments 1 and 2.

Influence of Rootstock on Injury and Recovery of Young Citrus Trees Exposed to the Freezes of 1950-51 in the Rio Grande Valley[1]

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INTRODUCTION

The effect of rootstock on the cold resistance of the scion has been reported by various investigators. Oranges and grapefruit on rough lemon rootstocks are more susceptible to cold injury than the same scions on sour orange rootstocks in Florida and California (Hume, 1926; Uphof. 1938; Hodgson and Wright, 1950). Likewise, orange varieties on Cleopatra mandarin exhibited a considerable degree of frost hardiness in Florida (Uphof, 1938). Rootstocks of the trifoliate orange greatly increased the cold resistance of varieties budded on it, but the use of this species is limited principally to satsuma (Swingle, 1909). Many citranges used as rootstocks are reported to induce cold resistance in the scion (Webber, 1943).

During the winter of 1950-51 two freezes in the Lower Rio Grande Valley caused damage to citrus comparable to that of the freezes of 1894-95 in Florida. The first freeze was of short duration and occurred on December 7, 1950. Temperatures were below 32°F. for 14 hours and reached a minimum of 25° for three to four hours. This freeze killed fruit, leaves and small wood of trees in many areas of the Valley. These injured trees in most instances put out a new flush of growth during January and were in a succulent condition at the time of the second freeze.

The second freeze commenced on January 31, 1951, and was of long duration. During the first phase, temperatures ranged between 25° and 32°F. for three days and were accompanied by strong northerly winds and a mist which covered the trees with ice. This phase was followed by two days of extremely low temperatures during which minimums of 18° to 20°F. were reached for several hours. Wood injury was severe and extensive on trees in all parts of the Valley. It is estimated that five million trees were killed.

This paper presents observations on freeze damage to the citrus trees in the extensive rootstock trial plots located at the Experiment Station at Weslaco, Engelman Gardens at Elsa, and Delta Lake at Monte Alto. The trees were one to three years of age at the time of the freeze. The December freeze causd only foliage and bark injury to the three-year-old trees at the Experiment Station and gave an opportunity to measure the influence of rootstocks on the resistance of the scion to cold injury. The same opportunity for obtaining this type of information was not available in the other two plantings, since all trees were frozen to the banks at Engelman Gardens and the trees at Delta Lake were not injured. A temperature of 24°F. for twenty minutes and 25°F. for four hours and fifteen minutes was recorded at the main office of Engelman Products Company about three miles from the Engelman Gardens rootstock planting as compared with a minimum of 25°F. for two hours and fifty-five minutes at the Rio Farms office about four miles from the Delta Lake planting. The minimum temperature at the Delta Lake planting was probably higher than at the Rio Farms office.

[1]These investigations are a part of the Cooperative Citrus Rootstock Project conducted by the U. S. Department of Agriculture and the Texas Agricultural Experiment Station, certain phases of which were carried on under the Research Marketing Act of 1946. The cooperation of Rio Farms, Inc. and Engelman Products Co. is gratefully acknowledged.

The second freeze killed all trees to the banks in each of the three rootstock plantings. The banks of soil covering about 14 inches of trunk above the bud union protected six to ten inches of the scion trunks from freezing. Many trees grew a new top from sprouts originating from this protected portion of the trunk. It was possible to measure the influence of the rootstock on the recovery of these cold-injured trees in all three plantings.

METHODS AND MATERIALS

The trees in the three experimental orchards are planted in four replicated plots of three trees of each scion – rootstock combination. Where grapefruit and orange scions are included in the same planting separate but adjacent blocks are made of the two scions. The planting distance is 25 x 25 feet in all instances.

The Experiment Station planting at Weslaco, established in December, 1947, consists of twelve Red Blush grapefruit trees on each of 39 different rootstocks. The soil is classified as Hidalgo fine sandy loam with a clay stratum containing calcium carbonate concretions 36 inches from the surface in most of the planting. The pH of the soil ranged from 7.6 to 8.1. The area is more or less flat, with no natural air drainage.

The Engelman Gardens planting, established in January, 1950, consists of twelve trees of Shary Red grapefruit on each of 24 rootstocks and a like number of Valencia orange trees on each of 14 rootstocks. The soil, a Hidalgo loam, has a pH of 7.8, is non-calcareous in the upper ten inches of soil, and is calcareous below. The topography is nearly level.

The Delta Lake planting, set out in April, 1950, consists of twelve trees of Shary Red grapefruit on each of 83 rootstocks and the same number of Valencia orange trees on each of 47 rootstocks. The soil, a Willacy fine sandy loam, is non-calcareous, and has a pH of 7.0. The topography is slightly rolling and the block of land lies to the west of one arm of the Willacy County water reservoir known as Delta Lake.

RESULTS

Effect of Rootstock on Degree of Cold Injury to Red Blush Grapefruit

The trees of the Experiment Station planting were three years old at the time of the December 7, 1950, freeze. They had been frozen to the banks nearly two years earlier by the freeze of January 30, 1949. After this earlier freeze all trees survived regardless of rootstock. The trunks of the trees on December 7, 1950, ranged from 100 mm. in circumference to those on citrumelo 4475 rootstock to 240 mm. for those on rough lemon (table 1).

From outward appearance all trees in the planting seemed dormant on December 7, 1950. The terminal growth and leaves were mature. The cold weather on the night of December 7 killed some leaves and caused bark splitting on limbs up to one inch in diameter. As shown in table 1, only five percent of the leaves on trees on Rangpur lime rootstock were killed as compared with nearly 35 percent for the sour orange and rough lemon and 52 percent for the Cleopatra mandarin. Thus, the resistance of the leaves of the scion to cold injury was influenced by the rootstock.

Bark splitting of the branches of the scion also varied with the rootstock. There was somewhat more bark splitting on trees on Cleopatra mandarin than on those on rough lemon and more on rough lemon than on sour orange or Rangpur lime.

Effect of Rootstock on Recovery of Cold-Injured Grapefruit and Orange Trees

Experiment Station Planting: All the Red Blush grapefruit trees developed a new flush of growth following the December freeze and were in a more or less succulent condition at the time of the second freeze. All trees on all rootstocks were then killed to the banks. None of the rootstocks under test had induced sufficient hardiness in the scions for them to withstand the prolonged and extremely cold weather.

A portion of the scion trunk, which was covered by the banks of soil, was uninjured on all trees at the time of unbanking one month after the freeze. The dead top of each tree was removed and a sloping cut was made in the sound wood of the trunk six to ten inches above the bud union. New shoot growth commenced on all trunks in early March. During the spring and summer twenty-four percent of the trees died but the remainder developed normal tops (table 1). All trees on Cleopatra, Temple (orange) and Sunki mandarins, Bergamot sour orange, Siam pummelo, Leonardy grapefruit, Rangpur lime, Savage citrange and Williams, Suwannee and Sunshine tangelo rootstock recovered from the freeze. A poor survival occurred for trees on sweet orange, King (orange) and Clementine mandarins, citrumelo 4475, Orlando tangelo, and certain others as shown in table 1. The trees on sweet orange, citrumelo and Orlando tangelo were affected with severe lime-induced chlorosis and were in poor vigor at the time of the freeze (Cooper and Olson, 1951). This probably contributed to the poor recovery of trees on these three kinds of rootstock at this location. Therefore their response would not necessarily be an indication of their inherent hardiness on non-calcareous soils.

The trees on King mandarin, however, were vigorous and healthy, with deep green foliage at the time of the freeze and therefore the poor survival of these trees from the freeze cannot be attributed to chlorosis. Olson (1951) found symptoms of cachexia on the Orlando, Yalaha, Pina and Minneola tangelos, Umatilla tangor and Temple, Chu Koa and Clem-

Table 1. Cold Injury and Tree Survival Data on Red Blush Grapefruit trees in the Experiment Station rootstock planting.

Rootstock: *Group*	Rootstock: *Variety*	*Circumference in mm. of trunk at time of freeze 12/7/50*	*Defoliation[1] %*	*Bark[2] Splitting*	*Survival[3] of Trees %*	*Complicating[4] Factors*
Sour orange	Florida	234	30	.9	91	
	Oklawaha	232	30	1.1	83	
	Bergamia	219	33	.8	100	
	Sauvage	235	33	.8	75	
	Bittersweet	230	33	.8	75	
Sweet orange	Florida sdlg.	170	40	1.0	25	Chlorosis
	Hamlin	159	33	.3	41	Chlorosis
Grapefruit	Duncan	155	28	1.0	75	Chlorosis
	Leonardy	213	22	.9	100	
	Natsu Mikan	177	37	1.1	66	Chlorosis
Pummelo	Siam	176	23	1.3	100	
	Thong Dee	165	24	1.2	83	Chlorosis
Mandarin	Cleopatra	209	52	1.8	100	
	Satsuma	165	33	1.1	75	
	Dancy	188	40	1.1	91	
	Chu Koa	180	38	1.4	83	Chlorosis
	Clementine	158	33	1.6	66	Chlorosis
	Sunki	229	32	1.0	100	
	Calamondin	195	47	2.0	91	
	King (orange)	177	31	1.4	50	
	Temple (orange)	147	25	.9	100	
Tangor	Umatilla	153	26	1.4	75	Chlorosis
Tangelo	Sampson	196	37	1.1	91	
	Williams	209	26	.9	100	
	Suwannee	163	51	1.5	100	
	Orlando	123	12	1.2	58	Chlorosis
	Sunshine	201	30	.6	100	
	Pina	169	39	.9	75	Chlorosis
	Watt	168	19	.9	66	Chlorosis
	Thornton	196	23	1.1	66	
	Yalaha	181	36	1.2	66	Chlorosis
	Minneola	205	31	1.2	91	
Miscellaneous	Rough lemon	240	35	1.6	91	
	Rangpur lime	222	5	1.2	100	
	Kalpi[5]	204	42	1.4	58	Chlorosis
	Lempum[6]	121	5	.6	91	Poor bud union
	Tavares limequat	159	43	1.8	50	Poor bud union
	Citrumelo 4475	100	35	1.2	58	Chlorosis
	Savage citrange	182	40	1.0	100	

[1]Defoliation resulting from the December freeze. The values given represent the mode for 12 trees of each rootstock.

[2]Bark splitting resulting from the December freeze. The values given represent the mode for the 12 trees of each rootstock: 0 for no bark splitting, 1 for bark splitting of twigs, and 2 for bark splitting of large limbs.

[3]Percentage of the 12 trees of each rootstock that grew a new top following the January freeze.

[4]See text for discussion on chlorosis.

[5]Hybrid of *C. macroptera* with the common Philippine mandarin.

[6]Hybrid of lemon with the pummelo.

Table 2. Influence of rootstock on percent of Shary Red grapefruit and Valencia orange trees that survived the freeze at the Engelman Gardens planting. All trees froze to the banks on December 7, 1950.

Rootstock		Percentage of trees with indicated scion that grew a new top.	
Group	Variety	Shary Red	Valencia
Sour orange	Florida	50	50
Sweet orange	Pineapple	100	75
	Homosassa	83	—
Sweet mandarin	Cleopatra	25	16
	Oneco	8	—
	Batangas	0	—
	Chu Koa	75	—
Tangor	653	16	16
Tangelo	Sunshine	83	—
	Webber	100	—
	Williams	50	58
	Pina	91	58
	Watt	91	75
	Sampson	50	—
	Seminole	33	50
	Minneola	—	75
	Thornton	75	91
Citrange	Morton	41	50
Lime-lemon	Egyptian sour lime	0	—
	Columbian sweet lime	58	—
	Butnal sweet lime	41	—
	Rangpur lime	83	—
	Sweet lemon	57	66
	Rough lemon	91	25
Severinia buxifolia	Small leaf	75	75

entine mandarin rootstocks in this planting. He did not, however, find any evidence of cachexia on any of the twelve trees on King mandarin rootstock.

Engelman Gardens Planting: Both Shary Red grapefruit and Valencia orange trees were included in this planting. The trunks of these trees had a circumference of approximately 60 mm. at the time of the first freeze. Although some of the trees had chlorotic leaves, none of them were stunted from chlorosis as in the Experiment Station planting. Every tree in the planting was killed to the bank by the first freeze.

A record of survival of trees on each rootstock is given in table 2. Only 50 percent of the grapefruit trees on sour orange and 25 percent on Cleopatra mandarin survived. On the other hand, there was excellent recovery for grapefruit trees on Pineapple and Homosassa orange; Webber, Sunshine, Pina and Watt tangelos; Rangpur lime and rough lemon. Little or no survival was observed for grapefruit trees on Egyptian sour lime, Oneco and Batangas mandarins and tangor 653.

In most instances tree survival was approximately the same for Valencia trees as for grapefruit trees. One notable exception is the poor survival of Valencia orange trees on rough lemon rootstock as compared with the good recovery of grapefruit trees on this rootstock.

Table 3. Effect of rootstock and salt treatment on the resistance of Shary Red grapefruit trees to cold.

		Control		Salt Added	
Plot	Rootstock Variety	Conc. of Chlorides %[1]	Degree of Cold Injury[2]	Conc. of Chlorides %[1]	Degree of Cold Injury[2]
A	Sour orange	0.3	0	1.8	0.8
	Williams tangelo	0.2	0	1.4	0.8
	Minneola tangelo	0.2	0	1.5	0.8
	Sampson tangelo	0.2	0	1.6	1.0
	Florida sweet orange	0.7	0	2.5	1.0
B	Sour orange	0.2	0	2.5	1.0
	Pineapple sweet orange	0.7	0	2.4	1.5
	Cuban shaddock	0.5	0.4	2.3	1.4
	Nakorn pummelo	0.2	0	1.8	1.4
	Duncan grapefruit	0.2	0	1.7	1.6
C	Sour orange	0.2	0	2.4	0.6
	Rough lemon	0.2	0	1.4	1.0
	Rangpur lime	0.1	0	0.4	0
	Sweet lemon	0.4	0	1.9	1.0
	Columbian sweet lime	0.3	0	2.6	1.0
D	Sour orange	0.3	0	1.8	0.8
	Cleopatra mandarin	0.1	0	0.7	0.2
	Calamondin	0.4	0	2.1	1.5
	Citrus noblis	0.3	0	1.6	1.5
	Rusk citrange	0.7	0.2	2.9	1.0
E	Sour orange	0.3	0.2	1.5	1.0
	Trifoliate orange	0.8	0	2.7	[3]
	Severinia buxifolia	0.3	0	0.6	0
	Etrog citron	0.9	0	3.5	[3]
	Citrumelo 4475	0.3	0	1.9	0.6

[1]Percent of chlorides in the leaves (dry-weight basis).

[2]The values given represent the mode for the 12 trees of each rootstock: 0 for no dead wood, 1 for terminal twigs dead, and 2 for killing of wood basal to the terminal growth.

[3]Trees killed by salt treatment prior to the freeze.

Delta Lake Planting: The Shary Red grapefruit and Valencia orange trees were approximately the same size as those of the Engelman Gardens planting. All trees were vigorous and healthy and showed no signs of lime-induced chlorosis. There was no sign of cold injury to any tree in the planting following the cold weather of December. The second freeze, however, froze all trees on all rootstocks to the banks.

Only ten percent of the trees in this planting failed to recover from the freeze. Since the loss was negligible for most rootstocks the data were not tabulated. All grapefruit trees on 49 varieties of rootstock, including Cleopatra mandarin and nine other mandarins, sour orange, eleven varieties of tangelos (including Orlando and Sampson), Rangpur lime, rough lemon, Pineapple and Homosassa oranges, and Savage citrange, showed from 91 to 100 percent recovery. In contrast, grapefruit trees on Kara mandarin showed only eight percent recovery; on King mandarin 41 percent; on Thomasville citrangequat 58 percent; on Rusk citrange, Sanguinea mandarin, and citrangor 43301-A-2, 66 percent; and on Rustic and Troyer citranges and Willow leaf and Choa Chou Tien Chieh mandarins, 75 percent.

The tree recovery for the Valencia scion on most rootstocks was similar to that for the Shary Red grapefruit. However, Valencia trees on King mandarin rootstock made a better recovery than grapefruit trees on the same stock.

Relation Between Rootstock, Soil Salinity, and Cold Injury

A study has been made of the salt tolerance of a number of scion-rootstock combinations (Cooper, Gorton, and Edwards, 1951). Five replications of year old Shary Red grapefruit on different rootstocks were planted in duplicate series of latin squares. Treatments consisted of salt additions and of controls. The salt was applied to the soil through the irrigation water. The base water supply contained approximately 720 p.p.m. of total soluble salts and this was used to irrigate the control plots. A 50-50 mixture by weight of NaCl and CaCl2 was added to the base water to give approximately 4200 p.p.m. of total soluble salts and this solution was used to irrigate the salinized plots.

Salinization began on May 31, 1950, and continued throughout the summer and fall. Analysis of the leaves of the trees for chloride showed that the specificity of the rootstock in conditioning the uptake of chlorides was outstanding. The injury to the leaves and stems of the trees was also found to be associated with the chloride content of the leaves.

The extent of cold injury that was observed on the trees in these experimental plots followed the December, 1950, freeze is presented in table 3. Both leaves and twigs were injured by the freeze but only twig damage is presented as leaves on some trees were killed by the salt treatment prior to the freeze.

There was practically no cold injury to twigs on the trees in the no-salts-added plots. The leaves of these trees contained less than one percent chloride. However, in the salt-added plots, cold damage to twigs was noted and the degree of damage was associated with the concentration of chlorides found in the leaves. Trees on sweet orange, Rusk citrange, and other stocks containing more than 1.4 percent chloride in the leaves showed considerable cold damage to twigs, while trees on Rangpur lime and *Severinia buxifolia,* which had 0.6 percent chloride or less in the leaves, showed no cold damage.

It appears from these data that soil salinity, which in turn affects the chloride content of the leaves and twigs of the scion, greatly influences the cold hardiness of the scion-rootstock combination. Combinations which tend to accumulate chlorides would be expected to be tender to cold when grown in a saline soil.

DISCUSSION

It is difficult to reconcile the results of these rootstock trials with the generally accepted opinions on influence of certain rootstocks in Florida and California. At the time of the December freeze, the grapefruit scion

on rough lemon in the Experiment Station planting showed nearly the same degree of hardiness as the sour orange while grapefruit on Cleopatra mandarin showed less hardiness. Since all trees on all rootstocks were frozen to the banks during the second freeze it was not possible to measure the relative resistance to cold injury of the rootstocks in these plantings at that time.

It was observed, however, that grapefruit trees on rough lemon rootstock, when frozen to the banks by the second freeze, showed better recovery than grapefruit trees on sour orange rootstocks. This response of a young tree that has had a portion of the trunk saved from freezing by banking is, however, not exactly comparable with that of older bearing trees on which observations on cold hardiness have been made in Florida and California. The inherent vigor of the rough lemon rootstock which was protected from cold injury by banking is probably a big factor in the excellent survival of trees reported for this rootstock.

The scion variety involved may also be a factor in recovery from cold injury. In the Engelman Gardens planting, grapefruit on rough lemon made a better recovery than Valencia on rough lemon.

There was no definite pattern for the grapefruit-Cleopatra mandarin combination. In the Experiment Station planting these trees were injured more by the December freeze than were those on sour orange. On the other hand, tree recovery from the severe January freeze was in general better for grapefruit on Cleopatra mandarin trees than on sour orange in the Experiment Station planting, worse than on sour orange at Engelman Gardens and the same as on sour orange at Delta Lake. The two 25-year-old Thompson grapefruit trees on Cleopatra mandarin at the Experiment Station showed about the same freeze damage as trees of the same age on sour orange rootstock.

The poor tree recovery of grapefruit on certain of the mandarins, such as the King and Kara, was consistent at all locations where tested. Also in the Delta Lake planting a low percentage of tree survival was observed for grapefruit on certain trifoliate hybrids, such as the Thomasville citrangequat and the Troyer citrange.

Certain soil characteristics may greatly influence the hardiness of any scion-rootstock combination. This is clearly shown by the influence of chlorides in the soil on the hardiness of Shary Red grapefruit on twenty-one different rootstocks. Grapefruits on sweet orange and Rusk citrange, normally fairly cold-resistant, become susceptible to cold injury when grown on a saline soil. The apparent lack of cold resistance of the trifoliate hybrids in the Delta Lake planting could be due to salt accumulation. Because of this great influence of salt on the response of rootstocks, it is highly desirable to test the adaptability of untried rootstocks in a given area before making rootstock recommendations.

SUMMARY

The degree of cold injury from the December 1950 freeze to three-year-old Red Blush grapefruit trees in the Experiment Station field planting was found to be influenced by the variety of rootstock. The Rangpur lime rootstock had a definite tendency to induce hardiness in the leaves of the grapefruit top. Cold injury to leaves and shoots was similar for trees on sour orange and rough lemon while it was more severe on trees on Cleopatra mandarin than on those on sour orange.

Observations on cold injury to Shary Red grapefruit trees grown in salinized plots indicated that high soil salinity greatly influences the degree of cold hardiness of certain scion-rootstock combinations.

Both grapefruit and Valencia orange trees (one to three years of age) in the different field plantings were frozen to the banks by the January, 1951 freeze. The development of new tops on these trees following the freeze was found to be influenced by the rootstock. Trees on rough lemon rootstock generally made a better recovery than those on sour orange. The recovery of trees on Cleopatra mandarin varied in the different plantings. The recovery of trees on King and Kara mandarins was notably poor.

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The Effect of Psorosis on the Survival of Red Grapefruit Trees After the 1950-51 Freeze in the Lower Rio Grande Valley of Texas

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After the 1949 freeze in Texas many citrus growers observed that losses were much heavier in trees with bark lesions of psorosis. It was also observed that certain of the apparently healthy trees were killed while others under similar conditions survived. These observations suggested that some of the casualties among the apparently healthy trees were also infected with psorosis.

At the time of the freeze in January and February 1951, accurate charts were available of twenty red grapefruit groves in which was recorded the location of healthy trees, trees with bark and leaf symptoms of psorosis, and trees with psorosis leaf symptoms alone. These records were the result of examinations made by the State Department of Agriculture in carrying out the program of budwood certification (White, 1951) in cooperation with the Lower Rio Grande Valley Nurserymen's Association.

Data on freeze damage were available from the twenty groves of red grapefruit which had been charted. These data showed that in many of these groves other conditions such as dormancy, pruning, cultivation, irrigation, varying temperatures, air drainage, and windbreaks were major factors in determining the degree of freeze injury. Four groves were selected for study in which these factors did not appear to influence the degree of freeze injury. The data reported here are from these four charted groves, all of which were red grapefruit on sour orange rootstock and were under observation for at least two years preceding the freeze.

RESULTS

The records show that there were 18 trees with bark symptoms of psorosis in the four groves (table 1). Only one of these trees survived the freeze. There were 36 trees showing only the leaf symptoms of psorosis of which two survived the freeze. Except for leaf symptoms, these latter trees were apparently healthy, although such trees often showed slight dwarfing and smaller sized fruit.

In contrast to the heavy losses in psorosis-infected trees, 95 (99%) of the 96 psorosis-free trees in these four groves survived the freeze. These results confirm the observation of Fawcett (1948) who reports ". . . trees having infestations of scale insects or red spider, and trees attacked by gummosis, scaly bark, or other diseases are more seriously injured by freeze than adjacent healthy trees."

An example of the effect of psorosis on freeze damage to red grapefruit trees at the Mercedes location (Table 1) is shown in figure 1. The living tree was psorosis-free, while the adjacent dead tree showed leaf symptoms of psorosis before the freeze. These trees were of the same strain of red grapefruit, of the same age and on the same rootstock.

