PROCEEDINGS

Of the Fifth Annual

RIO GRANDE VALLEY HORTICULTURAL INSTITUTE

Weslaco, Texas

January 10, 1951

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We particularly wish to express our gratitude to those listed below who assisted in the publishing of these proceedings and the securing of a group of outstanding speakers.

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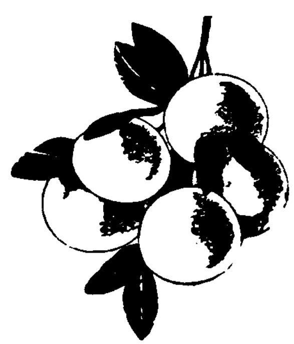
TABLE OF CONTENTS

COVER PICTURE: Valley Winter scene, showing young citrus trees banked with earth for freeze protection.



Program of the Horticultural Institute

CITRUS SESSION

Tuesday Morning, January 10, 9:30 A. M.

D. E. Kornegay, Chairman

President's Address: D. E. Kornegay, President, Rio Grande Valley Horticultural Club.

Tissue Analysis as an Aid in Evaluating the Nutritional Status of Citrus Trees: Walter Reuther, Principal Horticulturist, U. S. D. A., Orlando, Florida.

Nutritional Studies on Citrus at the Texas A. & M. College Substation 15: N. P. Maxwell and E. M. Kroth, Texas Agricultural Experiment Station, Substation No. 15, Weslaco.

Observations on the Citrus Industry of Italy: Guy Adriance, Head, Department of Horticulture, Texas A. & M. College, College Station, Texas.

VEGETABLE SESSION

Tuesday Afternoon, January 10

R. D. Lewis, Chairman

An Agricultural Program for Texas: J. A. White, Commissioner of Agriculture, Austin, Texas.

Market Requirements for Fresh Vegetables: Jim Irby, Produce Buyer for H. E .B. Stores.

Vegetable Breeding in the South: S. H. Yarnell, Principal Geneticist in Charge, U. S. Regional Vegetable Breeding Laboratory, Charleston, S. C.

GENERAL SESSION

Tuesday Evening, January 10

E. H. Poteet, Chairman

Citrus Blackfly Surveys in Mexico (illustrated by movies in color): N. O. Berry, U. S. D. A., Bureau of Entomology and Plant Quarantine, Harlingen, Texas.

Review of all papers in the Proceedings not presented on the Institute program: William C. Cooper, Physiologist, U. S. D. A., Weslaco.

EXHIBITS

Open to the public Tuesday morning, afternoon and night. January 10.

Norman Maxwell, Chairman of the Committee.

President's Address

D. E. Kornegay, *President, Rio Grande Valley Horticultural Club*

It is a pleasure to welcome you to the fifth annual Rio Grande Valley Horticultural Institute. It is our hope that the contents of the Proceedings published this year meet with your approval.

Since 1946 the Rio Grande Valley Horticultural Club has presented an Institute for the benefit of those interested in Valley horticulture. We wish to express our appreciation to Texas A and I College and the Texas A and M Experiment Station for the use of their facilities and also for the assistance of various staff members. The idea of an Institute was conceived by the head of the Texas A and M horticulture department, Dr. Guy Adriance, who called upon the Horticultural Club to conduct the first Institute. Since that time many other Valley groups have also cooperated with the Horticultural Club to make the Institute an annual event. As a matter of community service, many business organizations and individuals in the Valley have supported the Institute by contributing towards the expenses involved.

With the hope of presenting a compact Institute this year, the Planning Committee has confined the Institute to a one-day event. Each speaker to be presented today is considered an authority in his field. Their talks are included in copies of the Proceedings which are now available. Also included in the Proceedings are other horticultural papers of value to those interested in Valley horticulture.

To those of you who have made this Institute possible, may I express the sincere appreciation of the Horticultural Club.

Vegetable Breeding In The South

S. H. Yarnell, *Principal Geneticist in Charge,*
U. S. Regional Vegetable Breeding Laboratory,
Charleston, South Carolina

It is human nature to believe that one's own field of work is one of the most important and has almost unlimited possibilities for solving the problems of the time. To the engineer the gadgets that he invents—radar, airplane, synthetic plastics—are practically synonymous with civilization. The farmer feeds and clothes the world. The manufacturer turns the wheels of commerce, and the clergyman promotes eternal bliss. The plant breeder is no exception to this general rule. His ideal is a variety that grows vigorously under sunny or cloudy skies, produces well on all kinds of soils, is immune from attacks of insects and disease, ships and stores well, and has both eye and taste appeal. If not all of this is accomplished in the variety ready for introduction, it is not for lack of trying.

Fortunately for the grower, the near hit of the plant breeder, while perhaps not fully successful, usually has real value. For example, a variety that is resistant to but not immune from a disease may have distinct advantage over old varieties by requiring no dust or spray treatment when infestation is light; it may require only moderate treatment for good results when the disease is moderate; and it may be the only thing to produce a crop with the best treatment available when there is a serious attack. At the very least, resistance has reduced the cost of control; and at best it can permit a good income where complete failure might have been the result.

While the belief of the plant breeder that many of the growers' problems can be solved or greatly helped through breeding has a sound biological basis, such optimism must be tempered with the knowledge that breeding has two important limitations. These are the genetic or hereditary resources of any particular crop and the amount of time required to secure a particular combination of characters.

The first task of the breeder is to find a source of the character required to solve or alleviate a particular cultural problem. Two types of materials are usually available – the varieties grown commercially and in home gardens, and the related wild species. Most kinds of vegetables have a mixture of hereditary factors, varying in amount according to their natural means of pollination and the amount of attention received from plant breeders. Some varieties are, of course, more uniform than others of the same crop. In times past the wind-pollinated corn varieties were more than a little mixed. With the advent of hybrid corn we have inbreds that are more uniform than varieties of most other vegetables. A crop such as cabbage that is insect-pollinated has varieties that are quite variable in inheritance. Even the normally self-pollinated tomato exhibits a certain amount of variability.

The development of tomato varieties resistant to fusarium wilt affords a good illustration of the opportunities open to the plant breeder. By growing many varieties in a wilt-infested field it was found that they could be placed in three categories according to their degree of resistance. Most varieties, such as John Baer and Bonny Best, were completely susceptible. A few varieties like Duke of York and Livingston Globe had considerable natural resistance; other varieties, as Stone and Greater Baltimore, had some plants with resistance to the disease while many died. The selection of plants that survived on wilt-infested land and the testing of their progeny under similar conditions resulted in the development of new wilt-resistant varieties. Perhaps the first of these was Tennessee Beauty, produced by Essary at the Tennessee Station as far back as 1912. This resulted from a single-plant selection of Beauty. A single-plant selection of Stone made by Norton of the Maryland Station a few years later was developed as a variety in conjunction with Pritchard of the U. S. Department of Agriculture and introduced under the name of Norton in 1922. Two additional varieties of some importance originated in the same way. These are the Louisiana Wilt-Resistant, bred by Edgerton and Mooreland in Louisiana, and the Marvel, selected by Pritchard. Most resistant varieties introduced later were selected from crosses between resistant and susceptible varieties. These include Louisiana Red, Louisiana Pink, Marglobe, Break O'Day, Pritchard and Rutgers.

Within the last decade new sources of resistance have been discovered in two species related to commercial tomatoes. These were found by Bohn and Tucker working at the Missouri Station and by Porte and his associates in the U. S. Department of Agriculture in the small-fruited Currant tomato. While this type of resistance to Fusarium is almost complete the source material has small fruit. This necessitates several generations of back-crossing to the large-fruited type, at the same time carrying along the resistance to disease, to secure acceptable resistant commercial varieties.

The known varieties and related wild species constitute the major source of the many characters of interest to growers and used by breeders as their "stock-in-trade." The trick to breeding is to utilize the available materials in such a way as to get more and more of the characters desired by the grower into a single variety. Basically the job is to find the characters, make the crosses necessary to give the desired combination, make the necessary selections, test to be sure they breed true, and finally propagate and distribute the result. In fulfilling these requirements, the breeder can expect to run into certain kinds of complications.

Stated somewhat differently, the breeder is trying to speed up an evolutionary process that has been going on for millions of years and to direct the trend of change into channels that result in kinds of plants with increased economic value. We all recognize that any living plant or animal represents an enormously complex organism, subject to the vagaries of both heredity and environment. What is not so generally realized is that the numerous complexities involved can often be broken

down into small units that can be readily understood by all. The plant breeder, and this is also true of the grower, is usually not faced by one big, nearly unsolvable problem, but by a complex of a lot of small to medium-sized problems that can usually be licked if grappled with separately.

In making his crosses the plant breeder is interested in certain opposing characters. Let us suppose that he crosses a red-fruited, ie., red fruit fruited tomato. The resulting plants all have red fruit, i.e., red fruit is dominant. But when he grows the second generation, about one-fourth of a large population will have yellow fruit which breed true when self-pollinated. Another fourth, having red fruit, will also breed true when self-pollinated. The remaining plants, which constitute half of the individuals of the second generation, also have red fruit and will be found not to breed true but to behave just like the first-generation plants. Now it is impossible by observation to tell the true-breeding red-fruited plants from those that give one-fourth yellow plants in the next generation, but it is very simple to test them by growing another selfed generation. Better still, these "heterozygous" plants can be identified by crossing them back to the yellow parent, in which case the true-breeding reds produce only red-fruited plants as in the original cross, while the segregating plants give a population half of which have yellow fruit in crosses to the yellow-fruited parent. This illustrates a case of simple Mendelian inheritance.

The plant breeder, of course, has to work with more than one character. Suppose he has a red-fruited disease-resistant variety and a yellow-fruited susceptible variety and wants to get a new yellow-fruited disease-resistant variety. If we assume that disease resistance in this case behaves in inheritance like yellow fruit, the first generation will then consist only of red-fruited susceptible plants. But in the second generation we find again that one-fourth of the plants have yellow fruit. Of these yellow-fruited plants one-fourth will be disease resistant. Considering then the second generation, one-fourth of one-fourth, or one-sixteenth, will exhibit the new desired combination of yellow fruit and disease resistance. Since resistance to disease cannot be determined by inspection as can fruit color, suitable tests for resistance must be made, either in the field or in the greenhouse, by natural infection or by artificial inoculation. This is the sort of thing that the plant breeder does if the characters he works with have a simple Mendelian basis and are inherited independently.

Sometimes the characters are linked in inheritance. If the hereditary factors for fruit color and the disease resistance mentioned are closely linked the breeder might get only red-fruited resistant and yellow-fruited susceptible plants in the second generation instead of the new combination he is looking for. If there is partial linkage fewer than one-sixteenth of the second generation plants will have the new desired combination – perhaps only one out of 50 on the average. This means that the breeder must grow a large enough population to be sure of finding what he is looking for. As a matter of fact, the breeder is often working with several or even many separate characters and large plantings are the rule rather than the exception.

Two other complications might be mentioned to illustrate what the breeder is up against. A number of horticulturally important characters, such as fruit size and yield, depend on several hereditary factors or genes. There are two things the breeder can do to avoid the necessity of growing enormous populations to secure the combinations desired. For one thing, he can sometimes select parents, both of which have about the size, shape, and color of fruit required, which permits him to concentrate on some special problem such as fruit cracking. If this turns out to be impossible, as in the case of the cross to a small-fruited parent, he makes several back-crosses to the commercially desirable parent, making suitable tests to be sure that he carries along the character he is interested in.

Another difficulty that is encountered is the hybrid vigor that is found sometimes even in intervarietal crosses. This affects production, so that by the time the special characters are fixed the breeder finds that some of the high production that looked so good in his selections of the second generation has materially deteriorated. This means that he has to secure a more favorable combination of those hereditary factors affecting production.

It should be obvious that this brief review is not designed to make plant breeders out of commercial growers of vegetable crops. It *is* important for growers to have some understanding of the kinds of problems encountered by vegetable breeders, and to realize that their solution is on the whole complex, expensive, and time-consuming, if this work is to receive the moral and financial support necessary for satisfactory progress.

The rest of the discussion will deal with a brief survey of the vegetable breeding now in progress throughout the South, with special mention of the situation in one of the more important vegetable crops.

The breeding of vegetables is receiving a good deal of attention in the South. The amount of work varies with the importance or potential importance of the various crops in different States. As a matter of convenience it is customary to think of plant breeding as having two broad phases. The first involves the many and diverse activities that result in a new breeding line or selection that promises to become a new variety. The second phase consists of widespread adaptability tests of such material in comparison with standard varieties. This is a critical stage and its importance in the plant breeding program can hardly be over-estimated. Historically, the estimate of varietal materials was one of the first concerns of horticultural research and perhaps for this reason it enlists the aid of many workers who are not primarily concerned with the earlier stages of plant breeding.

There is at present a voluntary cooperative set-up for comparing new varieties and breeding lines with standard sorts for all vegetable crops of importance throughout the South. This is designed to serve the

second phase of vegetable breeding throughout this region as well as to permit the evaluation of new introductions from other regions as traditionally carried on in the individual States. The new system is much superior to the older uncoordinated work since the estimates of the value of new materials are based upon their behavior in comparison with a standard variety under many diverse conditions of growth. For each vegetable crop there is a chairman who assembles seed for each variety or stock to be tested. He sends out identical collections to the cooperators and summarizes the data and opinions at the end of each season. This permits a much more rapid evaluation of new materials than had been previously possible. By this means it is possible to cull out the poorly adapted lines in a single season; and by the end of the fourth year a breeder knows how his best lines compare with the best varieties grown commercially. The Southern Cooperative Vegetable Trials thus enable the breeder to determine which of his lines are likely to succeed; they enable the seed companies to increase the seed of new varieties with confidence; and they enable the growers to make sizable plantings of newly introduced varieties with a prospect of increased profit.

The region served by the U. S. Regional Vegetable Breeding Laboratory at Charleston, S. C., extends from Virginia westward through Kentucky, Arkansas, and Oklahoma to Texas and includes all states south and east. Since growing conditions are somewhat similar, we also cooperate with Hawaii and Puerto Rico. In addition, Maryland has recently joined the Southern Vegetable Cooperative Trials. If we exclude Maryland from the statistics on breeding we find that there are about 115 State and Federal workers active in one or both phases of vegetable breeding, in addition to those working on Irish potatoes and sweetpotatoes. Breeding is in progress with 22 vegetable crops (exclusive of the two kinds of potatoes, with which the Laboratory is not concerned).

Here in Texas W. H. Brittingham at College Station, working with N. P. Maxwell of the Weslaco station, are about ready to introduce Texas 107 green sprouting broccoli, which has led all commercial varieties in earliness and quality, as well as total center-head and side-shoot production. B. A. Perry has secured similar results with this line at the Winter Garden station. Dr. Brittingham is the chairman of the Southern Cooperative Broccoli Trials. He has several promising lines of southern peas (known less euphemistically to many as edible cowpeas). He has combined the high quality of the Cream Crowders with the earliness of the Blackeye in very productive lines. In addition, the plants assume a bush instead of the running habit, with the pods concentrated well above the foliage. His selections of lima beans from crosses between Fordhook 242 and the varieties Jackson Wonder and Green-seeded Henderson set well under adverse conditions and maintain the quality of the Fordhook parent. He has made mass selections from cabbage lines secured from the Vegetable Breeding Laboratory to secure Texas 4702, a productive, round-headed, hardy line with dark-green wrapper leaves.

B. A. Perry and O. H. Calvert at Winter Haven are continuing the work with cantaloupe begun several years ago by S. S. Ivanoff, by incorporating resistance to powdery mildew and improved shipping quality into Texas No. 1. Dr. Perry and his predecessor, L. R. Hawthorn, in cooperation with H. A. Jones of the U. S. Department of Agriculture and W. B. Cook of the Missouri Pacific Railroad, have been improving onions for a number of years. Excel (a yellow Bermuda type) and Texas Early Grano have been introduced. A white selection, L-690, has been released for seed increase. Adaptability, disease resistance, and new hybrid varieties are immediate objectives of this program. Additional co-operative work involving G. S. Pound of the Wisconsin station was begun last year on spinach to secure lines resistant to white rust, downy mildew, and blight.

The work of G. H. Godfrey on downy mildew resistance in the cantaloupe is well known in the Lower Valley. Here is a case of a cross between commerical and wild species with backcrosses to the commercial type to combine quality with resistance to disease. One of the selections, Weslaco Strain C, is about ready for introduction. Weslaco Strain C has now been crossed with California Mildew Resistant No. 6 to combine resistance to both downy and powdery mildew in a single variety.

In Texas, as in other southern States, tomatoes receive more attention than any other vegetable crop. Work is under way at College Station, Jacksonville, Stephenville, Winter Haven, and Yoakum, and has rather recently been organized for the Lower Rio Grande Valley.

At College Station the chief objectives of H. C. Mohr are the production of a commercial variety having resistance to southern blight and to Fusarium wilt. One strain of the Currant tomato has been found with resistance to southern blight. Pan America is the source of wilt resistance and it also increases size of fruit. In addition to resistance to these two diseases P. A. Young at Jacksonville has selections free from cat-face, fruit crack, and leaf roll. Selection Y914 is about ready for introduction. It has yellow fruit with thick locule walls. T. E. Denman continues to improve his Summer Prolific by crossing it with Red Cloud and a numbered selection to combine disease resistance with adaptability to adverse growing conditions during the summer in the West Cross Timbers area. The objectives of B. A. Perry are similar to those of T. E. Denman. A. L. Harrison is specializing in resistance to root-knot at Yoakum, but is also working on resistance to Fusarium wilt and the collar rot phase of early blight. Vegetable breeding at two other locations in Texas should be mentioned. These are the work of P. R. Johnson on southern peas at Tyler and that of Ralph Michael on sweetpotatoes at the Sweetpotato Laboratory at Gilmer. The former is securing southern peas that are resistant to Fusarium wilt, root knot, charcoal rot, and leaf spot. The crosses involve Cream and Purple Hull with resistant lines. Michael is continuing the work of R. E. Wright and is combining resistance to wilt with improved interior color and shipping and eating qualities. Texas Porto Rico and a new bush type, the Murff Bush Porto Rico have been introduced.

The vegetable breeding programs of several other southern States are about as extensive as those we find in Texas. Among the more important from a regional standpoint are the following: The development

of lima beans resistant to root knot by H. B. Cordner in Oklahoma; of tomatoes resistant to the same pest by V. M. Watts in Arkansas; the extensive breeding of sweetpotatoes, cabbage, tomatoes, and other crops by J. C. Miller and associates in Louisiana; the work of W. H. Greenleaf in Alabama on the pumpkin and other vegetable crops; the species hybrids of beans made by A. P. Lorz at Gainesville, tomato breeding by J. R. Beckenbach and J. M. Walter at Bradenton, and the watermelon breeding by G. K. Parris at Leesburg, all in Florida; the pepper breeding of A. H. Dempsey in Georgia; the development of the Palmetto cucumber by W. C. Barnes and the work of W. M. Epps on disease-resistant tomatoes in South Carolina; and the breeding for disease resistance in the tomato by F. D. Cochran and W. S. Barham in North Carolina. These are but examples of many far-reaching developments along this line.

In order to have any adequate understanding of vegetable breeding in the South it becomes necessary to view the work as a whole with respect to an individual crop. As with other kinds of research the vegetable breeder can make rapid progress working alone only because he has available the results in materials and know-how of a multitude of men who worked in the past and, of course, the results of current work in such fields as genetics, physiology, and plant pathology as these become available. In addition to this more formal help, which is traditional to scientific research, there is among those interested in vegetable breeding in our region a growing feeling of the importance of mutual interests and of the marked benefits to be derived form direct efforts to help each other. This should be evident from the account of breeding on a regional basis.

Tomato breeding projects are active in all of the States of the region as well as in Hawaii and Puerto Rico. Over 50 workers participate in some phase of this program. The chairman of this group is C. F. Andrus, tomato and watermelon breeder at the Regional Vegetable Breeding Laboratory. He is responsible for the cooperative trials, known as the Southern Tomato Exchange Program, and serves to help coordinate the breeding activities.

Objectives vary somewhat in the different states. While local adaptability still receives considerable attention, especially in the more important commercial districts, the importance of regional adaptability is being increasingly recognized. The wide adaptability of Rutgers was just a lucky break for that deservedly popular variety. Since such good fortune is comparatively rare, the widespread cooperative STEP trials are providing a factual basis for the selection of lines that are widely adapted. Fortunately, the benefits of these cooperative trials are cumulative as more and more valuable characters are combined with adaptability that is regional. This permits new combinations of horticultural characters, including disease resistance, to be made without sacrificing wide adaptability.

A good idea of the present status of tomato breeding in the region can be obtained by an examination of a list of breeding materials available for exchange prepared in 1949 by Mr. Andrus. No less than 175 items are included. Of these, around 120 lines are primarily of value because they carry resistance to various diseases, 13 in number. The diseases involved are anthracnose, bacterial wilt, collar rot, early blight, Fusarium wilt, late blight, leafmold, mosaic, root knot, Septoria, southern blight, spotted wilt, and Stemphylium. Several of these lines are resistant to two, three, or four diseases. Other lines are resistant to blossom-end rot or to fruit cracking, have a high content of ascorbic acid, solids, or lycopin, or set fruit under adverse conditions. Many strains of several wild species are also available.

Just getting some characters into a form that is usable in plant breeding sometimes requires the best efforts of several people working independently but with a recognized common interest. This is especially true where related wild species are involved. Each man who contributes has special training – the plant explorer who finds the species in its native haunts, the horticulturist or pathologist who recognizes valuable characteristics not found in commercial varieties, the biologist who effects the sometimes difficult cross between wild and commercial forms, perhaps with the aid of embryo culture, the geneticist who fixes the character in homozygous form, and finally the breeder who combines the new character with the older horticultural characters that make the new variety commercially acceptable. These steps were all involved in the development of breeding lines of tomatoes resistant to root knot now approaching the last stage of development at the Arkansas station and elsewhere. It is highly significant for the future of tomato breeding in an important commercial area like the Lower Valley that workers can draw on the accumulated results of others in developing new varieties to meet the problems of commercial growers.

The Regional Vegetable Breeding Laboratory at Charleston makes every effort to foster closer relationships among the vegetable breeders of the South for the mutual benefit of individual State programs and for the ultimate benefit of the commercial growers. The vegetable breeding conferences held at the Laboratory bring together not only the official collaborators from the several States but also many of their most active associates in this field. At these meetings information in regard

to current work is exchanged and discussed and consideration is given to the solution of mutual problems.

The active breeding program of the Laboratory is limited to seven crops: the breeding of tomatoes and watermelon is being done by C. F. Andrus, of snap beans and lima beans by J. C. Hoffman, of English or garden peas by J. A. Eades, and of cabbage and sweet corn by myself. In addition, chemical and physical analyses of varieties and breeding lines are made by Margaret Kanapaux. These include such things as the assay of vitamins, and the determination of the sugar content of sweet corn and the fiber content of snap beans. Much breeding material is sent out to State men for selection and as a source of resistance and other characters in breeding.

Obviously the success of any such program is largely dependent upon the cooperative spirit exhibited by the workers in all sections of the region. The degree of coordination achieved by the group thus far is producing results that promise much for the future of vegetable growing in the South.

Increasing Tomato Profits By Controlling Diseases

P. A. YOUNG, *Texas Agricultural Experiment Station, Jacksonville*

Dusting to control diseases and insects usually is just as important as cultivation, fertilization, and irrigation in producing large yields of marketable tomatoes. Failure in any one of these necessary jobs often makes tomatoes unprofitable. Fungicides and insecticides commonly are mixed together in standard dusts to control pests with minimum labor. This article is connected with controlling tomato diseases. Tomatoes are susceptible to more than 100 diseases but only about 17 of them are apt to be serious in the Lower Rio Grande Valley of Texas. These are discussed in similar groups (Young, 1946). It pays to prevent diseases from becoming serious.

Parasites That Live in the Soil

Root knot is one of the most destructive of all plant diseases. The nematode worms that cause root knot are too small to see with unaided eyes until the adult forms grow almost 1/16 inch long. They burrow into the roots of most kinds of plants in which they cause prominent knots 1/16 to 1 inch in diameter. Usually root-knot disease does not kill tomato plants but those with many knots early in the growing season produce few marketable fruits. Root knot is practically controlled by crop rotation with grasses such as sorghum, corn, or pasture grasses, (Friend, 1947) or by plowing the land successively 3, 5 and 7 inches deep at intervals of about ten days in hot dry weather (Godfrey, 1943). Soil fumigation is useful in killing nematodes where the soil and crop are very valuable (Godfrey, 1947, and Godfrey and Young, 1943).