Figure 1. Red grapefruit trees of the same age 45 days after the 1951 freeze. The dead tree at the left showed leaf symptoms of psorosis before the freeze. The living tree at the right was free of psorosis.

The observation that these trees with leaf symptoms and no bark symptoms of psorosis did not survive the freeze is a possible explanation of why many apparently healthy trees failed to survive freeze injury in 1949. Such apparently healthy trees may have been infected with psorosis, and more susceptible to freeze injury.

Table 1. Effects of Psorosis on survival of red grapefruit trees after the 1950-51 freeze in the Lower Rio Grande Valley of Texas.

			Trees showing bark symptom		*Trees showing leaf symptom*		*Healthy trees*	
Location	*Date planted*	*No. years observed*	*Alive before freeze*	*Alive after freeze*	*Alive before freeze*	*Alive after freeze*	*Alive before freeze*	*Alive after freeze*
A (Mercedes)	1942	4	0	0	4	0	24	24
B (Edinburg)	1939	4	12	1	20	2	28	28
C (Weslaco)	1935	2	6	0	5	0	21	21
D (Los Fresnos)	1936	2	0	0	7	0	23	23
Total			18	1	36	2	96	95

The observations on the relations of psorosis to freeze injury are further evidence of the potential benefit to be derived from the Texas Inspection and Registration of Citrus Trees and Certification of Nursery

Stock. The elimination of psorosis from nursery trees provides a more freeze-tolerant tree for future plantings.

CONCLUSIONS

Red grapefruit trees with leaf and bark symptoms of psorosis were more susceptible to freeze injury than psorosis-free trees under the conditions existing in Texas in the 1950-1951 freeze.

Red grapefruit trees with leaf symptoms and no bark symptoms of psorosis were more susceptible to freeze injury than psorosis-free trees under the conditions existing in Texas in the 1950-51 freeze. (The author does not wish to imply that all citrus trees killed in the Lower Rio Grande Valley of Texas in the freeze of 1950-51 had psorosis).

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Investigations of Citrus Rootstock Diseases in Texas

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The citrus rootstock commonly used in the Lower Rio Grande Valley of Texas is the sour orange, which is resistant to Rio Grande gummosis, cotton root rot, and *Phytophthora* foot rot. Grapefruit and orange trees on sour orange rootstocks, however, are highly susceptible to tristeza, a virus disease at present unknown in Texas. Therefore, other rootstocks are being tested for adaptability to Texas conditions because no one knows when tristeza might appear. This article is concerned with the present status of rootstock diseases in Texas, including two citrus disorders previously unreported from Texas: cachexia and a disorder of the Rangpur lime. The occurrence of *Phytophthora palmivora* in Texas citrus is also reported.

RIO GRANDE GUMMOSIS

Rio Grande gummosis of grapefruit trees is characterized by gumming blisters on the trunks or large limbs and by gum pockets beneath the blisters; the affected wood beneath a blister is buff colored and usually is bordered by a salmon orange to pink color that deepens in shade when exposed to the air. The affected wood has an odor similar to that of smoked fish. The wood stain does not extend beyond the bud union into the sour orange rootstock.

Rio Grande gummosis has been attributed to an actinomycete (Godfrey, 1945) and a virus or a heritable weakness (Klotz, 1951). Childs (1950) considered that Rio Grande gummosis was not a possible symptom of foot rot, psorosis or *Diplodia* infection.

Olson & Waibel (1951) showed that the wood stain was sometimes transmitted by insertion of chips of bark or wood from affected trees into healthy ones and at other times uncovered chisel cuts became infected naturally. However, a more consistent method of transmitting the disease to healthy trees was desired in order to determine the susceptibility of various rootstocks to the disease.

A block of 15-year-old Marsh White grapefruit and Valencia orange trees at Rio Farms were used as test trees. Various bacteria and fungi were inserted into chisel cuts on large branches and the incisions were covered with adhesive tape. The controls included taped and untaped

[1]These investigations are a part of the Cooperative Citrus Rootstock Project conducted by the Texas Agricultural Experiment Station and the U. S. Department of Agriculture, certain phases of which were carried on under the Research Marketing Act of 1946. The cooperation of Rio Farms, Inc., Monte Alto, and of Carl Waibel, Texas Department of Agriculture, in the Rio Grande gummosis studies is greatly appreciated.

chisel cuts. The inoculated limbs were chiseled open 75 to 100 days after inoculation, and the length of the pink stain parallel to the grain of the wood was measured.

In open chisel cuts and in cuts inoculated with chips of the salmon-pink wood from Rio Grande gummosis lesions (hereafter referred to as "pink chips") the characteristic wood stain sometimes developed. Inoculations with certain isolates of a fungus tentatively identified as *Diplodia natalensis* consistently resulted in the pink wood stain characteristic of Rio Grande gummosis (Figure 1). The symptoms occurring on grapefruit trees showed many similarities to the symptoms of Rio Grande gummosis: profuse gumming, a wood stain of similar color and odor, and longitudinal bark cracks. The pink wood stain induced by *Diplodia* was most extensive in grapefruit, less extensive in sweet orange, and least extensive in sour orange, where the pink stain was a thin border one mm. in width. In the grapefruit scion *Diplodia* inoculum caused a pink wood stain that extended to the bud union, but did not cross into the sour orange rootstock; this is also a characteristic of Rio Grande gummosis. *Diplodia* inoculum placed deep in the wood caused a pink stain within 90 days; similar inoculum placed between the bark and the wood (cambium region) did not cause the pink wood stain within the 90 day period of the experiment. The same pattern of infection occurred when chips of bark or pink wood from trees naturally infected with Rio Grande gummosis were used as inoculum (Olson & Waibel, 1951). The results of a typical experiment are shown in table 1. With the exception of one unidentified fungus, other bacteria and fungi, including *Diplodia* isolates from cotton, did not reproduce the pink wood stain.

Table 1. Results of typical experiment showing effect of inoculum source and part inoculated on occurrence of salmon-pink wood stain in orange and grapefruit trees, 90 days after inoculation.

Inoculum	*Part inoculated*	*Occurrence of stain in—* *Valencia orange* *Inoculations stained (number)*	*Valencia orange* *Stain index**	*Marsh White grapefruit* *Inoculations stained (number)*	*Marsh White grapefruit* *Stain index**
Control (none):					
Open cut in wood	----	0	0	5	46.5
Taped cut in wood	----	0	0	0	0
Diplodia	Wood	8	39.2	9	145.8
Pink chip	Wood	2	3.6	1	14.7
Control (none):					
Open cut in cambium region	----	0	0	0	0
Taped cut in cambium region	----	0	0	0	0
Diplodia	Cambium region	0	0	0	0
Pink chip	Cambium region	0	0	0	0

$$^{*}\frac{\text{Sum of lengths of pink stain (mm.) in successful inoculations}}{10 \text{ (number of inoculations attempted)}}$$

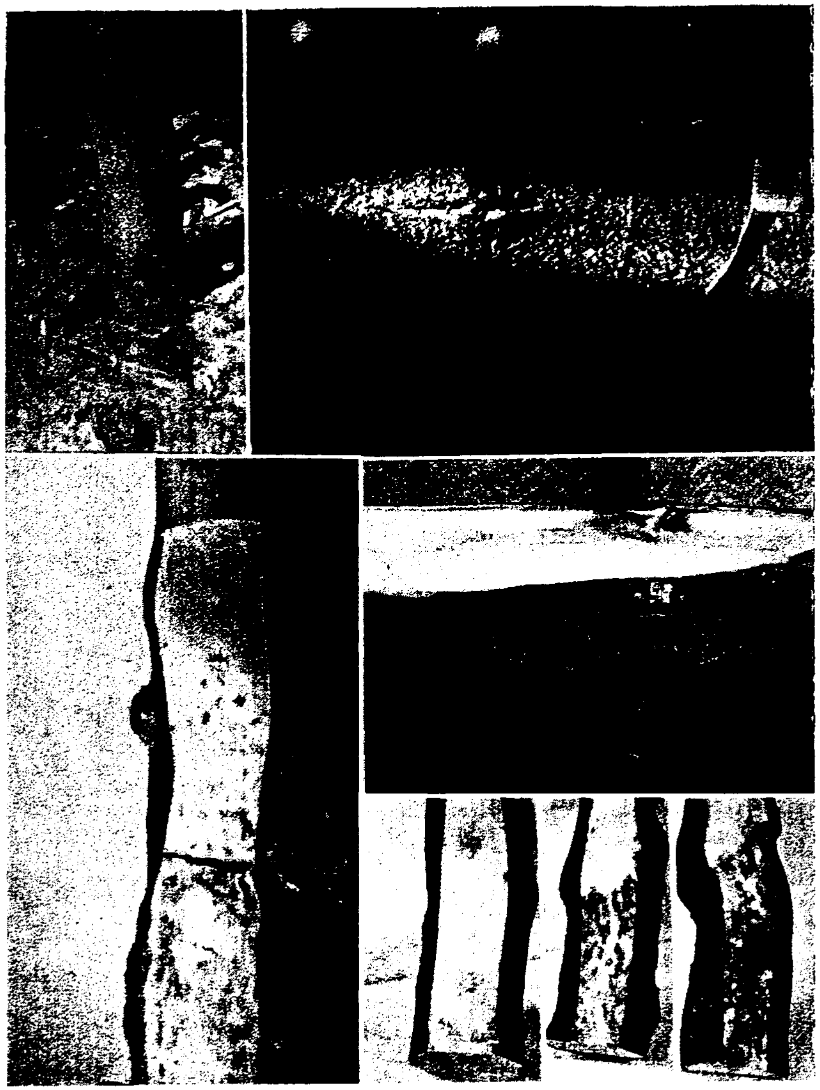

Figure 1. Rangpur lime rootstock disorder, *Diplodia* infection, and cachexia on various rootstocks. Upper left: the Rangpur lime disorder, below the bud union with Red Blush grapefruit. Upper right: blister symptom occurring six weeks after inoculation of a grapefruit branch with *Diplodia*. Middle right: pink wood stain 6 inches long 3 months after inoculation of a grapefruit branch with *Diplodia*. Lower left: wood pitting, associated with cachexia on the Orlando rootstock, stops at the bud union with grapefruit. Lower right: 4-year-old grapefruit on three rootstocks: sweet orange, Orlando and Temple. Gum impregnation of bark, a symptom of cachexia, occurs below the bud union with Temple and Orlando, but not on the Florida sweet rootstock.

In an experiment still in progress, a different technique of inoculation was used. Holes 7/32 inch in diameter and one inch deep were drilled in the branches, inoculum was added, and each hole was plugged by inserting a 1/4 inch dowel. The surface of the wound was covered with a wound dressing containing a fungicide. Six week after inoculation with *Diplodia* or pieces of dead fruit spurs, small blisters frequently occurred several inches from the point of inoculation (figure 1). These blisters resembled the blister stage of Rio Grande gummosis. Blisters occurred infrequently where pink chips were used as inoculum and did not occur in the controls or in unplugged holes.

Diplodia natalensis consistently occurred in the dark and necrotic wood of gummosis lesions, as was earlier reported by Godfrey (1945), but not in the pink wood stain. The salmon-pink color of the wood stain in advance of the *Diplodia* mycelium may be due to a pigment, produced either by *Diplodia* or by the interaction between this fungus and the citrus wood.

Certain strains of *Diplodia* may not be the sole cause of all symptoms of Rio Grande gummosis. Inoculations of an unidentified fungus, apparently not a *Diplodia*, consistently caused a pink wood stain that extended a shorter distance in the wood than the stain associated with *Diplodia*. Nevertheless, it would seem that many of the symptoms and characteristics of Rio Grande gummosis are the same as those of Diplodia gummosis (Fawcett, 1936), and that *Diplodia natalensis* should not be considered just a secondary invader in Rio Grande gummosis lesions.

CACHEXIA

Cachexia was first noted on Orlando tangelo trees in Florida (Childs, 1951). The disease is characterized by severe stunting, chlorotic foliage, bark cankers, and even death of susceptible trees. A distinctive feature is that the inner bark, or phloem, of affected trees shows a brownish discoloration due to impregnation with gum. The wood underneath the discolored bark is also pitted and indented in a characteristic manner.

Trees of four-year-old Red Blush grapefruit, grown on 43 different rootstocks at Texas Agricultural Experiment Substation 15, Weslaco, were examined in May, 1951, for the presence of this disease. The brown phloem and pitted wood symptoms occurred on ten different mandarin, tangor and tangelo rootstocks (figure 1), but they did not extend in any case beyond the bud union into the grapefruit scion. These are the first data on susceptibility of rootstocks to cachexia, but a similar disease, xyloporosis, is known on sweet lime rootstocks in Palestine (Reichert & Perlberger, 1934). The diseased trees were later examined by J. F. L. Childs, of this Bureau, Orlando, Florida, who confirmed the belief that the symptoms were typical of cachexia.

In the twelve replications of each rootstock combination, the numbers of trees with cachexia symptoms on susceptible rootstocks were as follows: two Chu Koa and three Clementine mandarins; two Temple and three Umatilla tangors; twelve Orlando, eleven Sunshine, ten Pina, ten

Thornton, seven Yalaha and two Minneola tangelos. Childs (1951) has reported that these rootstocks, as well as additional varieties, are susceptible to cachexia in Florida.

Rootstocks which showed no evidence of the disease on the twelve trees planted were of the following groups and varieties: *sour orange*, Florida sour, Oklawaha, Bergamia, Sauvage, and Bittersweet; *sweet orange*, Florida sweet and Hamlin; *grapefruit*, Duncan and Leonardy; *pummelo*, Siam and Thong Dee; *sweet mandarin*, Cleopatra, satsuma, and Dancy; *sour mandarin*, Sunki and calamondin; *tangor*, King; *tangelo*, Sampson, Williams, Suwannee, and Watt; *miscellaneous*, Rough lemon, Rangpur lime, Lempum and Natsu Mikan. Three or more trees were examined and no symptoms of cachexia were found on the Kalpi lime, Tavares limequat, citrumelo 4475, citrumelo 4606, citrumelo 4561, Savage citrange, Saunders citrange, and citrangor 45728.

Childs (1951) reported that cachexia is transmitted by buds from diseased trees and that buds from healthy Orlando tangelo trees do not transmit the disease. Since grapefruit scions in the rootstock planting at Weslaco were propagated from buds obtained in the Rio Grande Valley, it seems likely that the virus occurs in other grapefruit trees in Texas. The trees from which the budwood was taken were productive and vigorous, even though some psorosis occurred in the grove. There is at present no evidence that sweet orange or grapefruit trees on sour orange or Cleopatra mandarin rootstocks are injured by this bud-transmitted disease. However, varieties which are susceptible as rootstocks would be expected to be susceptible as scions.

"RANGPUR LIME DISEASE"

Grapefruit trees grown on Rangpur lime rootstocks are more salt-tolerant than grapefruit on sour orange or Cleopatra mandarin rootstocks (Cooper et al, 1951). However the use of Rangpur lime rootstock is limited by its susceptibility to a disorder occurring in various plantings in the Rio Grande Valley. For example, eleven of twelve grapefruit trees on this rootstock in the Weslaco planting showed evidence of this disorder. The disorder appears to start at the soil line and extends only to the bud union with Shary Red or Red Blush grapefruit or Valencia orange (figure 1). The disorder also progresses into the larger roots. The outer bark splits, produces gum, and later shells off. The inner bark under the part shelled off may be green. The wood is apparently not injured and to date it has not shown the wood pitting characteristic of cachexia. Affected four-year-old trees at Weslaco showed a girdling response: vein yellowing and prolific off-season flowering.

Other members of the mandarin-lime group, which includes the Rangpur lime, showing the disease are the Kusaie and Ling Ming varieties. Bark shelling of younger trees has also occurred on the Columbian sweet lime, Butnal sweet lime, sweet lemon and Lempum; the cause of bark shelling on these varieties may or may not be identical with the cause of the Rangpur lime disorder.

In the absence of wood pitting in the mandarin-lime types affected with the "Rangpur lime disease," the cause could not be established as either cachexia or xyloporosis. Since the disorder apparently starts at the

soil line, the cause may be a soil-borne organism rather than a bud-transmitted virus. Klotz and Fawcett (1930) showed that the Rangpur lime is attacked by *Phytophthora citrophthora*. However, the cause of the "Rangpur lime disease" has not been established in the present investigation.

COTTON ROOT ROT

During the summer of 1950 the soil in which forty different rootstocks were growing was infested with *Phymatotrichum omnivorum*, the cause of cotton root rot. A three-year-old Lakeland limequat seedling wilted suddenly and died in September, 1950, and a white spore mat, later turning tan, formed on the surface of the soil around the base. *P. omnivorum* was re-isolated from the roots. During the period June to September, 1951, additional seedlings wilted suddenly and died. The leaves hung and dried on the trees, and the brown strands and the characteristic acicular, cruciform hyphae of *P. omnivorum* were observed on the wet and disintegrating bark of the tap root and larger lateral roots. Seedling trees killed by *P. omnivorum* were of the following varieties or species: Yalaha tangelo, Thong Dee pummelo, Leonardy grapefruit, Watt tangelo, Hamlin orange, Ponkan mandarin, Willowleaf mandarin, Moroccan lemon, Siam pummelo, *Poncirus trifoliata, Severinia buxifolia* and Rangpur lime.

The freeze of January 1951 killed the tops of many seedlings and budded trees in the experiment. Since the young trees that failed to recover from the freeze may have been weakened by attacks of the cotton root rot fungus, relative susceptibility of the different varieties could not be determined. Bach (1931), however, showed that the sour orange is highly resistant to the cotton root rot fungus under conditions where several other rootstocks were susceptible. Intercropping of young citrus trees with crops such as alfalfa or cotton, which are highly susceptible to cotton root rot, favors the occurrence of this disease.

PHYTOPHTHORA DISEASES

The general use of the sour orange rootstock in Texas has made foot rot a problem of minor importance in Texas as compared to Florida (Fawcett, 1936). However, it is known in California and Florida that the sweet orange rootstock is susceptible to *Phytophthora* attack.

Since trees on sweet orange and certain other rootstocks in the Weslaco planting were stunted and chlorotic (Cooper, Olson, 1951), the trunks and roots of the 14 different susceptible rootstocks were examined closely for *Phytophthora* foot rot lesions, and none were found. However, it is known that a species of *Phytophthora* does occur on citrus in the Rio Grande Valley. This species was found to be the cause of "tip blight" of citrus seedlings grown for rootstock purposes (Olson, 1951). Cultures of it were sent to L. J. Klotz, Citrus Experiment Station, Riverside, California, who identified it as *P. palmivora*. This is the first report of the occurrence of *P. palmivora* on citrus in Texas; this fungus causes bark and fruit injury to citrus in India, Ceylon, the Philippines, Puerto Rico, Dutch Guiana, Trinidad, and Tanganyika (Fawcett, 1936).

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The Citrus-root Nematode in the Rio Grande Valley

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The citrus-root nematode, *Tylenchulus semi-penetrans* Cobb, is known to occur in most if not all of the principal citrus producing areas of the world. It has been reported (Goodey, 1933) as occurring in Algeria, Australia, Brazil, Palestine, South Africa and the United States. It was first found in 1912 in California on citrus roots. In Florida it has been suspected as the cause of spreading decline (Suit, 1948). Its presence in the Rio Grande Valley was reported for the first time by Godfrey in 1950. In his report he states that the citrus-root nematode "was found in early June 1950 for the first time in Texas on citrus roots," which "came from a failing Foster Pink grapefruit tree in an orchard near Mission, Texas in which several trees had already died." Shortly after this, infested citrus trees were reported in the vicinity of Harlingen and Donna (Godfrey and Waibel, 1950). This discovery of the citrus nematode at three widely separated points in the Valley on producing citrus trees indicated the possibility that it has been here for many years, is widely distributed and a probable cause of a loss in tree vigor and reduced productiveness in many instances.

A survey to determine the distribution of the citrus-root nematode in the Valley was initiated early in 1951 by Mr. Carl Waibel of the State Nursery Inspection Service and Dr. G. H. Godfrey of the Lower Rio Grande Valley Experiment Station. The first root samples were collected by Mr. Waibel in March and April from groves that were being inspected in the virus-free budwood registration program. A small sample of feeder roots was taken from one tree in each grove sampled. Even though the root sample was very small over 60 percent of the trees thus sampled were infested with the citrus-root nematode. Undoubtedly a larger and more representative sample of the groves would have given a much higher percentage of grove infestation. This initial survey showed, in general, that the main part of the citrus producing area, from Harlingen to west of Mission and some 10 miles wide, was heavily infested with the nematode.

Root samples were collected from what might be considered the outer fringe of the citrus producing area in the Valley in July to see if these areas had been invaded by the citrus-root nematode. The earlier part of the survey had indicated that the central part of the citrus producing area was generally infested. In order to obtain a fairly representative grove sample small feeder roots from 4 to 5 trees in each grove sampled were collected. As in the case of the earlier root examinations the roots were washed carefully in tapwater and stained with Orseillin BB. (In staining the roots were immersed for 60 minutes or longer in 70 percent isopropyl alcohol containing 0.5 percent Orseillin BB.) After staining, the roots were placed in clear water in a Petri dish and examined by means of a steroscopic microscope, magnification 18x, 36x and 54x. Infested roots were readily detected by the stained protruding sac-like females that were attached to the small feeder roots. Each grove sampled in this part of the survey was found to be infested with citrus-root nematodes.

There is yet considerable work to be done before the survey can be said to be completed. Information is needed on the intensity of infesta- tion and the possible occurrence of a sizable localized citrus producing area free of the nematode. However, the present survey results show that the citrus nematode is extensively distributed in the Lower Rio Grande Valley. It has been found in groves at or near the following places: Brownsville, Bayview, San Benito, Harlingen, Mercedes, Rio Rico Cross- ing, Weslaco, Donna, McAllen, Mission, Edinburg, Elsa, Linn, Raymond- ville, San Perlita, Lyford and at a number of places between these loca- tions. The citrus-root nematode is not confined to the Valley. It was found on citrus roots collected from a localized area in the Winter Haven District during the past summer.

The citrus-root nematode is a parasite that is potentially capable of causing or contributing to loss of vigor and may eventually kill heavily infested trees. Thomas (1923) in California found that heavily infested trees in large plots deteriorated slowly as compared to no reduction in vigor of uninfected trees. In a carefully controlled greenhouse test Baines (1950b) found that infested sour orange seedlings grew much slower than the controls. Godfrey (1950) in reporting on finding the citrus-root nematode in the Rio Grande Valley states, "It may be that it has just re- cently built up in abundance sufficiently to show its harmful effects on the trees. Again, it may help explain weaknesses in tree vitality that have long been unexplained." There can be no reasonable doubt but that the citrus-root nematode is an insidious parasitic pest. Light infestation of otherwise healthy vigorous trees may cause little or no loss in production. However, as the intensity of infestation increases and there is retardation in tree vigor because of poor grove care, or other causes, the harmful effects resulting from nematode infestation will become greater and may eventually kill the tree.

Once a citrus grove is infested with the citrus-root nematode there is little or nothing that can be done to eradicate it or reduce the infestation without killing the trees or seriously damaging them. It is the hope of nematologists than an effective inexpensive, non-phytotoxic nematocide will soon be developed. This would make it possible to treat effectively infested groves and not injure the citrus trees. However, until such a nematocide is available we will have to rely on other forms of control measures, as sanitary and preventive practices. It is evident that the most effective control measure would be to plant noninfested trees in land recently cleared, or land that has never been in citrus. In many instances this will not be possible. Old citrus soil infested with nematodes may be effectively treated with soil fumigants prior to planting. Excellent results have been reported from their use in California. Partial control, reduction in population or retardation of increase in numbers, may be possible through cultural practices as growing certain cover or green manure crops, and incorporating large quantities of organic matter in the soil. The cropping of old citrus land for 2 or 3 years or longer, following removal of the old grove and replanting the new, is a practice worth consideration. The citrus nematode can persist in fallow land for at least 3 years, and perhaps longer (Baines, 1950a). Intensive cropping of old citrus land

with non-citrus crops should greatly reduce the nematode population and may produce other desirable effects which we attribute to crop rotation practices.

A grower should plant only trees free of the citrus-root nematode if the land to be planted is free of the pest or the land is infested with a very low population as the result of treatment or short period of build-up. Clean nursery stock can be produced if care is exercised. Infested nursery trees, if bare rooted, can be successfully treated by immersing in hot water for a few minutes, the time varying with the temperature of the water (Baines, *et al*, 1949).

Until very recently the citrus nematode was thought (Goodey, 1933) to attack only citrus trees, but lately it has been reported that the olive is susceptible (Baines, 1951). It would seem that most citrus species are susceptible to the nematode. In California some selections or strains of the trifoliate orange, *Poncirus trifoliata* were found to be highly resistant to the citrus-root nematode, while other selections were infested severely (Baines *et al*, 1948; Baines, 1950b). Thus there appears to be a good possibility that highly resistant rootstock material can be obtained. Adaptability of such a rootstock to Valley conditions is another question.

The purpose of this paper has been to point out the wide distribution of citrus-root nematodes in the Lower Rio Grande Valley and the problems involved in its control. The effectiveness of control measures will depend upon the cooperation of those actively engaged in citrus production. This will mean the utilization of known control measures and continued research to find more effective and economical means of control.

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Natural Enemies of Scale Insects in the Lower Rio Grande Valley of Texas

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The citrus belt of the Lower Rio Grande Valley of Texas has passed through several periods in which citrus scale insects have been held under control by their natural enemies. Many growers purchased sprayers during the twenties to combat the California red scale, *Aonidiella aurantii* Mask. A storm blew an estimated 15 percent of the grapefruit from the trees on August 4, 1933 (Annual Report, 1933). Most of the leaves and fruit were blown from the trees and large branches were broken in many instances following the hurricane of September 5, 1933, which had gusts upward of 100 mph. During that year 40 inches of rain fell with the majority falling in July, August and September. Very little spraying was done following the hurricane year although Clark (1934) reported scale insects caused severe damage in many instances during a rather dry year in which 20 inches of rain fell. Scale insects have since been effectively reduced by biological control for many years except in some groves where scale infestations seemed to exist almost every year.

Before the December 7th freeze of 1950, several species of scale insects were observed to be extremely high in numbers. In some groves, Florida red scale, *Chrysomphalus aonidum* Linn., was predominant with some chaff scale, *Parlatoria pergandii* Comst., Grover's scale, *Lepidosaphes gloverii* Pack., and California red scale. Purple scale, *Lepidosaphes beckii* New., and Glover's scale predominated in some groves, while in other groves California red or chaff scale would seemingly be the only scale present. The chaff scale usually occurred at every location where observations were made. Biological control of these scale insects obviously was lagging far behind. The drift of insecticides applied to row crops adjoining citrus probably took a heavy toll of the natural enemies. Extremely dry weather, which is adverse to buildup of certain parasites, is a comtributing factor. Many other factors, of course, might explain the increase in scale populations.

As reported by De Bach (1951) after a visit made to the Valley area in December, 1949, California red scale seemed to be under biological control by the golden chalcid parasite, *Aphytis chrysomphali* Mercet, and the parasite *Aphytis* "A." Chaff scale was commonly parasitized by *Aphytis diaspidis* How. and *Aphytis* sp. was taken also from Florida red scale.

Large numbers of the twice-stabbed lady beetle, *Chilocorus confusor* Casey, survived the February, 1951 freeze. Defoliated trees covered with beetles were a common sight. After the freeze, one orange grove which had lost about 60 percent of its leaves was noted to have a few adult female chaff scale still alive on the leaves. The chaff scale eggs were apparently hatching normally. Upon visiting the grove some time later, no scale was found after extensive searching. It is presumed the lady beetles searched out the scale and destroyed it. At other locations, California red scale had built up to injurious numbers by July, with seemingly little control by their natural enemies. Young groves were the first to show

a buildup of this scale. By September some Glover's scale and chaff scale began showing up in some of the larger trees and at some of these places the twice-stabbed lady beetle was increasing in numbers.

Data taken from one grapefruit and one orange grove were used in following natural enemy population trends throughout the fall. In the grapefruit grove, Florida red scale predominated but California red, Glover's and chaff scale were present. In the orange grove, the same ratio existed except that more chaff and Glover's scale were present here. Numerous specimens of *Pseudohomalapoda prima* Gir. and *Aphytis diaspidis* How. were taken. The former was presumably parasitic on Florida red scale while the latter was parasitic on chaff scale. However, the golden chalcid parasite was the only parasite on which detailed observations were made.

Although scale populations were extremely dense, it was interesting to follow the natural enemy population after each sudden change in weather. As may be noted in table I, a sharp decrease in the chalcid population occurred between November 6 and November 13. The temperature for the three previous days had an average mean of 51.3° F. with an average minimum of 41.7° F. Two cold snaps had occurred before the November 29th record. The average minimum for November 21st and 22nd was 57° F., while that on November 25th and 26th averaged 35° F. Following that time parasites were difficult to find. The twice-stabbed lady beetles were less sensitive to low temperatures as they remained in large numbers. Populations of the green lace-wing fly were also observed to increase, although the actual numbers present were not recorded.

Table I. Changes in the number of beneficial insects on fruit and leaves in two groves between October 13 and November 29, 1951.

Beneficial Insects	*Number of beneficial insects per grapefruit sample on indicated dates*					*Number of beneficial insects per orange sample on indicated dates*			
	10/13	11/1	11/6	11/13	11/29	10/13	11/1	11/6	11/13
	insects per 100 fruit[3]					insects per 100 fruit			
Chalcids[1]	4	7	8	0	—	5	24	0	0
L. B. larvae[2]	92	64	14	29	—	34	5	0	0
L. B. adults	6	1	9	13	—	3	9	0	6
	insects per 500 leaves[4]					insects per 500 leaves			
Chalcids	293	182	52	9	0	129	57	9	2
L. B. larvae	5	7	3	9	3	3	3	0	1
L. B. adults	0	1	6	24	19	4	6	0	4

[1] *Aphytis chrysomphali* Mercet
[2] *Chilocorus confusor* Casey (twice-stabbed lady beetle)
[3] Fruit records made on 10 adjacent trees
[4] Leaf records made on 10 adacent trees

Several investigators have noted the increase in ants around infestations of honeydew producing insects. Newell and Barber (1913) noted this relationship with mealybugs and unarmored and armored scale insects. Clark and Friend (1932) reported increases in scale following oil treatment, due presumably to the destruction of natural enemies of the scale. Roberts (1946) suggested an ant control program in citrus groves to increase parasite and predaceous insect activity. De Bach *et al* (1950) cited excellent biological control of California red scale where ants were controlled. The scale increased to such an extent following DDT applications as to severely damage trees; the DDT treatment demonstrated the effect of inhibition of parasite activity.

More economical and successful control of ants has been possible with certain organic insecticides. Colonies treated during the spring when such colonies are small have been controlled more sucessfully. As reported by De Bach, treatment only of the ground and trunk of the tree is necessary in California since the Argentine ant is of concern there. In the Lower Rio Grande Valley, two acrobat ants of the genus *Cremastogaster* have been found frequently nesting in the trees. Split bark, dense foliage, bird's nests, base of trees, decayed wood, and crotches are nesting areas. Treatment applied in the trees should be limited to the nests, as unnecessary application of insecticides will lead only to destruction of beneficial insects. Several ants, which have their nests in the ground and also nurse these honeydew producing insects, enter the trees by way of the trunk or weeds which touch overhanging branches. These nests and entrance points should also be treated as these ants will also kill natural enemies or interfere with their activity. Chlordane spray at the rate of two pounds of 50% wettable powder per 100 gallons of water applied in two or three applications in the spring is recommended for control. A 5 to 10% chlordane dust can be used for treatment of the ground but the dust should not be allowed to drift to the trees.

A preliminary test to determine the effect on parasite activity by treatment of the soil and trunks of the trees with chlordane was carried out in a Pink Marsh grapefruit grove. Chlordane was applied at the rate of 1 pound per 100 gallons of water on November 8th. Only one check was made 21 days after the application. Nineteen chalcids and 39 twice-stabbed lady beetles per 1000 leaves were found in the chlordane treated area, as compared to no chalcids and 22 twice-stabbed lady beetles in the untreated area.

From the information presented herein, temperature has been indicated to have an outstanding effect on the populations of scale insect parasites. Parasites were reduced with the first cold norther and following the second norther, numbers were so small that it was difficult to locate these parasites. Populations of the twice-stabbed lady beetle seemed to be unaffected by the cold weather that prevailed. Another predator, the green lacewing fly, tended to withstand the minimum temperature encountered very well. The control of ants is stressed as a good program to increase biological control.

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The Desert Damp-Wood Termite in the Lower Rio Grande Valley of Texas[1]

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The desert damp-wood termite, *Kalotermes (Paraneotermes) simplicicornis* (Banks), has been found in destructive numbers in many young citrus orchards in the Lower Rio Grande Valley of Texas. This insect was first reported injuring citrus trees in California by Dr. Ralph H. Smith. Light (1937) has reported the presence of the desert damp-wood termite from the 99th meridian (Cortulla, Texas) to the 117th meridian (Barstow, California), a distance east and west of about 870 miles; and, from north to south, a range covering ten degrees of latitude from the 36th parallel (Las Vegas, Nevada) to the 26th parallel (San Blas de Sinalea, Mexico), about 607 miles.

Dr. George Wene of the Texas A. and M. Experiment Station at Weslaco, Texas, states that this insect has been reported before doing minor damage throughout most of the Lower Rio Grande Valley, especially on young trees which were planted on newly or recently cleared land. This damage was not extensive enough to warrant control measures.

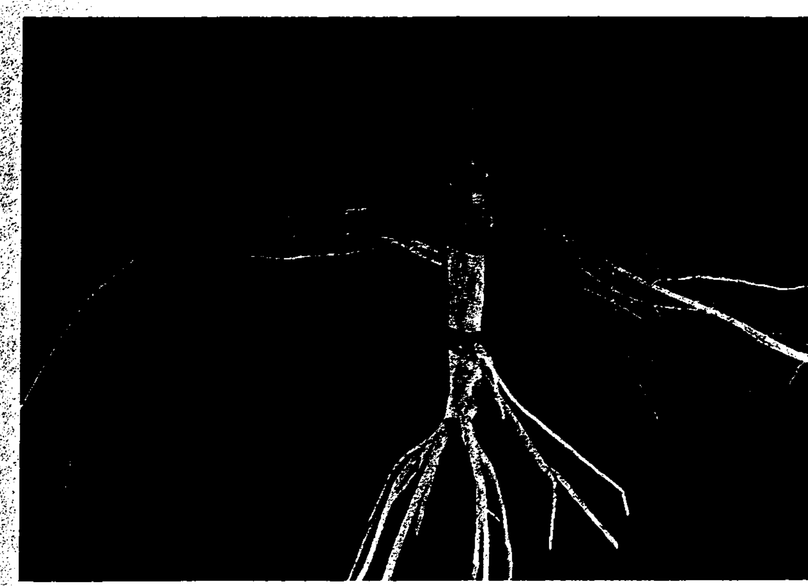
DAMAGE AND DAMAGE SYMPTOMS

The damage done to the root system is peculiar in that it seems to be more typical of rodent work than that of termites. The insect completely severs the taproot or lateral roots or both. The cut is straight across as though cut off with a saw. Sometimes the roots are cut entirely across in from one to four or more places as illustrated in picture 1. In several instances one or more incomplete cuts may be found. All cuts are begun from the outside and are only slightly wider than the thickness of the termite's body. Light (1937) reported similar observations.

It is interesting to note that some roots 1½ to 2 inches in diameter have been completely severed. Termite injury to roots more than 2 inches in diameter has not been found.

Trees which are severely damaged die suddenly. The wilting of leaves is the first visible symptom. They quickly wither and die as the tree cannot absorb an adequate supply of water due to the severe root damage. The damage is probably already accomplished before the first symptoms are noted. It is well to keep in mind that other conditions can cause wilting of the leaves and a diagnosis of termites, on this symptom alone, is not

[1] Reprinted from Journal of Economic Entomology Vol. 44, 1951.



Picture 1. An excavated, young citrus root system showing two complete cuts by the desert damp-wood termite.

justified. In some attacks by this insect the trees infested are in scattered positions with no apparent relation to one another. Light (1937) reports similar observations.

In the Santa Cruz Tract, northwest of Elsa, Texas, a 3-year-old orchard of about forty acres was inspected which showed the typical symptoms of the attacks of this insect. When a slight pressure was exerted with the finger on a typically infested tree, it was easily pushed over. It was then pulled out of the ground by hand with very little effort. It was interesting to note that one tree in this orchard had the taproot completely severed both 6 and 10 inches below the ground level, and that only 11 lateral roots remained. Several incomplete cuts were noted on a few of the remaining roots. A quick survey of this orchard indicated that 25 per cent of the trees were probably infested in that they maintained the typical symptoms of such an attack.

This orchard was in the dry-land area and was basin irrigated from watertank trucks.

DISTRIBUTION IN THE LOWER RIO GRANDE VALLEY OF TEXAS

In the Lower Rio Grande Valley of Texas, this insect seems to be most prevalent on recently cleared land, especially in the dry-land areas.

In the Santa Cruz Tract area, the damage of this pest can be found easily. It seems to be quite extensive in newly developed land where the soil is sandy and light, especially on tank-truck watered orchards. In this area, the damage seems to be most extensive in areas bounded by mesquite thickets, hedgerows, railroads, etc.

A survey made by this author and Dr. George A. Livingston on trees that were uprooted after the freeze of January and February 1951, did not show any termite damage to the root systems except in the dry-land areas starting two or more miles north of State Highway 107 between Elsa and Edinburg and extending to the northernmost limits of the Santa Cruz Tract. The damage extended from this area westward for twenty or twenty-five miles. It might be noted that this area is all relatively new citrus-producing land.

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Citrus Tree Decline at Winter Haven, Texas

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A "decline" or "root-rot" caused death of citrus trees in the Experiment Station planting at Winter Haven (Mortensen, 1947). This "decline" occurred on trees grown on a wide variety of rootstocks and indications of possible resistance were given for calamondin, Thomasville citrangequat and Rustic citrange stocks.

As the trees are now 4 years older and a few additional budded trees have reached 10 years of age, additional information is available on the malady. Table 1 gives a brief summary of the condition of the trees with 10 years or more of growth since they were set in the orchard.

It will be seen that calamondin has joined the ranks of susceptible stocks since 1947. One tree of Thomasville citrangequat shows signs of declining health in the fall of 1951; this may or may not be caused by the same malady. Rustic citrange is maintaining good health so far. Kansu (Ichang) and Changsha are still healthy trees but only a few specimens of each are available.

Rustic citrange seedlings were received from Dr. W. T. Swingle in 1932. All citranges are the result of crossing trifoliata orange with sweet orange. The original description by Webber in 1906 describes the Rustic citrange as a "bushy low growing tree." Since our seedlings are tall and vigorous, there might be doubt as to the identity of this stock. However, the description of the fruit and of the unusually long spines clearly sets it apart from other citranges. A possible explanation of the difference is the statement in Webber's description that the Rustic was budded on trifoliate orange stock which may have dwarfed the growth in comparison with seedling growth. At any rate our tree reached a height of more than 20 feet and a spread of 22 feet in 11 years of growth. Measurements were not taken in 1950 preceding the severe freeze of 1951 when the temperature reached 12° F. on February 2. Very severe damage occurred to the seedling tree set in 1932; the large branches were killed back to the trunk. However, seedlings in the nursery were uninjured at the same time, indicating that the old seedling was perhaps not dormant at the time of the freeze. This could easily have been the case since citranges normally begin blooming in early February There had not been any freeze injury in previous years when minimum temperature of 17° F. and 19° F. were reported at various times.

In the seed production the Rustic averages about 3.5 seed per fruit as compared with 20.2 for Carrizo, 4.1 for Rusk and 9.0 for Savage. In addition fruit production is lower than for other citranges. However, it is estimated that Rustic would produce 4,000 seeds per tree in an average of 3 years record at Winter Haven.

The stocks of Rustic in the orchard are all budded to satsuma varieties. Performance of orange and grapefruit varieties on this stock is not known.

Thomasville citrangequat originated from a cross of Nagami kumquat with Willits citrange in 1909. It is highly productive of seed and fruit and the tree is very hardy to cold. Oranges and satsumas both appear to do well on this stock.

Only 5 trees of 10 years or more are available on Kansu (Ichang) stock. This variety is described by Swingle (1943) as Ichang leman. It is extremely cold hardy, suffering no injury in 1951 at 12° F. Only 2 trees budded to orange are available but both are healthy although somewhat dwarfed. It is a high seed producer.

Changsha tangerine is a heavy fruit and seed producer but too few trees are available for evaluation on resistance to "decline." It has possibilities as a rootstock but needs additional testing.

It is very evident from table 1 that trifoliate orange and citrangedin are highly susceptible to this trouble. However, trees dying from exocortis (Klotz and Fawcett, 1948) of the trifoliate stock are included in the figures given since this trouble was not recognized in this area until recently.

The cause of the citrus tree "decline" is not yet known. Apparently it is brought about by crowding or stress on the trees. Soil is probably a factor. Of 95 trees on trifoliate stock planted in 1931 and 1932 in Crystal fine sand, a soil with a depth of 2 to 3 feet, only 22 trees have become diseased or died. In another orchard planted in 1932, 1933 and 1934, on shallow soils, averaging 8 to 10 inches in depth, 55 of the original 82 trees on trifoliate stock have succumbed. The spacing was the same in both orchards.

The freeze in February, 1951, killed weakened trees which normally would have taken up to several years to die. The freezing back of some trees may also cause "decline" to set in because of tree weakness. Further records will be taken in future years.

Not many orchards are planted on soils as shallow as those reported here, but the differences in survival on various stocks should be a guide in selecting rootstocks for future tests.

Table 1. Citrus Tree "Decline" in budded trees 10 years or older, October, 1951

Rootstock	*No. of trees*	*No. "declined"*	*"Decline" percent*
Calamondin	11	4	36
Carrizo citrange	25	8	32
Changsha	3	0	0
Citrangedin	8	5	62
Citrangequat, Thomasville	11	1 (?)	9 (?)
Citrumelo, Sacaton	31	6	19
Cunningham citrange	74	17	23
Kansu (Ichang)	5	0	0
Meyer lemon	6	5	83
Morton citrange	16	7	44
Rusk citrange	41	4	10
Rustic citrange	11	0	0
Savage citrange	40	16	40
Sour orange	19	2	11
Trifoliate orange	256	137	54
Uvalde citrange	26	5	19

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Internal Quality of Texas Grapefruit

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INTRODUCTION

Internal fruit quality has long been recognized as an important factor in the citrus industry. Citrus does not improve in quality once it is removed from the tree since it has no starchy reserve which might later turn to sugars, as is the case with some deciduous fruits. The public has long been accustomed to using skin color as a measure of ripeness and high quality for deciduous fruits. This same measure has been erroneously used as a measure of quality in citrus. Peel color is an unsatisfactory index of fruit quality since ripening is not coincident with the change of peel color from green to yellow. Much fruit attains high quality before turning yellow. Also, by exposing the fruit to ethylene gas, the fruit turns yellow prematurely. On one hand, waiting for fruit to attain a yellow color unnecessarily delays harvest, while the use of ethylene gas too early in the season results in marketing of immature, poor quality fruit which the public is deceived into thinking is mature.

Research workers in various citrus regions have found that the basic factors involved in internal quality are: (1) Brix (total soluble solids, which are mainly sugars); (2) total titratable acid, expressed as citric acid; (3) the ratio of solids to acids; and (4) juice content. The various citrus producing states have evolved laws based on the above fruit characters that are designed to prevent shipment of poor quality fruit. There are of course other fruit characters such as esters, organic acids and glucosides that influence flavor but there is no simple way of measuring them.

While considerable research on internal quality has been done in other citrus areas little has been done in Texas. Traub, Fraps and Friend (1929), in Texas, working with Marsh, Duncan, Thompson and Foster varieties, reported that changes from late August to mid-December in the constituents of the juice are not sufficient to cause changes in palatability. All samples analyzed contained juice which was tart, but no sour or very sour juice was encountered. The solids/acid ratio was similar in all varieties studied. They also reported that the solids decreased slightly while the acid decreased relatively more, causing a gradual rise in ratio of solids to acid as the season progressed. Wood and Friend (1941) reported that the Redblush variety was lower in acids than Marsh. Their data also showed Marsh and Thompson to have about the same acidity. However, their results were based on limited data. Wood and Reed (1938), in Texas, reported on two seasons work with Marsh grapefruit. In contrast to Traub, Fraps and Friend (1929), they found that the taste of fruit changed from acid to sweet as the season advanced and that bitterness

disappeared from most samples during November. They also reported a slight decrease in solids, a relatively larger decrease in acid and a subsequent rise in solids/acid ratio as the season progressed.

Due to the disparity of information concerning seasonal changes in quality of Texas grapefruit, experiments were initiated in 1950 to study seasonal changes in fruit quality of Marsh, Thompson and Redblush varieties at five locations over a five year period. Samples were to be taken at 30 day intervals from mid-August through April. The severe freeze of 1951 eliminated these plots after only five months data had been obtained. Since it will be several years before work can be continued, the trends noted in the brief work completed will be given in this paper. The only phase reported will be the effect of variety on soluble solids, solids/acids ratio, percent of juice by weight and vitamin C. While other less pronounced trends were noted, reporting them at this time might lead to erroneous conclusions.

PROCEDURE

Twenty trees each of Marsh, Thompson and Redblush varieties were selected in each of five locations. These locations were Bayview, Adams Gardens in the Harlingen area, Substation 15 at Weslaco, Rio Farms at Monte Alto and Goodwins in the Mission area. These localities were selected as representative of distinct regions. The trees were selected on the basis of normal appearance and vigor. With the exception of the Redblush variety all trees ranged from 15 to 20 years of age. Redblush trees 8 to 12 years of age were used, since older trees were not available. No attempt was made to regulate cultural practices as they necessarily varied with the region; however, care was taken that no abnormal practices were used. Since the Redblush trees at Substation 15 had insufficient fruit due to the 1949 freeze, data from this location are not included. In order to eliminate differences due to position of fruit on the tree, fruit was taken from each of the four sides of each tree at a height ranging as near as possible between the waist and chest. Fruit of approximately the same size was taken and ranged from 3½ inches at the first sampling date to 3¾ to 4 inches in diameter at the last sampling date.

Immediately after harvesting the fruit was taken to College Station and analyzed for Brix (total soluble solids), total titratable acids, solids/acid ratio, ascorbic acid (vitamin C), naringen, juice per fruit, percent of juice by weight, color of peel and color of flesh. Standard methods of analyses were used in all cases.