Fusarium wilt is caused by a fungus that lives in the soil and makes the tomato plants wilt before they mature good crops of fruits. The woody tissues become brown in the lower part of the stem. Fusarium wilt is controlled practically by crop rotation with 4 or more years between tomato crops, and by use of resistant varieties such as Southland, Rutgers, Stokesdale, and Grothens Globe (Maxwell, et al., 1949).

Verticillium wilt is caused by another kind of fungus that lives in the soil and causes slow wilting of many kinds of crop plants including tomatoes. The woody tissues become brownish-black almost to the tops of wilting tomato plants. Riverside and Essar tomatoes resist Verticillium wilt but these varieties may not be productive in Texas. Rotation with cereal crops is best for controlling Verticillium wilt. It is very important to avoid having diseased crops concentrate the casual fungus in the soil because it damages many kinds of cash crops.

Southern blight is caused by a white mold in the ground that rots the crowns of tomatoes and many other crop plants. When the soil is wet, the fungus makes a white collar around the dying stem and little yellowish or reddish bodies like mustard seeds form on the mold. They

are the reproductive bodies of the casual fungus and keep it alive in the soil in dry seasons or when the temperature is too hot or cold. Southern blight is controlled mainly by rotation with cereal crops especially corn, sorghum, and pasture grass.

Diseases of Leaves and Fruits

Late blight is one of the extremely destructive epidemic diseases of crop plants. It commonly ruins crops of Irish potatoes and tomatoes and has been destructive in the Lower Rio Grande Valley since 1931 (Taubenhaus & Ezekiel, 1931). It cannot survive in dead tomatoes through hot summers, so it might be helpful to destroy by cultivation volunteer and late-surviving tomato plants between the spring and fall crops. The casual fungus remains alive in diseased tomatoes even though the symptoms disappear in hot weather. In Florida and Texas, the late-blight fungus lives through the hot dry summers in the tubers from blighted Irish Potatoes. Some tubers are missed in digging operations in fields, and many little and cut tubers are left in cull piles where potatoes are screened and graded. Potatoes have a long dormancy period through hot weather. Sprouts arise from diseased tubers in early winter and develop the typical water-soaked brownish leaf spots that are 1/4 to 2 inches wide. In rainy and foggy weather, and when the soil is wet (which are common conditions in winter), white mold develops on the lower sides of the diseased spots in the leaves. This white mold bears countless numbers of spores (fungus-seeds) each 1/1000 of an inch in diameter. These are carried by wind, spattering rain drops and animals to the new crop of Irish potatoes that emerges early in the winter. They develop a few leaf spots that may escape notice until cool rains and fogs arrive. Late blight spreads very rapidly and may kill half or more of the leaves within a week.

Blighted fields look like they have had a killing frost (Friend, 1947). Rains carry spores from the leaves into the soil where they infect and rot the potato tubers, causing large losses in grading and shipping the potatoes, as in 1950. The late-blight spores are carried to nearby tomato seedlings that emerge in early spring and cause ruinous leaf spotting and fruit rots. Shallow light brown spots 1/4 to 2 inches wide develop quickly in the fruit peel before or after they are packed in lugs. Serious rotting of tomatoes in lugs results in rapid decrease in prices at terminal markets.

CONTROL: Late blight has been causing such large losses in the Lower Rio Grande Valley in recent years that drastic methods are justified to control it. The following methods are likely to be very profitable: (a) Destroy all tomato plants in fields, gardens, irrigation-ditch banks, etc., during at least 2 weeks in August. (b) Destroy the potatoes in the cull piles and kill volunteer potatoes that occur in fields when the new winter crop of potatoes appears in the fields. (c) Have fields of potatoes and tomatoes as widely separated as possible. (d) As soon as late blight has been reported in the vicinity, dust the fields of tomatoes and potatoes very thoroughly with a dust containing 6 per cent copper (such as Tribasic Copper Sulphate or Cuprocide). Zineb (Dithane Z-78 or Parzate) in 6½% dust also have been useful in controlling late blight.

It is necessary to dust potatoes and tomatoes thoroughly as often as once or twice a week to control late blight when it is spreading rapidly in rainy or foggy weather. Spraying with Bordeaux mixture (8-4-100) is superior to dusting to control late blight. Airplane dusting usually does not apply dusts thoroughly enough to control late blight. However the rotor of a helicopter is claimed to be superior in driving dust downward onto plants and making the dust billow upward from the ground and onto the lower sides of leaves where moisture remains longest. Good ground dusting machines are preferable. (e) Try to persuade farmers in adjacent Mexico also to control their late blight.

Early blight may damage tomatoes while they mature their crop, especially the fall crop. The casual fungus is favored by warm rainy weather. Early blight is recognized by the black spots 1/16 to 1/2 inch wide with noticable curved lines (target-board marks). A similar disease is grey leaf spot that causes numerous spots 1/16 to 1/4 inch wide. They are dark brown, gray, or black, and often become shiny and glazed, and may show yellow borders. A few thorough applications of copper dust usually controls early blight and grey leaf spot.

Bacterial spot (nailhead rust) and bacterial canker diseases are caused by 2 species of bacteria that make white spots in the tomato peel, spoiling it for market. In rainy weather either of these diseases may make most of the tomato fruits worthless in a field. Also they may damage or kill the leaves, and bacterial canker also causes cankers in tomato stems. The bacteria are carried on tomato seeds so it is important to use only Certified seed that has been chemically treated. If either of these diseases appears in a tomato field in rainy weather, the tomatoes should be dusted or sprayed thoroughly with copper once or twice a week until the weather becomes dry.

Tomato fruits that touch wet soil are likely to be rotted by soil-inhabiting fungi. The most common of these fruit rots are Rhizoctonia soil rot, Phytophthora buckeye rot, Phoma rot, and Rhizopus rot. Any method that helps to keep the surface of the soil dry will decrease tomato fruit rots. It is suggested that farmers pay close attention to weather forecasts to try to avoid irrigating just before rains. Stopping irrigation by noon in harvest season in dry windy weather may permit the surface of the soil to become dry by night. Rotation with cereal crops helps to decrease the abundance of the fruit-rotting fungi in the soil.

Virus Diseases

Virus diseases are caused by parasitic particles in the plants. Such particles of the tobacco-mosaic virus are only about 1/80,000 of an inch long and are identified in electron-microscope photographs. The most common virus disease of tomatoes is mosaic that is caused by the virus of tobacco mosaic. The symptoms consist of light green to yellowish blotches in the tomato leaves and decreased yield of marketable fruits.

The causal virus is easily transmitted by touching a diseased plant and then touching healthy plants; as in handling seedlings or pruning tomatoes. Unfortunately, this virus remains alive in commercially prepared smoking and chewing tobacco from which it gets on the hands of workers. They transfer it to the leaves of the tomato plants and about 2 weeks later, mosaic mottling appears in about 1/1000 of the plants that they touch. Touching one of these mosaic-disease plants gets so much virus on the hands that they can inoculate the next hundred plants that they touch. The younger the tomato plants are when they get mosaic, the less they yield. Tomato mosaic usually comes from the virus in the tobacco that the workers use. Hence, laborers are advised to wash their hands in strong soapy water or a strong solution of trisodium phosphate often when they are working with small tomato plants. No desirable, effective method has been found to persuade laborers to refrain from touching tobacco before they touch little tomato plants.

Spotted wilt (tip blight) and streak are other virus diseases that may damage tomatoes. Dusting the tomatoes to control insects and keeping tomato fields distant from fields of peppers, potatoes, and eggplants help to minimize damage from these diseases.

Physiologic Abnormalities

Blossom-end rot often results when rapidly growing tomatoes with fruits on them are injured by drying wind or insufficient water in the soil. When there is not enough water for both leaves and fruits, the leaves appear to remove water from the fruits. This may be demonstrated easily. Pull up two bearing tomato plants and remove the fruits from only one of them. Observe them for a few days and notice which group of fruits shrivel first. Usually, the fruits that are left on the vine will shrivel before the fruits that are removed. This gives us a valuable clue for minimizing blossom-end rot. Simply provide the tomato plants with a regular, adequate supply of irrigation water and blossom-end rot of tomatoes probably will not become serious. Rutgers and Stokesdale varieties are more susceptible than Marglobe and Pritchard to blossom-rot.

Puffing causes great loss in raising green-wrap tomatoes. Poor pollination of flowers due to rain or perhaps dry wind appears to be the main cause of puffing of tomatoes in fields. Some varieties such as Stokesdale were injured much more than Rutgers by puffing in 1950. Tomatoes are being selected to try to find suitable varieties with resistance to puffing and fruit cracking.

Standard Dusts

Many tomato farmers profit from a regular program of preventive dusting. It is fine insurance. Usually it is easy to keep tomatoes healthy but it is very difficult or even impractical to stop diseases after they have become abundant in a field. Preventive dusts are applied every 7 to 10 days starting when the tomatoes begin to bloom, or earlier if needed (as protecting tomato seedlings from late blight). Diseases and insects commonly damage tomatoes at the same time, so fungicides and insecticides are mixed together for efficiency and minimizing labor cost. However, the chemicals may be used separately. Either of the following formulae are likely to be satisfactory:

(a) 6% copper (from Tribasic Copper Sulphate, Copper-A Compound, Cuprocide, Spraycop, or other equal source); 25% dusting sulphur; 14% calcium arsenate; and 55% diluent dust (from Attaclay, Pyrax ABB, Diluex, or dust of equal adhesiveness and safety).

(b) 6½% Zineb (from Parzate or Dithane Z-78); 25% sulphur, 5% DDT, and 68½% diluent dust. Some farmers prefer to choose the specific chemicals needed for each separate dust depending on the pests to be controlled on that day. Other farmers need a standard, complete formula of dust on hand to be used as needed for all of the expected pests in the season. Many of the larger buyers of greenwrap tomatoes wash the fruits before they grade them and this minimizes danger from any DDT or arsenic on the peel. Dusts do not adhere well to the shiny surface of mature tomatoes.

Big Market for Good Tomato Plants

There is a fine opportunity to develop a thriving business of growing tomato seedlings in the Lower Rio Grande Valley for sale in regions farther north. In order that the seedlings may live and make money for the farmers who transplant them, known rules are necessary. Such rules are administered by the Georgia Department of Entomology at Atlanta for the extensive business of growing and shipping seedlings in Georgia. The purpose is to provide healthy tomato seedlings of known varieties that are packed to stay alive in transit. This purpose could be accomplished nicely in the Lower Rio Grande Valley by planting Certified tomato seeds in *non-irrigated* land near Mission to Zapata, *away from the winter fogs and crop of potatoes* from which tomatoes get late blight. Tomatoes transplant best when they are 6 to 8 inches tall, with stems 1/4 to 1/3 inch in diameter. Buyers need them about March 25th. The plants should be loosened in the rows with a plow and then gently lifted with plenty of roots. They should be packed promptly into baskets *with the roots always on wet moss* or wet rotten sawdust. Such plants are eligible for State Certification and the producer could build a fine reputation for high-quality tomato plants. His reputation would sell his plants at a premium.

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Control of Red Spider Mites on Vegetables

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During the 1949-50 vegetable growing season the red spider, *Septanychus texazona* McGregor, was a serious problem on eggplant, celery, and cucurbits. Because of the cool weather prevailing at that time, dusting sulphur, which is recommended for controlling this red spider mite on cotton, gave little or no control of red spiders infesting eggplants. As sulphur is injurious to cucurbits, experiments were conducted in order to find materials which can be used on cucurbits as well as other vegetables.

Data taken 6 days after treatment applications on cotton by Iglinsky and Gaines (1949) showed that sulphur gave a 97.1 percent control of *Septanychus* sp., now considered *S. texazona* McG., whereas a 1 percent parathion dust gave 88.9 percent control. Huckett (1948) obtained a 44-percent increase in the number of clean lima bean pods with the use of a 1 percent parathion dust as a control for the two-spotted spider mite, *Tetranychus bimaculatus* Hervey. He also found that dusting with 50 percent sulphur actually increased the number of lima bean pods injured by this spider mite. Records taken 3 days after treatment applications by Sherman, III, and King (1948) showed that parathion (2.5 pounds of a 25 percent dust per 100 gallons of water) was more effective than TEPP (1 pint per 100 gallons of water) in controlling the two-spotted mite infesting apples.

Procedure.—The plots were 0.02 acre in size for all experiments except number 4 which had plots 0.01 acre in size. Treatments in experiments No. 2, 3, and 5 were replicated four times while in experiments 1 and 4 they were replicated only three times. The type of plant infested by the red spider mite and the treatments[1] used in the various experiments are shown in the tables. The dust treatments were applied with rotary hand dusters at approximately 20 pounds per acre. The spray treatments were applied with a small garden sprayer at an approximate rate of 125 gallons of spray material per acre.

The efficiency of the various materials was determined by collecting 10 leaves at random from each plot and examining the leaves under a microscope in order to determine the average number of red spiders per leaf.

Results.—The data in Table 1 show that sulphur was ineffective as a control for red spider mites on eggplant. This experiment was conducted during a period of rather cool weather. Experiments 2 and 3 were conducted during periods of warm weather, and as shown by the data in

1 The active ingredients of the "Trade Named Materials" used in these experiments are: Aramite, 2-(p. tert.-Bulyphenoxy)-1-methyl-ethyl 2-chloro-ethyl sulfite; AgriSul, a compound containing 30.42 percent of calcium and sulphur; Dilan, 8.33 percent of 2-nitro-1-bis (p.-chloro-phenyl) propane and 16.67 percent 2-nitro-1, 1-bis (p. Chloro-phenyl) butane; Metacide, dialkyl nitroaryl thiophosphates; Karothane, dinitro caparyl phenyl crotonate; and R-242, p.-chlorophenyl phenyl sulfone.

Table 1.—Effectiveness of various insecticides in controlling red spider mites on eggplant. Treatments were applied on December 7, 1949.

	Average number red spider mites per leaf after			
	1 Day		8 Days	
Treatments	Number	Percent Control	Number	Percent Control
Dust: Sulphur	28.3	0.0	40.1	30.9
Dust: 1% Parathion	6.2	75.2	0.7	98.8
Spray: 1 Qt.20% TEPP per 100 gallons water	5.7	75.6	5.7	90.2
Untreated	24.2	—	58.0	—

Table 2.—Effectiveness of various insecticidal dusts in controlling red spider mites on celery. Treatments were applied on March 8, 1950.

	Average number red spider mites per leaf after			
	1 Day		6 Days	
Treatments	Number	Percent Control	Number	Percent Control
1% TEPP	5.2	65.3	16.5	66.2
1% Parathion	7.1	52.7	22.1	54.7
Sulphur	8.0	46.7	18.7	61.7
Untreated	15.0	—	48.8	—

Table 3.—Effectiveness of various insecticidal dusts in controlling red spider mites on celery. Treatments were applied on March 18, 1950.

	Average number red spider mites per leaf after			
	2 Days		8 Days	
Treatments	Number	Percent Control	Number	Percent Control
1% Parathion	0.6	89.1	3.8	73.4
Sulphur	1.4	74.5	6.3	55.9
1% Karothane	1.6	70.9	0.9	93.7
10% R-242	1.3	76.4	0.4	97.2
Untreated	5.5	—	14.3	—

Table 4.—Effectiveness of various insecticidal sprays in controlling red spider mites on celery. Treatments were applied on March 8, 1950

	Average number red spider mites per leaf after			
	1 Day		10 Days	
Treatments	Number	Percent Control	Number	Percent Control
1 Qt. 20% TEPP	2.0	79.3	8.1	41.1
1 Qt. AgriSul	2.3	76.1	1.9	87.4
2 Lbs. 15% Aramite	4.1	55.9	0.5	96.7
2 Lbs. 25% Karothane	0.9	93.0	0.7	95.4
2 Lbs. 15% Parathion	3.1	66.7	1.8	87.4
1 Qt. 30% Metacide	5.2	44.1	1.5	90.1
1 Qt. 25% Dilan	3.6	61.3	4.0	73.5
Untreated	9.3	——	15.1	——

Table 5.—Effectiveness of insecticidal dusts in controlling red spider mites on cucumbers. Treatments were applied on April 10, 1950.

	Average number red spider mites per leaf after			
	2 Days		4 Days	
Treatments	Number	Percent Control	Number	Percent Control
10% R-242	2.2	95.5	0.5	99.4
1% Karothane	45.0	8.4	40.8	49.8
1% Parathion	0.0	100.0	4.3	95.1
Untreated	49.1	——	81.3	——

Tables 2 and 3, sulphur gave better mite control, but the control obtained was not as good as some of the other materials. A 1 percent parathion dust gave excellent control, but this material looses its residual effectiveness quickly in warm weather as can be seen by the data in Tables 3 and 4. As can be seen by the data in Table 3, a 1 percent Karothane dust gave good control of mites on celery. The same concentration of Karothane did not reduce the spider population on cucurbits, as can be seen in the data taken 2 days after treatment application. However, the data in Table 5 show that Karothane prevented the population from increasing. The 10 percent R-242 dust gave excellent control of mites as can be seen in the data of Tables 3 and 5. This R-242 dust gave better residual control than did the 1 percent parathion dust. A 1 percent TEPP dust reduced the red

spider mite population immediately after application as is shown in the data of Table 2. The parathion, Karothane and R-242 dusts did not injure the cucumber plants.

Celery in this area is usually sprayed for the control of a number of diseases. Table 4 shows the effectiveness of a number of materials applied as high volume sprays. Aramite, Karothane, parathion, and Metacide all gave effective control of the red spider mite when applied as high volume sprays. AgriSul, containing a mixture of 30.42 percent calcium and sulphur, also gave good control. In experiment 1, TEPP gave good residual control of the red spider mite; however, this experiment was conducted during a cool period. In experiment 4, the TEPP spray treatment was applied during a period of much warmer weather and the residual control was not as good.

Summary.——The use of sulphur as a control of the red spider mite, *Septanychus texazona* McGregor, on vegetables is not too effective because of the cool weather prevailing during the vegetable growing season. Parathions gave good control and can be used safely on cucurbits. Karothane and R-242 gave better residual control of red spider mites than did parathion and can be used safely on cucurbits. Aramite also shows promise as a control of red spider mites. TEPP also controlled mites immediately after application, but had little or no residual effect during warm weather.

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Guide For Controling Insects and Diseases on Vegetable Crops in The Lower Rio Grande Valley (1950-51)

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RECOMMENDED CONTROL MEASURE

Insects or Disease	*Dust*	*Spray*	*Notes*
		BEANS — SNAP AND LIMA	
Aphids (Plant Lice)	1% Lindane or 1% Parathion	1 pt. 20% Lindane or 1 pt. 20% TEPP per acre	Apply at 5 to 7 day intervals. Dust 20 to 30 lbs. per acre. Use spray in 5 to 8 gals. of water per acre. Do not use lindane within 4 days of harvest or parathion within 21 days of harvest.
Flea beetles & Leafhoppers	5% DDT	1 qt. 25% Emulsifiable DDT per acre	Less than one beetle per plant can ruin the stand of seedlings. Examine crop often. Dust at the rate of 20 to 30 lbs. per acre. Use spray in 5 to 8 gals. per acre. Do not use DDT within 10 to 14 days of harvest.
Thrips	5% Chlordane or 1% Lindane	1 lb. of Technical Toxaphene per acre	May attack seedlings and older beans. Repeat as needed. Flea beetle and leafhopper control will usually control thrips also. Do not use chlordane or toxaphene within 10 days of harvest, or lindane within 4 days.
Corn earworm	5% DDT with Sulphur		The earworm and some other caterpillars and beetles feed upon the leaves. Do not use within 10 days of harvest.
Rust	Sulphur (325 mesh)	2¼:2½:100 Bordeux	Use 1 to 3 weekly applications beginning when rust appears, often before blooming. Bordeaux used in high volume spray has given good control.
		BEETS	
Beet webworm Flea beetles	5% DDT in Sulphur or 3% Chlordane plus 3% DDT		Both insects attack young plants. Fewer than one per plant often ruin the stand of seedlings. Examine crops often and protect new growth if needed. Watch for movement of beetles into field from outside.

Insects or Disease	*Dust*	*Spray*	*Notes*
		BROCCOLI	
Aphids	1% TEPP or 1% Lindane	1 pt. 20% TEPP per acre or 1 pt. 20% Lindane	Spray several times at 5 to 7 day intervals beginning when aphids first appear. Use spray in 5 to 8 gals. per acre. Use 20 to 30 lbs. of dust per acre. Start when population is low and repeat at weekly intervals. Do not use lindane within 4 days of harvest.
Cabbage webworm	5% DDT with Sulphur		Use 20 to 30 lbs. per acre. Do not use within 10 to 14 days of harvest—or (use on seed bed only).
Hornworm	5% Rhothane or 5% Chlordane		Use 20 to 30 lbs. per acre. Do not use chlordane within 10 to 12 days of harvest.
Cabbage worms	5% DDT or 5% Methoxychlor or 5% Rhothane	1 qt. 25% Emulsifiable DDT per acre	Use spray in 5 to 8 gals. of water per acre or dust at the rate of 20 to 30 lbs. per acre every 7 to 10 days as needed. Do not use DDT within 10 to 14 days of harvest.
Southern Cabbage worms	1% Lindane	1 pt. 20% Lindane	Use 20 to 30 lbs. per acre of dust. Use spray in 5 to 8 gals. of water per acre. Do not use within 4 days of harvest.
Downy Mildew and Black Spot	SEE CABBAGE BELOW		
		CABBAGE	
Aphids	3% BHC or 1% Lindane or 1% TEPP	1 pt. 20% Lindane or 1 pt. 20% TEPP per acre	Use spray in 5 to 8 gals. per acre or dust at the rate of 20 to 30 lbs. per acre. Apply every 5 to 7 days after aphids first appear. Do not use BHC after head begins to form or lindane within 4 days of harvest.
Cabbage worms	5% DDT or 5% Methoxychlor or 5% Rhothane	1 qt. 25% Emulsifiable DDT per acre	Use spray in 5 to 8 gals. of water per acre or dust at the rate of 20 to 30 lbs. per acre every 7 to 10 days as needed. Do not use DDT within 10 days of harvest.

CABBAGE (cont.)

Insects or Disease		Spray	Notes
Southern Cabbage worms	3% BHC or 1% Lindane		Use 20 to 30 lbs. per acre. Do not use BHC after head begins to form or lindane within 4 days of harvest.
Thrips	1% BHC plus 5% DDT		Make several applications at 7 to 10 day intervals. Use 20 to 30 lbs. per acre. Do not use after head begins to form—or (use on seed bed only).
Cabbage webworm	5% DDT with Sulphur		Use 20 to 30 lbs. per acre. Do not use within 10 to 14 days of harvest, or (use on seed bed only).
Downy Mildew and Black Spot	5% metallic copper or 10% Dithane Z-78 or 10% Parzate	2 qts. liquid Dithane or Parzate and 1 lb. of Zinc Sulfate per 100 gals. of water	Control downy mildew in seed beds. Repeat in field if spots appear on wrapper leaves. Use 3 or more weekly applications if black spot appears. Use liquid only in high volume spray.
Black Rot	Bichloride of Mercury (1 part per 1000) or 1 oz. in 7½ gallons of water.		Soak seed 20 minutes, rinse, dry surface of seed and plant.

CANTALOUPES

Do not use any compound containing Sulphur, DDT or BHC for cantaloupes.

Insects or Disease		Spray	Notes
Darkling beetles	5% Chlordane		Use 20 to 30 lbs. per acre when needed on seedlings. *Do not apply in presence of dew. Plants must be dry.*
Aphids or Thrips	1% Lindane or 1% TEPP or 1% Parathion	1 pt. 20% Lindane or 1 pt. 20% TEPP per acre	Use spray in 5 to 8 gals. water per acre and dust at the rate of 20 to 30 lbs. per acre. Do not use Lindane within 4 days or Parathion within 21 days of harvest.
Garden Fleahopper	1% Lindane		Use 20 to 30 lbs. dust per acre. Do not use lindane within 4 days of harvest.
Melon worms	1% Rotenone or 5% Methoxychlor or 40% Cryolite		Use dust at 20 to 30 lbs. per acre at 7 day intervals after first worms appear. Do not use insecticides within 4 days of harvest.

Insects or Disease	Dust	Spray	Notes
Red spider	1% TEPP or 1% Parathion or 2% Karathane		Apply at weekly intervals until controlled, use 20 to 30 lbs. per acre. Do not use Karathane within 10 to 14 days or Parathion within 21 days of harvest.
Cucumber beetles	5% Methoxychlor or 40% Cryolite		Use 20 to 30 lbs. dust per acre.
Downy Mildew	10% Zerlate or 10% Dithane Z-78 or 10% Parzate	2 qts. of Dithane or Parzate plus 1 lb. of Zinc Sulfate per 100 gals. of water	Use heavy poundages up to 35 to 40 lbs. when vines are large, at weekly intervals if mildew is present. Use liquid in high volume spray.
Powdery Mildew	1% Karathane	Use 1 qt. or 2 lbs. of 25% Karathane per 100 gals. water	Apply at weekly intervals at very first appearance of mildew spots (or see above downy). Use liquid in high volume spray.
Beetles, Melon Worms, and Downy Mildew	40% Cryolite or 5% Methoxychlor with one of the fungicides listed above for mildew		A mixture which will control disease and insects is usually best. Lindane may be added to the methoxychlor for aphid control. Do not use insecticides within 4 days of harvest.

CARROTS

Insects or Disease	Dust	Spray	Notes
Flea beetles	5% DDT with Sulphur or 3% Chlordane plus 3% DDT	1 qt. 25% Emulsifiable DDT per acre	Less than one beetle per plant can ruin the stand of seedlings. Protect new growth as needed and watch for movement of beetles from outside the field. Use spray in 5 to 8 gals. per acre and dust at 20 to 30 lbs. per acre.
Beet webworm	5% DDT with Sulphur		When needed on seedling carrots.

Insects or Disease	*Dust*	*Spray*	*Notes*
Leaf blight	5% metallic copper, or organic fungicides	5-3-50 Bordeux mixture	At first appearance and every 10 days as needed. Use dusts when leaves are damp. Include sticker in dust. Use Bordeux in high volume spray.
		CAULIFLOWER (See Broccoli)	
		CELERY	
Celery Flea Beetles	5% DDT or 3% Chlordane plus 3% DDT		Use 20 to 30 lbs. dust per acre. Flea beetles are very destructive to seedlings.
Celery worms	5% DDT		Use 20 to 30 lbs. dust per acre. Do not use DDT within 10 to 14 days of harvest.
Red Spider	Sulphur or 1% TEPP or 2% Karathane		Sulphur in hot weather and other materials when weather is cool. Do not use Karathane within 14 days of harvest.
Leaf Spot	10% Dithane Z-78 or 10% Parzate	2 qts. liquid Dithane or Parzate plus 1 lb. of Zinc Sulfate per 100 gals. of water	Use heavy poundage, 30 to 40 lbs. per acre. Apply as needed. Use liquid in high volume spray.
		CUCUMBERS (See Cantaloupes)	
		not use any material containing Sulphur, DDT or BHC on Cucumbers.	
		EGGPLANT	
Yellows (virus disease)	Sulphur dust (325 mesh)		Dust seed beds weekly. Repeat applications after transplanting.
Fleabeetles and Cucumber Beetles	5% DDT	1 qt. 25% Emulsifiable DDT	A few beetles can ruin a stand of seedlings.

Insects or disease	*Dust*	*Spray*	*Notes*
		EGGPLANT (Cont.)	
Horn worms	5% Rhothane or 5% Chlordane		Hand picking may be practiced in the seed bed. Do not use within 10 to 14 days of harvest.
Red Spider	2% Karathane or 1% TEPP		Use 20 to 30 lbs. per acre of dust. Do not use Karathane within 14 days of harvest.
Leaf & Fruit Spots	5% metallic copper or organic fungicide	2 qts. liquid Dithane or Parzate plus 1 lb. of Zinc Sulfate per 100 gals. of water	Apply weekly if diseases are present. Use liquids in high volume spray.
		LETTUCE	
Aphids	1% TEPP dust or 1% impregnated pyrethrins with 1% DDT	1 pt. of 20% TEPP per acre	The red lettuce aphid is often incorrectly called a "red spider." It must be controlled before heading. Shippers often cull entire fields or heads that have red aphids.
Plant Bugs (mirids)	5% DDT		Use 20 to 30 lbs. per acre as needed. Do not use within 10 to 14 days of harvest.
Loopers and Beetles	5% DDT		Use 20 to 30 lbs. per acre. Do not use within 10 to 14 days of harvest.
Downy Mildew	5% insoluble copper expressed as metallic or 10% Dithane Z-78 or 10% Parzate	2 qts. of liquid Dithane or Parzate plus 1 lb. of Zinc Sulfate per 100 gals. of water	Control downy mildew in seed-beds. Repeat in field if spots appear on wrapper leaves.
		MUSTARD	
Aphids, Worms & Beetles	1% Rotenone with Sulphur		May be used shortly before harvesting with no danger to consumer. Use 20 to 30 lbs. per acre.

Insects or Disease	Dust	Spray	Notes
Loopers	5% Methoxy-chlor or 5% Rhothane		Apply as needed, 20 to 30 lbs. per acre.
		OKRA	
Aphids	1% TEPP	1 pt. 20% Lindane or 1 pt. 20% TEPP per acre	Use 5 to 8 gals. water per acre in spray. Dust at 20 to 30 lbs. per acre as needed. Do not use lindane within 4 days of harvest.
Corn earworm	5% DDT		Use 20 to 30 lbs. per acre. Do not use within 10 to 14 days of harvest.
		ONIONS	
Thrips	1% BHC plus 5% DDT	1 lb. of technical Toxa-phene or 1 qt. 25% DDT emulsion per acre	Weekly applications beginning when 5 thrips are found per plant. (January-early February). Do not wait too late to start in. Badly damaged onions can seldom be "brought back" to make a good crop.
Leaf Blight	10% Dithane or 10% Parzate Dusts with sticker	2 qts. liquid Dithane or Parzate and 1 lb. zinc sulphate per 100 gals. of water	Apply weekly after first lesions appear. Combine with insecticide for thrips control. Add 3 lbs. 50% DDT wettable powder to Dithane or Parzate sprays for thrips. Apply dusts to moist leaves. Use high volume sprayers, low volume sprayers are not satisfactory for disease control. Complete coverage must be obtained.
		PEAS — ENGLISH	
Aphids	1% TEPP or 1% Lindane	1 pt. 20% TEPP per acre or 1 pt. 20% Lindane	Use 20 to 30 lbs. of dust per acre and 5 to 8 gals. of water per acre in spray. Do not use Lindane within 4 days of harvest.
Thrips	5% Chlordane		Use 20 to 30 lbs. per acre for at least 2 or 3 weekly applications. Do not use chlordane within 10 to 14 days of harvest.

Insects or Disease	Dust	Spray	Notes
Cabbage Worms	5% DDT with Sulphur		When needed, usually on seedling peas.
Powdery Mildew	Sulphur (325 mesh)		Every 7 days if mildew present.
		PEAS — BLACK-EYED OR COWPEAS	
Aphids	1% TEPP 1% Parathion or 1% Lindane	1 pt. 20% TEPP or 1 pt. 20% Lindane	Dust or spray every days when aphids first appear. Do not use lindane within 4 days or parathion within 21 days of harvest.
Curculio	10% DDT with Sulphur		The adult weevil must be killed before it lays eggs in the pods. Dust once when pods are about 1 inch long. Repeat after 7 days. A single dusting is of little value. Do not use DDT within 10 to 14 days of harvest.
Rust	Sulphur (325 mesh)	2½:2½:100 Bordeux mixture	Use 1 to 3 weekly applications before blooming if needed. Follow with curculio treatment. Use Bordeux in high volume sprayer.
		PEPPPERS	
Flea beetles & Cucumber Beetles	5% DDT or 5% Rhothane	1 qt. 25% DDT	Start early, use 20 to 30 lbs. per acre of dust and 5 to 8 gals. of water per acre in spray.
Darkling Beetle	5% Chlordane		Injury similar to cutworm damage, especially to seedling plants.
Weevil & Fruitworm	1% (gamma) BHC plus 5% DDT		Use the first application when fruit begins setting. Dust at least 3 times at 7 day intervals for initial weevil control. Repeat later if needed. DDT is needed for fruitworm control. Do not use within 10 to 14 days of harvest.

Insects or disease	Dust	Spray	Notes
Leaf Miner	5% Chlordane		Use every 7 days as needed beginning when leaf miners are injuring plants. Do not use within 10 to 14 davs of harvest.
Hornworm	5% Rhothane or 5% Chlordane		Use 20 to 30 lbs. per acre of dust. Usually found in seed beds.
Leaf and Stem Blight & Bacterial Spot	5% metallic copper or 10% Dithane Z-78 or 10% Parzate	2 qts. liquid Dithane or Parzate plus 1 lb. of Zinc Sulphate per 100 gals. of water	Weekly if needed until dry weather. Combine with insecticidal dusts. Use liquid in high volume spray.
		POTATOES — IRISH *Do not use BHC on Potatoes.*	
Thrips	5% Chlordane		Apply as needed — 20 to 30 lbs. per acre.
Blights (early & late)	10% Dithane Z-78 or 10% Parzate or 5% Copper	2 qts. either liquid Dithane or Parzate & 1 lb. Zinc Sulphate per 100 gals. of water	Weekly and after each rain. Begin when blight is *first reported in the Valley area.* Use liquid in high volume spray. Sprays may be better in bad blight year.
		RADISHES	
Aphids	3% (gamma) BHC or 1% TEPP		Do not use BHC within 10 to 14 days of harvest. Sprays haven't been effective.
Worms & Beetles	5% DDT or 3% Chlordane plus 3% DDT		When needed.
		SPINACH	
Flea Beetles & Loopers and Worms	5% DDT		A few can ruin the stand of seedlings and the quality of older spinach also. Do not use within 10 to 14 days of harvest.

Insects or Disease	Dust	Spray	Notes
		SPINACH (Cont.)	
White Rust and Blue Mold	10% Dithane Z-78 or 10% Parzate	2 qts. either liquid Dithane or Parzate and 1 lb. Zinc Sulfate per 100 gals. of water	Use dust at the rate of 30 to 40 lbs. per acre and liquid in high volume spray. Spraying preferred.
		SQUASH	
SEE CANTALOUPES			
Powdery Mildew	1% Karathane		Do not use within 14 days of harvest.
		SWEET CORN	
Corn Earworm (Obtain special leaflet)			
Flea Beetles	5% DDT		When needed — 20 to 30 lbs. per acre. *Dusts are not*
Budworms	None	2 qts. 25% DDT per acre	*effective.* Use every 5 to 7 days with at least 10 gals. water per acre.
		TOMATOES	
Fruitworm	5% Rhothane or 5% DDT		Dust 3 times at 7 day intervals beginning when fruit begins to set. Examine this for small worms and eggs and continue if necessary. Do not use within 10 to 14 days of harvest.
Flea Beetles	5% DDT or 3% Chlordane plus 3% DDT		Use 20 to 30 lbs. dust per acre. Usually found on seedlings.
Darkling Beetles	5% Chlordane		Use 20 to 30 lbs. dust per acre. Very destructive on seedlings.
Garden Fleahoppers	5% Chlordane		Usually severe on fall tomatoes. Use 20 to 30 lbs. dust per acre. Do not use within 10 to 14 days of harvest.

TOMATOES (Cont.)

Insects or Disease	*Dust*		*Notes*
Hornworms	5% Rhothane or 5% Chlordane		Use 20 to 30 lbs. per acre. Do not use within 10 to 14 days of harvest.
Blossom Thrips	5% Chlordane		Use when there is certainty that thrips are the cause of blossom fall.
Suck Fly	5% Chlordane or 5% Methoxychlor on young plants — 5% DDT with sulphur or 5% Methoxychlor on old plants		Heavy application — 30 to 40 lbs. per acre. Do not use within 10 to 14 days of harvest.
Blights and Grey Leaf Spot	10% Dithane Z-78 or 10% Parzate or 5% Insoluble Copper	2 qts. either liquid Dithane or Parzate and 1 lb. of zinc sulfate per 100 gals. of water	Early seed-bed treatment if leaf spot is present followed by 3 to 5 applications in the field at 7 day intervals Weekly and after each rain. Begin when blight is *first reported in the Valley area.* Use liquid in high volume spray.

TURNIPS — See Mustard

WATERMELONS — See Cantaloupes

Some melon growers are planning the use of "hoods" for dust applications for downy mildew control. See appendix.

ANY VEGETABLE

Cutworms	40% Cryolite in citrus meal	Dust or sprinkle upon ground around plants. Use heavy poundages.
Fall Armyworm	5% DDT	When needed except on cucurbits; then use Methoxychlor. Do not use within 10 to 14 days of harvest.

Insects or disease	*Dust*	*Spray*	*Notes*
Darkling Beetles	5% Chlordane		Seedling stage only.
Grasshoppers	10% Chlordane or 20% Toxaphene		Do not use within 10 to 14 days of harvest.
Ants	5% Chlordane		Apply to nests, or surface of soil.
Nematodes	There are no living nematodes in the upper 3 inches of soil in a plowed field during mid-summer. Three or four plowings designed to lift successively deeper layers of soil down to a depth of 10 inches will kill most of the nematodes in that 10 inches if the operations are performed during a 3 week period of continuously hot dry weather.		Chemical control is so expensive that it is practical to be used only on high income crops.

Remarks: Method of application is equally as important as the material used.

Dust

Ground Operated Dusters: Use insecticides at a minimum of 20 lbs. per acre. Use higher poundages on rank vegetation such as large tomato and potato plants. Fungiciddes generally should be used at a higher rate or in a range of 30 to 40 lbs. per acre. Tractor dusters should be especially designed for vegetable crops with 2 or 3 nozzles per row. The new mist-type dust applicators show considerable merit in that they make for better adherence of the materials to the foliage. Rotary hand-dusters are very useful in small plots. They should be used so that each row is dusted from both sides.

Airplane Dusting: Use insecticides and fungicides at a minimum of 30 lbs. per acre for best results. It is very important that swath widths be made no wider than the wing-spread of the airplane. To be sure of this and to insure a good, thorough application, it is necessary to use flagmen to mark the swath widths. Airplane dusting has failed in the control of aphids on cauliflower, broccoli, turnips, lettuce and some other low-growing leafy crops.

Sprays

Low Volume Sprays: Low pressure sprays show great promise for insect control, *but not for disease control.* The insecticide concentrate should be used at the recommended rate in 5 to 8 gallons of water per acre. These sprayers should develop approximately 60 lbs. pressure. Ground sprayers should have 2 or 3 nozzles per row. Airplane low volume sprayers may be used with good results on most vegetables. The droplet size of the spray is very important in the effectiveness of all low volume sprays.

High Volume Sprays: High volume sprays should be used in all disease control spraying. This will require approximately 300-400 lbs. pressure and the use of 2 or 3 nozzles per row. The recommended concentrate should be applied in 100-125 gallons of water per acre. Thorough coverage is very essential.

INSECTICIDES — CAUTION!

It is important to read all labels carefully for special precautions and an antidote in case of accidental poisoning.

In general, insecticides break down much faster when the temperature is high. For this reason such insecticides as DDT, Toxaphene, Chlordane, etc. may be used within 10 days of harvest when temperatures are in the 90's. At the cooler fall and winter temperatures, they should not be applied within 14 days of harvest.

Parathion: This insecticide is extremely dangerous to handler and recommended safety precautions must be observed. Very small amounts may cause illness or death. Workers may obtain fatal doses through contact with the skin, by breathing vapors or drift, and accidentally by way of mouth (for example, by smoking).

The following precautions regarding Parathion must be observed: Do not breathe dust or mist or enter drift; wear Bureau of Mines approved respirators; have shirt sleeves rolled down, change clothes and bathe immediately after finishing work. Follow all precautions printed on container labels. Do not use parathion within 21 days of harvest.

TEPP: It should be handled in the same manner as Parathion because it is a related phosphate compound and extremely toxic to both man and animal. This material breaks down rapidly, however, and does not leave any poisonous residues on the crops. Vegetables may be eaten safely within 2 or 3 days after application.

DDT: This insecticide is toxic to all warm blooded animals. It is a slow acting poison and takes 40 to 72 hours to kill most of the insects which it will control. DDT may stunt the growth of several different vegetable seedlings, such as tomatoes and cucurbits. It should not be used within 10-14 days of harvest.

Methoxychlor and Rhothane: These two new chemicals are similar to DDT and kill many of the insects that DDT controls. They are less toxic to humans and their use is encouraged, especially near harvest time.

Chlordane: This material may burn certain vegetable seedlings; use only as recommended. Do not use nearer than 10 to 14 days of harvest.

Toxaphene: This is a toxic material and should be used with caution. There is danger from the residual effect of this material and for this reason, we have recommended it sparingly.

BHC: Benzene Hexachloride severely burns all cucurbits and young snap beans. It may give objectionabble odor or taste to several different vegetables, particularly beans and turnip greens. It will not affect the flavor of cabbage, onions, carrots, and peppers. *Many canneries will not buy produce known to have been dusted with BHC.* Do not use nearer than 10-14 days before harvest.

Lindane: This is the pure gamma isomer of benzene hexachloride. It has not injured cucurbits and may not produce an objectionable odor or taste when used on vegetables. This material is expensive. Do not use nearer than 4 days of harvest on crops to be eaten.

Karathane: This is a new material and may not be readily available. It shows much promise as a fungicide and miticide. Do not use within 10-14 days of harvest.

Rotenone: This chemical does not leave residues dangerous to the consumer and can be used effectively and safely for turnip aphids, beetles and worms on many crops only a few days before harvest.

Sulphur: Insecticides containing sulphur should not be used for the control of insects on cucumbers, cantaloupes, and watermelons and young tomatoes since plant injury may result from its use.

Some of the chemical names used in this report are trade names. These chemicals have scientific names, but they are not as widely known and confusion might result from their use. Any product with the same chemically active ingredients may be used in place of those recommended.

The Valley Experiment Station has developed a portable hood which, when used, will give better coverage and increased effectivness from insecticide and fungicide applications. These are particularly valuable when the wind is moderately high. These hoods are made of light weight conduit tubing and covered with muslin. This hood may be built 3 feet wide, 2 feet high and 8 feet long for row crops or wider and longer for vine crops such as watermelons and cantaloupes.

Tissue Analysis As An Aid in Evaluating the Nutritional Status of Citrus Trees

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Theory, Purpose, and Limitations of Leaf Analysis

About two-thirds of the fresh weight of the woody parts of a citrus tree is dry matter, while one-third of the fresh weight of leaves is dry matter. About one-eighth of the fresh weight of the fruit is dry matter. Only about one-eighth of the dry matter of leaves and less for fruit is made up of ash, or mineral constituents such as calcium, potassium, magnesium, and phosphate. Consequently, the major portion of the dry matter of citrus leaves and fruit is composed of organic materials, such as sugar, starch, citric acid, cellulose, protein, and the green pigment chlorophyll. The bulk of the weight of these organic materials is contributed by the elements carbon and oxygen supplied by carbon dioxide gas, which is absorbed from the air by the leaves.

Green leaves could not synthesize food materials essential for growth and fruiting of plants without the mineral nutrients taken up from the soil by roots. If we think of a leaf as a manufacturing unit, these mineral nutrients may be regarded as essential cogs in the complex machinery used for the manufacture of food. The raw material is mainly carbon dioxide from the air, and energy is supplied by sunlight and transformed by chlorophyll, in a reaction medium of water supplied by the roots. To complicate matters further, most of the mineral nutrients combine with the products they help to manufacture, and perform other functions in other parts of the plant. One of the purposes in analyzing leaves for mineral content, then, is to attempt to judge the completeness and balance of the mineral portion of machinery used for food manufacture during growth and fruiting.

Laboratory and sand-culture studies have indicated that the 12 mineral elements known to be essential for normal plant growth interact with each other and with such environmental factors as light, temperature, and moisture supply in highly complex ways (Shear et al, 1946; Ulrich, 1948). Because of these and other complexities, it does not seem possible to establish universally applicable simple, clear-cut standards of classification for deficient, optimum, and excess ranges of concentration for the various minerals in plant tissues. In commercial crop production, however, the number of factors, nutritional or environmental, subject to appreciable influence by practical cultural methods is limited. Furthermore, many nutrient elements are fixed between relatively narrow limits by native supplies in the soil. Thus, it is usually possible with a given crop to determine empirical standards of composition for leaves or other tissues which are useful in a fairly broad region and range of soil types for determining which essential mineral elements are likely to be limiting or otherwise unfavorably influencing productivity. In the Rio Grande Valley, as in other irrigated regions, fruit growers are also concerned with certain elements not known to be essential, such as sodium and chloride ions, but which may nevertheless interfere with normal growth if present in too great concentration in tissues.

Tissue analysis should not be regarded as a substitute for orchard fertilizer trials, but rather as a means of amplifying the usefulness of the results obtained from such tests, by making possible their application to a broader range of soil conditions. Well designed field fertilizer experiments form the primary foundations for the intelligent interpretation of tissue analysis. Neither should tissue analysis be regarded as a substitute for soil analysis. Information obtained from such data supplements that obtained from tissue analysis. Information from both of these sources may profitably be used in conjunction with that obtained from the past history of the orchard and current observations to give a diagnosis of maximal value for future operation.

Factors Influencing Mineral Composition of Citrus Leaves

Age of leaves and season: The data of table 1 show that citrus leaves change rapidly in composition as they mature. This change is most rapid during the first two or three weeks when they are growing rapidly in size.

TABLE 1. The effect of leaf age on nitrogen and mineral composition of spring-flush leaves of Valencia orange on Rough lemon stock in Florida[1]

Date of	Leaf age,	**Mean dry wt.	Mean** percent in dry matter					
Sampling	Weeks	per leaf, mg.	N	P	K	Ca	Mg	Na
2-27-48	1	26	4.58	.53	1.80	1.43	.375	.036
3-11-48*	3	75	3.58	.32	2.06	2.33	.408	.062
4-22-48	9	224	2.76	.24	1.66	3.05	.387	.076
6-4-48*	15	237	2.76	.19	1.44	3.83	.421	.074
7-16-48	21	245	2.41	.13	1.48	4.19	.423	.071
9-2-48	28	255	2.33	.13	1.20	4.14	.401	.071
10-21-48*	35	264	2.46	.14	1.12	3.92	.407	.089
12-8-48	42	268	2.60	.13	1.19	3.94	.404	.121
1-24-49	49	280	2.65	.14	0.99	3.94	.387	.143
LSD at .05		17	0.12	0.02	0.19	0.16	0.026	—

*Mixed fertilizer (low in K and Mg) applied 1 to 3 weeks before these sampling dates.

**Mean of values obtained from analysis of five samples obtained from five replicate plots of uniform 6-year-old trees in a vigorous commercial orchard, all receiving the same fertilizer treatment. See table 6 for interpretation of the chemical symbols used for each element.

[1] From data of Smith and Reuther (1949, b)

Between about 3 and 6 months of age, the leaves appear to be in the prime of life and the concentration of most mineral constituents in them does not change rapidly. After this, old age sets in, and some constituents decline in concentration, while others, such as calcium, sodium, and chlorine, accumulate. It will be noted from table 1 that a moderate fertilization in May is followed by a decline in nitrogen content of the leaf during late spring and summer, presumably because it is utilized in leaf and fruit growth. After a similar fertilization in early October, the nitrogen content of the leaf increases during late fall and winter, thus indicating considerable activity in nitrogen uptake by citrus roots while the top is relatively dormant. When the bloom flush is produced in the early spring, nitrogen will again decline in these old leaves (Smith and Reuther, 1949, b) because of utilization by the developing new leaves and flowers which they subtend. Thus leaves are in some degree reservoirs for nitrogen and mineral elements which may be utilized in growth and fruiting. Other studies (Chapman and Parker, 1942; Roy and Gardner, 1945) have shown that whereas nitrogen may be taken up by roots almost as actively during late fall and winter as in other seasons, calcium, potassium, magnesium, and phosphorus are not. These are taken up most actively from early spring to late summer. However, it must be recognized that in a given season, uptake by roots and concentration in leaves are not always intimately related because of utilization by the crop and new growth.

The type of season — the amount and distribution of rainfall, temperature conditions, amount of sunlight, and so forth — also influences the composition of leaves, probably because these factors affect root activity, top growth, and fruitfulness. Work with deciduous fruit trees (Cain and Boynton, 1948) as well as with citrus (Chapman and Brown, 1950) has shown that crop load may have an important bearing on leaf composition.

Rootstock: The data summarized in table 2 show that rootstock influences the concentration of major elements in leaves appreciably, but affects the concentration of "trace," or micro-nutrient, elements, even more. The effects of rootstock on composition of scion leaves are probably caused in part by differences in rooting habit or distribution in the various soil layers (Savage et al, 1945), and in part by some inherent differences among the various stocks in selectivity of the nutrient-absorbing root tissue.