RESULTS

Total Solids. As the season progressed the solids decreased slightly. Values for all samples on all dates were relatively high ranging from a minimum of 10.09 to a maximum of 12.90. Table 1 shows that the mean solids for Marsh were slightly higher than Thompson for all dates except December 11. However, the greatest difference at any one date was only 0.26, which is slight. Mean values for Redblush were generally lower than Marsh and Thompson.

Titratable Acid. Acid values evidenced a more constant and relatively greater decrease than solids as the season progressed. Table 1 shows a very appreciable influence of variety on acid values. Thompson consistently gave lower values than Marsh and Redblush was consistently lower than either Thompson or Marsh. These differences were quite distinguishable to the taste. Table 1 also shows that as the season progressed, the magnitude of the differences became greater.

Solids/Acid Ratio. The ratio rose rapidly as the season progressed since the acid values decreased at a relatively greater rate than solids. Table 1 shows that Thompson had higher mean values than Marsh and Redblush was higher than either. The differences increased in magnitude as the season progressed, which was merely a reflection of differences in acid.

Table 1. Effect of variety on solids, acid and their ratio as evidenced by the mean values of four locations.

Date	% Soluble Solids			% Acid			Ratio		
	Marsh	Thompson	Redblush	Marsh	Thompson	Redblush	Marsh	Thompson	Redblush
8/21	11.65	11.50	11.33	1.99	1.95	1.82	5.86	5.92	6.29
9/18	11.72	11.46	11.11	1.81	1.74	1.60	6.47	6.58	7.02
10/16	11.29	11.14	11.29	1.68	1.52	1.38	6.94	7.56	8.42
11/13	11.19	11.02	10.87	1.54	1.41	1.26	7.30	7.80	8.85
12/11	11.47	11.39	11.01	1.42	1.31	1.11	8.02	8.67	10.32

Vitamin C. Table 2 shows that vitamin C values decreased as the season progressed and apparently were not influenced by variety.

Percent of Juice by Weight. Table 1 indicates that the percent of juice by weight increased as the season progressed. There was evidence of a leveling off in November and December. Variety apparently had no influence.

Table 2. Effect of variety on vitamin C and percent of juice by weight as shown by mean values of four locations.

Date	Vitamin C (mg./100 cc Juice)			% Juice by Weight		
	Marsh	Thompson	Redblush	Marsh	Thompson	Redblush
8/21	45.7	47.2	47.6	33.8	33.2	33.8
9/ 8	45.9	46.9	43.9	42.7	40.1	41.7
10/16	37.4	35.9	38.1	47.2	44.6	45.8
11/13	37.9	37.2	38.6	47.7	49.4	50.0
12/11	36.6	36.2	35.2	49.1	49.1	48.8

DISCUSSION

While the data presented in this paper were obtained from adequate samples, the results are not taken as conclusive. Data from representative orchards for a period of years are needed for a complete picture.

Some of the trees used in this experiment had not completely recovered from the 1949 freeze and a considerable amount of off-bloom fruit was present. Such fruit was avoided as much as possible but some

was probably included. However, such fruit should be distributed equally throughout the samples and affect all data equally.

The younger age of Redblush trees might have a slight influence on the results. Apparently it did not cause the lower acid and higher ratio values found in this variety since Wood and Reed (1938) reported fruit from 10 year old Marsh trees to have slightly more acid and lower ratios than those from 15 year Marsh trees. Hilgeman (1941), working with 7 and 24 year old Marsh trees in Arizona, did find fruit from younger trees to have lower acid and higher ratio values; however, the age difference in this case is quite wide and environmental conditions in Arizona are quite different. Even so, there is no adequate explanation for the different results obtained.

All factors considered, there appears little doubt that Thompson was less acid than Marsh and Redblush was less acid than Thompson. These differences were reflected in ratio values and borne out by taste tests. Since the public appears to prefer a sweeter fruit, those varieties with lower acid might be considered of higher quality. Data at later dates is needed since further reduction in acid values would have resulted in flat tasting fruit for some plots.

Data on flesh color and naringen were not included since less data was obtained due to changes and refinements in the methods used. There is need for work to determine the factors influencing flesh color of Thompson and Redblush. While there was a general decrease in color as the season progressed, changes were erratic. There was a decided decrease in red flesh color following the abnormally low temperatures in December. There is also a need for work with factors affecting naringen and its influence on quality.

There was some indication of differences in quality due to location, but they were lacking in consistency.

Compared with data reported by Florida workers (Harding and Fisher 1945), Texas grapefruit is of exceptionally high quality as based on solids, acid and solids/acid ratio. This can be explained by the favorable environmental conditions in Texas. Sour orange rootstock, which is used almost entirely in Texas, has been shown to produce fruit of considerably higher quality than that grown on Rough lemon, the major rootstock in Florida (Harding and Fisher, 1945). Low rainfall in Texas is probably a factor. Sites (1949), in Florida, found that in years of heavy rainfall the solids and acids of Florida fruit is considerably lower than in years of low rainfall. Chandler (1950) indicates that sugar content does not seem to be appreciably affected but that a cool climate causes high acidity. Also, Texas growers generally do not have to apply oil sprays to control scale, a practice, which if ill-timed, prevents the formation of normal solids. Due to unfavorable environment Florida growers are forced to apply arsenical sprays to their trees if the fruit is to pass maturity standards as early as Texas fruit. Reitz (1949) has pointed out that it is impractical for Florida growers to try to meet Texas standards. Thus, it would seem that Texas growers should maintain the highest standards of quality of their fruit. Probably every responsible resident grower in the Valley will agree that much of the first Texas fruit marketed is not top quality.

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Effect of Harvesting and Packing Operations on External Quality of Texas Grapefruit

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Texas citrus producers and shippers have found a ready market for good quality grapefruit. Recognizing the importance of maintaining established markets and of opening new ones, the Texas Agricultural Experiment Station in cooperation with the Texas Citrus Commission set up in 1950 a marketing research project designed to further this end. The information presented in this paper is based on results of preliminary work conducted during the short 1950-51 season.

PRESENT METHODS OF QUALITY CONTROL

Present methods of quality control for grapefruit were checked at various points in the harvesting and packing operations. The check points were as follows: on the tree; in the field lugs; at the shed; following the automatic dumper; prior to the grading operation; in the packing bins; and finally in the shipping container ready for market. The number of bruises, the amount of scale, mite damage, and the number of blemishes, cuts and rotten spots were recorded for each fruit coming under the surveillance at the check points. Records were taken in four orchards and four packing sheds located in various parts of the Valley. The methods of handling fruit were virtually the same at all four orchards and at the packing plants.

The bruise accumulations on grapefruit during harvesting and packing operations are shown in percent in figure 1. Considerable bruising occurred during the harvesting operation since only 11 percent of the fruit on the trees were bruised, but when checked in the field lugs at the orchard the amount of bruised fruit had increased to 59 percent. The handling of the fruit in field boxes from the grove through the color rooms and dumping belt in the shed brought the percentage of bruised fruits up to 69 percent. The processing of the grapefruit through the washing, grading and packing operations left the average packed-out box with 81 percent of bruised fruit. Over two thirds of the bruises accumulated during harvesting and packing house operations.

The classification of fruits in respect to the percent of scale, rust mite, blemishes and cuts present on fruit as it entered the grading table and again after it was packed is shown in table 1. With the exception of scale, practically the only fruit eliminated in the grading process was that on which rust mite and blemishes were severe. The better elimination of scale infested fruit may be due to the fact that scale was more conspicuous than rust mite damage and blemishes and was, therefore, picked up more frequently by the grader. The external quailty of fruit in the packed out box still leaves much to be desired when it is considered that

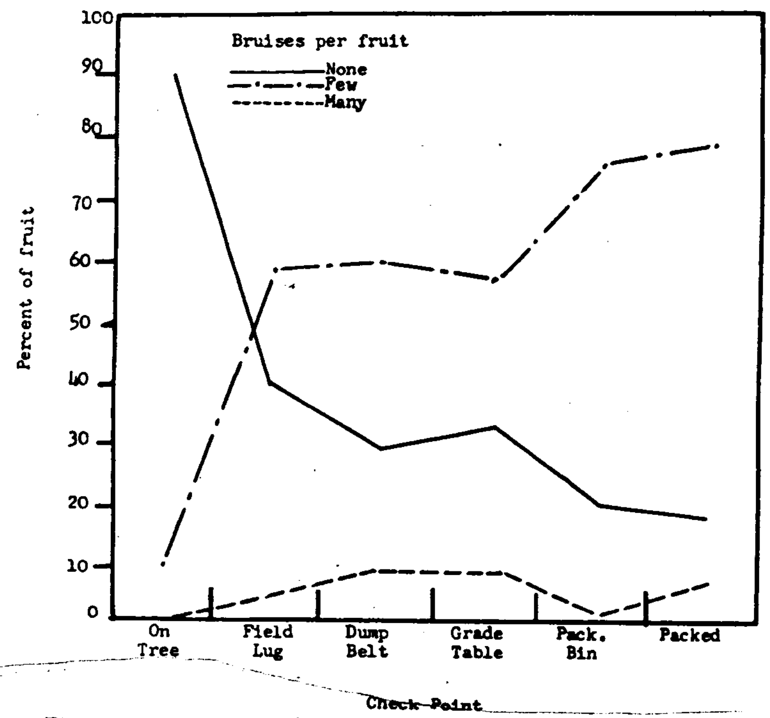

Figure 1. Bruise accumulations on grapefruit during harvesting and packing operations as shown by percent of bruising at various check points.

33 percent of the fruit contained slight to moderate amounts of scale, 66 percent of it exhibited rust mite damage and blemishes and 25 percent of it contained slight to severe cuts.

IMPROVEMENT IN QUALITY CONTROL

The harvesting operations were responsible for approximately two thirds of the bruises found on fruit in the packed boxes. The first step in the improvement of quality control was to find a method which would

Table 1. Differences in external quality of grapefruit occurring between ungraded and packed fruit.

	Ungraded Fruit					*Packed Fruit*				
External quality factors	*None %*	*Slight %*	*Moder-ate %*	*Severe %*	*Total Fruits No.*	*None %*	*Slight %*	*Moder-ate %*	*Severe %*	*Total Fruits No.*
Scale	42.3	53.4	4.0	.3	335	66.0	31.2	2.8	0	1320
Rust mite	35.9	41.8	15.5	6.8	287	31.1	53.3	14.2	1.4	1325
Blemish	29.2	49.6	15.5	5.7	276	33.7	54.2	11.3	.8	1297
Cuts	79.4	19.1	1.5	0	249	78.9	14.9	5.0	1.2	1325

reduce the bruising in this operation. A grove in the lower end of the Valley was selected and divided into two portions and the percentage of bruised fruits on the trees were determined for each lot. The pickers were allowed to harvest 10 field lugs of fruit from Lot A in their accustomed manner. They were then instructed to pick 10 boxes from Lot B and to handle them as carefully as they could. They were particularly asked to guard against bruising the fruit and were offered a small monetary reward if they did a satisfactory job. The results are presented in table 2. It was clear that a real increase in the amount of bruise-free fruit was obtained when the fruit was carefully handled. Approximately 83 percent of the fruit prior to harvest was free of bruises. The percentage of bruise-free fruit was reduced to 49 percent following harvesting operations in the usual manner as contrasted to only 76 percent when carefully handled. The advantage gained through careful harvesting practices was maintained during the packing house operations.

The effect of different types of containers on the degree and amount of bruising was also investigated. Two types of shipping containers were used; the ordinary wirebound 1 3/5 bu. bruce box and a paperboard container holding approximately half that amount. Paperboard containers have been used in experimental shipments of Arizona grapefruit and oranges. R. E. Seltzer has reported favorably on their performance in tests conducted in 1948, 1949 and 1950. They have also proved to be quite successful in shipping bulk tomatoes (Showalter *et al*, 1951), peaches (Alderman, 1948), and apples (Pre-Pack-Age, 1950-51). The paperboard boxes used in this work were rectangular in shape and of double strength full over-lap construction. No provision had been made for ventilation, but the inner board had been impregnated with phenol compound to guard against the formation of molds and rots.

The ability of these paperboard containers to prevent excessive bruising of fruits packed in them was gratifying. A comparison of the amount of bruising on fruits packed in these boxes and fruits packed in the bruce box is shown in table 2. It is interesting to note that 9.8 percent of the fruit of lot A and 8.7 percent of lot B showed many bruises per fruit when packed in wirebound boxes. No fruits of this classification were found in the packed paperboard containers when checked at the terminal market. Lot B fruit, which was carefully harvested and packed in paperboard containers, was 55 percent bruise-free when checked at the terminal market; lot A fruit, which was harvested in the usual manner, was only 33 percent bruise-free.

These results indicate that bruising of fruits can be reduced by careful harvesting practices and the use of paperboard containers. The dimensions of the boxes used in this work were unsatisfactory and gave rise to serious packing problems. Considerable more work must be done before the paperboard container can be considered as practical.

CONSUMER REACTION TO EXTERNAL QUALITY

Consumer reaction to external quality in grapefruit was studied through the cooperation of The Great Atlantic and Pacific Tea Company who graciously donated the services and facilities of their Sheppard Street

Table 2. Percent bruised fruit occurring at check points, when two harvesting methods are compared.

	Percent bruised fruit in Lot A, harvested in normal manner.				Percent bruised fruit in Lot B, carefully harvested.			
Check Point:	*None*	*Few*	*Many*	*Total Fruit No.*	*None*	*Few*	*Many*	*Total Fruit No.*
On Tree	82.8	17.2	0	379	82.8	17.2	0	379
Field Lug	49.4	49.4	1.2	629	75.7	23.3	1.0	563
Following Into Dumper	34.5	56.5	9.0	232	—	—	—	—
Following Grade Table	42.8	51.6	5.6	215	—	—	—	—
Packed Bruce Box Term. Market	14.9	75.3	9.8	295	22.3	69.0	8.7	197
Packed Paper-board box Term. Market	33.3	66.7	0	30	55.4	44.6	0	168

Store in Houston. Fruit from the preceeding experiments was divided into high external quality and average external quality, the latter group containing fruit of a quality generally found on the market. The difference in external quality of the two lots of fruit was reflected in consumer reaction at the store. Equal amounts of fruit from both lots were placed side by side on a produce table in the Sheppard Street Store and offered to the public at one price. Records were taken of the number of purchases and the number of fruits per purchase until the supply of high quality fruit was exhausted. A total of 506 fruits were sold of which 312 or 62 percent were high quality fruits and 194 or 38 percent were average quality. The ratio of sales of high quality fruit to low quality fruit was 1.3:1, which was closer than might be expected judging from the amount of high quality fruit moved. The purchaser of high quality quality fruit bought three at a time while the buyer of average quality fruit took only two fruits. However, a few customers took fruit from both piles more or less indiscriminately.

SUMMARY

The methods of harvesting and handling grapefruit among four Valley packing houses studied were essentially the same. The external quality of packed fruit from these sheds was only fair, and subsequent tests involving harvesting and packing operations indicated that careful handling of the fruit greatly reduced the amount of bruising and enhanced the quality rating. Packing the fruit in paperboard boxes lessened the amount of bruising in transit over fruit packed in the wirebound bruce boxes.

The average customer preferred fruit of good appearance to that of fair or average appearance and, at the same price, they bought more high quality fruit than average quality.

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The Effect of Maleic Hydrazide on the Growth of Citrus Seedlings

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The severe freeze of January and February, 1951, killed or severely damaged approximately 90 percent of the citrus trees in the Lower Rio Grande Valley of Texas.

Citrus trees do considerable growing during the winter in the Lower Rio Grande Valley and are often in an active state of growth when a cold spell comes.

Dormant trees in the Valley are reported by Cintron (1950) to be less injured by freezing temperatures than trees which are in an actively growing condition.

If some way could be found to produce a temporary dormant condition in these trees for a period of about two months during the coldest part of the winter it might prevent much of the cold damage.

Schoene and Hoffmann (1949) reported that certain concentrations of maleic hydrazide have a pronounced, but temporary, inhibiting effect on plant growth.

The work reported here was initiated in order to determine the effect of a maleic hydrazide spray as a growth inhibitor on citrus seedlings.

METHODS

Maleic hydrazide was used in the form of MH-30, a diethanolamine salt of maleic hydrazide, as supplied by the Naugatuck Chemical Company, Naugatuck, Connecticut. This compound is water soluble and contains 30% maleic hydrazide by weight. A wetting agent, Dreft, was added to the spray as recommended by the manufacturer. Dreft was used at 1.9 grams (0.05%) per gallon of spray. Distilled water was used as a diluent.

Each seedling was sprayed individually; a canvas screen around each seedling prevented the drift of spray material to adjacent seedlings. The spray, a fine mist, was applied in such a manner as to thoroughly cover the trunk, limbs, and leaves.

Measurements of height and diameter were made every two weeks.

RESULTS

Maleic hydrazide acted as a growth inhibitor on sour orange and Cleopatra mandarin orange seedlings. The data given in table 1 show the average total growth [1] of citrus seedlings which were sprayed with different concentrations of maleic hydrazide. It will be noted that most concentrations inhibited the growth of the younger seedlings to some extent, but no significant effects were noted where concentrates less than 0.1%

[1]Average total growth as used in this paper is the product of the square of the average increase in diameter and the average increase in height. It is given in cubic millimeters.

Table 1. Effect of maleic hydrazide on the average total growth of citrus seedlings ten weeks after spraying.

Seedling		*Replications per treatment*	*Total Growth[1] of Seedlings after Treatment*						
				Dreft	*Maleic Hydrazide–Concentrations*				
Age (months)	*Variety*	*(no.)*	*Control*	*Alone*	.025%	.05%	0.1%	.25%	.50%
5	Sour Orange	5	37	32	8	9	2	3	2
5	Mandarin	5	6	11	6	7	3	2	2
18 & 30	Sour Orange	8	3116	4647	2703	1648	2414	2168	333

[1]See footnote on page 58.

were applied to the seedlings. The older seedlings were only slightly affected by concentrations of .25% and less, but were noticeably affected at a concentration of .50%.

The duration of inhibition of the average growth in height and diameter was greatest in the younger trees and at the higher concentrations (table 2). It will be noted that a concentration of .025% did not materially affect the growth processes of any of the seedlings used in this experiment.

Table 2. Duration of inhibition of the average growth of citrus seedlings sprayed with maleic hydrazide.

Seedling		*Inhibition in weeks of height increase by indicated concentrations of Maleic Hydrazide.*					*Inhibition in weeks of diameter increase by indicated concentrations of Maleic Hydrazide.*				
Age, months	*Variety*	.025%	.05%	0.1%	.25%	.50%	.025%	.05%	0.1%	.25%	.50%
5	Sour orange	0	0	4	4	6	4	8	10	10	10
5	Mandarin	0	0	6	6	6	0	0	0	8	8
18	Sour orange	0	0	4	4	6	0	0	4	4	10
30	Sour orange	0	0	0	0	4	0	0	0	0	6

These data indicate a definite decrease in growth of those seedlings sprayed with maleic hydrazide. The younger seedlings and those receiving the greater concentration were retarded the most.

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Effects of Rooting Media Upon The Asexual Propagation of Ornamental Plants

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The purpose of this research was to compare the rooting of six ornamental plants when propagated asexually on four different media. It is hoped that this information will be helpful to home gardeners or nurserymen wishing to propagate these common ornamentals.

METHODS

A wooden box twenty inches wide by thirty inches long and six inches deep was partitioned so as to contain four equal sections. A different type of rooting medium was placed in each section of the box. The materials used were fine sand, peat moss, sawdust and vermiculite. During the period October 30 to November 6, 1950, cuttings from six different ornamentals plants were prepared and placed in the media. Six cuttings were taken from each plant and placed in each section of the box. This made a total of 36 cuttings per section and 144 cuttings per box. Cuttings were taken from six separate plants, making twenty-four of each kind in the box. This method was duplicated eight times or a total of nine boxes prepared with 1296 cuttings.

Hardwood cuttings of all varieties were taken. Leaves were removed and cuttings were prepared in lengths of five to six inches. They were set at a seventy-five degree angle in the media. The ornamental plants used as a source of cuttings are shown in table 1.

Propagating boxes were placed directly on the ground under a half-shade and covered with clear panes of glass to help regulate the humidity about the cuttings. Plants were sprayed with water twice each week. Twice during the propagating period, the temperature dropped to 21° F. and all plants would have been seriously damaged if they had not been given some protection.

At the end of three months, the cuttings were removed from the media and classified. A value of one to ten was used to classify individual cuttings with regard to amount and health of roots and leaves. For example, the cutting having the most roots was given a grade of ten while the cutting with the least amount of roots was given a grade of one. Cuttings graded 8 to 10 were considered excellent. Those graded 5 to 7 were fair, while those graded 1 to 4 were poor. Excellent cuttings are the most desirable, while cuttings classified as fair are satisfactory for all practical purposes.

Position of roots was noted on all cuttings. Some cuttings were rooted at more than one position. In that case, both were tabulated and the one showing the greatest amount of roots was circled.

In consideration of the position of leaves, the buds on the cuttings were numbered from apex to heel starting with the top bud as number one.

Table 1. Effect of four media on the number of excellent, fair, and poor cuttings of six ornamental plants.

Specie of Plant	Number of plants in each classification			
	Excellent	Fair	Poor	Not Rooted
	Peat Moss			
Sanderiana Bougainvillea	27	8	5	14
Tangerine Bougainvillea	2	22	1	29
Florida Jasmine	0	4	26	24
Waxleaf Ligustrum	0	10	13	31
Turk's Cap	24	21	5	4
Flowering Pomegranate	18	22	5	9
Totals	71	87	55	111
	Sand			
Sanderiana Bougainvillea	4	7	7	36
Tangerine Bougainvillea	0	13	6	35
Florida Jasmine	0	0	17	37
Waxleaf Ligustrum	0	8	1	45
Turk's Cap	41	7	0	6
Flowering Pomegranate	21	14	6	13
Totals	66	49	37	172
	Sawdust			
Sanderiana Bougainvillea	2	8	14	30
Tangerine Bougainvillea	0	11	1	42
Florida Jasmine	0	14	19	21
Waxleaf Ligustrum	0	12	11	31
Turk's Cap	17	26	6	5
Flowering Pomegranate	13	23	12	6
Totals	32	94	63	135
	Vermiculite			
Sanderiana Bougainvillea	21	9	0	24
Tangerine Bougainvillea	3	25	4	22
Florida Jasmine	0	6	19	29
Waxleaf Ligustrum	14	20	4	16
Turk's Cap	41	11	0	2
Flowering Pomegranate	20	16	3	15
Totals	99	87	30	108

RESULTS AND DISCUSSION

Position of roots and leaves. The specie of plant and not the type of medium determined the position of roots on the cuttings. The only important exception was sand. In sand, roots on node and internode were about equal in number for all plants, while less than ten percent of these cuttings rooted at the heel. The position of the leaf on the cuttings appeared to be influenced by three main factors: specie of plant, amount and health of the roots, and health of stems and leaves. Position of leaves and roots had very little influence upon the rooting of cuttings. Cuttings with strong healthy roots and leaves are desired, regardless of their position.

Environmental factors affecting the experiment. Two major factors reduced the percentage of rooted cuttings in all types of media. (1) *Temperature.* During the propagation period these cuttings had no bottom heat applied. Extremely low temperature affected the Bougainvillea and Turk's Cap. Though no plants are known to have been killed by low temperature, several turned yellow and growth was retarded.

(2) *Disease.* Apparently the only plant specie in this experiment affected by disease was Florida Jasmine. The disease, "die-back," was probably present on the stock plants since no other plant was affected by the disease.