TABLE 2. The effect of rootstock on trunk circumference, leaf weight, ash, and mineral composition of foilage of 5-year-old Valencia orange trees[1].

Rootstock	Trunk circ. (mm.)	Leaf wt. (mg.)	Mean[2] percent in dry leaves: Ash	N	P	K	Ca	Mg	Mean[2] parts per million in dry leaves: Mn	Cu	Fe	B	Zn	Na
Sour orange	165	267	10.49	2.55	0.136	2.11	2.26	0.488	69.0	4.97	74.7	67.3	16.7	485
Grapefruit	210	264	11.23	2.56	0.141	2.62	2.11	0.369	62.3	5.62	59.3	93.6	21.7	514
Cleopatra	212	292	10.60	2.50	0.140	1.97	2.33	0.482	87.7	5.30	87.3	81.1	33.7	489
Sweet orange	239	282	10.58	2.63	0.150	2.30	2.16	0.408	53.3	7.28	81.7	84.1	18.7	515
Rusk citrange	245	272	10.44	2.81	0.145	1.76	2.41	0.514	80.2	8.34	125.9	94.6	19.7	527
Rough lemon	288	308	10.89	2.74	0.141	1.98	2.44	0.510	85.0	5.32	101.6	79.7	20.3	497
Maximum diff. (percent)	75	17	8	12	10	31	16	39	65	68	112	41	102	9
Sig. of treat.	**	**	**	**	*	**	**	**	**	**	**	**	**	—
L S D at .05	27	20	0.38	0.13	0.010	0.22	0.20	0.049	14.7	2.24	13.3	13.1	4.8	—

[1] From data of Smith, Reuther, and Specht (1950)

[2] Mean of 9 values obtained from 9 samples from 9 replicate plots in each case.

* Signifies that the odds for significance exceed 19:1, but are less than 99:1.

** Signifies that the odds for significance exceed 99:1.

L S D Signifies the least difference for significance between any two means, with odds of 19:1.

The data of table 2 were obtained from a rootstock experiment located on light, sandy soil typical of that used for citrus culture in central Florida. You will note that sour orange produced the smallest trees, and Rough lemon the largest, while those on Cleopatra were intermediate in size. A few years hence, when similar data are obtained from some of the cooperative rootstock experiments set out in Texas by Dr. Cooper, it is probable that the relative growth of the scion variety will present a different picture in the heavier, more fertile soils of the Rio Grande Valley. However, in most instances the rootstocks will doubtless show the same selectivity indicated by these Florida studies in taking up the various nutrients. For example, sour orange rootstock produces lower boron content of leaves than Cleopatra in Florida. Similar studies in Texas (table 3) indicate that this same relationship holds. This selectivity of rootstocks to uptake of such ions as boron and chloride may be an important factor in the choice of stocks for commercial planting in the Rio Grande Valley.

Scion: Not only rootstock but also scion variety affects the mineral composition of leaves. Thus, studies in Texas (table 3) indicate that leaves of Shary grapefruit trees on Cleopatra stock are richer in potassium and calcium than leaves of comparable Valencia trees on the same stock. A similar relationship holds for these varieties on sour orange stock. Studies in California (table 3) show that leaves of Navel orange on sour orange stock are richer in nitrogen, phosphorus, and potassium and lower in calcium than comparable Valencia leaves on the same stock. The same relationship holds for Rough lemon stock.

TABLE 3. The effect of scion on the nitrogen and mineral composition of citrus foliage

Scion and	Mean percent in dry matter						Parts per Million	
Rootstock	N	P	K	Ca	Mg	Na	Cl	B
Texas data of Cooper, Gorton, and Olson (1950)								
Valencia on Cleopatra	—	—	1.98	3.60	0.28	0.10	0.25	203
Shary on Cleopatra	—	—	2.46	4.07	0.27	0.27	0.17	250
Valencia on sour orange	—	—	2.78	3.10	—	0.15	0.31	130
Shary on sour orange	—	—	3.02	4.03	0.17	0.25	0.26	180
California data of Chapman and Brown (1950)								
Valencia on sour orange	2.20	0.096	0.42	6.75	0.44	—	—	—
Navel on sour orange	2.79	0.120	0.80	5.43	0.37	—	—	—
Valencia on Rough lemon	2.63	0.114	0.44	5.37	0.48	—	—	—
Navel on Rough lemon	2.85	0.120	0.64	4.86	0.48	—	—	—

These effects of scion on leaf composition are probably due largely to inherent differences in metabolism and structure among varieties, and possibly in part to the effect of the scion on the selectivity of the rootstock. It is clear that the influence of both scion and rootstock must be considered in attempting to evaluate the probable nutritional adaptation of a particular scion-rootstock combination, and in interpreting the mineral analysis of its leaves.

TABLE 4. A comparison of the analysis of leaves from commercial Valencia orange orchards in Texas, Florida, Arizona, and California. Spring-flush, non-fruiting terminals sampled in the summers of 1947 and 1948[1]

Region and No. of Samples	Location	Range	Mean dry wt. per leaf mg.	Percent in dry matter N	P	K	Ca	Mg	Na	Parts per million in dry matter Zn	Cu	Fe	Mn	B
Texas 1	Rio Farms	—	357	2.50	0.11	0.87	5.4	0.33	0.06	26	7	82	28	89
1a*	" "	—	292	2.58	0.13	1.58	4.8	0.27	0.05	26	10	40	12	131
2**	" "	—	196	2.50	0.15	0.72	4.9	0.36	0.06	22	7	53	22	62
3	Elsa	—	263	2.30	0.12	0.46	5.5	0.31	0.12	20	10	64	24	194
4	"	—	181	2.40	0.15	0.72	4.0	0.32	0.08	26	8	78	27	239
5	McAllen	—	232	2.40	0.12	0.46	3.3	0.29	0.03	20	9	62	21	125
6	Los Fresnos	—	271	2.40	0.11	0.57	5.9	0.30	0.17	22	10	105	29	55
7**	" "	—	256	2.12	0.11	0.61	5.2	0.36	0.17	24	10	77	32	118
8	" "	—	270	2.02	0.10	1.18	5.7	0.32	0.11	24	10	57	31	80
9**	Harlingen	—	221	2.02	0.12	0.65	5.6	0.33	0.09	18	11	74	48	91
10	Weslaco	—	275	2.30	0.12	1.08	5.8	0.26	0.05	19	11	71	30	111
		Mean	252	2.30	0.12	0.73	5.1	0.32	0.09	22	9	69	28	118
Florida 37 locations	Central Pinellas	Max.	336	3.00	0.16	2.20	5.5	0.51	0.09	30	10	102	85	305
		Min.	231	2.15	0.11	0.95	2.3	0.29	0.04	16	5	36	20	33
		Mean	285	2.66	0.14	1.56	3.4	0.39	0.05	21	7	61	37	92
Arizona 17 locations	Salt River Yuma	Max.	273	2.68	0.17	1.65	5.4	0.64	0.14	25	11	47	34	294
		Min.	164	1.82	0.12	0.72	2.4	0.26	0.02	8	5	18	7	47
		Mean	216	2.16	0.15	1.22	4.2	0.35	0.04	15	9	36	13	108
Calif. 10 locations	Imperial Riverside Los Angeles	Max.	306	2.75	0.17	1.53	4.8	0.33	0.03	33	10	64	17	87
		Min.	168	1.92	0.12	0.31	2.7	0.18	0.02	8	5	30	9	30
		Mean	234	2.42	0.14	0.71	4.0	0.27	0.02	18	8	45	13	57

[1] From data of Reuther, Smith, and Specht (1949).
* Chlorotic leaves.
** Low-vigor orchards associated with saline soil and imperfect drainage.

Region: The data summarized in table 4 compare the composition of Valencia orange leaves in Texas with results obtained in a similar manner in other citrus-growing States. The data indicate that leaf composition in Texas orchards is more like that of California and Arizona than of central Florida. This would be expected since the western soils used for citrus are primarily of the calcareous type common in semi-arid regions where irrigation is necessary, and the citrus soil of central Florida is of the acid, highly leached, sandy type common in the humid coastal plain region of the Southeast. Perhaps the outstanding difference is the higher calcium and lower potassium level in leaves from Texas and the other western states as compared with those from central Florida. Phosphorus and magnesium levels do not vary greatly in the several regions compared, except that a few low-phosphate orchards were encountered in Texas, and a few low-magnesium orchards in California.

The heavy metals zinc, copper, manganese, and iron occur in about the same concentrations in Texas orchards as in central Florida, but are higher than in the Arizona or California orchards sampled. None of the orchards sampled in this survey showed symptoms of boron excess or deficiency. The range in boron content of Texas leaves was not greatly different from that found in Florida or Arizona leaves, but was somewhat higher than for the California samples.

Fertilizer treatment: A basic assumption in the use of leaf analysis is that a deficiency or low availability of a specific nutrient element in the soil will be reflected by a low concentration in the leaves, when other nutrient levels (and such factors as temperature, light, soil moisture, and soil aeration) are favorable for satisfactory growth and yield. Moreover, if the nutritional disturbance has not progressed too far, adding to the available supply of fertilization, nutritional sprays, or injection will increase the concentration in leaves and other tissues. The data in table 4 and a large volume of similar data in the literature (Chapman and Brown, 1950; Goodall and Gregory, 1947; Lilleland, 1946; Ulrich, 1948) substantiate this assumption but emphasize that there are many interrelationships among nutrients which tend to complicate matters.

In table 5 yield and leaf analysis data are summarized for a field fertilizer experiment with young, bearing Valencia orange trees on Rough lemon stock on light, sandy soil. The purpose of this experiment was to study the effects of three major fertilizer elements — nitrogen, potassium and magnesium — on growth, yield, and fruit quality, and to relate these to leaf composition. Fertilizer elements other than these three were applied uniformly to all plots. The data summarize the primary effects produced by three rates of application of each fertilizer element.

The data obtained for the 1948-49 season indicate that yield and nitrogen content of the leaf increased as the rate of nitrogen applied to the soil increased. A similar effect was produced by potassium; but the yield increase was relatively small and due mainly to increased fruit size. Heavy magnesium fertilization did not improve yield, but did increase magnesium in the leaf.

TABLE 5 The effect of fertilizer treatment on yield and on nitrogen and mineral composition of foliage of six-year-old Valencia orange trees in Florida[1]. 1948-49 Season

Treatments and statistical Indices	Mean yield lbs. per tree	Mean percent in dry matter N	P	K	Ca	Mg	Mean dry wt. per leaf mg.
Low N	80	2.16	0.153	1.83	3.65	0.366	276
Med N	111	2.33	0.140	1.64	3.81	0.392	279
High N	138	2.54	0.134	1.42	3.86	0.414	286
F value	***	***	***	***	**	***	N.S.
Low K	103	2.38	0.145	1.30	4.03	0.409	288
Med. K	106	2.31	0.137	1.67	3.70	0.394	280
High K	120	2.35	0.142	1.91	3.58	0.368	274
F. value	***	**	**	***	***	***	*
Low Mg	105	2.36	0.138	1.67	3.73	0.368	281
Med. Mg	113	2.32	0.145	1.62	3.80	0.388	279
High Mg	112	2.34	0.141	1.60	3.79	0.416	280
F value	N.S.	N.S.	*	N.S.	N.S.	***	N.S.
L S D at .01	12	0.06	0.007	0.09	0.20	0.019	—

[1] From data of Reuther and Smith (1950).

Statistical indices:

N.S. indicates that the effect of treatment is not significant.

L S D at .01 is least difference between any two means required for significance by odds of 99:1.

* indicates significance by odds of at least 19:1.

** indicates significance by odds of at least 99:1.

*** indicates significance by odds of at least 999:1.

Further examination of these data show that not only did the rate of fertilization with nitrogen, potassium, and magnesium affect the respective concentrations of these elements in the leaf, but other nutrient elements also were affected. Thus, heavy nitrogen fertilization increased not only nitrogen in the leaf but also the concentration of calcium and magnesium, and depressed phosphorus and potassium. Similarly, increasing the rate of potassium fertilization increased leaf potassium, but depressed calcium and magnesium, and did not consistently affect nitrogen or phosphorus. The above secondary effects of these nutrients also have been established by other workers with citrus (Chapman and Brown, 1950; Finch and McGeorge, 1945) and other tree crops (Cain and Boynton, 1948).

To illustrate how the level of one element may influence the effects of other elements on yield response and leaf composition, let us assume that the magnesium level in the soil of this experiment was deficient and the magnesium content of the leaves from the low-magnesium plots was about half of the value actually obtained. Doubtless, yield response to medium and heavy magnesium fertilization would then have been obtained. In addition to this expected primary effect of the hypothetical magnesium deficiency on yield response, certain secondary ramifications would also be probable. A further breakdown of the yield data could be expected to show that at the low rate of magnesium fertilization associated with deficiency, heavy potash fertilization would depress yield because it would repress magnesium uptake and aggravate the deficiency, and the rate of nitrogen fertilization would have little or no effect on yield.

These data tend to show that standards of leaf composition for classifying a plant or an orchard as inadequately, adequately, or excessively supplied with a particular nutrient cannot be set up without regard for the supplies of other nutrients. Except in cases of extreme deficiency or excess, it is necessary to consider the pattern formed with other elements, or the nutrient balance (Shear et al, 1946), to classify the nutrient status of the plant by means of leaf analysis.

Interpretation of Leaf Analysis

As a result of extensive studies in California Chapman and Brown (1950) have proposed the tentative standards for nutrient status classification of orange leaves presented in table 6. These authors also point out some of the same interrelationships of elements discussed in the previous section. In general, our studies tend to confirm these standards with the exception of potassium. The critical value for the beginning of deficiency, in terms of growth and yield for this element, appears far too low, although definite leaf symptoms may not occur above this level. Likewise, with the elements nitrogen, magnesium, phosphorus, iron, manganese, zinc, copper, and boron there is no question that definite deficiency symptoms usually occur in the deficiency range proposed, but our studies suggest that vigor and productivity reduction may begin at slightly higher levels in most cases. Studies now in progress should eventually clarify some of these matters.

TABLE 6. Tentative standards proposed by Chapman and Brown (1950) for nutrient status classification of mineral element concentrations in 3- to 7-month-old spring-cycle orange leaves.

Element and symbol	Dry matter basis	Deficient less than	Normal range[1]	Excessive, more than
Nitrogen (N)	Percent	2.0	2.0 to 3.2	3.5
Phosphorus (P)	Percent	0.08	0.09 to 0.18	0.40
Potassium (K)	Percent	0.35	0.4 to 1.1	2.0
Calcium (Ca)	Percent	1.5?	3.0 to 5.5	7.0
Magnesium (Mg)	Percent	0.15	0.2 to 0.4	0.6
Sodium (Na)	Percent	0.0*	0.02 to 0.15	0.25
Sulfur (S)	Percent	0.13	0.2 to 0.3	0.4
Chlorine (Cl)	Percent	0.0*	0.02 to 0.2	0.25
Iron (Fe)	p.p.m.[2]	50	70 to 200	?
Manganese (Mn)	p.p.m.	15	20 to 80	200
Zinc (Zn)	p.p.m.	15	20 to 80	?
Boron (B)	p.p.m.	12	20 to 100	200
Copper (Cu)	p.p.m.	4	4 to 10	15

[1] The range found in high-yi lding orchards in California

[2] Parts per million

* These elements are not known to be essential for normal tree growth

Of all the major nutrient elements, nitrogen has the most overriding influence on leaf analysis interpretation. If the nitrogen level is not known, it is almost pointless to attempt to classify the status of any of the other nutrients. Furthermore, an analysis of leaves for nitrogen at one time during the season does not always bear a definite relationship to the over-all course of nitrogen nutrition during the season. From the standpoint of obtaining good yield, it is important that a high nitrogen level prevail during the bloom and set period in the Spring. A temporary slight deficiency during late summer would not be so detrimental to yield as one occurring in the early spring, for example.

Fortunately, with tree crops most of the major elements are not thus subject to major changes in classification status during the course of one season, and data obtained from a single sampling in midsummer, for example, reflects more accurately the current season's status of the tree with respect to elements other than nitrogen.

An example of the kind of information that can be secured from analysis of leaves will be obtained from a comparison of Texas samples 1, 1a, 5, and 8 in table 4. In sample 1, all nutrients appear to be in a range favorable for satisfactory vigor and productivity. In sample 1a, iron and manganese appear to be deficient, and this probably is related to the chlorosis noted. Corrective measures would first involve examination of soil texture, pH, and drainage conditions in this part of the orchard. In sample 5, potassium may be somewhat low for maximum yield and best fruit size, and the value of heavy potash fertilization should be tested. In sample 8, nitrogen is obviously quite low, and probably phosphorus also. Had nitrogen been high in this sample, no particular significance would be attached to a phosphorus level of 0.10 percent, since heavy nitrogen is known to depress phosphorus concentration in leaves. In this orchard, nitrogen and phosphorus fertilization might profitably be tested.

So far we have dealt mainly with the interpretation of orange leaf analysis. This is because we have more information on oranges than on other citrus types. It remains for future studies to develop standards for grapefruit. However, it is not anticipated that more than minor adjustments will be necessary, possibly somewhat lower nitrogen and higher potash and calcium than for oranges, or for most deciduous fruits for that matter. The strong effects of rootstock and scion should be borne in mind in predicting the nutritional performance of a particular combination in a soil known to be deficient in a particular element. Thus, on a boron-deficient soil it might be expected that Shary grapefruit on sour orange stock would not fare as well as Shary on Cleopatra (table 3).

Analysis of Fibrous Roots

Studies in California (Lilleland, 1946), Texas (Cooper et al, 1950), and Florida (Nagpal, 1949) suggest that in some instances certain elements, such as sodium, chlorine, and certain heavy metals, may accumulate in large quantities in fibrous roots without a proportionate accumulation in leaves. These accumulations may interfere with the normal uptake of other nutrients. It is likely that future developments will point to the desirability of having analysis of fibrous roots for certain elements to supplement leaf analysis data.

Collection and Preparation of Leaf Samples

Just what type of leaves or other tissues will best indicate nutritional status of most elements is a problem that has not been fully explored with citrus. However, for the present it is suggested that samples be collected from mature, non-fruiting, spring-flush leaves without selection as to whether or not such leaves subtend a new flush of growth. In other words, if little new growth is present on the tree sampled, then most of the terminals sampled would not subtend new growth. On the other hand, if new growth were prevalent, then most of the terminals sampled would subtend new growth. These samples should be obtained about June 15 to August 15 when the bloom flush occurs during February or March. After a little experience, this flush can be readily recognized by matching the gloss, color, and size of these leaves with those subtending spring-bloom fruit. Frequently spray residues help to mark leaves of a certain age. The importance of sampling leaves of a definite age cannot be overemphasized. Leaves of the June or July flush may be sampled in a similar manner between October 15 and December 15. Summer-flush leaves are usually larger than spring-flush leaves and differ slightly in their mineral composition (Smith and Reuther, 1949, b).

In sampling an orchard it is usually desirable to obtain leaves from at least two groups of trees in each portion of the orchard to be sampled. Usually it has been found satisfactory to collect about 50 leaves per sample in an ordinary paper bag, obtaining 1 leaf from each of 10 terminals well distributed around a tree, and combining these with leaves similarly obtained from four more trees. Any normal, undamaged leaf on the terminal may be taken. Trees sampled should be uniform and in a compact group so that they represent a particular condition or problem area in the orchard. Comparison of problem area samples with those obtained in a more normal portion of the orchard is frequently helpful.

If only the major nutrient elements are to be assayed, wiping the leaves with a moist cloth will be adequate cleansing. If the heavy metals are to be assayed, then it is usually necessary to wash the leaves in an acidified detergent (Smith et al, 1950), particularly when spray residues are present. Leaves are then dried in paper bags in an oven at 50 to 65 C., and ground to a fine powder in a suitable mill before analysis. For major elements, the analytical methods used in our Orlando laboratory (Smith and Reuther, 1949, b) have proved convenient and satisfactory.

Summary

This paper brings together and reviews pertinent information in the literature concerning the value and limitations of tissue analysis as an aid in evaluating the nutritional status of citrus trees. The influences of such factors as leaf age, season, rootstock, scion, and fertilizer treatment are discussed in relation to effects on leaf composition. It is suggested that analysis of fibrous roots may also be of value in evaluating the status of the heavy metals and salinity. Data are presented comparing the analyses of leaves from some representative Texas orchards with those from other citrus sections in the United States. Tentative standards proposed in the literature for classification of the nutrient status of orange leaves are presented and discussed in the light of other work. A suggested interpretation of the analyses of a few leaf samples obtained in Texas orchards is presented. A method of colecting and preparing citrus leaf samples for analysis is outlined.

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Salt Tolerance of Various Citrus Rootstocks[1]

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INTRODUCTION

Previous studies of the salt tolerance of citrus rootstocks have shown that the Cleopatra mandarin rootstock has greater salt tolerance than the sour orange (Cooper et al, 1948 and 1950). When Shary Red grapefruit and Valencia orange trees on Cleopatra mandarin and sour orange rootstocks were grown in soil plots irrigated with a 5000 parts per million salt solution (50-50 mixture of sodium chloride and calcium chloride (NaCl and CaCl2), salt-excess leaf symptoms as indicated by necrosis and defoliation were more severe on the trees with sour orange rootstock than on those with Cleopatra mandarin rootstock. Associated with these differences in leaf injury were differences in the accumulation of chlorides in the leaves. The concentration of chlorides in the leaves of trees on sour orange was twice as great as the concentration of chlorides in the leaves. The concentration of chlorides in the leaves of trees on sour orange was twice as great as the concentration of chlorides in the leaves of trees with Cleopatra rootstock. In these tests the roostock did no appear to influence greatly the accumulation of sodium and calcium in the leaves.

A systematic study of the salt tolerance of a large number of scion-rootstock combinations is now in progress. The present paper reports results of tests on Shary Red grapefruit growing on twenty different rootstocks. The effects of excessive salt treatment on leaf damage and the accumulation of chlorides in the leaves are presented.

PROCEDURE

The seeds of the citrus varieties used as rootstocks were planted January 27, 1948, and the resulting seedlings were transplanted to the nursery on September 28, 1948. The seedlings were budded with Shary Red grapefruit scions on April 29, 1948. The resulting trees had trunks of approximately half-inch diameter when transplanted to the test plot area on January 2, 1949.

Each test plot was fifteen feet square, containing five rows of trees with five trees per row. A strip of asphalt gravel siding, providing a root barrier eighteen inches deeper than the ground level, was placed around each plot.

Five trees of each of five different rootstocks were planted in a latin square design in each of the fifteen plots. Sour orange was included as a standard or control in each plot. Thus, only four test rootstocks were included in each plot and five plots were required for a single irrigation treatment of the trees on the twenty different rootstocks.

[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 the U.S. Regional Salinity and Rubidoux Laboratories is gratefully acknowledged.

The irrigation treatments used in this planting included:

1. Untreated (Rio Grande water which contained approximately 750 p.p.m. salt)
2. Salt added (50-50 mixture of NaCl and CaCl2 added to the Rio Grande water to make 4000 p.p.m. salt)
3. 6 p.p.m. boron

Only the results of treatments 1 and 2 are reported in this paper. The results of the boron tests will be reported in a separate paper.

The salt solutions were prepared and applied to the plots as described in a previous report (Cooper et al, 1950). All plots were irrigated at the same time with approximately two and three-quarter inches of the respective test solutions at fifteen-day intervals from May 31, 1950 to September 30, 1950, a period of seventeen weeks. During this period only about one-half inch of rain fell in the test plot area. The soil of the test plot area was a Brennan fine sandy loam with a pH of 7.0.

Leaf samples were collected from the trees on July 21, 1950, and September 22, 1950. Five leaves were selected from spring-flush twigs of each tree. A composite sample was made of the leaves from the five trees of each rootstock in a single plot.

The leaves were wiped with a moist cloth, rinsed with distilled water, oven-dried at 75°C., and ground to a fine powder in a Wiley mill. Chlorides were determined by the standard A.O.A.C. (1945) procedure for the plant tissue.

RESULTS

Typical salt-excess leaf and plant symptoms (Cooper et al, 1950) were observed to occur in varying degree on the trees of the various rootstocks growing in the plots irrigated with salt solutions. These symptoms included leaf necrosis, defoliation, and terminal shoot necrosis. For purposes of rating the severity of salt-excess damage the following numerical classifications were used:

0–No obvious salt injury
1–Slight injury–some leaf necrosis but no defoliation
2–Moderate injury–prevalent leaf necrosis and partial defoliation
3–Severe injury–almost complete defoliation
4–Very severe injury–complete defoliation and dying back of twigs.

The data for severity of salt-excess damage on the trees irrigated with the salt solution, as observed on September 15, 1950, is shown in Table

Table 1. Severity of salt-excess injury and concentration of chlorides in leaves of Shary Red grapefruit on different rootstocks in plots irrigated with a solution containing 4000 p.p.m. salt.

Rootstock variety	Severity of injury[1]	Conc. of Chlorides, % in leaves, dry weight basis
Plot A—Concentration of salts[2] in saturation extract of soil—2800 p.p.m.		
Sour orange	1.2	1.8
Williams tangelo	1.2	1.4
Minneola tangelo	1.4	1.5
Sampson tangelo	2.2	1.6
Florida sweet orange	3.2	2.5
Plot B.—Concentration of salts[2] in saturation extract of soil—2500 p.p.m.		
Sour orange	2.6	2.5
Pineapple orange	2.4	2.4
Cuban shaddock	2.0	2.3
Nakorn pummelo	2.4	1.8
Duncan grapefruit	1.6	1.7
Plot C—Concentration of salts[2] in saturation extract of soil—3010 p.p.m.		
Sour orange	1.6	2.4
Rough lemon	1.4	1.4
Rangpur lime	*0.2*	*0.4*
Sweet lemon	1.6	1.9
Columbian sweet lime	1.4	2.6
Plot D—Concentration of salts[2] in saturation extract of soil—2380 p.p.m.		
Sour orange	1.4	1.8
Cleopatra mandarin	*0.4*	*0.7*
Calamondin	1.6	2.1
C. noblis	1.0	1.6
Rusk citrange	2.2	2.9
Plot E.—Concentration of salts[2] in saturation extract of soil—2660 p.p.m.		
Sour orange	1.2	1.5
Trifoliate orange	3.4	2.7
Severinia buxifolia	*0*	*0.6*
Citron	3.8	3.5
Citrumelo No. 4475	1.0	1.9

[1] See text for key to severity of injury
[2] Determination made on soil samples of the upper two feet of soil taken on July 21, 1950.

1. It is seen that trees on a number of rootstocks showed about the same severity of damage as that occurring on sour orange rootstock. Trees on other rootstocks, however, showed less damage in some cases and more damage in other cases than developed in trees on sour orange.

In classifying the various rootstocks according to their salt tolerance, the large variation observed in the response of the sour oranges in the different plots has to be considered. It is seen that the damage varies from the numerical value of 1.2 for trees on sour orange in plot E to 2.6 for trees on sour orange in plot B. It appears that these differences in plant response are not due to differences in soil salinity. The plots were all irrigated with the same 4000 p.p.m. salt solution. The salt concentration of the extract of the saturated soil for these two plots was very near the same, being 2660 p.p.m. for plot E and 2500 p.p.m. for plot B. These differences in the response of the trees on sour orange seems to be the magnitude of the experimental error for this experiment.

For the purposes of this discussion, rootstock combinations showing salt-excess injury within the range shown by the sour rootstocks in the five different plots will be considered as having practically the same degree of salt tolerance as sour orange.

The rootstocks falling into the same group as sour orange include Williams tangelo, Minneola tangelo, Sampson tangelo, Pineapple orange, Cuban shaddock, Nakorn pummelo, Duncan grapefruit, Rough lemon, sweet lemon, Columbian sweet lime, Calamondin, and Rusk citrange. The damage to trees on citrumelo No. 4475 and *Citrus nobilis* was so near that of sour orange that they, too, may be classed with this group.

In contrast to the above group the salt injury to trees on Cleopatra mandarin, *Severinia buxifolia,* and Rangpur lime was sufficiently less than that observed on any tree on sour orange for these rootstocks to be considered as being more salt tolerant than sour orange. The rootstocks of trees showing more salt damage than trees on sour orange include Florida sweet orange, trifoliate orange, and citron. The damage was severe on trees with these three rootstocks, most of these trees being dead or nearly dead on September 21, 1950.

The concentration of chlorides in the leaves from samples taken on July 21, before excessive defoliation had occurred on any tree, are also given in Table 1. It is seen that in general there is a close correlation between tree damage and chloride accumulation in the leaves. The concentration of chloride in leaves of trees on sour orange rootstock varies from 1.5 to 2.5 percent of dry matter, while that of leaves of trees on the three salt-tolerant rootstocks ranged from 0.4 to 0.7 percent, and that of the three intolerant rootstocks ranged from 2.5 to 3.5 percent. The 2.9 percent chloride in the leaves of trees on Rusk citrange suggests that this rootstock may be less tolerant of salt than is sour orange.

Chloride determinations made on leaf samples taken on September 30, 1950 show higher values for all rootstocks than were obtained in the July 21 samples, but practically the same differences among rootstocks were evident. The values for sour orange ranged from 2.0 to 2.7 percent, while Rough lemon was 3.0 percent, Rangpur lime 1.1 percent, Cleopatra mandarin 1.9 percent and Severinia 0.7 percent.

Leaf necrosis was not observed on any trees in the untreated plots. Concentrations of chlorides in the leaves were in all instances considerably lower than in the leaves on trees in the salt plots. The concentration in leaves of trees on Rangpur lime, Cleopatra mandarin, and *Severinia* was 0.1 percent while the concentration in leaves of trees on sour orange was 0.4 percent and that of trees on Florida sweet orange and citron rootstocks was 0.9 percent.

DISCUSSION

These tests indicate that the Cleopatra mandarin rootstock is more salt tolerant than the sour orange stock and corroborates the results of two previous tests with these rootstocks. The tests also reveal that the Rangpur lime and *Severinia buxifolia* rootstocks are salt tolerant.

The tolerance of *Severinia buxifolia* corroborates Swingle's (Webber, 1948) observation that this species is very resistant to salt injury. Whether it has promise as a rootstock for commercially grown citrus is open to question. Webber (1948) reports results with trials of *Severinia buxifolia* as a rootstock for Marsh grapefruit at Riverside California. All were living at the end of the tenth year in the grove. The trees were loaded with smooth, good-sized fruit, but the yield per tree was small because the trees were dwarfed. The recent discovery (Grant et al, 1949), that sweet orange trees on *Severinia buxifolia* rootstock are susceptible to tristeza virus disease eliminates this variety from serious consideraton at the present as a rootstock for the Rio Grande Valley.

The Rangpur lime, unlike *Severinia*, is known to be tolerant of tristeza. The grapefruit trees on this rootstock looked the best of all trees in these tests. The trees had normal green leaves and were growing vigorously in the saline soil, while trees on sour orange, Rough lemon, sweet lemon, and Columbian sweet lime rootstocks in the same plot were defoliated and some were dying.

Shultz (1939) reports that in Tucuman, Argentina, the Rangpur lime has given promise of being a good rootstock for varieties of the sweet orange, grapefruit, and mandarin. In Argentina this rootstock tends to stimulate fruiting at an early age and gives good yields of high quality fruit. In Brazil (Webber, 1948), however, trees on Rangpur lime were found to grow well for only a few years and then gradually decline. Klotz and Fawcett (1930) and Brieger and Moreira (1945) report the Rangpur lime as being highly susceptible to *Phytophthora* gummosis. In Java, Ochse (1931) reports that the Rangpur produces a high percentage of nucellar seedlings and has proved a valuable rootstock for grapefruit.

The Rangpur has not been adequately tested as a rootstock in the United States. It has, however, been included in all of the new rootstock plantings in the Rio Grande Valley. In the three-year-old grapefruit planting at Weslaco, trees on Rangpur have grown as vigorously as trees on sour orange and rough lemon stocks and these trees are tolerant of the chlorosis disorder of this area (Cooper and Olson, 1950). However, quite recently lesions of an unidentified cause have appeared on the trunk below the bud union of these trees. Until the Rangpur lime has been more thoroughly tested, it should not be used in commercial plantings.

The lack of salt tolerance shown by the sweet orange rootstock in these tests, coupled with the susceptibility of grapefruit on sweet orange rootstock to lime-induced iron chlorosis (Cooper and Olson, 1950), practically eliminates this variety from further consideration as a promising rootstock for this area.

The lack of salt tolerance shown by the trifoliate orange rootstock may explain in part the reported (Hume, 1909) unadaptability of this variety to the Rio Grande Valley. Other factors, however, may also be involved.

The response of the Nakorn pummelo, which was salt intolerant, did not conform with previous observations on this species by Reinking and Groff (1921). They report that pummelos of the highest quality were grown in the Nakorn Chaisri region of Thailand where a high concentration of salt was present in the irrigation water and soil. Analysis of the water showed the presence of 20,000 p.p.m. salt, whch is five times the salt concentration of the irrigation water used in this test. The surface soil and subsoil of the pummelo groves contained from 0.8 to 2.5 percent salt. No mention was made by Reinking and Groff of any indications of salt-excess leaf symptoms. This apparent salt tolerance of the pummelo in Thailand was not observed in these trials where the pummelo was used as a rootstock. Possibly a pummelo seedling, as in the case of the trees reported on by Reinking and Groff, might show more salt tolerance than a pummelo rootstock with a grapefruit scion. Also different varieties of pummelos may vary in their response to excess salt. In the absence of a chemical analysis for chlorides of the leaves of the trees in Thailand it is difficult to compare the Thailand and Rio Grande Valley data.

SUMMARY

One-year-old nursery stock of Shary Red grapefruit on twenty different rootstocks were grown for seventeen weeks under differential salt treatments. These treatments included untreated Rio Grande water and Rio Grande water to which a 50-50 mixture of sodium chloride and calcium chloride was added to make a 4000 p.p.m. salt concentration. The chloride content of the leaves and the severity of injury to the leaves of the grapefruit scion were used as indicators of salt tolerance.

Cleopatra mandarin, *Severinia buxifolia*, and Rangpur lime rootstocks were found to be more salt tolerant than sour orange. Williams tangelo, Minneola tangelo, Sampson tangelo, Pineapple orange, Cuban shaddock, Nakorn pummelo, Duncan grapefruit, Rough lemon, sweet lemon, Columbian sweet lime, and Calamondin showed only moderate salt tolerance, or about the same degree as sour orange. The Florida sweet orange, trifolate orange, Rusk citrange, and citron were less tolerant than sour orange.

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Studies on the Transmission of Rio Grande Gummosis of Grapefruit[1]

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Rio Grande gummosis has been reported in grapefruit plantings in Texas (Godfrey, 1945), Florida (Childs, 1950), Arizona (Fawcett, 1948, a) and California (Klotz, 1950). The disease is characterized by gum exuding from gum pockets beneath blisters, usually on the trunk. The symptom most sharply distinguishing it from other trunk and branch diseases of citrus is the salmon-pink wood stain which extends irregularly beneath the blisters. The flat band of stained wood usually does not extend so far inward as the psorosis wood discoloration (Fawcett, 1948, a) and is less apt to run toward the center. Godfrey (1945) observed that the pink sapwood stain stopped at the bud union, and did not extend into the sour orange rootstock. Fawcett (1948, b) reported a single tree in which the wood stain extended beyond the bud union into the Rusk citrange rootstock. Godfrey (1945) considered that an actinomycete-like organism was the probable cause of the disease, although pure cultures of such an organism were not isolated from diseased tissue.

A study of the transmission of this disease is an important phase of the citrus rootstock problem in Texas for two reasons. First, any rootstock under consideration to replace the sour orange should not be susceptible to Rio Grande gummosis. Second, grapefruit trees with Rio Grande gummosis are not eligible for registration as a source of budwood for the propagation of certified trees in Texas (Waibel, 1950).

This article is a report of studies on the transmission of Rio Grande gummosis by inoculating apparently healthy grapefruit and Valencia trees with chips of naturally infected wood, gum, and bark.

A block of fifteen-year-old Marsh grapefruit and Valencia orange trees at Rio Farms, Monte Alto, Texas, were used in these experiments. No visible trunk symptoms of Rio Grande gummosis or psorosis were observed on the test trees used, although both diseases occur in the Rio Farms planting. (Apple et al, 1947). Inoculations were placed in large branches, 2 to 4 inches in diameter, and in twigs, one-half to ¾ inch in diameter. Inoculations were made in two ways, (a) by placing the inoculum into chisel cuts into the xylem, or wood, and (b) by placing the inoculum in the cambium region, between the bark and the wood, in the same manner as buds would be inserted into a "T" cut for the propagation of nursery trees.

In the first series of experiments, five different transmission materials were inserted into test grapefruit trees and the wounds were wrapped with "Floratape," a waxed paper preparation sometimes used in nursery

[1] These investigations are a part of a cooperative citrus rootstock project conducted by the U.S. Department of Agriculture and the Texas Agricultural Experiment Station, certain phases of which are being carried on under the Research Marketing Act of 1946. The cooperation of Rio Farms, Inc., is greatly appreciated.

practice in this area. Chips of apparently healthy wood were used as a control. The four sources of inoculum were the heavily colored pink-colored wood from the advancing border of the wood stain, buff colored wood with traces of pink wood from just behind the advancing border, gum exuded from the cracked blister, and bark adjacent to the crack through which the gum exuded. Two inoculations of each of the 20 different treatments were made in each of four trees. This experiment was repeated on three different 90 day periods, making a total of 480 inoculations in the first experiment. Three months after the inoculations were made, the lesions were chiseled open, and the length in millimeters of the pink wood stain was measured.

The results of the first experiment are given in Table 1. Certain generalizations can be made on the basis of these data.

1. Placement of inoculum between the bark and sapwood, in a manner similar to the technique used in budding, did not reproduce the pink wood stain symptom in a 90-day period.
2. Placement of inoculum into the wood reproduced the disease symptom within 90 days.
3. When inoculations were made into the wood of the larger branches, the pink wood stain occurred more often ,and the stain extended a greater distance than when inoculations were made in smaller branches or twigs.
4. The time of the year apparently influenced the transmission of of the disease. Inoculations in January reproduced the disease more often than did March inoculations, while few successful inoculations were obtained in June.
5. The occurrence of the pink wood stain in the control treatments in the wood inoculations made in January and March suggests that much of the infection in the wood inoculation was the result of a high incidence of natural infection. Therefore, any comparison of the relative efficiency of disease transmission by the four materials from diseased wood cannot be made from this experiment.

In a second series of experiments, greater care was exercised to prevent natural infection. The area adjacent to the point of inoculation was rubbed with a cloth moistened with a solution of 1-1000 mercuric chloride. The tools were flamed in alcohol. The inoculum was inserted in chisel cuts, and the incisions, except in one treatment, were covered tightly with adhesive tape.

The following treatments were used:

1. No inoculum, wound not taped.
2. No inoculum, wound taped.
3. Healthy grapefruit wood used as inoculum, taped.
4. Bark adjacent to gumming lesion of Rio Grande gummosis on grapefruit used as inoculum, taped.
5. Pink wood from Rio Grande gummosis lesion on grapefruit used as inoculum, taped.
6. Healthy orange wood inoculum, taped.
7. Pink wood from a wood stain of Navel orange used as inoculum, taped.

Each treatment was replicated 10 times on both twigs and branches. One series was inoculated into Marsh grapefruit and a second series was inoculated into Valencia orange, making a total of 280 separate inoculations performed on May 10. As in the first experiment, the inoculations were opened 90 days later.

The results of this second experiment, presented in Table 2, can be summarized as follows:

1. Natural infection in grapefruit, as indicated by pink wood stain symptom, occurred in the uninoculated-chisel cuts not covered by tape.
2. Taped, uninoculated chisel cuts in grapefruit did not become infected; when healthy grapefruit wood was used as inoculum no infection occurred.
3. The pink wood stain symptom occurred when the bark adjacent to gumming Rio Grande gummosis lesions was inoculated into grapefruit, but not where pink wood was used as inoculum in the same trees.
4. No pink wood stains were obtained in Valencia orange trees from any of the above-mentioned treatments.
5. Infection occurred in the branches, but not in the twigs, for the above treatments.
6. The above pattern of results from Table 2 are those expected if natural infection occurred in uncovered injuries in grapefruit wood. No natural infection occurred when these injuries were taped. The introduction of diseased tissue from grapefruit beneath the covered wounds reproduced the pink wood stain symptom in grapefruit.
7. The results obtained from inoculations with either diseased or apparently healthy orange wood do not make such a clear pattern. Inoculations of either Valencia or Grapefruit branches with apparently healthy orange wood resulted in a pink wood stain; the same material inoculated into twigs infected the Valencia but not the grapefruit. In another preliminary experiment, a few Hamlin orange twigs also showed a pink wood stain 3 months after inoculation with pink wood from Rio Grande gummosis lesions on grapefruit. Inoculations into the larger branches of the Hamlin also had no effect. In the experiment reported in Table 2, inoculum obtained from a pink wood stain of the Navel orange also reproduced the pink wood stain in grapefruit branches.

Discussion

The results of these experiments, particularly the one summarized in Table 2, tend to confirm Godfrey's (1946) belief that Rio Grande gummosis is an infectious disease, which can be transmitted from diseased grapefruit trees to apparently healthy grapefruit trees. Transmission apparently requires the introduction of the causal organism deep into wounds in the wood. However, the failure to reproduce the pink wood stain within 90 days by inoculations into the cambium region does not mean that infection might not appear after a longer period of time. Nevertheless, it appears that rapidly-healing bark bruises are not as susceptible to infection as had been thought (Godfrey, 1946). Pruning wounds on large branches, and broken branches that expose wounds deep in the wood of large branches would appear to be more usual avenues for infection.

On the basis of these preliminary trials, one can conclude that the Valencia orange is less susceptible to Rio Grande gummosis than is the grapefruit. Such a generalization agrees with field observations in groves where grapefruit was grown adjacent to Valencia trees. In such groves, Rio Grande gummosis often occurred on the grapefruit, but the blister and wood stain symptoms have not been noted on the trunks or larger branches of the orange trees. However, cuts through gumming orange twigs and small branches sometimes reveal a pink wood stain. While Godfrey (1945) has considered the sweet orange as susceptible to the disease, additional work is needed to establish that staining in orange twigs is related to Rio Grande gummosis of grapefruit.

These experiments provide some guidance in methods to be used in determining rootstock susceptibility to Rio Grand gummosis. However, an accurate evaluation of the host-parasite relations and rootstock susceptibility must await identification and proof of the causal organism or contagious principle of Rio Grande gummosis.

Summary

1. Two experiments, totaling 760 inoculations, were made on Marsh grapefruit and Valencia orange trees in order to study the transmission of Rio Grande gummosis.
2. On the basis of the experimental results, the following observations were made:
   a. Grapefruit was susceptible to the disease; Valencia orange was comparatively resistant, but not immune.
   b. Inoculum placed deep in the wood reproduced the disease in 90 days.
   c. Inoculum placed between the bark and the wood did not produce disease within 90 days.
   d. The disease in grapefruit spread faster in large branches than in twigs.
   e. The success in transmitting the disease by inoculations appeared to vary with the time of the year.
3. An accurate check on these generalizations must await identification of the cause of the disease.

Table 1. Effect of source of inoculum, date of inoculation, and method of inoculation on the expression of Rio Grande gummosis symptoms in grapefruit.

Placement of inoculum	Inoculum source, grapefruit	Occurrence of the pink wood symptom of Rio Grande gummosis 90 days after 3 inoculation dates.					
		January 23		March 23		June 29	
		No.*	Spread, mm**	No.	spread, mm.	No.	spread, mm.
Wood of Branches	check	5	224	4	112	0	0
	pink wood	7	277	4	168	0	0
	buff wood	8	279	4	112	0	0
	gum	5	276	2	167	1	950
	bark	8	286	0	0	1	950
Wood of Twigs	check	2	26	2	85	0	0
	pink wood	3	62	0	0	0	0
	buff wood	3	192	0	0	0	0
	gum	1	80	1	62	0	0
	bark	3	37	0	0	0	0
Cambium of Branches	check	0	0	0	0	0	0
	pink wood	0	0	0	0	0	0
	buff wood	0	0	0	0	0	0
	gum	0	0	0	0	0	0
	bark	0	0	0	0	0	0
Cambium of Twigs	check	0	0	0	0	0	0
	pink wood	0	0	0	0	0	0
	buff wood	0	0	0	0	0	0
	gum	0	0	0	0	0	0
	bark	0	0	0	0	0	0

* "No." refers to the number of inoculations that caused the pink wood stain, out of a total of 8 inoculations.
** "Spread, mm." refers to the average length in millimeters of the pink wood stain, not considering those inoculations that did not produce such a stain.

Table 2. Effect of source and type of moculum on the occurrence of the pink wood stain in grapefruit and Valencia Orange branches of two sizes.

Inoculum Source	Type	Incision Taped	Occurrence of pink wood stain, 90 days after inoculations on branches of two diameters. White Marsh Grapefruit No.*		Valencia Orange No.	
			No.*	Spread, mm.**	No.	Spread, mm.
			Branches 2-4 inches in diameter			
------	------	no	2	155	0	0
------	------	yes	0	0	0	0
grapefruit	healthy	yes	0	0	0	0
grapefruit	RGG bark	yes	3	94	0	0
grapefruit	RGG pink wood	yes	0	0	0	0
orange	healthy	yes	3	98	1	57
orange	pink wood	yes	1	150	0	0
			Branches up to 1 inch in diameter			
------	------	no	0	0	0	0
------	------	yes	0	0	0	0
grapefruit	healthy	yes	0	0	0	0
grapefruit	RGG***bark	yes	0	0	0	0
grapefruit	RGG pink wood	yes	0	0	0	0
orange	healthy	yes	0	0	4	4
orange	pink wood	yes	0	0	0	0

* "No." refers to the number of inoculations that caused pink wood stain, out of a total of 10 inoculations on five different trees.
**"Spread, mm." refers to the average length in millimeters of the pink wood stain, not considering those inoculations that did not produce such a stain.
*** RGG refers to Rio Grande gummosis.

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Nematodes on Citrus[1]

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Nematodes injurious to citrus roots are being investigated at Riverside to find efficient means of control.

The amount of damage caused by the pest is being determined in greenhouse and orchard tests.

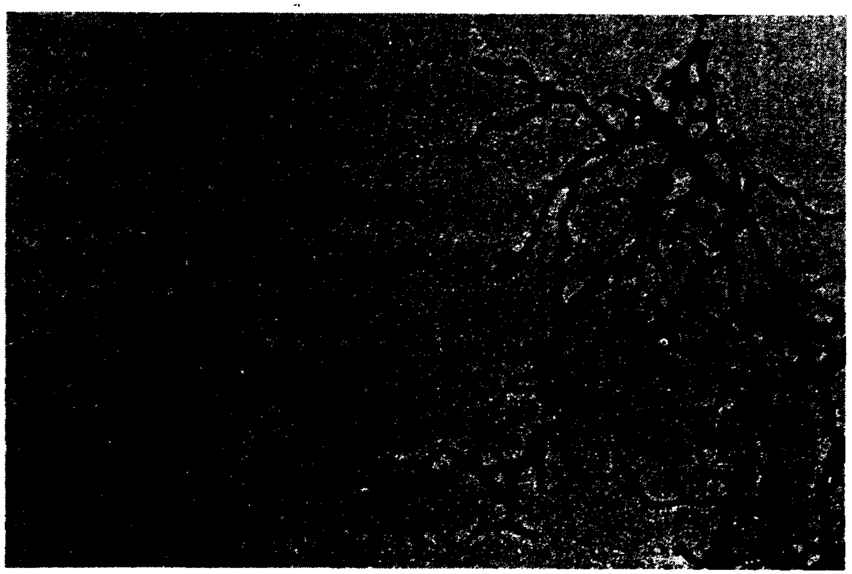
Soil is under study to identify the temperature range most favorable for the survival of the nematodes.

Citrus and related trees are being tested for their susceptibility and resistance to the soil-borne pest.

Chemical control experiments include chemicals applied in irrigation water and as fumes.

The larvae or young nematodes are wormlike in shape, whitish, and about 1/50 of an inch long. Only the females infect and feed on citrus roots.

The female larvae bore into the small feeder roots until approximately a fourth of the length of the nematode is in the root tissues. Then the part of the nematode extending out from the root surface becomes greatly enlarged. The mouth of the female is equipped with a short spear-like organ which punctures root cells in feeding. Eggs are laid in a mucilaginous material and frequently 75-100 unhatched eggs are found near the female. Soil particles adhere to the egg masses and roots, severely infested, appear encrusted.