The factors of temperature and diseases reduced the number of rooted cuttings. Results established definite trends, however, that will be helpful in future plant propagation. Table 1 compares the different types of medium by indicating the number of excellent, fair and poor cuttings of each of the six ornamental plants.

Because all cuttings required identical care, the only factors of economic importance were cost of media and value of rooted cuttings. Value of cutting is estimated at seventy-five cents per plant which was the average value of all plants at the end of one year's growth. Cuttings classified as excellent and fair were counted as satisfactory plants. Table 2 shows the net value of cuttings in the four types of medium.

Table 2. A comparison of the net value of the plants grown in four rooting media.

Type of Medium	*Lbs. Used*	*Actual Cost*	*No. Plants Rooted*	*Total Value*	*Net Value*
Peat moss	13.50	$1.49	158	$118.50	$117.01
Sand	108.00	No cost	115	86.25	86.25
Sawdust	18.00	No cost	126	92.50	92.50
Vermiculite	11.25	3.38	186	139.50	136.12

CONCLUSIONS

Vermiculite gave the best results as a general purpose medium. Thirty percent of all cuttings in vermiculite were excellent while twenty-seven percent were fair. Peat moss was second with twenty-two percent excellent and twenty-seven percent fair. Third was sand with twenty percent excellent and fifteen percent fair cuttings. Fourth was sawdust with ten percent excellent and twenty-nine percent fair cuttings.

Peat moss was outstanding as a medium for rooting Sanderiana Bougainvillea and can also be recommended for Turk's Cap and Flowering Pomegranate. Sand gave satisfactory rooting of Turk's Cap and Flowering Pomegranate. Sawdust gave results similar to sand for all plants except Florida Jasmine, which did better on sawdust. Vermiculite was the outstanding medium for Waxleaf Ligustrum and Tangerine Bougainvillea. It also gave satisfactory results with Sanderiana Bougainvillea, Turk's Cap and Flowering Pomegranate.

Processing and Utilization Research on Citrus Fruits[1]

C. H. Fisher[2] and John R. Matchett[3]

INTRODUCTION

Citrus fruits are the subject of much research throughout the U. S. Department of Agriculture, and by other organizations, directed at improvements in all stages of production, processing, marketing and use. Two phases of this research are assigned to the Bureau of Agricultural and Industrial Chemistry, whose program encompasses investigations to improve the processing and utilization of major agricultural crops throughout the United States. Studies of the processing and utilization of citrus, in this Bureau, are concentrated at three field stations located in the large citrus growing areas of Texas, Florida and California.

The stations in Weslaco, Texas, and Winter Haven, Fla., are administered through the Southern Regional Research Laboratory in New Orleans, while the station in Pasadena, Calif., is administered through the Western Regional Research Laboratory in Albany, Calif. In addition, other units of the Bureau, including the Eastern and Northern Regional Laboratories at Philadelphia, Pa., and Peoria, Ill., as well as the two regional laboratories already mentioned, do much work that is of general interest and value to the citrus grower and processor, for the reason that citrus products have much in common with other farm crops as regards their handling, storage, processing, composition, enzyme activity, chemistry, microbiology and the utilization of byproducts.

To assure efficient prosecution of this extensive program of research, Dr. G. E. Hilbert, Chief of the Bureau, has assigned to one of the authors of this paper (J.R.M.) the responsibility for coordinating, not only the research on citrus, but also that on other fruits and vegetables.

The research on citrus, as well as that on other commodities, has been greatly aided by the active cooperation of growers, processors, commodity associations, and others interested in advancing the status of the citrus industry. Nowhere is this cooperation exemplified better than in the three field stations mentioned above. The Texas and Florida Citrus Commissions, and the Arizona Desert Grapefruit Industry Board, for example, have coooperated generously, even to the extent of supporting work done by research fellows located in the field stations. Out of such cooperation, specifically that between the Florida Citrus Commission and the Winter Haven Station, came one of the greatest of all modern advances in food processing, the development of frozen concentrates.

[1]A report of research, certain phases of which were conducted under the Research and Marketing Act.

[2]Director, Southern Region, Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture.

[3]Assistant Chief, Bureau of Agricultural and Industrial Chemistry.

A Look Back

Such is the present organization of research on the processing and utilization of citrus that dates back to 1911, when it was first initiated in Los Angeles at the request of California citrus growers. Even then, citrus growers were interested in the possibilities of chemistry as a means of improving the utilization of citrus fruits, with emphasis on finding markets for the surplus after the demand for fresh fruit was filled. In 1949 the work started nearly 40 years earlier at Los Angeles was moved to a new laboratory building at Pasadena, where now 15 employees, under the leadership of Dr. E. A. Beavens, are engaged.

For two decades California was the center of all the Bureau's citrus research. Then in 1931, the laboratory in Winter Haven, Fla., was established, followed the next year by what is now the Weslaco Station in the Rio Grande Valley of Texas. Both these laboratories, like the one in California, were the outgrowth of local interest, cooperation, and financial support. The Florida station today is manned by 13 persons under the leadership of Dr. M. K. Veldhuis. Seven employees, headed by W. C. Scott, work in Weslaco.

The Impact Today

The citrus industry, whose interest in this research program has never lagged, is well aware of the results and of their benefits to both growers and processors. These benefits, manifested in deep-seated changes in the industry and in consumer customs and preferences, are in the form of new and improved products coupled with better processing methods and machinery for producing them.

A few statistics will illustrate the impact of these developments. The production of citrus fruit in the United States has expanded from 85 million boxes in 1936 to more than 150 million boxes in the 1950 season. While much of this increased production is utilized as fresh fruit, of which consumption has risen from 30.7 pounds per capita during 1920-29 to 55.9 pounds in the recent ten-year period of 1942-51, a large part of the present production of citrus is used in processed form. This trend is growing rapidly. On the average, individuals consumed 10.35 pounds of canned citrus a year in the period 1947-50, compared with only 3.35 pounds in 1940, 0.89 pounds in 1935, and 0.12 pounds in 1930. The development of frozen concentrates and improvements in the utilization of citrus byproducts are also factors in the changing citrus picture.

CITRUS JUICES

A brief description of some of the more important research findings contributed to this picture may be helpful. Let us consider first of all the improvements that have been made in single strength juices. In spite of the frozen concentrate development, these are still important to millions of persons because they appreciate the lower cost of the single strength

juices and they lack the low-temperature facilities needed to store concentrates; and the production of single strength juices continues to exceed any other form of processed citrus.

Canning

The citrus field stations initiated investigations of the problems involved in canning immediately upon being established. From these investigations came a steady stream of information that helped develop and maintain a successful citrus canning industry. The contributions include new information on deaeration, pasteurization, nature and cause of flavor changes, role of peel oil, action and control of microorganisms, and enzyme activities – and more information is constantly being obtained.

During the past year, for example, the Winter Haven Station obtained new, basic information on problems involved in the pasteurization of canned citrus juices. The study provided new information on the relation between the extent of pasteurization and keeping quality of canned orange juice. A taste panel, it was found, could distinguish between juices that had been subjected to pasteurization for 40 seconds and those subjected for 1½ seconds, when these juices were served after having been stored for six months at a temperature of 70 degrees F.

Temperatures used in these pasteurization studies ranged from 140° to 280° F. When temperatures of 160° F. or higher were used, swollen cans were not found and tests for the enzymes phosphatase and peroxidase were negative. Temperatures of 190° or higher were required to inactivate the enzyme pectinesterase. This enzyme destroys cloud stability in the canned product and, if it is not inactivated during pasteurization, the juice in the upper portion of the can will be clarified and a sludge will settle to the bottom or a curd may form. It has been found that the presence of this enzyme can be readily detected based on the activity of pectinesterase to hydrolyze methyl ester groups to give acid groups, which increase the acidity. A practical pasteurization index, based on changes in acidity, was devised.

The steam injection method of the Western Regional Laboratory is of interest in not only pasteurization but in evaporation. The method has three advantages: No heat exchange surface; purees can be handled; and speed in heating and cooling. The method is valuable where the material to be processed is heat labile, or where heat transfer is a problem. If vacuum cooling is used, the volatile flavoring constituents are removed and must be recovered if these flavors are to be returned to the product.

Flavor Changes

The darkening and development of off-flavors during the processing and storage of citrus-juice products materially reduces their quality. In attempting to learn the nature and causes of these undesirable phenomena, the Bureau has studied the composition of citrus products and changes in composition that occur on processing and storage, giving particular attention to the peel oil, lipids, volatile constituents, (essence), carbohydrates, flavonoids, enzymes, and nitrogenous constituents. For example, it was demonstrated at Weslaco that grapefruit juice must be free from excessive peel oil to have the best flavor and keeping quality. Early investigations at Winter Haven showed that limonene, the principal constituent of peel oil, gives off-flavors on oxidation.

Evidence obtained at the Winter Haven Station suggests that the off-flavors that sometimes develop in canned orange juice are due in part to oxidation of the fixed oil in the juice. In tests, this oil, comprised largely of glyceride esters, from fresh orange juice had a bland taste and aromatic odor, but that from old canned juice had a stale, tallowy odor, a rancid taste and a bitter aftertaste. A number of tests showed that changes in the oils are brought about by oxidation. Higher ketones and hydroxy acids were found in the extract from the old juice. The effect of antioxidants in the juice has been investigated.

The volatile flavoring materials ("essence") that may readily be removed from the juice by distillation have been studied by the Pasadena and Winter Haven Stations in efforts to obtain more information on flavor phenomena. At Pasadena, the volatiles from fresh juice were found to contain furfural, ethanol, methanol, acetaldehyde, acetone, hydrogen sulfide, carbon dioxide and other materials not completely identified. The analysis of the volatiles from the aged juice has not been completed, but it has already been observed that the furfural content increases on storage.

Also at Pasadena chromatographic techniques have been applied to the qualitative analysis of nitrogenous compounds in fresh and processed Valencia and navel oranges and in grapefruit, lemon, tangerine, and lime juices extracted from California, Florida, and Texas fruits. It was found that the organic nitrogen in citrus juices is present largely in the form of free amino acids and other relatively simple molecules. The various citrus juices contained the amino acids alanine, aspartic acid, asparagine, glutamic acid, and serine in amounts approximating the vitamin-C content of the juces. In addition, Valencia orange juice contained arginine, proline, and another major constituent believed to be sarcosine. Proline, but neither arginine nor sarcosine, was found in navel-orange juice. Grapefruit and tangerine juices were identical in respect to their major nitrogenous constituents, containing arginine in addition to the five amino acids found in all the juices.

Quantitative filter-paper-partition chromatography studies of fresh and heat-treated orange, lemon, grapefruit, and lime juices show that all contain small but significant amounts of both cysteine and gluthathione, and that about 25 percent of each of these compounds is destroyed by heating. The foreign flavors and aroma developed in processed citrus products may be due in part to the formation, from these two sulfur-containing compounds, of hydrogen sulfide and other sulfur-containing decomposition products.

The presence of relatively large amounts of free amino acids in citrus juices indicates that the role of these compounds in deteriorative changes of processed fruit juices may be even more important than previously suspected. This is particularly true in concentrated juices where more nearly optimum conditions are provided for the Maillard (browning) reaction between amino acids and sugars.

Because of the importance of flavor and aroma and their retention on storage, all three citrus stations are continuing to study problems in this field. These studies are giving additional information on the causes of flavor and flavor instability and on the role played by peel oil, lipids, nitrogenous compounds, etc.

FROZEN CONCENTRATES

While improvements are constantly being made in the canning of citrus juices, research on frozen concentrates is receiving more and more emphasis, and has led in recent years to what may be considered the outstanding success story in citrus utilization. This work started in the middle 1930's and moved gradually for ten years toward a successful process that is now the basis for utilizing millions of boxes of fruit a year. To be more specific, during the 1950-51 season, 23 million boxes of oranges (almost a third of the oranges grown in Florida) were used to make concentrate. During the 1945-46 season, when this product was first made commercially, it utilized about 1/5 of 1 percent of the total orange crop.

The history of this development is a story of persistence and cooperation. Here are the highlights. An early investigation at Winter Haven provided useful information on the relation between concentration and the temperatures required for successful storage. It was found, for example, that the effect of concentration was to decrease the shelf life and that it was impractical to store 42° and 65° Brix concentrates at room temperature. It was reported in 1936 that Texas grapefruit juice that had been concentrated from 4 volumes to 1 volume and stored 18 months below 40° F. proved satisfactory for preparing reconstituted juice or carbonated beverage base. Tangerine concentrates were prepared in 1937 that contained up to 62 percent total solids. When diluted with water, they lacked the tangerine flavor, but the addition of an emulsion of tangerine oil improved the product.

The specific findings, resulting from cooperative work with the Florida Citrus Commission, that led to the development of the fabulous frozen concentrate industry were announced by the Department of Agriculture in 1945. The improved concentrates were prepared for the first time at the Winter Haven Station by L. G. MacDowell, E. L. Moore and C. D. Adkins of the Florida Citrus Commission, who added single strength juice to concentrates to restore successfully the characteristic aroma that is lost in concentrating.

From Texas Grapefruit

Pioneer work undertaken at the Weslaco Station has already been of considerable help to those interested in the development of a frozen citrus concentrate industry in the Rio Grande Valley. The problem of producing, from pink and red grapefruit, concentrates that would give reconstituted juice having an attractive appearance is one of the most important that has been tackled by the staff at Weslaco. They found that a distinctive pink color, suggestive of the fruit itself, can be obtained by incorporating a small amount of the grapefruit pulp in the concentrate. Concentrates produced experimentally at the Weslaco Laboratory retained also the mild flavor generally considered one of the most delightful characteristics of Texas pink or red grapefruit. With these qualities, concentrate from pink or red grapefruit might command a premium on the concentrate market comparable to that commanded by the fresh fruit in the fresh market.

The current program at the Weslaco Station includes work aimed at developing concentrates of improved stability and quality, obtaining more information on the coloring matter and other characteristic constituents of pink and red grapefruit, and procuring any information that will facilitate the manufacture of high-quality products from Texas citrus fruits. In addition, the possibility of developing concentrates stable at about room temperature is being studied.

Studies in Florida

The Winter Haven Station has continued its studies of concentrates, giving particular attention to the problems of the new industry. Working cooperatively with the industry, the Station has examined samples of the fruit and products at different stages of the processing operations, to determine the nature and number of microorganisms.

Information to aid processors and handlers in selecting proper conditions for the safekeeping of frozen citrus concentrates has been obtained in recent cooperative work by the Florida Station and a commercial processor of citrus fruits. These studies are being continued to obtain additional data that will be helpful in seeing that frozen concentrates reach the consumer in good condition.

In a recent study of the flow of heat through large masses of concentrate, heat transfer coefficients were calculated. For such masses, thawing of the frozen concentrates at relatively low temperatures, that is, about 35° F., was found to be preferable to thawing at higher temperatures .

The current program includes a study of the relative merits of "essence," peel oil, puree and single strength juice in providing flavor and aroma. Since the industry has been troubled with gelation and clarification of some of the citrus concentrates, the Station is looking for information that will explain the phenomena and afford remedial measures. The development of concentrates of greater stability at about 32° F. and higher temperatures is also receiving attention.

The Trend at Pasadena

The Pasadena Station has made great progress in its efforts to produce satisfactory products of unusually high concentrates. For example, this Station has made a satisfactory product that differs from the standard

frozen concentrate in that the concentration is 7 to 1 instead of 4 to 1 and peel oil instead of single strength juice is used to provide flavor.

CITRUS POWDERS

Because citrus powders stable without refrigeration should have some advantage and applications not possessed by frozen concentrates, preservation by dehydration to effect maximum retention of nutritive value and flavor has been actively studied at the Western Regional Laboratory. Color, flavor, and vitamin retention were encouraging; in some instances the dried product retained as much as 80 percent of the Vitamin C and all of the vitamin A originally present. This research has been discontinued.

UTILIZATION OF CITRUS BYPRODUCTS

As a result of increased processing (almost half the 1950-51 crop), the volume of byproducts has grown to large proportions in all the citrus growing areas. These byproducts of citrus processing annually amount to about 2.5 million tons of solids and more than 4 billion gallons of liquid effluents. New and expanded uses are needed for these, as well as for culls and surplus fruit.

Citrus Pulp and Molasses as Feed

At the request of the owners of a dehydration plant for producing stock feed from citrus cannery waste, the Weslaco Station in 1940 made a detailed study of their process and equipment and suggested the omission of pressing and the introduction of a two-stage drying system. These changes made it possible to prepare a better feed with no material increase in cost.

Because of the interest in feeds containing both pulp and molasses. the Winter Haven Station has made a thorough study of citrus pulp enriched with various proportions of citrus molasses. The addition of molasses did not introduce a storage problem; it gave mixed feeds an increased tendency to absorb moisture, but the effect was very small. Neither plain nor molasses-added pulp became sufficiently moist at 70 percent relative humidity to support the growth of molds, although both became moldy at 80 percent.

The Station also developed a convenient method for estimating the soluble solids in dried citrus pulp feeds. The method can be used as an index of the amount of molasses present, or to determine the effectiveness of adding various amounts of molasses in raising the content of soluble solids in the feed. Feed mills already are using this method to advantage in their regular operations and to develop data that should be useful in overcoming the wide variations now found in citrus feeds and in establishing satisfactory standards for their manufacture and marketing.

Fermentation Products

The press liquor and molasses from citrus pulp manufacture, containing sugars, are potential starting materials for making many fermentation products, including alcohol, citric acid, yeast, lactic acid, glycerol, vitamin B12, butyl alcohol and acetone.

The Winter Haven Station has developed technically feasible methods for making alcohol and feed yeast from citrus byproducts and has accumulated useful information on the production of butyric acid. Alcohol, feed yeast and lactic acid have been made, either commercially or on a pilot-plant scale, from citrus byproducts in Florida. Technical assistance was given to the operator of an alcohol plant in the development of methods of separating calcium pectate during the concentration of the waste liquors and for separating and using naringin from the waste liquors of grapefruit canneries.

In 1947, Dr. Veldhuis of the Winter Haven Station published a description of an extensive study of the production of torula feed yeast. Operations were carried on continuously, 24 hours a day for 5 weeks. The quantity of waste liquors processed average about 180 gallons per hour. The yields of yeast under optimum conditions were 50 percent or more of fermentable sugar. Operating data needed for the design of a full-scale plant were obtained.

Pectin

Commercially, pectin is prepared from citrus peel, 1950 production being limited to California. From 4 to 5 million pounds of pectin are produced annually from about 100,000 tons of fresh peel.

The largest use of pectin is in the production of jams and jellies. Ordinary pectin used in making jams and jellies requires the use of about 65 percent sugar and small amounts of acid to form a stable gel. Bureau scientists have studied a modified pectin that requires only calcium to form stable gels. This type of pectin is called "low methoxyl pectin" to distinguish it from ordinary pectins, which have higher methoxyl contents.

Bureau research has shown that such pectins can be used for coating foods for protective purposes, preparing certain types of pudding powders and for other specialized purposes. Low-methoxyl pectins are made commercially, but they cost more than ordinary pectin. However, they have large potential uses in producing puddings and coating candied fruits and chocolate bars, etc.

It has been shown in work at the Southern Regional Laboratory that certain pectin products are similar to CMC (carboxymethyl cellulose) in that they can be used to retard the soiling of cotton fabrics. In laundering tests, the pectin products were applied to the fabrics in the rinse water. This treatment coated the fibers with pectin and improved the soil-resistance of the fabric. It is possible that this application will afford a large outlet for pectin.

Research workers at the Western Regional Laboratory have made amides from pectin that should prove useful as detergents and emulsifiers. The amides were made by treating pectin with lauryl and similar amines.

Allyl derivatives of pectin have been shown in work at the Eastern Laboratory to have the ability to form, through oxidative polymerization, protective coatings of potential usefulness.

Because more basic information on pectin is needed if the practical pectin problems are to be solved efficiently, much of the Bureau's research has been aimed at learning more about the fine structure and fundamental properties of pectin. By the application of chromatography, X-rays, and crystallography, much additional information was obtained in 1950-51 about the composition and properties of pectin and a component that appears to be attached to the pectin molecule through ester groups or hydrogen bridges.

Seed Oils

Glyceride oils may be recovered from citrus seeds, which consist of about equal parts of oil, meal and hulls. An estimated total of about 700,000 pounds of citrus seed oils was produced in the United States during the 1948-49 season.

Seed oil from the grapefruit was studied by the Bureau as early as 1930, and during the 1937-38 season in Florida a company initiated production. The crude oil produced was sold too the textile industry for making sulfonated oil.

The work on grapefruit seed oil at Winter Haven was followed by investigations at the Western Regional Laboratory of the properties and potentialities of orange seed oil. It was found that the oil should be useful either for food or industrial purposes. About 570 pounds of oil and 1,240 pounds of press cake can be made from 1 ton of air-dried seed.

The oil pressed from seeds of Valencia oranges grown in Texas was found to belong to the class of semidrying oils, being low in linoleic acid derivatives. It had a bitter taste due to the presence of isolimonin, but this constituent could be removed by refining to make the oil edible.

Obacúnone, along with the bitter principles limonin and nomilin, were identified in Florida seed oil in 1951.

Limonene and Peel Oil

It has been estimated that up to 10 million pounds of limonene could be recovered annually. Work that might prove useful in finding industrial outlets for limonene, obtained during the concentration of press water, has been done at Weslaco and (on dipentene) at the Bureau's Naval Stores Research Station at Olustee, Florida. Some of this work has shown that plastics can be made by polymerization of limonene under suitable conditions.

Peel oil is manufactured in substantial amounts; it is estimated that the potential supply of oil from waste peel is about 20 million pounds annually. The Winter Haven Station has studied the properties of orange oils produced in different localities in Florida. These investigations showed that failure of many such oils to meet U.S.P. specifications could be overcome by blending the oils.

Glycosides

As early as 1931, work by the Bureau showed that naringin, the bitter glycoside in grapefruit, could be made at relatively low cost. Efforts to develop outlets for naringin have been made. A study of the hydrolysis of naringenin (obtained with the sugars rhamnose and glucose from naringin) showed that the products p-coumaric acid and phloroglucinol, could be obtained in yields higher than 50 percent. Phloroglucinol, now manufactured from coal tar products, sells at about $15 per pound, but its market is extremely limited.

Hesperidin, the glycoside from oranges, and naringin and certain materials derived from them have been studied for some time by the Bureau to ascertain their potentialities as pharmaceuticals. It was demonstrated that some of these materials resemble rutin in that they have "vitamin P activity" and can be used advantageously in treating frostbite, radiation injuries, and fragility of capillaries associated with hypertenson. The Bureau is continuing its study of the physiological properties and pharmaceutical possibilities of citrus glycosides.

CONCLUSION

From these examples, it will be seen that in their research on the processing and utilization of citrus, scientists of the Bureau of Agricultural and Industrial Chemistry have accumulated a vast fund of knowledge on the chemistry and technology of this important agricultural crop. Out of this knowledge, may come many additional achievements as the research is continued in cooperation with other interested agencies and the citrus industry, both growers and processors. Future research on the utilization of citrus undoubtedly will continue to stress efforts to decrease the weight and bulk of processed products and to improve quality from the standpoint of flavor and storageability. Practical developments in some directions, however, may have to await more fundamental research on the chemical, enzymatic and microbiological changes that occur during the processing operations.

Furthermore, it should be emphasized that research to improve the utilization of citrus cannot stand alone. It must be, and is, a part of an overall research program of much greater scope in which other agencies of the U. S. Department of Agriculture, a number of State Experiment Stations, and the processing industry itself are engaged. Just as the investigations of the past 40 years have helped bring citrus to its present position as a major agricultural commodity, apart and distinct from other fruits and vegetables as a class, the continuation and strengthening of this research would seem to promise valuable contributions to further progress in the future.