Sour orange roots infected with the citrus-root nematode. Left, Noninfected roots; *right*, roots infected by the nematode. They appear thicker, and soil particles adhere. Enlarged 2 times.

[1]Reprinted from California Agriculture 4(8): 7. 1950.

The amount of damage caused by the nematode has not been reliably determined.

In one of the current experiments young sour orange seedling trees, inoculated with the nematode, were 12% shorter than similar, but non-infested trees, one year after inoculation.

Usually, considerable time is required for a high population of nematodes to build up on the roots of the inoculated trees, even though large numbers of nematodes are applied to the soil. The reduction in growth of the inoculated trees may be greater after the roots become infested severely.

Observations indicate that nematodes do not directly kill trees but apparently reduce their growth, and possibly, yield.

The experiments show that temperature of the soil affects the activity and development of the nematode. Only slight infection of orange roots occurs at 59° F. and at 95° F. The optimum temperature of the soil for infection and development of the nematode is between 77° F and 88° F. During the winter and early spring when the soil temperature is below 59° F the nematode becomes quiescent, but does not die.

In fact, larvae of the citrus-root nematode were found to live longer at low than at high temperatures. In moist soil in the laboratory larvae remained alive for 2½ months at 91° F, 6½ months at 81° F, for one year at 70° F, and for more than one year at 59° F and 48° F.

In the field the citrus-root nematode has persisted in fallow land more than three years, and in soil in five-gallon containers for more than two years. Thus a long period free from citrus is required to eradicate the nematode from soil.

A large number of species and varieties of citrus tested in the field and in the greenhouse were found to be susceptible to the nematode. Some close citrus relatives, such as *Atalantia citroides*—Cochin China atalantia, *Eremocitrus glanca*—Australian desert lime, *Fortunella* sp.—kumquat, and *Microcitrus australasica*—Australian finger-lime are also susceptible.

Some selections or strains of the trifoliate orange—*Poncirus trifoliata*—are highly resistant to the citrus-root nematode, while other selections are infested severely.

The following species of trees, botanically close to citrus, were examined and found to be immune to the nematode: *Balsamocitrus Dawei*—Uganda powder flask-fruit, *Clausena lansium*—Wampee, *Murraya paniculata*—Orange jassamine, and *Severinia buxifolia*—Chinese box-orange.

Some of the resistant plants, such as the resistant trifoliate orange, may be of value as nematode-resistant parents in the development by breeding of satisfactory nematode resistant rootstocks for citrus. Such breeding work is underway.

Many tests of the efficacy of different dosages of ethylene dibromide and a mixture containing about equal parts of 1,2-dichloropropene and 1,2-dichloropropane have been conducted on bearing Valencia orange trees in an orchard. These chemicals were applied in irrigation water.

Other chemicals have been tested in the laboratory and on young trees in the greenhouse.

Results obtained to date do not justify recommendations for the use of any of the chemicals tested for controlling nematodes on the roots of living citrus trees.

A number of the chemicals used for fumigating agricultural soils are effective for killing the citrus-root nematode in bare land to be used for replanting to citrus. However, even high dosages of the chemicals have not always completely eradicated the nematode in the field.

In some cases, fumigation of soil with high dosages of soil fumigants has resulted in poor growth of orange trees in the greenhouse.

The Joppa Orange

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The need for a better early seedless orange than Hamlin has stimulated grower interest in the Joppa and Jaffa varieties. However, there appears to be some confusion surrounding the origin and characteristics of these two varieties. The Dillar orange, from Arizona, and some of the Rico selections, from Puerto Rico, might be confused with these older seedlings from the true orange of Jaffa—the Shamouti. The Joppa variety, which originated in California, is often confused with the less precocious, somewhat coarser Jaffa orange of Florida origin. Neither of these varieties is similar to the egg-shaped Shamouti orange, but both of them are superior to the parental variety under Texas conditions. Visitors from Palestine, who have seen and compared the Shamouti and Joppa trees in the Station collection, state that Joppa is more like their Belladi orange (the common sweet orange of Palestine). They admit, however, that this "common" orange is superior, under Valley conditions to the true Shamouti orange.

The Jaffa variety originated in 1883 as a seedling grown by General Sanford, of Florida. The seed was imported from Palestine, presumably from seed of the world famous Shamouti. It was recommended by the Florida Horticultural Society for many years, and Mr. T. Ralph Robinson reports that there is still some interest in the Jaffa variety because of its relative seedlessness, long season, and the cold resistance of the trees. There are some excellent old orchards of this variety in the Valley, but the trees are relatively less productive during their early life than comparable trees of the Joppa variety. They are more productive than Valencia trees but less productive than those of the Hamlin variety.

The Joppa orange originated in 1879 as a seedling in the A. B. Chapman orchard near San Gabriel, California. The seed was imported from Joppa, Palestine. The original Valley trees were brought in from the R. M. Teague Nurseries by the Llano Grande (Crockett) Nursery in 1919. This variety has not received recognition in California, but it certainly appears to be a promising variety under Valley conditions. The trees show an upright habit of growth, resembling Navel orange trees in some respects. The medium size, spherical fruits are relatively seedless, and resemble Valencia oranges in general appearance and holding quality. Joppa is an early variety and the flavor of the fruit is definitely superior to that of the Hamlin variety.

It is not the purpose of this article to encourage the planting of Joppa oranges, but rather to point out the fact that the Joppa orange (from California) is better adapted to Valley conditions than the Jaffa orange which originated in Florida.

Nursery Inspection in the Lower Rio Grande Valley

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Citrus culture in Texas began some time prior to 1850, when citrus seed were planted by individuals for yard trees. The success of these trees encouraged the Texas Department of Agriculture to hire H. Harold Hume to investigate the status and possibilities of the citrus fruit industry in South Texas. Hume's report, published in 1909, encouraged the further expansion of citrus plantings. As the industry developed, the Department assisted in securing the passage of the law to establish a citrus experiment station in Hidalgo County, in order to help the development of the citrus industry (Delcurto et al, 1925). Thus, the Texas Department of Agriculture has a long history of cooperation with other agencies working to improve and protect the citrus industry, it has no desire to conduct its own research program. The Department's primary function is to provide nursery inspections, enforce quarantines and to guard against the introduction and spread of disease and insect pests.

The foundation of a healthy citrus industry lies in a healthy citrus nursery tree. In February, 1949 the Department approved a program of inspection and registration of citrus trees in Texas and the certification of nursery stock. The objective of this program is to improve the bud-wood source for citrus nursery trees, particularly as regards the elimination of Psorosis, and includes every known factor for the improvement of nursery stock (McDonald and McKay, 1949). Through the cooperation of the Lower Rio Grande Valley Nurserymen's Association, and the Texas A. & M Experiment Substation No. 15, this program is now well under way.

By the spring of 1950, 15,571 trees had been inspected for leaf symptoms of Psorosis. At this time 263 parent trees were registered for use as disease-free, true-to-type, high quality budwood trees. Four of the 263 trees have since been dropped from registration for various reasons. An additional 108 newly selected trees are being tested for possible registration next year. In the fall of 1950 and spring of 1951, 159,000 certified nursery trees will be ready for sale. Each certified nursery tree bears a lead seal, placed on the tree by the state nursery inspector. It is not a certified tree unless it bears the state seal. It is hoped that in the near future only state certified trees will be grown in Valley nurseries.

In an effort to aid the nurseryman to produce the best stock possible, the nursery stock is inspected several times a year for disease and insects. If the stock is free of disease and insect pests, a certificate of inspection is issued, enabling the nurseryman to offer this stock for sale to the public If the stock is infested with insect pests they are reported to the nurseryman and control measures are recommended. California Red Scale moving out of the nurseries on nursery stock can be disasterous and expensive to other citrus plantings. Infestations of several insects and scales new to the Valley have been found and eradicated on this nursery stock. Many tests were conducted under the direction of Dr. George Wene, Entomologist at the Texas A. & M. Experiment Substation No. 15, and improved control measures for these pests were obtained. This service has helped the nurserymen to prevent expensive losses in his nursery and prevented the spread of these destructive pests.

Rio Grande gummosis has been considered one of the most serious grapefruit diseases in the Valley area, and has always been a stumbling block to the state registration program. A citrus tree with Rio Grande gummosis cannot be registered as a parent tree, although it is not known that this disease is transmitted through the budwood. One of the 263 parent trees registered this past spring was dropped from the program recently because it now shows lesions of Rio Grande gummosis on the trunk. Many rejected trees had outstanding production records in the past. After the outbreak of Rio Grande gummosis, these potentially valuable trees could not be used as a source of budwood. The nursery inspector has assisted Dr. E. Olson, Pathologist, Texas Citrus Rootstock Investigations, and Dr. G. H. Godfrey, Pathologist of the Texas A. & M. Experiment Substation No. 15, in studies of this disease (Olson and Waibel, 1951).

Discovery of the Citrus Nematode, *Tylenchulus semipenetrans,* in the Valley followed a complaint that the declining replacement trees in a grove were faulty nursery stock. Samples of the feeder roots were taken by the inspector. Dr. Godfrey identified the cause of the decline as citrus nematode. This was the first report of citrus nematode in Texas (Godfrey and Waibel, 1950). The full extent of citrus nematode infestation in the Valley has not yet been determined

Seedling diseases have caused heavy losses in Valley nurseries. This year approximately 1,000,000 citrus seedlings were killed in seed beds. Dr. E. Olson made studies of this problem at the request of the nursery inspector. A *Phytophthora* fungus was established as the cause of the disease and tentative control measures were suggested (Olson, 1951). Studies are being made by the department for antiseptic solution dips that will induce rather than retard germination on seed imported from other citrus areas.

Many red grapefruit sports have occurred in grapefruit groves throughout the Valley. Twelve different red grapefruit strains were propagated under individual names such as the Webb Red Blush, Henninger Ruby Red, etc. The owner of each sport tree has claimed that his strain is superior. Fruit from the original sport trees or from first progeny has been obtained for studies to determine the differences between strains of red grapefruit. The Texsun Citrus Exchange's Research Laboratory, under the direction of E. M. Burdick, have studied these red grapefruit strains to ascertain differences in chemical composition, color, flavor, and texture. This laboratory likewise investigated the more obvious changes taking place during maturation such as acid, solids, and naringin content in the fruit (Maurer et al, 1950). It is believed that many of the differences observed were caused by differences in soils, irrigations, fertilizations, and cultural practices, rather than by inherent differences in strains.

Mr. N. Maxwell, Citrus Horticulturist at the Texas A. & M. Experiment Substation No. 15, has been provided with nursery trees of seven of the most popular red grapefruit strains, grown on both Cleopatra Mandarin and Sour Orange rootstocks, to compare these when grown under similar conditions. The inspector has also aided Mr. Maxwell and Dr. P. W. Rohrbaugh, Director of the Texas A. & I. Citrus and Vegetable Training Center, to obtain disease free budwood to establish variety test plots.

The location of hundreds of varieties now grown in Texas has been charted, in order to provide a local source of budwood for uncommon varieties. If the variety is not grown in Texas, special permission may be granted by the Department for its introduction. Many requests for information and budwood of Texas varieties are received from foreign countries and other states. In this manner help has been given to individuals and agencies in Mexico, South Africa, Spain, France, Argentina, Brazil, Guatemala, as well as Arizona, Florida and California.

The development of the frozen citrus concentrate industry in Texas will create many new problems. The Texsun Citrus Exchange's Research Laboratory was supplied with various varieties of fruit for testing as frozen concentrates. These studies demonstrated that certain varieties have important advantages over others in making quality products. It is probable that greater demands for fruit adapted to use as concentrate will result in increased demand for nursery stock of these superior varieties.

Quick Decline in California, Tristeza in South America and probably in Louisiana, is a potential threat to the Texas industry. Nurserymen have sought assistance in selecting a Tristeza-resistant rootstock. A new rootstock of this area should be Tristeza-resistant, salt tolerant, foot-rot resistant and be able to produce heavy crops of high quality fruit. Full cooperation has been given to Dr. W. C. Cooper, Physiologist, Texas Citrus Rootstock Investigations, in studies on this problem.

Each year a survey is made of all nursery stock at the same time that the stock is inspected for disease and insect pests. A summary of the 1950-1951 survey is shown in Table 1. The information from this survey is a guide to future production of nursery stock and helps to prevent shortages as well as overstocks, which often have disasterous effects on the nurservey business. This survey also assists the nurserymen and the grower to locate varieties, rootstocks and seedlings. Some three hundred nurseries, florists, and dealers are covered in this inspection and survey in this area.

The introduction of new diseases and pests from other areas is a constant threat to the industry. Plant material of foreign origin is inspected and fumigated at the port of entry and then released to the grower, who keeps it in quarantine for two years. Many transmissable diseases are not visible on inspection at the port of entry, but appear during the quarantine period. It is dangerous to grow this material out in the open even in an isolated area since insects may spread disease to other plants. An insect-proof partitioned screen house would be a safe place to test this material and would enable more frequent inspections with the saving of time and expense. A separate screened house for use in testing suspicious declining citrus trees for Quick Decline is also needed.

The Department has cooperated with the Texas Avocado Society in conducting variety tests and graftwood treatment tests (Waibel, 1949) for the control of scale and insects on foreign introductions. The Department welcomes the opportunity to help this new and promising industry get a start in this state.

Table 1. Citrus Nursery Inspection Report. September 11, 1950.

Citrus Nursery Stock Grown	*Number*
Grapefruit on Sour	378,885
Grapefruit on Cleo	53,879
Orange on Sour	500,637
Orange on Cleo	56,607
Lemon	3,935
Lime	2,741
Tangerine	11,271
Kumquat	2,400
Miscellaneous	3,215
Registered Grapefruit on Sour	55,253
Registered Grapefruit on Cleo	31,850
Registered Orange on Sour	39,671
Registered Orange on Cleo	32,500
TOTAL	1,172,844
Trees not for Sale	177,960
Total Trees for Sale	995,884
Ratio of Grapefruit and Orange	
Total Grapefruit	510,867
Total Orange	623,415
Ratio of Rootstocks Sour & Cleo	
Total Trees on Sour	998.008
Total Trees on Cleo	159,836

Registered Trees	
Registered Trees on Sour	94,924
Registered Trees on Cleo	64,350
TOTAL	159,274
Seed Planted	
Local Texas Seed	66½ bu.
Sour Florida Seed	70¼ bu.
Cleo Florida Seed	10 bu.
TOTAL	146¾ bu.
Seed Bed	
Cleo Seedlings	264,850
Sour Seedlings	2,411,540
TOTAL	2,676,390
*Lined Out Stock**	
Cleo Seedlings	123,919
Sour Seedlings	433,956
TOTAL	557,875
Seedlings Lost in Seed Beds	
Sour Seedlings	785,000
Cleo Seedlings	202,000
TOTAL	987,000

*Budded trees that would not make saleable trees by this spring are included in this group.

Through the support of the Lower Rio Grande Valley Nurserymen's Association and the Texas Department of Agriculture, the citrus nursery inspector studied the Citrus Black Fly in Valles, Mexico, and citrus diseases and insects in California and Florida. Through the courtesy of various federal and state agencies in these areas the inspector was shown means of identification, control measures, quarantine regulations in operation, and research being conducted on these various problems. This information has enabled him to do a better job in this area.

The Department of Agriculture, although limited in man power, will cooperate wherever and whenever it can with any agency interested in improvement and protection of agriculture in Texas.

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Cover Crops

J. R. Padgett, *Rio Farms Crop Experimental Farm, Edcouch, Texas*

The old saying that "There is no progress but what exacts its penalties" is often demonstrated in the Rio Grande Valley. We cleared our brush lands; we converted our sparse pastures into rich and prolific fields and we trebled and quadrupled their value. We assaulted the mighty Rio Grande with our pumps and appropriated the waters it had brought from the slopes of the Rockies a thousand miles away. We created an agricultural paradise.

Soon the penalties began to accrue. In its long journey down the river, the water picked up the salts, the sodas and the alkalies of the lands drained by the river. These minerals we spread out upon our lands.

The trade winds that originate in the Carribean increased in intensity as we removed the brush barriers to their assaults. Today our fields are clean, naked and exposed to the eroding effect of our nearly constant winds. Its effects are disastrous. Drifting sands blister and bury our small seedlings. Our mature vegetables are scarred and distorted until the profit is lost in the cull pile. Our cantaloupes and cucumbers are twisted from the rolling vines.

In our greed we reckoned without nature. We failed to leave the shelter belts of native timber that would have broken the force of the winds. The answer to the wind erosion problem is permanent wind breaks and use of cover crops when lands are idle. For permanent wind breaks eucalyptus and the much maligned athel appear to be best. Two years ago we would have included Australian Pine in this list. It is a beautiful tree, thrives without much water and makes a fast growth; but is very susceptible to cotton root rot and for that reason is short lived. There is widespread objection to the athel because it normally exhausts a wide strip of crop land on each side of the hedge. This can be overcome. On Rio Farms we run a chisel two feet deep and twelve feet from the hedge once a year. This confines all athel root growth to a twenty-four foot space which appears to be ample for substantial growth. Crops beyond the twelve foot space allotted to the athel hedge are normal. Improvement in the crops, of whatever kind, on the leeward side of an athel hedge easily compensates for the twenty-four foot strip of land allotted to the growth of the hedge.

In the selection of a cover crop there is much latitude. One can choose from a long list of cover crops that will best solve the particular problem. If one wishes to store nitrogen while providing a cover to wind erosion, there are the clovers, vetch, Austrian Winter Peas and alfalfa for winter planting.

For several years Cordell Edwards, Soil and Irrigation Specialist for Rio Farms, has conducted carefully controlled experiments in the use of nitrogen storing cover crops in citrus orchards. Against these leguminous crop areas he compared a control area of natural vegetation, weeds, Johnson grass, etc. Mr. Edwards found that he obtained more organic matter from the check (Natural crops) than from any of the legumes.

A paragraph from his report on his 1949-1950 Experiment is interesting—"After the first chopping with a stalkcutter, the plots were watered to see which cover crop would produce a second growth. Alfalfa was the only legume that produced a second growth and at this time it has made three new crops since planting. The question comes up as to how much nitrogen did these legumes return to the soil. The answer to this would be – not anymore than the natural vegetation, because there were no nodules (which manufacture nitrogen) on any of the roots of the legumes. From the results shown this year, alfalfa would make an ideal cover crop, because of the additional crops that can be gotten from one seeding of alfalfa and also it is not so competitive for water as the taller growing legumes and weeds."

Another interesting statement comes from Arizona, where more intensive work has been done with cover crops than any other citrus areas. From Arizona comes the admonition that cover crops should not be plowed under in citrus orchards when the tree's demand for nitrogen is high, particularly the bloom period. A freshly turned cover crop demands and extracts considerable quantities of nitrogen from the soil during the disintegrating process. For that reason it should be returned to the soil when the orchard's need for nitrate is low. For the same reason, crops closely following a cover crop will need extra supplies of nitrogen to produce maximum growth.

Mr. Edward's investigations into the benefits of a cover crop for reducing soil temperatures have definitely established certain facts. A variable of from 25 to 40 degrees in reduced temperatures can be expected in soils protected by cover crops, with an average somewhere around 30 degrees. These lower soil temperatures contribute materially to the vigor of an orchard during the summer months.

On the crop lands it appears that the Hubam type clovers and common vetch are the best winter cover crops. There is some advantage from clover where one needs a tall cover crop that will afford maximum wind protection to small seedlings. It will also produce more tonnage of green manure per acre than any of the winter legumes. However, we have been consistently disappointed in the quantity of nodules it has produced even when properly inoculated.

On the sandy loams of Rio Farms all of the winter legumes have been under observation by Wm. T. Dudley, Farm Advisor, for several years. He has found that the common vetch produces far more nodules than any of the legumes. It produces an average green manure crop of around seven tons per acre. It has a very fibrous root system which enables it to hold down light soils in even the heaviest winds. He feels that it is the most desirable winter cover crop for open fields except where a tall growing variety is needed to protect small seedlings from wind damage.

Of the summer cover crops there are many from which to choose. Sesbania, Crotolaria Junica and Brabham Cow Peas are probably the most valuable of the legumes. We personally rule out sesbania because it is a host to nematodes. Crotolaria Junica seed are hard to obtain but, when available, this crop will produce far more tonnage of green manure than

any other legume. Our efforts to induce it to store nodules have been disappointing yet we regard it as the most valuable of all the summer legumes. Our favorite combination for maximum yield of green manure is a mixture of Crotolaria Junica and Brabham Cow Peas. These two crops planted two rows on a bed with the Crotolaria in one seed hopper and trailing Brabham cow peas in the other, produced in 1948 a crop of 27 tons per acre of green manure. It was turned under, the land irrigated and a crop of lettuce planted thirty days later. So complete was the disintegration of this crop in thirty days that only a few pieces of the heavier stems of the Crotolaria remained.

The grain sorghums remain to be considered as cover crops. They can contribute a high tonnage of fiber that is quickly assimilated into the soil. This adds greatly to the porousness of the soil and hence its ability to hold water for longer periods. Chemical forms of nitrogen can be bought and placed in the land but organic matter is equally as important and must be grown upon the land. Thus, it would appear that in choosing a cover crop its ability to add a maximum of organic matter would seem of more importance than the storing of nitrogen in the soil.

Tip Blight of Citrus Seedlings in the Lower Rio Grande Valley[1]

E. O. Olson, *U. S. Department of Agriculture, Weslaco, Texas*

Each year many citrus seedlings, grown for rootstock purposes in the Rio Grande Valley of Texas, have died in the seedbed. Carl Waibel, citrus nursery inspector, (Waibel, 1951) estimated that 785,000 sour orange and 202,000 Cleopatra mandarin seedlings were lost in the seedbed between May and September of 1950. The greatest part of this loss occurred in those sections of the Valley where a series of heavy rains fell in late May and early June. Losses were negligible in those sections not receiving this series of rains.

The infected seedlings developed brown watersoaked areas at the terminal growing point, the petioles of the leaves, and the leaf blades. The symptoms differed from typical "damping-off", in that the water-soaked brown areas did not start at the ground level of the stem. The disease appeared suddenly in individual seedbeds, and in wet weather appeared to spread rapidly into previously healthy plants. If the leaves and the ground surface remained dry, there was no serious spread of the disease. Following the watersoaking symptom, affected tissues dried and died. When smaller plants were killed, the dead plants stood brown and erect with the dead leaves still attached. On many larger seedlings only the lower leaves turned brown, dried and abcissed; these plants often put out new shoots from below the dead terminal shoot. The roots did not appear to be injured until the whole stem had become infected. Symptoms, 10 days after the onset of the disease, are shown in Figures 1 and 2.

This article reports studies to establish the cause of this disease.

Experimental Results

Isolations were made in May and June, 1950, from diseased Cleopatra mandarin seedlings grown near McAllen, from diseased sour orange seedlings grown near LaFeria, and from both varieties grown at Texas Agricultural Experiment Station, Substation 15, near Weslaco. All three collections were from seedlings being raised under half-shade. From each collection of diseased plant material a *Phytophthora* species was isolated in pure culture; no cultures were obtained of *Rhizoctonia*, usually considered the commonest cause of damping-off of citrus seedlings.

The *Phytophthora* fungus was grown on potato-dextrose agar in petri dishes for 10 days. In order to obtain swarm spores the agar and mycelium were immersed in sterile water for another 10 days. The cultures were then warmed in water at 28-30 degrees C. for 3-5 minutes,

[1] These investigations are a part of a cooperative citrus rootstock project conducted by the U. S. Department of Agriculture and the Texas Agricultural Experiment Station. Certain phases of this work were carried on under the Research Marketing Act of 1946.

and cooled to 15-18 degrees C. for one hour. When swarm spores were produced in abundance, a water suspension of mycelium and swarm spores was sprayed on the leaves of seedlings grown in gallon cans of soil. At the same time control plants were sprayed with water. The sprayed plants were immediately covered with "Parafilm" to maintain a high humidity around the plants. After these plants had been kept for 5-7 days at 78-80 degrees F., in reduced light condition, observations were made on the differences between the inoculated and check plants.

The experimental results are given in Table I. On the inoculated plants watersoaked brown areas appeared on the leaf blades and petioles, and the terminal bud shoot died and turned black. There was no injury to the roots of the inoculated plants. No injury to the terminal bud shoot occurred on the check plants, and relatively few leaves died compared to inoculated plants. Of the inoculated seedlings the smaller plants subsequently died in greater numbers than did the larger seedlings.