Benzene Hexachloride Contamination in Processed Tomatoes and Turnip Greens

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Although benzene hexachloride is an effective insecticide, its usefulness is limited on food crops because of its persistent characteristic penetrating odor. The undesirable effect on tomatoes has been recognized for some time and more recently it has been shown to impart off-flavors to various tubers and to the juice of treated oranges according to Griffiths *et al.* (1950). Crude mixtures of benzene hexachloride appear to be more objectionable than the products high in the gamma isomer. Hensill *et al.* (1950) have claimed that the undesirable taste imparted can be avoided in tomatoes by using the gamma isomer not later than thirty days before harvest.

The presence of peculiar off-flavors and discolored can linings in processed tomatoes and turnip greens during the past few seasons have increased to the point where they are of considerable importance to the processor. Benzene hexachloride was suspected of producing the off-flavors and the following experiments were conducted in an effort to throw more light on the problem.

TOMATOES

One series of plots were treated three times at weekly intervals with 3% gamma BHC, another received three applications of 1% BHC, while two other series of plots received single applications of 1% and 3% gamma BHC. Four days after the final application the tomatoes, along with some from an untreated plot, were harvested and canned as juice according to good commercial practice[1]. Examination of experimentally aged samples showed off-flavors in proportion to the amount of BHC applied. Salt was found to improve the flavor of those samples receiving only 1% BHC, but it failed to mask the off-flavors in those receiving 3% BHC. Only slight staining of the can lining could be detected immediately upon opening, but a definite discoloration developed upon standing exposed to the air for a short time. The discoloration ranged from a slight gray to a slate black color and was proportional to the amount of BHC applied. No off-flavor or can lining discoloration was observed in those samples which came from untreated plots. A strong musty odor of BHC was given off during the laboratory hot-breaking operation and this simple test can easily be used to identify BHC treated tomatoes.

TURNIP GREENS

Turnip greens were dusted with 3% gamma BHC and 1% lindane. Ten days later these greens were canned along with some untreated greens. Tasters graded the untreated greens as fair. The turnip greens

[1]W. C. Scott, U. S. Fruit & Veg. Prod. Laboratory, assisted in processing the various samples.

dusted with 1% lindane were graded as "slightly off odor" whereas those which were dusted with 3% gamma BHC were graded as "definite repulsive odor." The off-odors could be definitely detected when both the lindane and BHC treated samples were cut. This odor can be described as a very musty odor like spoiled hay. The cans containing greens treated with 3% gamma BHC were definitely discolored; some discoloration was noticed in those cans which contained the 1% lindane-treated greens.

SUMMARY

These data indicate that benzene hexachloride and lindane should not be used on tomatoes or turnip greens grown for canning purposes.

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Parathion and DDT Residues on Vegetables

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Experimental work has shown that parathion and DDT are very effective in controlling a large number of insects. Since these insecticides were so effective preliminary experiments were conducted in order to determine the amount of residues[1] remaining on edible parts of vegetables at specific intervals after insecticidal treatments. Data of this nature will be very valuable at such time when the Pure Food and Drug Administration establishes residue tolerances for parathion and DDT on edible crops.

PARATHION RESIDUES

Lettuce. The lettuce selected for this study was at the time of the first treatment application judged as being three weeks prior to harvesting. The plots were 0.02 acre in size and each treatment was replicated three times. The treatments consisted of 0.5 and 1-percent parathion dusts and the check or untreated area. The dusts were applied three times at weekly intervals with rotary hand dusters at approximately 20 pounds per acre.

A lettuce head was selected at random in each plot at the time intervals as shown in table 1. Then the three heads from each treatment were trimmed as if prepared for shipment. The lettuce heads were ground finely and a sample was taken for analysis. The trimmed portions of the lettuce head, which consisted of outside leaves, were ground and a sample was taken for analysis.

Considerably more parathion was found in the outside leaves than in the edible portion of the lettuce head as can be seen by the data in table 1.

Table 1. Parathion residues found in lettuce after treatment applications.

Concentration of Parathion	*Time of Sampling After Treatments*	*Parts per Million of Parathion on Outside Leaves*	*Parts per Million of Parathion on Inside Head*
0.5	1 week after first dusting*	0.23	0.08
1.0	1 week after first dusting	0.28	0.08
0.5	1 week after second dusting	0.35	0.10
1.0	1 week after second dusting	0.40	0.10
0.5	1 week after third dusting	0.16	0.03
1.0	1 week after third dusting	0.48	0.03
0.5	2 weeks after third dusting	0.0	0.01
1.0	2 weeks after third dusting	0.29	0.02

*Applied on 12-24-48.

The amount of parathion absorbed by the outside leaves in all but one sample increased slightly with each treatment application. However, the parathion residue in the outside lettuce leaves dropped considerably in

[1]Analyses for residues were made by W. G. Godbey, chemist of The Agricultural Consultant Laboratories, Weslaco.

the samples taken 2 weeks after the third treatment application. It is significant to note the very minute amounts of parathion, 0.01 to 0.10 ppm, were found in the edible portions of lettuce heads.

Cantaloupes. Mature melons were dusted with 0.5 and 1-percent parathion at approximately 25 pounds per acre on June 4, 1949. The maximum temperature was approximately 98° F. at this time. Four days after treatment applications 4 melons were pulled from each treatment plot for analysis. A sample consisted of the rind or heart of two melons. Very little parathion was found in the heart or flesh of these melons as can be seen by the data in table 2.

Table 2. Parathion residues found in cantaloupes 4 days after treatment application.

Concentration of Parathion	Part Examined	Parts per Million of Parathion	
		Sample 1	Sample 2
0.5	Rind	0.05	0.02
1.0	Rind	0.17	0.15
—	Rind	0.0	0.01
0.5	Heart	0.0	0.0
1.0	Heart	0.01	0.0
—	Heart	0.0	0.0

Turnip Greens. On October 25, 1949, mature turnip greens were dusted with 1-percent parathion at approximately 30 pounds per acre. A week later these turnip greens were canned[2]. Then six cans of turnip greens which had been dusted with parathion and six cans of untreated greens were analyzed for the presence of parathion. The amounts of parathion ranged from 0.34 to 0.51 ppm in the greens dusted with parathion. The untreated greens averaged 0.04 ppm.

DDT RESIDUES

Sweet Corn. Sweet corn was commercially sprayed for the control of the corn earworm, *Heliothis armigera* (Hbn.), on May 3, 1948 with the recommended 1% DDT - 99% mineral oil solution, using the individual ear method of application. Approximately 2 cc of the DDT-Mineral oil solution was sprayed on the silk of each ear. The kernels from 3 ears were analyzed for DDT at 5, 8 and 12 days after the treatment application (the 12th being the day on which the sweet corn was harvested). The sweet corn showed the following amounts of DDT: 5 days after application 0.2 to 0.5 ppm; 8 days after application 0.1 to 0.15 ppm; and 12 days after the treatment application the analysis reading was zero.

Broccoli and Cauliflower. The question of DDT residues on broccoli and cauliflower was a major concern to vegetable shippers during January 1949. Six samples with known insecticide histories were collected during that month from vegetable packing sheds and analyzed for DDT. Each sample consisted of either 2 bunches of broccoli or 2 heads of cauliflower. The data in table 3 shows that very small amounts of DDT were found on broccoli or cauliflower which had been harvested 8 or more days after the last application.

[2]W. C. Scott, In Charge, U. S. Fruit & Veg. Prod. Laboratory assisted in canning the turnip greens.

Table 3. DDT residues found on broccoli and cauliflower collected at the packing sheds.

Vegetable	Sample No.	Area Obtained	Dusting History	Days since Last Dusting	ppm of DDT
Broccoli	1	Weslaco	One time: 5% DDT	30	0.0
	2	Los Fresnos	Three times: 5% DDT	8	0.0
	3	Elsa	Three times: 5% DDT	14 (washed)	0.0
	4	Elsa	Three times: 5% DDT	14 (unwashed)	0.12
	5	Weslaco	One time: 5% DDT	30	0.15
Cauliflower	6	Los Fresnos	Twice: 5% DDT	8	0.05

SUMMARY

At harvest time varying amounts of parathion residues were found on the following vegetables: Lettuce heads, 0.01 to 0.1 ppm; flesh of cantaloupes, 0.0 to 0.01 ppm; and turnip greens 0.34 to 0.51 ppm.

The following amounts of DDT were found at harvest time on these vegetables: sweet corn, 0.0 ppm; broccoli, 0.0 to 0.15 ppm; and cauliflower, 0.05 ppm.

The Tomato Russet Mite

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The tomato russet mite, *Phyllocoptes destructor* Keifer, was found for the first time during June 1950 in the Lower Rio Grande Valley near Progreso. A 10 acre section of a 100 acre field of tomatoes looked as if it had a severe case of early or late blight. Both late and early blight require damp or humid weather to build up to epidemic proportions whereas the tomato russet mite increases to destructive numbers only during hot and dry weather. This mite has previously been reported in Texas at Jacksonville by Young (1949) and by Young *et al* (1951) at Laredo.

The adult mite is yellow in color. It is slightly humped, wedge-shaped in appearance and is approximately 1/250 of an inch long. This mite damages tomatoes by sucking the sap from the leaves, stems and fruit. The mite infestation usually starts on the lower leaves. The first symptom is a bronzing of the ventral surface of the lower leaves. As the feeding continues the leaves become brown, then paperlike, and finally drop off. When a leaf becomes brown in color the mites migrate to leaves higher up on the plant. Bailey and Keifer (1943) states that russet mites will abandon injured drying portion of leaves and migrate to fresh green portions. On severely injured plants mites can be found on the stem end of green fruits. Severe mite infestations will cause plants to loose their leaves which results in a reduction of tomato yields.

An experiment was conducted to determine if the recommended control measures used in other areas would be effective in the Lower Rio Grande Valley. The plots were 0.02 acre in size. Each treatment was replicated three times and applied with rotary hand dusters at approximately 25 pounds per acre. The treatments applied are shown in table 1.

Table 1. Control of the Tomato Russet Mite.

Treatments	*Mites per Leaflet 48 Hours After Dusting*	
	No.	*% Reduction*
Sulphur	0.7	91
5% DDT + 50% sulphur	1.5	82
2% EPN 300	0.3	96
1.5% Metacide	0.3	96
1% Parathion	0.7	91
10% Sulphenone	0.8	90
Untreated	8.2	—

The efficiency of the various treatments was determined 48 hours later by collecting 10 leaflets at random from the tops of tomato plants in each plot and then determining the surviving adult mites. The data in the table shows that sulphur gave good control of the tomato russet mite. Either a 1-percent parathion or a 10-percent sulphenone dust was as effective as sulphur, while 2-percent EPN 300 or 1.5-percent Metacide ap-

pears to be slightly more effective. A mixture of 5-percent DDT with 50-percent sulphur gave commercial mite control. Therefore, if other insects are present in the field along with the tomato russet mite control of these insects can be obtained by combining the proper insecticides with a dust mixture containing at least 50-percent sulphur. If mite control is desired within a week or so before the harvesting of canning tomatoes use either 10-percent sulphenone or an insecticide containing at least 50-percent sulphur instead of straight sulphur so as to minimize the danger of sulphur contamination to processed tomatoes.

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Control of Onion Thrips During the 1951 Season

GEORGE P. WENE and A. N. WHITE, *Texas A&M System, Weslaco.*

The onion thrip, *Thrips tabaci* Lind., causes severe damage to onions in the Lower Rio Grande Valley during January, February and March. When the onions mature during late March and early April the onion thrips migrate to seedling cotton, where an uncontrolled infestation may ruin the stand in a short time. Because the small acreage of onions was damaged by the January, 1951 freeze, little research was possible on onions. However, severe infestations on seedling cotton made possible additional research on thrip control.

With low volume sprays Mayeux and Wene (1950) reported good control of onion thrips with the following insecticides applied at the designated rates per acre: 1-pound aldrin, 1-pound toxaphene, 0.5 pound dieldrin and 0.5 pound heptachlor. Sloan and Rawlins (1951) also reported good control with dieldrin and heptachlor applied as a spray at the rate of 1-pound of toxicant per acre.

METHOD

The first experiment was with onions; the treatments, as shown in table 1, were applied with a 3 gallon garden sprayer. Because these insecticides are toxic to warm blooded animals, the plots were small, consisting of a single row of onions 25 feet in length. Each treatment was replicated three times. The effectiveness of the various materials was measured by averaging the number of surviving thrips on 10 plants selected at random in each plot at definite time intervals after treatment applications.

Table 1. The effectivness of the systemic insecticide "Systox" in controlling onion thrips on onions.

	Thrips per Plant after			
	3 Days		10 Days	
	No.	% Red.	No.	% Red.
0.38 Lb. Systox[1]	4.9	42	15.9	24
0.19 Lb. Systox	6.0	29	16.9	20
0.1 Lb. Systox	8.4	0	16.2	23
0.25 Lb. Parathion	0	100	7.1	66
Untreated	8.4	—	21.0	—

[1]32.1% Trialkyl thiophoospliate plus 67.9% emulsifier 8139.

The remaining 3 experiments were conducted on cotton which had just emerged from the soil. The plots were approximately one acre in size and each treatment was replicated 3 times. The treatments shown in tables 2, 3 and 4, were applied with a commercial low volume sprayer. Efficiency of the various treatments was determined by counting the total number of thrips surviving on 25 cotton seedlings selected at random from each plot at definite time intervals after treatment applications.

Table 2. Control of onion thrips on seedling cotton with low volume sprays.

Insecticide per acre	Thrips on 25 Seedling plants after					
	1 Day		5 Days		16 Days	
	No.	% Red.	No.	% Red.	No.	% Red.
0.5 lb. Aldrin	1.7	95.6	15.0	92	7.0	84
0.25 lb. Aldrin	3.0	91.9	37.7	79	10.7	76
0.13 lb. Aldrin	3.7	90.0	65.3	63	14.7	67
1.0 lb. Toxaphene	2.7	92.7	16.3	91	10.0	78
Untreated	37.0	—	177.3	—	44.7	—

Table 3. Control of onion thrips on seedling cotton with low volume sprays.

Insecticide per acre	Thrips on 25 Seedling plants after					
	1 Day		5 Days		16 Days	
	No.	% Red.	No.	% Red.	No.	% Red.
0.19 lb. Dieldrin	3.7	87	15.0	92	8.3	85
0.10 lb. Dieldrin	4.0	86	19.7	90	11.3	79
0.25 lb. Heptachlor	3.3	89	16.7	91	12.7	76
0.13 lb. Heptachlor	0.7	98	37.0	81	25.3	53
0.17 lb. Parathion	3.3	89	41.7	79	38.0	29
0.25 lb. Metacide[1]	2.0	93	39.7	80	33.7	37
0.8 lb. Chlordane	0.3	99	26.7	86	17.3	68
0.25 lb. Q-137[2]	0.3	99	66.0	66	20.0	62
Untreated	29.0	—	195.7	—	53.7	—

[1] 6.2% O, O-diethyl O-p-nitrophenyl thiophosphate plus 24.5% O, O-dimethyl O-p-nitrophenyl thiophosphate plus 2.7% related phosphates plus 66.6% inert materials

[2] 25% 1, 1 bis (p-ethyl phenyl) 2, 2 dichlorethane

Table 4. Control of onion thrips on seedling cotton with low volume sprays.

Insecticide per acre	Thrips on 25 Seedling plants after					
	1 Day		5 Days		16 Days	
	No.	% Red.	No.	% Red.	No.	% Red.
0.25 lb. Aldrin	3.0	87	30.3	82	53.7	38
0.13 lb. Aldrin	3.7	84	46.7	73	77.4	11
0.25 lb. Heptachlor	1.3	94	34.0	80	56.3	36
0.13 lb. Heptachlor	1.3	94	38.3	77	56.0	36
0.37 lb. Q-137[1]	0.5	98	47.0	72	34.0	61
1.0 lb. Toxaphene	5.0	78	33.0	80	57.0	34
Untreated	23.0	—	169.7	—	87.3	—

[1] 25% 1, 1 bis (p-ethyl phenyl) 2, 2 dichlorethane

RESULTS

Systox[1] is considered a systemic insecticide which is absorbed by the plant and subsequently kills certain insects feeding thereon. The data shown in table 1 indicates that Systox has little value as a control measure for onion thrips.

Eight days after treatment applications on cotton, winds of approximately 40 miles per hour occurred. This windy weather lasted two weeks, and resulted in a decrease in the thrips population, as shown in tables 2, 3 and 4. The treatments in experiment 4 were applied in winds approximately 25 miles per hour; the treatments in experiments 2 and 3 were applied with little or no wind present. The cotton seedlings had just emerged from the soil; at this stage 1 thrips per plant can cause severe injury. The build-up of thrips shown 5 days after treatment application probably was caused by thrips migrating in from mature onions or other vegetables.

The data in table 2 shows that 0.25- and 0.5-pound aldrin per acre was as effective as 1-pound of toxaphene. The data in table 3 shows that dieldrin at 0.19 pounds per acre was the most effective insecticide tried. The following insecticides also gave effective control: dieldrin at 0.10-pound per acre; heptachlor at 0.25 pound per acre; chlordane at 0.8 pound per acre; and Q-137[2] at 0.25 pounds per acre. The organic phosphates, metacide and parathion, were effective immediately after application but did not have the residual effectiveness of the other insecticides, as shown in table 3.

The data in table 4 shows that the application of low volume sprays during high winds will give effective control for a few days; these low volume spray applications do not have the residual effect of similar sprays applied during calm weather (illustrated by the data in tables 2 and 4).

Q-137 applied at the rate of 0.37 pounds per acre was more effective than 1-pound of toxaphene, 0.25 pound of aldrin or 0.25 pound of heptachlor, as shown in table 4.

SUMMARY

The systemic, "Systox," was ineffective in controlling onion thrips.

One tenth pound of dieldrin, 0.25 pound of aldrin, 0.8 pound of chlordane, 0.25 pound of heptachlor and 0.37 pound of Q-137 per acre applied as low volume sprays were equally as effective as 1 pound of toxaphene applied in the same manner.

Metacide and parathion gave control immediately after application, but did not have much residual effect.

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[1]Systox—32.1% trialkyl thiophosphate plus 67.9% emulsifier 8139.
[2]Q-137—25% 1, 1 bis (p-ethyl phenol) 2, 2 dichlorethane.

Identification of Sugars in "Rio Sweet" Cantaloupes

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"Rio Sweet" is the name given to a new disease-resistant variety of cantaloupe developed by Dr. G. H. Godfrey of Texas Experiment Station, Substation 15. Along with its desirable disease resistance, Rio Sweet exhibits unusual sweetness. This characteristic gave emphasis to an interest in identifying the sugars present in the new variety. Accordingly, the Texas Experiment Substation requested the U. S. Fruit and Vegetable Products Laboratory to undertake a study of sugars present in the new variety.

A qualitative study was made by means of paper chromatography and the results are reported here. Sucrose, glucose, and fructose were detected.

Few investigations have been reported in the literature over the past 20 years on the sugar constituents of cantaloupes. Morozov (1938) reported sucrose in muskmelons, and Jacob and White-Stevens (1941) reported sucrose and hexose sugars in melons. Akman and coworkers (1946) found the concentrated syrup to contain 48.4% reducing sugars and 1.94% sucrose. Glucose, fructose, and sucrose were detected in melons (Cucurbitaceae) by Aleksandrova (1929) who determined the maximum sucrose content to be 5.47%.

PROCEDURES

Determination of Total Sugars

The total sugar content of a number of representative samples of Rio Sweet cantaloupes was determined on the sugar scale of the refractometer. The average content was found to be 13 to 14%.

Chromatographic Procedure

The sugar constitutents of Rio Sweet were studied on extracts of the juice from the edible portion of the melon by use of filter paper chromatography according to the general principles outlined by Partridge (1948, 1949).

Whatman[3] No. 1 filter paper strips were irrigated by the descending technique with n-butanol-acetic acid-water (4:1:5), phenol saturated with water, and with n-butanol-ethanol-water (7:2:2) at 20° C. for periods varying from 24 to 96 hours. After irrigation the paper strips were dried in an electric oven at 105° C. for 5 to 10 minutes and were then sprayed

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3 The mention of trade products does not imply their endorsement by the Department of Agriculture over similar products mentioned.

evenly with ammoniacal silver nitrate, aniline hydrogen phthalate, and/or naphtho-rescorcinol-trichloroacetic acid. Sugar spots were developed by heating in the electric oven at 105° C. for another 5 minutes.

Known sugars of recognized purity were used as controls in the identification of the unknown sugars on the papergrams. All spottings of paper strips with sugar solutions were made with capillary tubes. Circular spots (1 to 3 mm in diameter) were found by trial and error to give the most desirable and reproducible papergrams under the conditions used.

Preparation of Extracts

Three extracts were prepared to obtain results under different experimental conditions.

An 80% ethanol extract, after filtration and without further clarification, was concentrated over the water bath under reduced pressure, a few drops of chloroform were added, and the extract stored in the refrigerator for chromatographic examination.

A water extract was clarified by several procedures before concentration and storage. The juice was expressed with a stainless steel hand-press and the extraction completed with 80% ethanol in a Soxhlet apparatus. One aliquot of the extract was clarified with neutral lead acetate; a second, also clarified with lead acetate, was then passed through a Zeo-Karb-H column[3]; a third was passed in succession through a Zeo-Karb-H and a De Acidite[3] column.

In the preparation of a third extract the experimental conditions found to give the most desirable results were followed. Juice from the edible portion, 442 g., of a Rio Sweet cantaloupe (13.5° Brix) of prime quality was expressed as completely as possible with a stainless steel hand-press and the pomace was extracted with 80% ethanol in a Soxhlet apparatus. The alcohol was removed by concentration over a steam bath under reduced pressure. The alcoholic concentrate was combined with the aqueous extract and the combined extracts were clarified with neutral lead acetate, filtered, and deleaded with potassium oxalate. The total extract and washings, 1.2 liters, was divided into three portions.

Without further treatment, one aliquot, 500 ml., was concentrated to about 100 ml., chloroform, 4 drops, was added as a preservative; and the solution stored in a refrigerator.

The remainder, 700 ml., was twice passed through a Zeo-Karb-H column (3.5 by 30 cm.) to remove cations. The effluent and washings, 800 ml., were divided into two equal parts. One portion, 400 ml., was concentrated to about 75 ml., and was stored in a refrigerator.

The second part, 400 ml., was treated by two passes through a De-Acidite column[3] (3.5 by 30 cm.), concentrated to about 100 ml., and was stored in a refrigerator.

RESULTS AND DISCUSSION

Papergrams, irrigated with n-butanol-acetic acid-water, when developed by spraying with aniline hydrogen phthalate and naphthoresorcinol-trichloroacetic acid, gave spots for three sugars. The same carbohydrate

patterns were repeatedly obtained in papergrams of aqueous extracts clarified with neutral lead acetate.

A paperstrip (8 by 39 cm.) after being irrigated for 53 hours with n-butanol-acetic acid-water and sprayed with aniline hydrogen phthalate, when spotted with the unknown sugar solution and with D-sucrose, D-glucose and D-fructose at 2 cm. intervals, gave similar spots and advancements in excellent agreement.

A papergram (4.5 by 50 cm.) irrigated for 24 hours with n-butanol-acetic acid-water, sprayed with naphthoresorcinol-trichloroacetic acid, and developed in the usual manner gave spots for the unknown sugars in agreement with D-sucrose and D-fructose. RF values were calculated to be 0.14 for D-sucrose and 0.23 for D-fructose in the unknown and known solutions.

The carbohydrates pattern obtained by spotting a paperstrip (4.5 by 50 cm.) with a mixture of the unknown solution and a solution containing D-glucose, D-sucrose, and D-fructose, consisted of three distinct circular spots after irrigation with n-butanol-acetic acid-water and development with aniline hydrogen phthalate.

Somewhat improved papergrams were obtained after irrigation with n-butanol-ethanol-water.

Since RF values for L-sorbose, D-mannose, D-arabinose, D-xylose, D-maltose and D-galactose. as recorded by Partridge (1948) are quite close to those for sucrose, glucose, and fructose, papergrams were developed after spotting with the unknown solution and solutions of the known sugars indicated. In no case were the carbohydrate patterns obtained in close agreement with those obtained for the sugars present in Rio Sweet cantaloupe extracts.

A paperstrip (8 by 39 cm.) spotted with an extract of sugars from Rio Sweet cantaloupe clarified by filtration with Hyflo Super Cel[3] and each of the three prepared extracts described in the preceding section gave the same carbohydrate patterns after irrigation with n-butanol-ethanol-water and development with aniline hydrogen phthalate. Spots obtained from the deionized solution were somewhat more regular and distinct.

A sample (15 ml.) of the deionized and concentrated solution was hydrolyzed with 6 N hydrochloric acid at 40° C. for 6 hours. After treatment with DeAcidite the hydrolysate was concentrated to about 10 ml. over a steam bath and under pressure reduced by the water pump. A paperstrip (4.5 by 50 cm.) irrigated with n-butanol-ethanol-water, and sprayed with aniline hydrogen phthalate gave two spots, a reddish brown spot in agreement with that for D-glucose, and a less intense but distinct spot for D-fructose. Hydrolysis with 1 N hydrochloric acid at room temperature (about 30° C.) for 24 hours did not change the original carbohydrate pattern.

SUMMARY

D-sucrose, D-glucose, and D-fructose were detected as constituent sugars of Rio Sweet cantaloupes by paper chromatography. Acid hydrolysis revealed no additional sugars. Aqueous extracts gave the same qualitative results as 80% alcoholic extracts.

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Development of a Water Supply for the Lower Rio Grande Valley

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The International Water Treaty between the United States and Mexico, ratified on November 8, 1945, will provide conservation for beneficial use of the waters of the Lower Rio Grande between the two countries. The construction of storage works provided by the Treaty and the proper diversions will make possible a dependable water supply for the Valley and eliminate the past erratic flows. The problems relating to the conservation and the equitable distribution of the international waters of the Rio Grande have confronted the two countries since the beginning of this century.

There is no better way of beginning a discussion of the Water Treaty between the United States and Mexico than to emphasize that it is a joint undertaking of two sovereign countries to assure mutual benefits through the solution of mutual problems. It is not, therefore, an agreement whereby Mexico relinquished any of its rights in order to cooperate in the solution of United States problems, or vice versa.

The principal problems of the Lower Rio Grande for which the Water Treaty provides solutions are conservation of waters of the reach of the international stream below Fort Quitman, Texas, and their equitable distribution between the two countries.

Large growing communities in extensive areas in the United States are entirely dependent for their existence and future development upon the use of the waters of the Rio Grande, the potential supply of which is limited.

Drought and development on the tributaries of the lower Rio Grande have so depleted the natural flow that at the present time there is not sufficient water during low-flow periods to supply established uses in the United States and Mexico. At the same time millions of acre-feet of floodwaters have emptied annually into the Gulf of Mexico, and floods have caused serious damage. It was apparent years ago that only by agreement between the two Governments could the maximum feasible conservation of these floodwaters and their equitable distribution between the two countries be brought about.

On the lower Rio Grande, where most of the water supply originates in Mexico, a division of waters was necessary which, when stored in reservoirs and international dams, would protect existing uses.

It may be well to mention at this time that since the problems are joint and the required action to remedy them is joint, a single international agency was obviously required to apply the Water Treaty. Under the Treaty, the agency charged with this responsibility is the International Boundary and Water Commission, formerly the International Boundary

Commission. The joint Commission consists of two Sections: that of the United States with headquarters at El Paso, Texas, and the Mexican Section with headquarters in Ciudad Juarez, Mexico.

The Treaty is the product of long and patient negotiations on the part of both Governments, with every detail receiving careful consideration. Attempted negotiations of this important Treaty over a number of years having failed, the American Section of the former International Water Commission was abolished in 1932, and its duties, powers and functions were transferred to the United States Section of the then International Boundary Commission. Meanwhile irrigation developments in both countries proceeded steadily, and it became increasingly apparent that some agreement should be reached by the two countries with regard to an allocation of the water supply. Investigations of the situation were facilitated when in 1935 the Congress passed an Act extending the powers and duties of the United States Section of the International Boundary Commission.

A great mass of data relating to water supply, present and prospective developments in both countries, flood control, and related matters was compiled prior to the final negotiations. Some of these data were compiled from investigations carried on by the International Boundary Commission. Other data were procured from various sources – national, State, and local agencies – all of which were consulted frequently during the course of the negotiations on various points to be covered by the Treaty.

So far as the Rio Grande is concerned the effects of the Treaty are limited to the reach between Fort Quitman, Texas, and the Gulf of Mexico. Fort Quitman is about 85 miles below El Paso. The waters of the stream above Fort Quitman were allocated to the two countries under the Treaty of 1906.

The Water Treaty of 1944 allocated to the United States all of the waters contributed to the main stream by the principal United States tributaries below Fort Quitman, principally the Pecos and Devils Rivers; one-third of the contributions to the main stream from the principal Mexican tributaries above Salineno, Texas, which Mexico guarantees to be not less than an average of 350,000 acre-feet per year in cycles of five years, and one-half of all other flows in the Rio Grande, except those from the San Juan and Alamo Rivers, Mexican tributaries below Salineno, Texas, which empty into the Rio Grande below the Falcon Dam site. To Mexico, the Treaty allocated all of the contributions to the main stream from the San Juan and Alamo Rivers; two-thirds of the contributions from the principal Mexican tributaries above Salineno, subject to the guarantee to the United States of the minimum average of 350,000 acre-feet per year from these sources, and one-half of all other flows occurring in the main channel of the Rio Grande.

Of great importance is the provision in the Treaty for the construction of three major international storage dams between the Big Bend and the head of the Lower Valley, to provide capacity for conservation storage, flood control and the retention of silt. As is well known, the water

problems of the Lower Rio Grande Valley have largely been due to the absence of the regulation that could only be provided by main stream storage, which was impossible without an international agreement. The Treaty further recognized the needs of the Lower Valley of both countries by specifying that construction of the international storage dams should begin with the lowermost major international storage dam.

This dam, the Falcon Dam, is a multiple-purpose structure for conservation storage, flood protection and generation of hydro-electric energy. It is being constructed jointly by the two Governments, through their respective Sections of the Commission and is now more than one-third completed.

The Falcon site is about 75 miles downstream from Laredo, Texas. The structure will create a reservoir with a capacity of 4,085,000 acre-feet and a surface area of 114,000 acres at the maximum flow line elevation of 314.2 feet. Upstream from the dam to the towns of San Ygnacio, Texas, and San Ygnacio, Tamaulipas, an axial distance of about 40 miles, the reservoir will average about 4.5 miles in width at the maximum flow line elevation, but beyond those towns it will be contained within the present river channel. Of the total maximum reservoir surface area, 55,000 acres are in the United States and 59,000 acres are in Mexico.

Of the 4,085,000 acre-feet maximum capacity, 300,000 acre-feet is initially reserved for dead storage for minimum power head and silt detention, and 2,100,000 acre-feet for conservation storage. The remaining 1,685,000 acre-feet is reserved for flood control and additional silt detention (400,000 acre-feet) after upstream storage is provided. The conservation storage capacity required by each for storage of water allocated to it by the Water Treaty: 1,230,600 acre-feet, 58.6 percent, to the United States, and 869,400 acre-feet, or 41.4 percent to Mexico. The regulated water supply to be provided by Falcon Dam is urgently required for the large areas of lands already developed in the Lower Rio Grande Valley of the United States, and for substantial areas already developed and additional large areas to be developed in Mexico. Because of this urgency the Water Treaty requires that the dam be completed by November 1953. The present work program, if not held up by lack of critical materials, will meet that schedule.

The estimated cost of Falcon Dam and Power Plants is $46,065,000 exclusive of certain items to be borne separately by each Government within its own territory, such as costs of lands, construction camps, relocation of towns, highways and utilities, and for access roads, administration, superintendence and engineering. The estimated cost of the dam without power plants is $33,407,000, prorated between the two countries in the proportion of the conservation storage capacity allocated to each, that is, 58.6 percent to the United States and 41.4 percent to Mexico. The additional cost of the power plants is $12,658,000 to be borne equally by the two countries. The bases for division of costs of construction, as well as of joint operation and maintenance of the international storage dams and power plants, are established by the Water Treaty.

The Commission has however, no jurisdiction over the distribution within either country of its share of the waters as allocated by the Treaty. The responsibility of the Commission in this respect is that the water shall be divided in the manner provided by the Treaty.

Studies and investigations carried on by the Commission had established the bases upon which the provisions of the Water Treaty relating to equitable distribution of waters of the Rio Grande below Fort Quitman were negotiated, and had established in a general way the requirements for and feasibility of the conservation works provided for in the Treaty. Subsequent to the signing of the Treaty the two Sections of the Commission have carried on intensified studies to determine definitely the conservation requirements under the formulas established by the Treaty and the requirements for flood control and silt detention, and to complete the necessary technical data for the planning of the works. Because of the urgency of the lowermost international storage dam, the Commission's efforts during the first years after the Treaty became effective were largely concentrated on developing plans for the construction of that dam.

In the development of plans for Falcon Dam and Power Plants both Sections of the Commission have consulted freely with the interested agencies of their respective Governments, particularly with the Bureau of Reclamation and the Corps of Engineers of the United States, and the Ministry of Hydraulic Resources of Mexico, as well as with some of the outstanding engineering consultants of both countries. The Bureau of Reclamation is performing the design work on behalf of and under the supervision of the two Sections.

Plans for the dam and power plants were formally adopted by the Commission and submitted for the final approval of the two Governments in Minute No. 192 of the meeting of the two Commissioners in Ciudad Juarez on September 7, 1949.

The dam is of rolled earth fill construction with a total axial length of 26,294 feet, of which 10,133 feet is in the United States and 16,161 feet in Mexico. The crest of the dam, at elevation 323.0 feet is 35 feet wide and the maximum height, above present river bottom, is about 150 feet. The upstream slope is 3 to 1 with a 20-foot berm in the river section at elevation 225, and thence a 4 to 1 slope to the original surface. The downstream slope is 2 to 1 to elevation 250 and thence 4 to 1 to elevation 190 where the slope breaks to 2 to 1 to the original ground surface. In the maximum section the distance between the upstream and downstream toes of the dam is approximately 1,000 feet.

An oil-surfaced roadway and sidewalk will be constructed along the entire length of the dam and a beam-type guardrail will be installed along both edges of the crest for protection of traffic.

The spillway is located through the left abutment about 1,400 feet from the left bank of the river. It is a reinforced concrete structure of conventional design controlled by six 50- by 50-foot fixed wheel gates. The gate sills are at elevation 256.7 feet. The maximum design capacity of the spillway is 456,000 second-feet when the reservoir water surface elevation is at 314.2 feet. The flood storage capacity in the reservoir is

sufficient to limit the discharge of all floods which have occurred during the past 50 years to a maximum discharge through the spillway of 60,000 second-feet, and the additional capacity provided in the spillway could pass a "super flood" nearly three times larger than has ever occurred during the period in which records are available, without causing failure of the dam.

Separate outlet works are provided for each country. The United States outlet works consist of a concrete gravity dam section adjacent to the spillway in which are embedded four 13-foot penstocks through which water is admitted to the turbines or by-passed to the river channel below. The upper end of the penstocks is protected by a trashrack structure and admittance of water to the penstocks is controlled by fixed-wheel type gates. At the lower end water passing through the penstocks is admitted to the turbines through 84-inch balanced valves or by-passed to the river. The required capacity of the outlet works of 4,500 second-feet at reservoir water surface elevation 248 feet is obtained by water passing through two of the power turbines combined with the water passing through the by-pass line.

The Mexican outlet works consist of a 22-foot diameter penstock whose upper end is located in a conventional-type tower structure. Water is admitted to this penstock through a single fixed-wheel gate. At the lower end the single penstock terminates in manifold sections with the water passing first through 168-inch butterfly valves to the turbines and secondly through 108-inch butterfly values to the by-pass line to the river. The outlet works are designed to provide a capacity of 3,531 second-feet at reservoir water surface elevation 255.9 feet and 6,357 second-feet at water surface elevation 265.7 feet. These discharges are obtained by a combination of discharges passing through two turbines combined with the discharge of the outlet valves.

Additional outlet capacity for either country is provided for in the spillway.

The power plants, one on each side of the river, are near the downstream toe of the dam and are identical in size, space, generating and service equipment, facilities for servicing, and ease of operation. Each will contain initially three vertical-shift, single-runner, Francis-type turbines, each of which will develop 14,750 horsepower at a rated head of 100 feet and a speed of 163.6 revolutions per minute, and three 3-phase, 60-cycle, vertical waterwheel generators rated on 10,500 KW, 6,900 volts. Provision is made for the possible later installation of a fourth unit in each plant. While each plant has a centralized control room and separate and independent facilities, the two will be inter-connected for transfer of electric energy from one to the other.

It is estimated that the Falcon Power Plants will generate annually about 200,000,000 kilowatt hours of prime energy and 50,000,000 kilowatt hours of secondary energy. Under the Water Treaty this energy will be divided equally between the two countries, as is the cost of construction of the plants.

Estimated major construction items for the dam and power plants include 29,415,00 cubic yards of earthwork, 296,550 cubic yards of concrete, more than 10 miles each of tile drains, drill and grout holes, and road guardrails, 15,000 tons of reinforcing steel, and 7,500 tons of gates, valves, penstocks and other metal works.

Joint construction of Falcon Dam and Power Plants and division of construction costs between the two Governments in accordance with the provisions of the Water Treaty are being accomplished through an agreed-upon allocation to the two Sections of the Commission of the various items of materials, equipment and construction work. This allocation was made on the basis of the estimated costs of the various items and in proportions determined in accordance with the Treaty provisions. Schedule No. 1 consists of the items allocated to the United States and Schedule No. 2 consists of those allocated to Mexico. Construction work under each schedule is being performed by contract awarded in accordance with the laws of the respective country. The lowest bidder for the Schedule No. 1 work was the joint venture operating as Falcon Dam Constructors, and for Schedule No. 2, the same joint venture operating as Constructora Intercontinental, S. A. Contracts were awarded in November 1950, the contractors were organized to begin work by January 2, 1951, and actual construction began a week later. The work under both schedules is being performed under the supervision of the joint Commission, exercised through the respective Sections.

On November 1, 1951, over two and three-quarter million cubic yards of excavation had been completed on Schedule No. 1 and over fifty-three thousand cubic yards of concrete placed, which together with embankment placing and other work showed a completion of this Schedule of 38 percent. On Schedule No. 2 the work in Mexico showed on the same date over three million seven hundred thousand cubic meters had been excavated and over two million three hundred thousand cubic meters of embankment placed. Almost three million pounds of reinforcing steel had been used on the project by the same date.

Elsewhere on the Rio Grande, I can report that investigations are nearing completion regarding the location of the uppermost storage dam in the Big Bend region. Aerial mapping and field surveys have covered approximately fifteen possible dam sites over a distance of about 340 river miles. Geologic studies have been made of these areas and test drilling performed in selected locations to investigate, within broad reaches, the general character and relative permeability of formations underlying and adjoining the rims of prospective reservoir sites. Hydrologic studies have been made to determine losses and gains in the river's flow in reaches under consideration. A number of additional gaging stations are being operated to obtain the required data. Evaporation and sedimentation studies are being conducted in the areas under investigation. A final report and recommendations as to the location of the upper dam or dams, covering all phases of the investigations, are expected at an early date.

A flood control diversion dam for the lower Rio Grande has been long under consideration by the two Governments. At the time of the record flood of 1932, the Commission was actively engaged in developing

plans for levees on both sides of the Rio Grande to form a river floodway as well as for the development of shorter inland channels for carrying excess flows to the Gulf. This latter course was necessary because of the limited capacity of the river channel at Brownsville-Matamoros. In addition to these floodways a means was proposed of providing for a division of floodwaters in excess of the river's capacity through the floodways themselves and a diversion dam was proposed. However, deferment of the construction of the diversion dam was asked by Mexico pending an agreement covering the equitable division of the waters between the two countries. The Water Treaty constitutes that agreement.

The Commission, by Minute No. 196, dated December 18, 1950, recommended the construction of a diversion dam to be located at the Anzalduas site, with the costs to be divided equally between the two countries. Estimates have been prepared and details of the gate structure surmounting the dam are being studied by technical advisers of both countries. At the present time Congress has not appropriated the funds for the United States portion of the work.

The development of the Lower Rio Grande under the Water Treaty includes all those basic elements of storage and river control that are necessary to conserve and put the available river flow to useful and beneficial purposes. I want to repeat that those features of conservation such as the Falcon Storage Dam and the two upper dams provided by the Treaty and now under joint investigation are of necessity international. Under the provisions of the Treaty the distribution of the stored water is prorated on about a fifty-fifty basis and in estimated quantities based on past records of flow approximately one million acre-feet of water is to be available to each country from the Falcon Reservoir. With upper storage works completed, some increase in this amount is contemplated.

Other works in both countries along the Rio Grande between Fort Quitman, Texas, and the Gulf of Mexico are of course included in the over-all development, such as levees along the river, floodways and grade-control structures, and works for the canalization, rectification and artificial channeling of certain reaches of the river.

The Water Treaty provides that the Commission shall keep a record of the waters belonging to each country and those that may be available to each at a given moment. However, the internal distribution of the waters of either country is not within the jurisdiction of the Commission or of the respective Sections. The distribution of the United States share is governed by the laws of Texas. It is therefore apparent that in order to assure maximum usefulness of the water supply that will be provided by the international works, steps must be taken to assure an equitable distribution among the qualified water users and to provide such additional distribution facilities as may be necessary.

Salt and Boron Survey of Citrus Groves in the Lower Rio Grande Valley of Texas 1950

E. M. Kroth, J. R. Eccles and Stanley B. Crockett[1]

Members of the U. S. Bureau of Reclamation, U. S. Geological Survey, and local agricultural agencies suspected late in 1947 that boron existed in toxic concentrations in the shallow ground waters of the Lower Rio Grande Valley of Texas.

A committee was appointed in October 1948 by the Director of the Texas Agricultural Experiment Station to make plans for a salinity and boron survey of the citrus soils of the Lower Rio Grande Valley. Help was asked from, and given by the U. S. Regional Salinity and Rubidoux Laboratories, Riverside, California. L. V. Wilcox of the Salinity Laboratory, with the assistance of the local committee, inspected the citrus plantings of the area in December 1948 and decided upon a course of investigation.

PROCEDURE

Poor tree condition appeared to be associated with a water table close to the soil surface, but was not limited to soil types or irrigation district boundaries. Consequently, selections of paired sites were made in groves of White Marsh grapefruit on sour orange rootstock. The only important known variable between members of a pair was the depth to the water table. The high water table member had water 3 to 4 feet from the soil surface for prolonged periods of the year, while the low water table site had water below 8 to 10 feet most of the time. A site usually consisted of five test trees in a row; the test trees being separated by five other trees, thus permitting the sampling of a fairly large sized area of land for each site. Ten paired and three single low water table sites were chosen for the study. The soils of the sites were classified by personnel of the U. S. Division of Soil Survey* All trees were classified as to apparent health, vigor and productiveness, and were rated as excellent, good, fair, poor and very poor.

Leaf samples of about 250 representative mature leaves two or three growth cycles back from the growing tip or leaves behind mature fruits were collected, composited, dried at 70° C and ground in a Wiley mill. Soil samples were taken at the drip zone and at the southwest side of each test tree with a two-inch auger. Two depths, 0-6" and 6-36", were sampled; the soil from each depth of all five locations in a site being carefully mixed to form a composite sample. Samples of irrigation water were taken where possible, and ground water wells were dug at some sites from which water was taken for analysis. Depth to water table was recorded in these wells at the time of sampling.

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*E. H. Templin and Harvey Oakes, Soil Survey Section Department of Agronomy, Texas Agricultural Experiment Station and United States Department of Agriculture.

Mr. Wilcox supervised the sampling in December 1948 and the samples were sent to the Salinity Laboratory at Riverside, California for analysis.

All samples were analyzed by methods used in the Salinity Laboratory by Wilcox and Hatcher (1947). Sodium, boron, and chloride in the leaves were determined; sodium, chloride, boron and electrical conductivity were determined on the soil saturation extracts; and pH measurements were made on the saturated pastes of the soil samples. Determination for boron, sodium, chloride and electrical conductivity were made on the water samples.

An unpublished report of these analyses was made to the local committee by the director of the Salinity Laboratory, H. E. Hayward (1949). The report included a recommendation for making the same analytical determinations on samples taken at later dates in order to remove effects due to seasonal variability. Consequently, plans were made in 1950 to resample, over a period of years, all sites in existence (a few orchards on survey sites had been pulled out for various reasons). The original conditions were to be repeated and the same analytical methods were to be used where possible.

Soil samples were taken in August and December, 1950; leaf samples were collected in August, 1950*. The defoliation caused by the freeze on December 7, 1950 prevented the collection of leaves at that time. Additional leaf sampling was made impossible by the freeze of January 31-February 6, 1951 which killed or severely damaged the test trees. This report is made on the results of analysis of the samples collected in August and December of 1950. Since these results closely agree with the 1948 studies, publishing of a combined report containing both sets of data is contemplated.

The methods used for analysis of the 1950 samples were the same as those used for the 1948 samples except that boron was determined by the carmine method of Hatcher and Wilcox (1950). Sodium and pH determinations were not made on any samples taken in 1950. Laboratory techniques were tested by use of portions of the 1948 samples which had been stored at Weslaco.

RESULTS

The 0"-6" soil samples were considered to be more affected by local climatic and management conditions than the 6"-36" samples so the data from the 0"-6" samples are not included in this report.

Five of the sites had been irrigated in 1948 or a few years previous to that date with drainage water or a mixture of drainage water and river water. These waters contained from 1.0 to 3.8 p.p.m. boron and from 411 to 1067 p.p.m. chloride. Since these waters were of different quality

*Valuable assistance in this sampling was given by N. P. Maxwell, Assistant Horticulturist, Texas A&M Substation 15, Weslaco, Texas.

than those used on the other sites, data from these five sites were compared with those from the 18 sites which received Rio Grande water regardless of water table. Results of this comparison are given in table 2.

The data from the 18 sites which received water from the Rio Grande river only were compared on a water table basis. The condition of trees ranged from excellent to fair on the low water table sites and from poor to very poor on the high water table sites. Significantly greater quantities of chloride were found in the leaves and soil of the sites with a high water table (table 1). Electrical conductivity of the saturation extract was also significantly greater on the high water table sites. The boron content of the leaves or saturation extracts of the soils did not vary with the position of the water table. Boron and chlorides in the ground waters showed no change with depth to the ground water. No significant correlation was found between the chloride and boron contents of leaves and soil extracts on the 18 sites.