The *Phytophthora* was reisolated from dying bud shoots of inoculated seedlings. Nine of 16 cultures from inoculated Cleopatra seedlings and 8 of 10 from inoculated sour seedlings were the *Phytophthora* species used for inoculation.

Discussion

The symptoms of the disease observed in Texas appear to be identical with a "stem and tip blight" of citrus seedlings reported from Israel. Reichert and Perlbeger (1936) observed that "the upper end of the stem withers progressively, darkens gradually to a deep brownish black, dries, and dies. The blight progresses from the end of the stem downwards to the main stem and upwards to the petioles and to the leaves. Sometimes the disease also appears on the lower part of the stem and on the root collar and progresses upwards. The causal agents of this disease are two species of the fungus *Phytophthoras Ph. parasitica* and *Ph. citrophthora*. The disease has been found often on Sweet Lime and rarely on Bitter Orange." Johnston (1946) also reports seedling losses from *Phytophthora* in California.

The inoculation experiments in Israel (Perlberger, 1936) indicated that a large number of the seeds of fruit infected with *Phytophthora* is killed inside the fruit, that of the remainder a large part rots in the earth before it can germinate, and that some of the seeds that germinate become infected a short time after germination. While Perlberger was able to obtain infection when *Phytophthora* was added to the soil, he was not able to explain how the fungus in the soil could initiate infection at the growing tip of the seedling rather than at the soil level.

On the basis of what is known about brown rot of citrus fruit and foot rot of the trees, both of which are caused by *Phytophthora* species, it seems certain that the seedbed outbreaks in Texas and Israel (Perlberger, 1936) are related to excessive water in the soil and high humidity; arid conditions stopped the development and spread of the disease in both areas. During prolonged periods of heavy rainfall or irrigation the fungus grows to the surface and develops its swarm spores in the water. Subsequent rains splash these spores against the seedlings. The leaves and shoots of the smaller seedlings appear to be more easily inoculated by the splashed spores, hence it is likely that they would be killed under conditions where older, taller seedlings might lose only their lower leaves. The Cleopatra mandarin, which grows more slowly than the sour orange, would therefore be susceptible to this disease for a longer period of time.

Size of seedling is probably not the only factor involved in susceptibility to this disease. On the basis of limited observations, some varieties appear to be more susceptible than others. Of the 90 varieties of citrus grown in one seedbed, some showed no damage, other varieties showed only leaf spotting, while in other varieties 60-75% of the seedlings were killed. Since these varietal plantings were not replicated and were planted at different dates, relative varietal susceptibility could not be determined at this time.

Since no experiments on control measures have been conducted in Texas, the following suggested control measures are only tentative:

1. Good drainage of the seedbeds is probably the most important control measure.
2. Avoid excessive shading of the plants.
3. Thorough application of water at longer intervals is probably better than too frequent sprinklings.
4. Spraying the seedlings with Bordeaux every two weeks or drenching the soil with a Ceresan solution has been recommended in Israel. The Ceresan solution (2 ounces per 50 gallons of water) is applied at the rate of 3 to 4 quarts per 10 square feet. The Bordeaux spray is more effective when applied before the outbreak of the disease than when applied after the outbreak.

TABLE I. Effect of **Phytophthora** inoculations on citrus seedlings.

Seedling Variety	Treatment	No. Plants	Effect one week after treatment: No. dead leaves	Effect one week after treatment: No. dead terminal growing points
Cleopatra (4")	Inoculated	20	18	9
Sour (6")	Inoculated	12	16	5
Cleopatra (4")	Control	16	0	0
Sour (6")	Control	16	0	0
Cleopatra (2")	Inoculated	41	36	34
Cleopatra (2")	Control	18	3	0
Cleopatra (5")	Inoculated	24	55	19
Sour (8")	Inoculated	22	38	13
Cleopatra (5")	Control	24	0	0
Sour (8")	Control	27	0	0

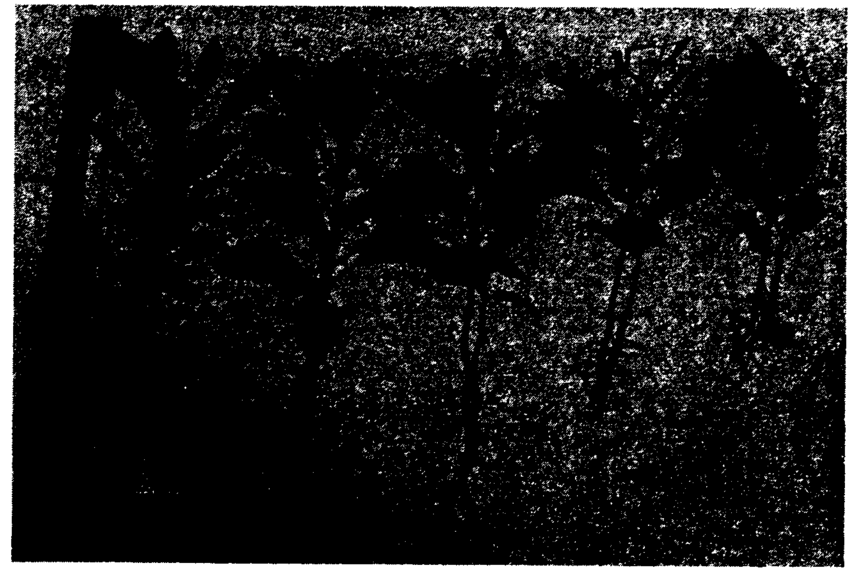

Figure 1. Symptoms of *Phytophthora* infection of sour orange seedlings. The specimen to the left is a healthy plant, while the rest show the dying back of the terminal bud shoot; the center three plants show spots of gum on the margin between the diseased and healthy wood. *Phytophthora* was isolated in pure culture from the four diseased plants.

5. After the outbreak of the disease, watering should be reduced (Perlberger, 1936) and a 3-3-100 Bordeaux spray promptly applied (Johnston, 1946).
6. Growing seedlings on ground previously planted to seedlings is not recommended.
7. Since citrus fruit is subject to infection by *Phytophthora*, only seeds from whole, healthy fruit should be used. The fruit should be picked from the tree, not from the ground (Perlberger, 1936).

Conclusions

1. A tip blight of citrus plants grown in the seedbed is described.
2. Pure cultures of a *Phytophthora* species were isolated from three collections of diseased seedlings.
3. Inoculations with a water suspension of mycelium and swarm spores of the fungus reproduced the disease, and the organism was reisolated from these diseased seedlings.
4. The symptoms of the disease observed in Texas appear to be identical with a "stem and tip blight" of citrus seedlings reported from Palestine.
5. The relationship of excessive water in the seedbeds to attacks by *Phytophthora* is discussed.
6. Tentative control measures are suggested.

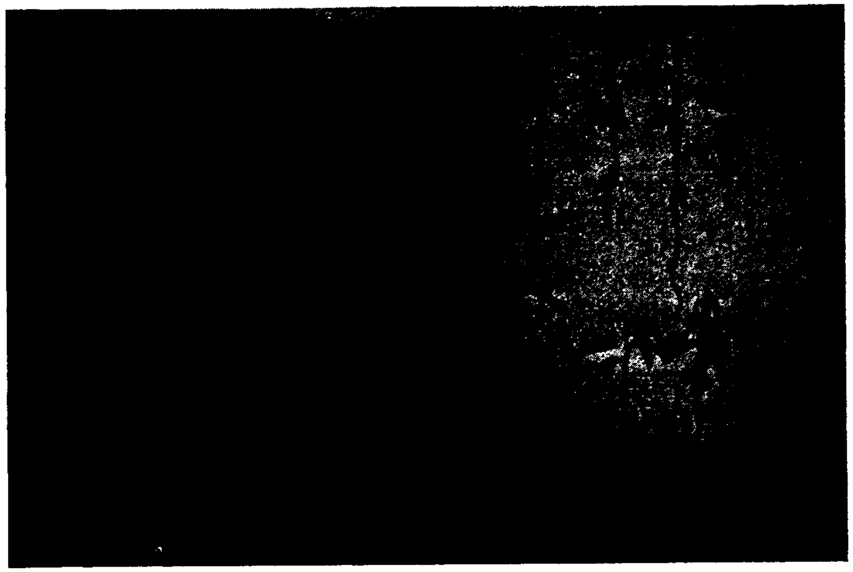

Figure 2. Symptoms of *Phytophthora* infection of Cleopatra mandarin seedlings.

The single specimen at the lower left is a healthy plant. The plants in the upper row show dying of the terminal bud and of the lower leaves, respectively. Four of the plants in the lower row were killed. *Phytophthora* was isolated in pure culture from the diseased plants shown.

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Possibilities in Biological Control of Citrus Pests

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Some of the greatest successes in the use of the biological method of controlling insect pests have been obtained on citrus. The classic example is the complete control of the cottony-cushion scale, *Icerya purchasi* Mask., on citrus in California by the introduction from Australia of the Vedalia ladybeetle, *Rodolia cardinalis* Muls., and the parasitic fly, *Cryptochaetum iceryae* (Will.), in 1888-1889. Other successes have followed in California, such as the control of the Citrophilus mealybug, *Pseudococcus gahani* Green, by the parasites, *Tetracnemus pretiosus* Timb. and *Coccophagus gurneyi* Comp., which were imported by the Division of Biological Control of the University of California from Australia in 1928. The introduction of new natural enemies still is the primary line of approach in all biological control problems and the possibilities are certainly far from exhausted.

Within the past three or four years, however, we have learned that promising possibilities in biological control of citrus pests in southern California exist that we were more or less unaware of. Field ecological studies in citrus groves untreated for several years have furnished most interesting leads. Although nearly all citrus groves in California receive regular insecticidal treatments, a few have been found and intensively studied which have not received insecticidal treatments for from 10 to 24 years. All commercial varieties of citrus are represented and, by and large, commercially clean crops are produced each year. Major pests in these groves against which biological factors have been demonstrated to play a predominant part in control include the California red scale, *Aonidiella aurantii* (Mask.), the yellow scale, *Aonidiella citrina* (Coq.), the citrus red mite, *Paratetranychus citri* McG., the black scale, *Saissetia oleae* (Bern.), and mealybugs, *Pseudococcus* spp. It appears in addition that certain minor pests in these groves may be held in check fairly well by natural enemies but no formal proof has as yet been acquired.

There are certain pests which have not as yet been studied intensively from the ecological point of view, which may not have really effective natural enemies. Future studies, of course, may modify this view. However, it appears that the most difficult problems may be represented on navel oranges by the citrus thrips. *Scirtothrips citri* (Mouult.), on Valencia oranges in coastal areas by the purple scale, *Lepidosaphes beckii*, and on lemons by the citrus bud mite *Eriophyes sheldoni* and in certain localities by the citrus thrips.

Granting that a certain few groves in southern California are under satisfactory natural control, one wonders why more groves have not developed similarly. Possible explanations which may apply in general to each pest will be based upon the pest which we have studied most, the California red scale.

It has been thoroughly demonstrated experimentally that the California red scale is under very satisfactory natural control in certain groves, primarily throught the work of the golden chalcid, *Aphytis chrysomphali* Mercet (DeBach, Fleschner and Dietrick, 1950). Adjacent groves in most instances are treated for California red scale once a year. This treatment, either an oil spray or fumigation, has been practiced since the red scale was first found in California and, as far as is known, years before the parasite was present in the state. Such treatments produce violent oscillations in red scale populations in addition to the fact that they eliminate the majority of any parasites which might be present. Under such conditions alone it would be extremely difficult for any but an extremely favored and efficient parasite to control the host. *Aphytis* is a very efficient searcher but in addition to insecticides other factors affect it adversely. *Aphytis* does not reproduce on adult or first stage scales, hence during periods when these stages are predominant, and this occurs about three times a year, parasite populations are reduced. Climatic extremes, especially in interior areas, such as high temperatures and low humidities, or very low temperatures sometimes kill many parasites. All these factors tend upon occasion to permit the red scale to increase. Such an increase might later be stopped by the parasite but the psychology of the citrus grower based, first, upon knowledge obtained before parasites were established in the new red scale infestations in the state and, later, in treated groves, upon what red scale would do if treatment were neglected, is to treat for red scale as soon as it shows a tendency to increase. It is obvious, therefore, that it would take an extremely fortunate combination of circumstances to allow any given grove to go untreated long enough for natural control to be attained.

Is it possible, then, to extend biological control into groves now regularly treated? The author believes that it is in at least certain citrus areas but it does not appear to be practical through the simple cessation of treatment. Such a course would, in most cases, result in severe pest infestations before natural enemies could "catch up" with the host. It appears that mass production of parasites in the insectary for field colonization may be the single most important phase in the attainance of a satisfactory natural balance. Such a procedure is now being tested with the California red scale and *Aphytis*, and although failures have occurred successful control has also been attained (DeBach, Dietrick, Fleschner and Fisher, 1950). Such a procedure does not imply merely releasing a few parasites in the groves to get control; rather it entails colonization of parasites at certain definite favorable periods each year, in large numbers and it may mean colonization of natural enemies for several years before a balance is attained or perhaps indefinitely. In the latter case it might mean spending as much money for natural enmies as is spent for insecticidal treatments. Growers association insectaries of some type will undoubtedly be ncessary if this method is found to be practical.

Beside colonization of natural enemies, other practices may be followed which will favor natural enemies. Those include ant control, dust control, perhaps cover crops which will serve as reservoirs to keep general predators present in the citrus grove and last, but not least, the use of insecticides least harmful to all natural enemies present, when such use is necessary because natural enemies are not adequate to control any given pest. The desirability for and methods of ant control on citrus in the Rio Grande Valley have been discussed by Roberts (1946). We have found

in California that the Argentine ant, *Iridomyrmex humilis* Mayr., attacks natural enemies of nearly all pests and consequently in groves having adequate natural enemies present, nearly all pest populations will be increased from several fold to many hundred fold on ant-infested trees as compared to ant-free trees. Road and grove dust are commonly observed to be associated with pest increases. We have found that so-called "inert dusts" may be very detrimental to field populations of natural enemies.

The limited period of observation which I enjoyed in the Rio Grande Valley during December, 1949, revealed some interesting biological control possibilities. These have been partially reported previously. (DeBach 1950). Most of these observations were purposely restricted to diaspine scale insects. The California red scale which was once the most serious pest of citrus in the Rio Grande Valley now appears to be under biological control. Two species of *Aphytis* commonly parasitize it, *A. chrysomphali* and *Aphytis* "A". These two parasites appear to be equally effective against the yellow scale. *Aphytis* "A" is a designation used in California to represent a species imported from China in 1948. Apparently this species was accidentally imported into Texas some time ago, presumably with red scale from the Orient.

The twice-stabbed laddybeetle, *Chilocorus confusor* Casey, was common nearly every place in the field, feeding upon armored scales. Its work was most evident in heavy infestations of the chaff scale, *Parlatoria pergandii* Comst., the purple scale, *Lepidosaphes beckii* (Newm.), and the Glover's scale, *Lepidosaphes gloveri* (Pack.). The chaff scale was commonly parasitized by another species of *Aphytis*, *A. diaspidis*. Immature stages of *Aphytis* were also found on Florida red scale, *Chrysomphalus aonidium* (Linn.). Glover's scale frequently was found to be parasitized by *Prospaltella elongata* Doz. An *Aphytis* was also taken on Glover's scale, as was a *Thysanus* which probably is hyperparastic. An unknown predatory mite, which fed upon scale eggs, was often found under purple and Glover's scales.

The chaff scale was by far the most abundant scale observed by the writer. Certain infestations of this scale appeared to be capable of causing commercial loss, whereas most of the infestations of the other species of scales seen were well within economic bounds. Roberts (1946) stresses the fact that if ants are controlled, the parasites and predators will keep aphids, scale insects, white flies and thrips pretty well under check. He does not feel that the use of sulfur for mite control is detrimental to parasites and predators but Clark and Friend (1932) found that monthly applications of lime-sulfur solution to citrus trees produced an extraordinary increase of California red scale over that of unsprayed trees. They ascribed the increase to the detrimental effect of lime-sulfur against parasites and predators. It is known in California that sulfur dust is very harmful to certain parasites. It seems possible, therefore, that the general sulfur dust program as now carried out in the Rio Grande Valley for mite control might seriously disrupt the work of certain beneficial species.

Since the natural balance on citrus in the Rio Grande Valley appears so favorable that few insecticidal treatments are now necessary, it would behoove the industry to back careful studies designed to maintain or improve this status. Investigations concerning biological control of mites would appear to be of considerable importance, inasmuch as these pests seem to furnish the prime cause for insecticidal treatments. Meantime it might be valuable to investigate additional acaricides, as well as sulfur, with respect to the effect they have on beneficial insects and possible pest increases.

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Progress Report on the Citrus Blackfly Surveys in Mexico

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In December 1949 surveys were undertaken in Mexico to determine the distribution of the citrus blackfly (*Aleurocanthus woglumi* Ashby). Up to the end of August 1950 inspections had been made throughout the States of Tamaulipas and Nuevo Leon, in northeastern Mexico, and in Sonora and Baja California in localities where there appeared to be any possibility of the blackfly becoming established.

The work in Mexico is set up on a basis whereby the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture works in cooperation with the Defensa Agricola of the Mexican Department of Agriculture in Sonora and Baja California and the local blackfly committees in Tamaulipas and Nuevo Leon.

Inspection for the citrus blackfly is a different type of work from inspection for larger insects. Sometimes the only evidence of an infestation is the presence of egg spirals on leaves. Several infestations have consisted of only one egg spiral on one leaf. The adult fly is rarely seen unless the infestation has developed considerably, and egg spirals, larvae, and pupae are plentiful. To do this type of work properly, the inspector must have good eyesight and a temperament that will permit him to work slowly and carefully. The men need to be trained to look at leaves and not at trees, for eggs, larvae, and pupae of the blackfly are found only on leaves. Fortunately, we have been able to employ in Mexico men who are admirably suited for this type of work. They have made excellent inspectors.

Areas of Inspection and Infestation

Intensive inspections have been made in all the citrus plantings from Matamoros up the Rio Grande to Villa Acuna, which is just across the river from Del Rio, and along the highways from Reynosa to Monterrey and southward through Montemorelos, Linares, and Victoria. Inspections have also been made off the main highway and in several other citrus areas in Mexico in which it appeared the blackfly might have become established. Most of the infestations discovered so far have been located in or near towns or around tourist courts, bus stops, and restaurants. All the trees in the towns of Matamoros, Nuevo Laredo, Sabinas Hidalgo, Cadereyta, Monterrey, Montemorelos, Reynosa, China, Linares, and San Fernando have been inspected. The blackfly committee has made the inspections in the city of Victoria.

Of particular interest to Texas citrus producers is the very light infestation found in Matamoros in January 1950. This infestation was located in a patio on the southeast corner of the city's main plaza, near one of the bus stations. It consisted of larvae and pupae on approximately 20 leaves on 2 trees. These trees and all other citrus and other blackfly hosts within an area 9 blocks square were sprayed four times. The entire city has been thoroughly inspected twice since these sprayings, and the sprayed area has been inspected three times without any other blackflies having been found.

Four infestations were also found in the Montemorelos district. The infested groves are along the main highway on the outskirts of the city.

In the immediate vicinity are service stations, truck stops, and many fruit stands, favorite spots for trucks to stop and rest. Although it has not been proved that adult blackflies are carried extensively in motor vehicles, the infestations found during these surveys have been in localities through which there is heavy motor traffic or where local residents have frequent opportunity to travel to and from other blackfly-infested areas. The four infestations in Montemorelos were also given the standard four-spray treatment and, although three more detailed inspections were made, no more live blackfly material has been found there.

Inspection work in Monterrey was begun in February, and within a short time infestations were found over a considerable part of the city. By the end of August 341 infestations had been found. All these infestations were located in dooryard plantings. None of them involved any commercial groves. A spray campaign was promptly begun by the blackfly committee with excellent results. It cannot be said that eradication has been secured in Monterrey, but the infestation has been materially reduced. On a reinspection just completed live blackfly material was found in only 10 dooryard plantings, and in none of them was the amount of such material very great.

Infestations were also found in El Carmen district, about 20 miles northwest of Victoria. Other infested properties were found in the villages of Hidalgo, Tomaseno and Station Santa Engracia, and in the Ejido Santa Engracia. In El Carmen district the infestation was rather far advanced, larvae and pupae being found on more than 100 trees in one grove. The other findings were in noncommercial plantings, and blackflies were not so numerous as at El Carmen.

Promptly upon the discovery of the blackfly in these localities, the blackfly committee brought in its spray crews and began its eradication campaign. Apparently excellent results are being obtained, as reinspections here have not disclosed any live blackfly material.

In Sonora citrus growers of California and Arizona began a spray campaign against the blackfly in November 1947, in cooperation with Mexican citrus growers. The immediate purpose of this campaign was to reduce the numbers of blackflies in this northernmost West coast infestation and thus minimize the danger of further spread toward Arizona and California. This campaign, which was carried on under the direction of Dr. R. S. Woglum of the California Fruit Growers Exchange, was terminated in May 1948. Soon afterwards work in the same area was undertaken by the U. S. Bureau of Entomology and Plant Quarantine in cooperation with the Mexican Government. The campaign was successful in reducing the danger at the Arizona border.

In Baja California the crew is making inspections among the citrus plantings in the northern part of the territory. Here, as well as in Sonora, the citrus area is scattered, plantings not being contiguous as they are in northeastern Mexico, but the possibility of the blackfly becoming established in these groves is as great as in any other citrus area. There is direct water and air communication between the infested plantings at La Paz in the southern part of the peninsula and the citrus area in the northern part around Ensenada. Many other citrus pests are present, and it appears reasonable to presume that the blackfly can also be introduced and become established there unless the groves are frequently inspected and measures taken to eradicate it if it is found.

Control of the Texas Citrus Mite

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The Texas citrus mite, *Eutetranychus clarki* (McGregor), is a minor pest of citrus and has been found in damaging numbers in the Edinburg area. Sulphur dusting has ben recommended as a control for this insect. But in the past two or three years, this insect has been found in groves which had been well dusted with sulphur for rust mite control. Because of the lack of control with sulphur in the Edinburg area, preliminary experiments for the control of the Texas citrus mite was started.

In the first experiment, five eight year old trees were covered with large canvasses. The entire block was then airplane dusted with sulphur at the rate of 50 pounds per acre. A short time afterward the canvasses were removed. Then with hand dusters, 2 of the trees were dusted with 10 percent R-242*; 2 with 1 percent EPN** dust and the fifth tree remained untreated. Three days after the treatment applications, an examination of the leaves showed the following number of Texas citrus mites per leaf: 10 percent R-242, 2.1; 1 percent EPN, 3.9; sulphur (airplane dusted), 7.6; and 17.3 on the undusted tree.

In the second experiment, 15 acres of a grove were dusted with a mixture of 5 percent R-242 in sulphur at the rate of 50 pounds per acre. Another 15 acres was dusted with sulphur used at the same rate. Five trees were left untreated on the north side of the grove. Two days later an examination of the leaves showed an average of 1.0 mites per leaf on the trees dusted with 5 percent R-242 in sulphur; the trees dusted with straight sulphur averaged 11.4 mites per leaf whereas the untreated trees averaged 9.1 mites per leaf. A total of eight inches of rain fell between the third and eighth day after treatment application which resulted in a reduction of the Texas citrus mite population. Counts taken 10 days after the treatment application showed the following average number of mites per leaf: 5 percent R-242 in sulphur, 3.6; sulphur, 5.4; and an average of 8.8 in the untreated area. This data indicated that the addition of R-242 increased the effectiveness of sulphur in controlling the Texas citrus mite.

The data show that sulphur will not kill Texas citrus mites within 2 days of application. However, quick control of the Texas citrus mite can be obtained with either a 1 percent EPN or a 10 percent R-242 dust.

*P-chlorophenyl phenyl sulfone

**ethyl p-nitrophensyl thionobenzenephosphate

Use of Cyanamid Defoliant as a Control For California Red Scale

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For the past two or three years the cotton defoliant, cyanamid dust, or a combination of 50 percent cyanamid with 1 percent parathion dust, has been sold as a control for California red scale, *Aonidiella aurantii* (Mask). These dusts were usually applied by airplane at the rate of 20 pounds per acre late in the morning after the dew had disappeared.

Experiments conducted in the fall of 1947 showed that a single application of cyanamid dust gave little or no control of California red scale. At that time it was noticed that a considerable amount of leaf drop occurred in the cyanamid treated plot while very little leaf drop could be seen in untreated blocks.