When the data from all 23 sites were arranged and analyzed on the basis of quality of water, no significant differences were found in the chloride content of the leaves and soil extracts nor in the conductivity of the soil extracts. However, highly significant differences were found in the boron content of the leaves and the saturation extracts of the soil samples. These differences occurred regardless of whether the samples were from high or low water table sites (table 2). There were no significant differences in the boron and chloride contents of the ground waters.

Table 1. Effect of height of water table on the chloride and boron content of grapefruit leaves, soil saturation extracts, and ground water, and the electrical conductivity of the soil saturation extracts of 18 orchard sites irrigated with Rio Grande water.

Treatment and Statistical Significance	*Electrical Conductivity Saturation Extract (millimhos/cm)*	*Chloride*			*Boron*		
		Leaves %	*Saturation Extract (E.P.M.)*	*Ground Water (E.P.M.)*	*Leaves (p.p.m.)*	*Saturation Extract (p.p.m.)*	*Ground Water (p.p.m.)*
High Water Table (mean of 8 sites)	4.8[1]	.64	20.07[2]	23.43[2]	142	.64	2.16
Low Water Table (mean of 10 sites)	2.29[1]	.27	7.05[2]	20.55[2]	137	.49	9.74
Significance of mean differences	••	•	••	None	None	None	None

1. To change millimhos/cm to parts per million multiply by 700 (approximate)
2. To change E.P.M. to parts per million multiply by 35.5.
* Indicates significant difference (odds of 19:1).
** Indicates highly significant difference (odds of 99:1).

DISCUSSION

Effect of Water Table on Salt Accumulation: The chloride content and electrical conductivity of the saturation extracts of the soil samples from the high water table sites significantly increased over that of the low

water table sites (table 1). However, the total soluble salts in the high water table sites as indicated by the conductivity of 4.8 millimhos is not excessive according to Richards et al. (1947).

The increase in chloride content of the soils of the high water table sites is reflected in the chloride content of the leaves taken from these sites. The average chloride content of the leaves increased from .27% on the low water table sites to .65% on the high water table sites. However, this increase in chloride was probably not entirely responsible for the poor condition of the trees on the high water table sites. The work of Cooper and Gorton (1951), Cooper et al. (1951) and Cooper, Gorton and Olson (1951) has shown that grapefruit leaves from trees on sour orange rootstock and growing in soil with a low water table would accumulate from 1.5% to 2.5% chlorides when irrigated with water carrying 4000 p.p.m. soluble salt. These leaves showed salt injury when the chloride content was about 1% of the total dry weight.

Since the total salinity of the soil of the high water table sites and the chloride content of the leaves from these sites are below the limits suggested by Richards and Cooper it is inferred that part of the poor tree condition on the high water table sites is due to suffocation of the deeper roots. The poor tree condition on the high water table sites was undoubtedly due to a combination of reduced root system and chloride toxicity. Improved soil drainage would probably reduce the injury from both causes.

Effect of Water Table on Boron Accumulation: The boron concentrations in the saturation extracts of the soil from high water table sites were not significantly different than those from low water table sites (table 1). Hayward (1949) has indicated that the boron concentration of

Table 2. Effect of quality of irrigation water on chloride and boron content of grapefruit leaves, soil saturation extracts, and ground waters, and the electrical conductivity of the soil saturation extracts of 23 orchard sites without regard to height of water table.

Treatment and Statistical Significance	*Electrical Conductivity Saturation Extract (millimhos/cm)*	*Chloride*			*Boron*		
		Leaves %	*Saturation Extract (E.P.M.)*	*Ground Water (E.P.M.)*	*Leaves (p.p.m.)*	*Saturation Extract (p.p.m.)*	*Ground Water (p.p.m.)*
Drainage Water (mean of 5 sites)	3.45[1]	.51	13.28[2]	30.30[2]	426	1.03	1.84
Rio Grande Water (mean of 18 sites)	3.34[1]	.43	12.51[2]	22.37[2]	139	.56	4.91
Significance of mean differences	None	None	None	None	••	••	None

1. To change millimhos/cm to parts per million multiply by 700 (approximate)
2. To change E.P.M. to parts per million multiply by 35.5.
** Indicates highly significant difference (odds of 99:1).

the soil saturation extract for grapefruit trees should be less than 1.0 p.p.m.; this concentration produced easily recognizable injury on orange trees, and grapefruit are probably more sensitive to boron than oranges. No individual values were above 1. p.p.m. in the soil extracts from the low water table sites and in only two cases were the values greater than this in the extracts from the high water table sites.

Wilcox (1948) reported that normal grapefruit leaves contain from 50 to 100 p.p.m. boron; boron injury was indicated when the value was above 300 p.p.m. In this present study where both high and low water table sites received Rio Grande water the mean value for boron in the leaves was 142 p.p.m. on the high water table sites. This value was not significantly different from 137 p.p.m. boron of the low water table sites (table 1). These values were not high enough to indicate boron injury on either the high or low water table sites. It seems probable that boron toxicity was not an important factor in causing the poor condition of the trees on the high water table sites.

Effect of Quality of Irrigation Water: A comparison of the data from all 23 sites on a water quality basis showed that the only significant differences were in the boron content of the leaves and the soil saturation extracts. A mean value of 426 p.p.m. boron in the leaves occurred on sites irrigated with drainage ditch water. The mean value for the saturation extracts was 1.03 (table 2). Both were high enough in indicate injury due to boron.

The mean boron values for the leaves and soil extracts from sites receiving Rio Grande water was 139 p.p.m. and .56 p.p.m., respectively. These low values do not indicate boron injury. None of the boron values for leaves from the sites receiving Rio Grande water was above 250 p.p.m. The indications are that where good irrigation water was used, there was no boron problem.

Normally, high chlorides in leaves and soil extracts would be found where irrigation water high in soluble salts was used. However, two or more years had passed since this type of water had been used in the five sites under study. Apparently rains and good irrigation water had flushed out the injurious quantity of salts so that significant differences in chloride content of leaves and soils no longer existed.

Chemical Composition of Ground Waters: This study showed there was no significant difference between the boron and chloride contents of shallow ground waters from high and low water table sites or from those receiving low quality irrigation water (tables 1 and 2). The number of of samples taken may have been too small to reveal actual significant differences. However, there is research evidence, and the experience of some Valley citrus growers has demonstrated, that ground water, when it has collected in drainage ditches, is unfit for irrigating citrus. The lowest mean value for chloride in ground water was 20.55 E.P.M., equivalent to 730 p.p.m. chloride. McGeorge (1940) reported that water carrying more than 290 p.p.m. chloride is poor water for irrigation purposes.

The lowest mean value for boron in ground water was 1.84 p.p.m. Wilcox (1948) reported that concentrations above 1 p.p.m. boron in irrigation water would be injurious to citrus.

CONCLUSIONS

Boron is a problem in Valley citrus production only when it occurs in irrigation water in excess of about 1.0 p.p.m. Height of water table is not a vital factor as far as boron is concerned.

Practically all shallow ground water in the Valley contains boron and chloride in such quantities as to make drainage ditch water unfit for irrigating citrus.

High water table causes the accumulation of soluble salts, including chlorides.

Chloride content of leaves will reflect the chloride content of the soil on which the trees are growing. Leaves from trees on high water table land will have a higher chloride content than leaves from trees growing on well drained, properly irrigated soils.

Good soil drainage, good quality of irrigation water, and good irrigation management are the keys to most of the salt and boron problems of Valley citrus production.

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Some Factors Relating to the Marketing of Commercial Vegetables

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The modern fresh vegetable industry took definite commercial form immediately after the end of World War I. This was due to two steps which happened almost simultaneously. These were the development of new areas in Texas, Florida, Arizona and Southern California suited to the production of winter and early spring vegetables and the extension of railroad service to those areas through expansion of refrigerator car service. These developments enabled housewives to obtain most fresh vegetables at all seasons of the year.

ACREAGE

The rapid growth of truck crop production is best indicated by the following acreage totals in the United States for the census years named: 521,850 acres in 1919; 1,381,710 acres in 1929; 1,769,940 acres in 1939; and 1,786,660 acres in 1949. The peak of truck crop acreage, which does not include white or sweet potatoes, was reached in 1946, when 2,047,490 acres were planted. This acreage produced 9,064,900 tons of truck crops, a volume which was marketed at very unsatisfactory prices to growers. As a result acreage was reduced in subsequent years until 1950 when 1,819,710 acres were planted. This production again was above the capacity the market could absorb at satisfactory returns to producers. As a result acreage declined 9 percent in 1951 to 1,663,230 acres, with some improvement in prices to producers.

Thus the truck crop acreage of 1919 has multiplied nearly four times in three decades. However, since 1946, when the post-war peak was reached, acreage has been fairly uniform and has ranged from 1,663,230 to 1,842,760 acres.

While truck crops might well be defined as "commercial vegetables for fresh market sale," the statistics for truck crops do not include certain acreages used for market garden production in areas close to consuming centers. Accurate figures of this type of production are not available from all parts of the country and so have not been included.

White and sweet potatoes have not been included in the truck crop figures, except in the case of early commercial white potatoes. Because of a different trend in the case of these crops, it will be necessary to discuss them separately.

TRENDS

Requirements for white potatoes have steadily declined for many years. The final estimate for 1951 was 325 million bushels which was 10 million bushels less than the USDA goal for that year and 104 million bushels less than the crop of 1950. The acreage in 1950 was 1,696,400, which was reduced to 1,353,100 acres in 1951, the lowest level since 1867.

This reflected a decline of nearly 60 percent since 1943, the wartime peak year. Production was maintained by a rapid rise in per-acre yields which began in 1945 with 155 bushels and increased in 5 seasons by about 63 percent to 253 bushels per acre in 1950 and to 241 bushels in 1951, the two highest yields on record.

Somewhat the same trend was true in the case of sweet potatoes. The production in 1951 was estimated at 28,278,000 bushels, 43 percent below 1950, and 54 percent below the 1940-49 average. The 1951 crop was the smallest since 1881. Acreage harvested during the past year was 37 percent below 1950 and only one-third of the record high acreage harvested in 1932.

Before considering individual vegetables grown for fresh market, it would seem desirable to compare them with the volume of vegetables grown for processing, because these two groups are competitive. Processed vegetables are in two major classes, depending upon whether heat or quick freezing is the method of preservation.

The acreage grown for processing did not exceed that for fresh market until 1942 when the tremendous expansion for World War II maintained the acreage at about 2 million acres through 1946. After that year it declined to about 1,700,000 acres. This level prevailed until 1951, when 1,880,500 acres were planted to furnish increased supplies for defense purposes.

FARM PRICES

We cannot attribute low farm prices to lack of consumer purchasing power, because factory payrolls have been at the highest level in all history in 1951. The best index of such income is that by Cornell University, which is computed on a base of 1910-14, making it comparable to USDA farm prices. Thus while factory payrolls have varied from an index of 550 to 560 through August, 1951, average farm prices indexes for 1951 were 264 for all crops and 302 for all farm products. The farm price index of fresh vegetables for the same period was 239, while that of "other vegetables" (white and sweet potatoes and dried beans), was 192. Fruits as a whole were 193, indicating that the same general conditions affect that portion of the industry. Poultry and its products, with an index of 226, was the only other group with a similar price level. These commodities include those which received the lowest farm prices during 1951.

Comparable farm price indexes for other products were meat animals 411, livestock and its products 335, cotton 335, food grains 243, feed grains 237 and dairy products 284.

Thus it seems clear that farm prices must be increased if they are to offer an incentive for the production of fruits and vegetables as compared with other products which now yield a more attractive net return to the producer. This might be achieved through higher selling prices, reduced distribution expenses, or lowered production costs. However, as much of the cost of these products is due to the large amount of hand labor involved, it will be difficult to adjust costs except as the wages of labor decline or the need for it is lessened through mechanization to a degree which does not appear feasible at this time.

PER CAPITA CONSUMPTION

Per capita consumption has shown a steady increase during each five year period throughout the past three decades. While melons showed only a relatively small increase of 15 percent, the use of other fresh vegetables was even greater and amounted to over 25 percent. Consumption of canned vegetables has doubled.

For the period 1945-49 the average per capita consumption of fresh vegetables was 260 pounds, of canned vegetables was 40.9 pounds (processed weight) and of frozen vegetables, 2.5 pounds(processed weight). The consumption of white potatoes has declined to 104 pounds in 1951 or about one-fifth from 1920-24 to 1945-49. During the same period sweet potato consumption declined one-third to about 16 pounds.

Per capita consumption of fresh tomatoes increased from 26.2 pounds in 1920-24 to 31.8 pounds in the 1945-49 period while consumption of carrots almost doubled in the same period from 7.1 pounds to 13 pounds. The use of fresh cabbage expanded from 36.5 pounds in 1920-24 to 39.3 pounds in 1945-49, while lettuce consumption increased one-half to 15.4 pounds. Per capita consumption of commercial onions for fresh market averaged 10.9 pounds during the 1938-47 period, with the latest year available, 1947, being 12 pounds.

Directly related to fresh vegetables are fresh and canned citrus fruits. Consumption of fresh oranges and grapefruit has almost doubled in the past 30 years while canned citrus segments and juice have also shown decided increases. These citrus products, especially juices, are directly competitive with certain fresh vegetables, as they provide the same nutritional benefits.

TEXAS PRODUCTION

The size and importance of the Texas fresh vegetable industry are indicated by the 225,800 acres harvested in 1951, or 14 percent of the total U. S. acreage. Texas ranked third as only California and Florida harvested larger acreages. The Texas acreage produced 510,500 tons valued at $35,257,000. While Texas has only one seventh of the total U. S. truck crop acreage, it is well to remember that the marketing takes place in the winter and early spring seasons when other areas are not shipping.

DISTRIBUTION MARGIN

In 1948 the California Farm Bureau Federation became concerned by consumer complaints concerning retail prices of perishable farm commodities grown and consumed within that state. Accordingly a research study was planned with BAE and the University of California, and results have become available within recent months. These include separate reports

on fresh tomatoes, asparagus, celery and seedless grapes during the season of 1948 and 1949. These analyses present a factual viewpoint with regard to perishable products consumed in close proximity to point of production.

Tomatoes: In the publication (Fisher, 1951) on fresh tomatoes some of the findings are as follows:

"Losses due to waste and spoilage are appreciable – comprising about 12 percent of the physical quantities or 4 pounds to a 32 pound lug box."

"The retail margin is an important element in the total spread from producer to consumer. Even if physical losses due to waste and spoilage are not included, the retail margin is more than 42 percent of the total marketing margin. . . . In conclusion it may be stated that there seem to be large and unexplained variations in retail margins. There may be good reasons for this variation that have not been brought to light in this study and offer a fertile field for further investigation."

During this period, the average retail price paid by consumers was found to 11.2 cents per pound, of which the farm price was only 29 percent, or 3.2 cents per pound. This indicates a marketing margin of about 6.3 cents per pound with the small transportation cost and wastage eliminated (table 1).

Asparagus: Another commodity studied in the same series was fresh asparagus (Foytik, 1951). "The average retail price paid by the consumer was 19.5 cents per pound. Of this amount one-quarter of the consumer's dollar was accounted for by the retailer's margin – to reimburse the retailer's expense and to compensate for spoilage occurring within the distributive channel. Another one-quarter covered all other distributive charges incurred in packing, transporting and wholesaling. Almost half of the retail price was returned to growers to cover their production and harvesting costs." Of 32.3 pounds in the average crate, only 4 pounds were reported as unmerchantable at retail because of spoilage loss. Additional data are shown in table 1.

Celery: "California consumers paid an average price of 19.0 cents *per stalk* for celery purchases at retail during the survey period. Approxi-

Table 1. The distribution of the consumer's dollar in 4 California crops.

Where the Consumer Dollar Goes	*Tomatoes per pound*	*Asparagus per pound*	*Grapes per pound*	*Celery per stalk*
Retail price	11.2c	19.5c	10.6c	19.0c
Wastage	1.3c	.3c	1.0c	1.0c
Realized return	9.9c	19.2c	9.6c	18.0c
Retail margin	4.2c	5.3c	3.2c	6.6c
Wholesale Margin	.7c	1.7c	.9c	2.7c
Transportation	.4c	.5c	.7c	1.1c
Packing	1.4c	2.8c	1.4c	1.6c
Total Margin for distribution	6.7c	10.3c	6.2c	12.0c
Total Margin less transportation	6.3c	9.8c	5.5c	10.9c
Returns to Producer	3.2c	8.9c	3.4c	6.0c
Percent of Consumer's Dollar to Producer	29%	46%	32%	32%

mately one-third of the consumer's dollar was accounted for by the retailer's margin. Another third covered all other distributive charges incurred in packing, transporting, and wholesaling. The final third was returned to growers to cover their production and harvesting costs." Loss of celery by spoilage was found to be 5.2 percent (Foytik, 1951). Additional data are shown in table 1.

Seedless grapes: "California consumers paid an average price of 10.6 cents per pound for seedless grapes. Approximately one-third of the consumer's dollar was accounted for by the retailer's margin. Another third covered all other distributive charges incurred in packing, transporting, and wholesaling. The final third was returned to growers to cover their production and harvesting costs." (Foytik, 1951). Spoilage was 2.5 pounds per lug or 9.3 percent of the quantity in the original lug, which is quite similar to that in the case of tomatoes. Additional data are shown in table 1.

While the figures in table 1 cannot be considered final, they indicate the size of the total margin which these California commodities bear between farm and consumer, even when transportation is only a small factor.

Early potatoes: A study of "Farm to Retail Margins for Marketing Southeastern Early White Potatoes in Philadelphia, New York, Chicago and Cincinnati in 1949" (Garrott, 1950) should be somewhat comparable to the margins of the same crop grown in Texas. The producing areas studied were Dade County and the Hastings area of Florida, Baldwin and Escambia Counties in Alabama, the Charleston area of South Carolina, the Aurora and Elizabeth City areas of North Carolina, and the Eastern Shore area in Virginia. Data are shown in table 2.

"Average marketing charges were 4.8 cents per pound for the 66 test shipments from 7 southeastern producing areas (from Dade County, Florida to the Eastern Shore of Virginia). The average marketing charge would be more than 5 cents per pound if the shrinkage, waste and spoilage, of approximately 10 percent were taken into consideration. The retail price for these shipments average 7.5 cents per pound of which the grower received 36 percent, or 2.7 cents, and the marketing agencies 64 percent"—or 4.8 cents per pound, of which transportation was about 1 cent and retailing 2.35 cents per pound.

Table 2. The weighted average marketing charges for the 66 southeastern potato shipments.

Weighted Average Marketing Charges for 66 Southeastern Potato Shipments	*Cents per Pound*	*Percent*
Retail price	7.51c	100%
Retailing	2.35c	31.3%
Wholesaling	.48c	6.4%
Transportation	1.04c	13.8%
Shipping point service	.95c	12.6%
Total Marketing Margins	4.82c	64.1%
Total Marketing Margins less transportation	3.78c	50.3%
Growers' returns	2.69c	35.9%

"The return to growers in the areas covered in this study varied from $1.01 per cwt. for potatoes shipped from the Elizabeth City area of North Carolina to New York City to an average of $3.01 per cwt. for those shipped from the Hastings area of Florida to Philadelphia. The cost of marketing services between the farm and the retail sale varied considerably from area to area, and accounted for a large part of the variation in the grower's return."

"The most variation in specified margins for these test shipments was found in the retail margin. Potatoes from Dade County marketed in New York City had the highest average retail margin, $5 per cwt., while this charge for potatoes from Virginia marketed in Philadelphia averaged only 86 cents per cwt. With the exception of the lots followed from these two areas to New York and Philadelphia, representing the high and low of the retail margins, the charge for this service varied only slightly."

It is evident that the average margin for marketing early potatoes, without transportation of 1.04 cents per pound, was 3.78 cents per pound, almost one and one-half times the price received by the producer for growing the crop. However, this margin is much less than the margins which prevailed for the more perishable commodities in California, with transportation charges omitted.

CONCLUSIONS

The commercial vegetable industry expanded rapidly from 1920 to about 1940, especially in the areas producing for the late fall, winter and spring markets. Since that time acreage has held quite uniform and in 1951 was slightly less than it was in 1939.

During the post war period the high peaks in acreage and production were in 1946 and 1950. In each year production was greater than the market would absorb except at such low prices to growers that acreage declined the next season.

The reverse trend has been true of white and sweet potatoes. The large increase in per acre yield, combined with decreased consumption, has resulted in the 1951 acreage of white potatoes, the smallest in 85 years, producing a crop approximately equal to requirements. The 1951 sweet potato crop was the smallest since 1881 and was less than half of the average from 1940-49.

There has been wide variation in the per capita consumption of vegetables since 1920. The consumption of canned vegetables has doubled and the quick frozen industry has become important only in recent years. The per capita consumption of fresh vegetables has increased over one-fourth, while that of melons is 15 percent greater. During the same period white potato consumption decreased about one-fifth and that of sweet potatoes about one-third. Texas is fortunate that the use of carrots has doubled and that substantial increases have occurred in fresh tomatoes, cabbage, commercial onions, and lettuce.

Farm prices received for fresh vegetables have been among the lowest of any group of crops during recent seasons. The truck crop farm price index for 1951 average 239 and for other vegetables 192, as compared with 264 for all crops and 302 for all farm products. The 1951 fresh vegetable acreage was reduced by 9 percent because of the very unsatisfactory returns in 1950. A higher income for growers might be achieved through higher selling prices, reduced distribution expense or lowered production costs.

Higher market prices might be secured by reduced production and marketing whenever present volumes prove excessive, by better varieties, grading and packaging, and by more aggressive merchandising. The marketing of produce at prices which will not pay the cost of marketing should be stopped. Such sales result in a direct loss to the producer and also have an indirect effect upon the selling price of the whole supply by offering a volume which cannot be sold on a sound economic basis. In these instances producers subsidize consumers and others in the channels of distribution.

Research studies indicate that the margins which prevail from farm to consumer absorb from 60 to 75 percent of the retail price paid by the consumer for fresh vegetables. These margins appear to vary mostly between 4 and 7 to 8 cents per pound. They become a first charge on the proceeds of sales and an obstacle against increased sales volume when needed. While efficient distribution is a necessary expense, substantial economies can and must be made in this field through elimination of unnecessary operations, reduction of preventable wastage, increased volume of business, and as complete modernization of facilities as is possible.

Reduced costs of production must be achieved whenever possible through higher yields of merchantable products per acre, varieties which are more resistant to disease and insect damage, substitution of machine for hand labor whenever feasible, and generally better production methods and practices.

The 1951 vegetable acreage for fresh market sale appears to have been more than sufficient in view of returns received by growers. Any increase above this acreage would be reasonably likely to result in even lower prices to growers, as it did in 1946 and 1950. Any important expansion of vegetable acreage should be considered only for processing purposes and with the assurance of satisfactory prices to producers, through firm contracts with processors.

Whenever feasible, some fresh market vegetable acreage might well be shifted to other crops offering a more attractive and stable price during the coming season.

The entire fresh vegetable and fruit industry must carry out a systematic and aggressive program for the improvement of merchandising practices so as to sell more produce. Growers, shippers, distributors and retailers all have an essential part in such a program.

Areas such as Texas which produce for the early markets usually have high production and distribution costs and hazards. Therefore, they must be prepared to meet serious competition from processed vegetables, especially of the quick frozen type. However, the addition of a processed outlet is usually an advantage to growers, because it creates competition among outlets and lengthens the season during which the product can be marketed.

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