During August, 1950 a grower had 5 applications of cyanamid dust applied during the first 15 days and a mixture of 50 percent cyanamid with 1 percent parathion dust also applied 5 times during the latter part of the month. Adjacent to this grove were 5 rows of trees which received no insecticidal treatments except sulphur and was considered as an excellent control area. Both groves were examined on September 6. When compared with the control area, the cyanamid treated grove had a terrific amount of leaf drop. In the dusted grove an average of 9.1 mealy bugs, *Pseudococcus citri* (Risso), per fruit were found whereas none were seen in the control area. An examination of the fruit showed 36.1 California red scales per square inch area while only 13.3 were found on the same area in the control grove. Leaf population counts showed approximately 2.4 California red scales per leaf for both groves but this data cannot be considered as significant since the cyanamid treated trees had shed a great many leaves. It does show that the scale was not controlled by dusting.

These results indicate that the cotton defoliant dust, cyanamid, is of no value as a control for California red scale. Furthermore, repeated use of this material will create a scale and mealy bug problem.

Observations on the Citrus Industry of Italy

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Citrus production in Italy presents some interesting contrasts to that in the United States, and there is good reason to believe that each region has something to learn from the other. One of the most striking contrasts in the picture in Italy is the small size of the individual orchards, many of which are smaller than one acre, and comparatively few of which exceed 10 acres in size. The very small individual holdings, and the rugged nature of the terrain, result in the practice of cultivation almost exclusively by hand labor. The fact that hand labor is available in such large amounts, and that an effort is made to use as much of it per unit area as possible, leads to the rather startling situation that more cultivation is given the orchards than may be necessary or even advisable. Furthermore, the depth of cultivation is in many cases extreme, in view of most of the recent results and trends in the United States.

The distribution of the citrus plantings in Italy is also of interest. It is surprising to find a considerable acreage up as far as Genoa and down on the west coast; there is considerable acreage, especially in mixed plantings, of oranges, tangerines, and lemons in the vicinity of Rome and some plantings on the east coast from Foggia toward Bari and below. The area around Sorrento and Amalfi, just below Naples, has some very fine orchards of late oranges and some lemons, which are protected in winter by straw mats, placed on frames above the trees. The lemons here are pruned quite flat, to facilitate the placing of the covers, but the orange trees are of full standard size. Going on down into Calabria, there is a considerable area of orange production and some lemons; but the citrus of primary importance here is the Bergamot orange, grown for the production of essence. There is also an acreage of approximately 12,000 on the Island of Sardinia, and plantings here are said to be increasing.

The dominating area in citrus production for Italy, however, is the Island of Sicily, with more acreage than all the rest of the country together. Latest reports show approximately 40,000 acres of oranges, 20,000 of tangerines, and nearly 60,000 of lemons. While some older orchards are mixed with other fruits, the majority of this acreage is in specialized plantings. Some of these plantings are quite old, 60-75 years, but many are comparatively young and more orchards are being set all the time. The trend at present is away from lemons, with considerable increase in tangerine acreage, and a substantial increase in oranges as well.

Within the Island itself there is considerable specialization of planting, and a brief survey might be of interest. Some of the principal zones of lemons are in the province of Messina, both to the south around Santa Teresa Riva and to the northwest, as far as Santa Agata Miletello; in the province of Catania, there is a zone of importance around Acireale, where the Citrus Experiment Station is located; in Siracusa, there is a very specialized zone of lemons; and in Palermo, the area around Bagheria is most important. Oranges are grown in several areas, but the one of primary importance is in the area of Adrano and Paterno in Catania, and Lentini and

Francofonte in Siracusa. Some of the most beautiful trees, with heavy crops of oranges of finest quality, were observed in this area. Mandarins are of primary importance around Palermo, where there is considerable acreage in the famous "Conca D'Oro" near the city, and in the Ciacullo district to the east, where there are some very fine orchards and a considerable program of expansion. Acreage of tangerines in this region is in excess of 5,000 and there is considerable interest in new plantings. The concensus of opinion in Sicily is that tangerines offer the best field for expanding production, in view of their acceptance on domestic and export markets.

Production figures for citrus in Sicily are also of considerable interest; averages for 3 years 1947-49, show lemons, 340,000 long tons; oranges 200,000 long tons; and tangerines, nearly 60,000 long tons. These figures are for fresh fruit, and those on citrus products will be given later in the discussion.

Varieties

A study of citrus varieties in Sicily reveals a surprisingly restricted area in the planting of some of the best types, and there is a strong belief that they succeed best in these particular areas. In the case of lemons, this is particularly true, though it was observed also in the oranges varieties.

LEMONS: Principal varieties include Femminello, Interdonato, and Monachello, but many lemons are grown under other names, and there are several strains of the principal varieties, especially Femminello.

Femminello was the most widely planted variety in Sicily, up to the time of discovery of mal-secco, the disease that has wrought havoc with the Sicilian lemon industry. In the region of Santa Teresa Riva on the east coast below Messina, there was a highly specialized zone of lemon production, and Femminello was universally planted, because of its high quality and the fact that it was well adapted to the practice of "forcing" for the production of a summer crop, known as "Verdelli." Since it is extremely susceptible to mal-secco, Femminello has been almost eliminated from this area, which was the point where the disease first made it appearance on the island. It has been replaced by Monachello, a newer variety that is quite resistant to the disease. Femminello is oblong, medium size, rind of medium thickness, pulp fine, juice abundant and high in acidity, seeds few, aborted. Tree is of medium vigor, very heavy and regular bearer, and fruit ships well. It would beyond question be the most important variety for both fresh market and products manufacture, except for its susceptibility to the mal-secco disease.

Interdonato is considered to be a hybrid between lemon and citron, and was discovered by Colonel Interdonato at Nizza Socilia about 1875. The plant is vigorous, with rather sparse branching, and is quite resistant to the attacks of mal-secco. The fruit is quite elongated, with prominent nipple, skin of fine texture and comparatively thin. Seeds are few, juice abundant, but not very acid. There is only one season of flowering, and the fruit all matures in early fall, October and November. It may be forced in some sections, but appears not well adapted to this procedure.

Monachello is a comparatively new variety, reported to be a strain of an older variety *Moscatello*. It has attracted considerable attention in zones where mal-secco has destroyed the Femminello, because of its resistance. At Santa Teresa Riva, one of the worst disease areas, several trees were observed which had had one branch budded to Monachello and another to Femminello. In every case, the Monachello was still growing well, while the Femminello branches had all died. Fruit of this variety is long oval in shape, with small nipple. Rind is thin and smooth and flesh is of excellent texture with abundant juice, although not high in acid. Monachello is a variety primarily adapted to the production of "verdelli" or summer lemons and as such, it should be planted on rather light soils of medium fertility, where growth responses can be controlled.

In connection with lemon varieties, a brief review of the practice of "forzatura" for the production of "verdelli" is in order. Lemons in Sicily do not ordinarily bloom and produce fruit over a considerable part of the year. It was estimated that where forcing was not practiced, the season of harvest in the vicinity of Acireale was: November, 24 percent; January, 30 percent, and March, 44 percent. When forcing was practiced, the season was: December, 5 percent; February, 20 percent; April, 30 percent, and June-July, 45 percent.

The practice consists in withholding of irrigation from the latter part of June for a period of 30 to 40 days. The trees go into a state of arrested growth, which should not reach the point where partial defoliation and loss of the fruit on the trees occurs. When irrigation is resumed the first application is very light, and is followed at intervals of 3 to 4 days by three other applications, the last of normal quantity. Inorganic fertilizer is also applied, just before or between irrigations. The trees when handled properly retain the crop already present, but bloom again and more profusely, to produce a good crop of summer lemons. While such a practice seems quite drastic, it has been practiced over a period of 60-70 years, with increasing skill and efficiency. It is, however, included in a rotation of the different parts of the orchards, and not oftener than every 2 to 3 years on individual plots.

The present situation in Italy at the present time is such that there is urgent need for a new variety of lemon, to combine the good features of high yield, good acid quality of juice, forcing quality and shipping quality of the Femminello, with resitance to disease, particularly mal-secco. The Citrus Experiment Station at Acireale has a program of selection and testing, which it is hoped will result in the discovery of such a variety.

ORANGE production, especially in Sicily, is restricted to a very limited area around Catania and Siracusa on the east coast, but there are scattered plantings on various parts of the island. Across the Messina Strait, there is a heavy concentration of oranges north of Gioia Tauro, and of bergamots around Reggio Calabria and to the south.

Tarocco is a comparatively new variety, discovered in the province of Siracusa in the early part of the century; but it has attained widespread popularity, and is grown wherever its adaptability will permit. It is considered to reach its highest stage of perfection in the vicinity of Francofonte and the fruit from this area is in great demand for the export trade to European countries; but it grows well in many other areas along the east coast of Sicily. The fruit is large and heavy, with a medium to thin rind, frequently showing some red coloration. The shape is broadly ovate and there are five projections around the calyx, as characteristic as those in the Delicious apple. Flesh is fine textured, juicy, and with some red coloration, though other specimens do not show color. Quality is very fine, and the fruit has a characteristic flavor that is highly esteemed. Season is Sicily is November to January.

Moro is a remarkable orange in three respects: it is extremely early, especially for a blood orange, October to early December; it is a very heavy bearer; and the color of the flesh is such a deep mixture of red, dark red, and purple, as to give a most striking effect. The fruit is medium or slightly above in size, round to slightly oblate, and the rind, while deep orange, seldom shows any red color externally. Flesh is perhaps slightly coarse, seeds few to none, flavor very distinctive, and quality quite good.

Sanguinello Moscata is a selection from the ordinary blood orange Sanguinello, of which there appear to be several types. The season of this variety is later than the preceding, and it serves to fill the same demand on the market in regular succession, February through April. It is of medium to large size slightly oblate, and shows rather extensive coloration of the rind. Flesh texture is fine, seeds practically none, flavor and quality of the highest.

These three varieties of blood oranges stand out above all the others, and appear to have promise of excellent performance in America, if they can be brought in. There are also among the "blond" oranges, as they are called in Italy, two varieties that deserve careful attention.

Belladonna or ionda elladonna is a midseason variety, ripening in December and hanging on the trees in good condition until April. The fruit is slightly oval in shape, deep orange in color, and very attractive in appearance. Flesh quality and flavor are excellent and there are few seeds or none. Not considered to equal in quality of the best blood oranges, but would probably be preferred by most people not familiar with that type. In the opinion of the writer, this variety is underrated in Italy.

Ovale or Calabrese is the most important of the so-called "Blond" oranges in Italy. It has many qualities to recommend it, especially its high quality and the fact that the fruit hangs well on the tree up into the summer and even to October and November. The fruit is distinctly oval in shape, clear yellow in color, juice abundant and excellent quality, and seeds few to none. It is considered to be a very good shipping variety. The tree is exacting in cultural requirements including fertilization and it also has a peculiar characteristic of producing off-type individual branches, with a fruit that is round to oblate and full of seeds, in contrast to the normal fruit that is oval and seedless. The variety is said by many to be superior to Valencia and it is certainly worthy of trial.

The tangerine group in Sicily is not made up of clearly defined varieties. There are small plantings of such as Dancy, King, and others but the majority are known simply as mandarins. As grown in Palermo, in the area of greatest concentration, the fruit is medium size, good color and quality, but with many seeds. Season of maturity is November and early December and fruit remaining on the trees in January is dry and puffy. In the Ciaculli area near Palermo, a late maturing strain has been propagated, that produces fruit just beginning to mature in January, when all the early fruit is gone. This late strain has a considerable number of seeds, but is of very fine quality. There appears to be a need for more varieties of tangerines, especially to extend the season.

Bergamot oranges constitute a very important crop in the area around Reggio Calabria, where there are plantings of approximately 10,000 to 12,000 acres. There are four recognized varieties of Bergamot, namely Femminello, Castagnaro, Melarosa, and Torulosa. The first named is considered by Directors La Face of the Experiment Station for Essences at Reggio Calabria, to be by far the most desirable; and the second, Castagnaro, produces an essence that is stronger than that of Femminello, though not as good quality. The other two are considered inferior in quality of essential oil produced.

The tree of the Bergamot orange is slow growing, rather open, with dark and slightly crinkled leaves, and the wood is very brittle, so that protection from wind is essential. The fruit is round to slightly obovate in shape, with a small, sharp nipple. Color of the rind is yellow, but not as clear as that of lemon. Flesh is greenish yellow, firm and somewhat mucilaginous, and seeds are many and prominent; though mostly abortive, with few viable. The fruit is said to be very rich in pectin and the residue from the essence plants is used to produce commercial pectin, in either liquid or powder form.

Soils and Sites

The soils most prevalent in the citrus orchards are different types of clay, frequently resulting from decomposition of limestone. Sandy areas are found in a few places, and the thinner, lighter soils are frequently utilized for the production of summer lemons. Such soils respond more readily to changes in cultural conditions, and are therefore best suited to the practice of "forzatura". Actual soil types are obliterated, as far as structure is concerned, on the hillsides, where rocks have been dug out, walls and terraces constructed, and the area in between filled with soil carried in baskets. The amount of hand labor used in reclaiming and fitting land on these hillsides is almost beyond imagination, and in many cases the resulting orchard may well be regarded as a large scale pot culture. The soil on the hillsides is usually rather heavy and sticky, and even on the terraces, careful attention must be given to drainage. Air drainage is usually good, but where it has been obstructed, as in one large block near Francofonte, the frost hazard becomes very serious.

In the level areas along the streams, and especially in the Plain of Catania, soils may be somewhat lighter; but heavy soils in these areas are subject to severe problems of drainage. Many orchards in such areas show definite evidence of "wet feet" and the damage from root rot and gum disease is apparent. The small size of the individual holdings is a contributing factor toward lack of adequate drainage.

Wind breaks are very important in all of the areas along the coast, where winds are frequently quite strong over a considerable part of the year. Probably the most common windbreak in Sicily and Calabria is the olive; and even this hardy tree barely survives without producing any fruit, on the windswept coast south of Reggio Calabria. Eucalyptus, Australian pine, and many other trees are also used, and in the area farther north, around Amalfi and Sorrento, artificial structures, consisting of frames covered with branches or straw mats, are used.

Cultural Practices

Cultivation is predominantly by hand, due to the small size of the individual plantings, the type of terrain, and the fact that hand labor is available. in fact, citrus is considered one of the most desirable crops, because of the number of man hours utilized per unit of area. As an example, one orchard in the Paterno area is cultivated on the following schedule: first cultivation (zappatura) in March, probably much deeper than would be advocated in the United States; second, in May, to build irrigation basins (conche); third, in July, rather shallow; fourth, in September, also rather shallow, and fifth in September, on early maturing varieties, to hasten maturity--late varieties do not receive this cultivation.

In no case observed or discussed was there any consideration of the program of non-cultivation as practiced in California, through the destruction of weeds and grass by spraying; or of the program of sod mulch, with use of mower or stalk cutter, as used in some groves in Texas. By standards of both of these areas, cultivation is carried beyond that recommended or considered desirable in citrus areas of the United States, and yet there is the irrefutable fact that many of these orchards here in Italy are 60 to 75 years old, and are still maintaining profitable production.

Fertilization consists primarily in the application of large quantities of organic matter, both in the form of cover crops, and as additional material brought into the orchard. All vegetable and other organic refuse is collected, even from the cities, and composted with manure and other material on the farm. The green manure crop is buried in trenches, and manure and compost is added at the time. Usually this is done in the fall, and some phosphate fertilizer is applied in the same trench. The most common green manure crop over the whole area is the broad bean (Fava) which produces a large volume of organic matter. Inoculation of legumes is not a widespread practice, but is receiving some consideration at the present time.

Inorganic fertilizers are also used to a considerable extent, and there is even a feeling among technical workers that the use of nitrogenous fertilizers has been carried to extremes. There is, of course, widespread difference in the use of these inorganic materials; and recommendations for their use are complicated by the extreme variability of the soils in the small plots, especially those that have been filled in with varying mixtures of soil. The common feeling at the present time seems to be that a balance

of the three materials of nitrogen. phosphate, and potash is desirable, even though the best use of the two latter is not fully understood. Nitrogen is naturally used in advance of blossoming to aid in fruit setting, and as in all cases in the United States, gives very satisfactory results. It is probably that increased applications of fertilizers in general will be indicated in the future, but there is need for more specific information.

Minor element deficienty may be indicated by the yellow color of new shoots, and even older leaves in many orchards. This is attributed locally to various other causes such as cold weather, poor drainage, or disease and insect damage; and unquestionably these may all be responsible under some conditions. In one orchard, soil applications of iron sulphate were made regularly, but there is no evidence of experimental work in foliar application of the various minor elements. With the prevailingly heavy soils, such deficiencies may not exist, but possibly some analyses and tests might be of value.

Orchard Layout and Interplanting

One of the most noticeable features of Italian agriculture is the intensive utilization of the land, and the question naturally arises as to whether such use is most efficient. In the case of citrus orchards, planting distances vary from slightly over 12 feet with tangerines up to 21 and 22 feet with some of the more recent orange plantings. In addition to the close planting, the young orchards are used to grow vegetables, grain, or other crops for several years, to offset expense of bringing the orchard into production. In most of the citrus orchards, there is comparatively little interplanting of grapes or other fruit trees, as is observed in the almond orchards and those of other deciduous fruits. Some of the older orchards are set in even older plantings of olives, since these latter are almost everlasting. Data on the relation of number of trees per acre to yield are not readily available. but should be of interest.

Pruning

The close planting mentioned above has an important bearing on pruning in two ways. In the first place, many of the old orchards, both lemons and oranges, are pruned rather high, in order to permit other cultures beneath them. The fruiting areas of such trees is quite restricted, and it is difficult to see how profitable production can be obtained. It is interesting to note, however, that the orchards of more recent planting, are headed lower and have a much larger baring area.

Severity of pruning is considerably more than is the usual practice in America. The trees are thinned to a considerable extent and the more vigorous growth is removed, leaving almost exclusively the "so-called" fruiting wood. Water sprouts are removed several times a year, so there is little purely vegetative wood to be removed at time of pruning. A certain amount of heading back is also done, and all in all, the trees are kept within rather closely prescribed shape and size. It is also evident that the pruning is much more detailed than is customary in America.

Irrigation

Almost the entire area of citrus cultivation in Italy is under irrigation, and especially in Sicily, where concentration is greatest, irrigation is essential. Most of the water comes from wells, which vary in depth from 12-15 feet up to more than 100 feet There are few reservoirs in the area, but the nature of the rainfall, which comes in hard downpours of limited duration through the winter, and the rugged nature of the terrain, make it difficult to conserve water in small reservoirs. There are, however, at least nine major irrigation projects under construction in Sicily alone, and several on the mainland; these are reclamation projects sponsored by the Government, and should provide much better facilities in the areas that they will serve.

Application of water to the land is almost exclusively by the basin method. Water is carried either in underground lines of tile or in open flumes of brick or tile, lined with cement. Irrigation practice is very carefully conducted, with special attention to the needs of individual areas or even individual trees, in contrast to the rather uniform applications in the large orchards in California and Texas.

The extreme of specialization in irrigation is observed in the practice of forcing for the production of "verdelli" or summer lemons. Water is withheld in June and July, up to a certain critical stage in the growth processed in the tree, and then when irrigation is resumed, frequent and very light applications are made, in order to avoid a response of sufficient magnitude as to cause shedding of leaves or fruit already present. Here again, each tree is given individual attention in a very skillful system of management.

Insects

No attempt will be made to list all the various insects attacking citrus in Italy, but a brief consideration of two very important ones should be given. One group, the *scale insects*, is no novelty in any of our American citrus areas, and there is a varied assortment in Italy. The chief point of interest here is the fact that government regulations have been established, as in California, to provide for enforced control whenever there is a population of sufficient magnitude in any area. Control measures, however, are conducted systematically by grove owners, and most orchards are quite clean. Some fortunate areas have little or no trouble with scale insects. Fumigation with cyanide is probably the most common control method, but due to small size of individual groves, the equipment used is reminiscent of that in use when the writer was employed near Riverside, California, in 1915. In the same way, where the oil sprays are us d, good control was observed in a lemon orchard of about 30 acres, where only hand sprayers had been used. No power sprayers were observed and much of the terrain is of such nature that their use would be impossible. In other areas, however, it would seem that through some sort of cooperative organization, good use could be made of power equipment and machines for both fumigation and spraying.

Mediterranean Fruit Fly is present in most of the citrus areas, and while it attacks primarily the fleshy fruits, it does occasional damage to

citrus. There is considerable difference among the citrus fruits in their resistance to this pest. Lemons are not attacked, and among the oranges, only the very early or the late varieties are damaged. The tangerines are also very subject to attack and damage is sometimes severe. In some cases, the orange is resistant to the attack of the fruit fly, through a response of forming a seal of gum around the egg which then fails to devlop. Fruit of sour orange was observed in February that has been so attacked, with the resulting appearance of a small blotch of yellow on the rind, and the dark pin spot of gum surrounding the egg in the center of the area. Belladonna and Ovalc both show this same response.

Ants and many other insects are to be observed in the orchards and are noted in various monographs and bulletins on citrus; but the two mentioned above cause most of the trouble, or require the most careful supervision on the part of groveowners.

Diseases

Aside from "mal-secco" which will be discussed later, the diseases causing trouble in Italian citrus are quite familiar: root rot, caused by *Rhizoctonia* in the seed beds, and by *Phytophthora* on older trees; gum diseases, caused by *Pythiacystis* and *Phytophthora*, the former more prevalent on lemons and the latter on oranges; and bacteriosis, caused by *Phytomonas*, the latter causing damage more in the nursery than in older trees.

Mal-secco is a disease causing wilting and dying back of twigs and branches, and in susceptible varieties and species, the death of the entire tree. The disease was noted in Sicily in 1922 and was studied by Dr. Savastano, Director of the Citrus Experiment Station, and also by Dr. H. S. Fawcett. Identification of the fungus was made in 1929 by Dr. Petri, of the Division of Vegetable Pathology in Rome, and the name *Deuterophoma tracheiphila*, Petri was established. Descriptions of the disease and its effects are given by Dr. Fawcett in his book on citrus diseases and also in Vol. 2 of the more recent work "The Citrus Industry". It is impossible to over-emphasize the detrimental effect that this disease has had on lemon production in Sicily, and the research and control measures are very interesting. A comprehensive survey of the problem, with suggested procedures, has recently been published by Dr. G. Ruggieri, Director of the Citrus Experiment Station at Acireale.

The fungus may enter the plant through the stomata in the leaves, or through any wound or injury. Under ordinary conditions, the movement of the disease downward through the plant is very slow, and the plant is not killed immediately; but in case of a rather general infection, such as may occur following hail damage, the disease may spread very rapidly and kill the tree in a short time. The same rapid growth also occurs when infection takes place on the main trunk or the roots, because the sour orange rootstock is extremely susceptible. Under ordinary conditions of infection, it has been found possible to keep the disease under control by careful pruning, to the extent that the tree may be maintained in profitable production. The season of most rapid growth is from late winter through April or May and again from September to November. The hot dry weather of July and August checks it completely, and in conjunction with pruning and grove sanitation, gives the grower a chance to clean up the orchard rather thoroughly.

Resistant varieties have been sought constantly since it was first determined that the standard *Femminello* lemon was most susceptible. *Interdonato* and *Monachello* were found to be quite resistant, and many more varieties and selections have been tested with limited success. A comprehensive breeding program and study of available strains and sports is still under way, with the possibility that other good varieties resistant to the disease may be obtained.

Rootstocks and Propagation

Since rootstocks and propagation procedure are of primary importance in disease control, they are mentioned at this point. The only rootstock in commercial use in Italy at the present time is the sour orange (arancia amara or melongolo). This stock has been used over a long period of years, because of its notable resistance to foot rot and gum disease; but of all the citrus species of commercial value, including the lemon, the sour orange is most susceptible to mal-secco. When infection of the sour root stock occurs as a result of poor sanitation, the tree invariably dies within a short time. No other root stock has been tested on a considerable scale, though there is at present a considerable interest in *Cleopatra* mandarin, as a result of its demonstrated resistance to quick decline. Sweet orange and rough lemon have both been eliminated years ago on account of susceptibility to foot rot and gum disease.

The susceptibility of sour orange to mal-secco has put an end to a practice that was common for many years – that of planting sour orange seedlings in the permanent location and budding with scions from a specially selected tree known to the grower. In the nursery the sour seedlings can be sprayed at frequent intervals, to prevent the fungus from getting a start; and only the trees with good budded tops and no sour orange branches are set out.

Double working is practiced to some extent, with the thought that a sandwich of sweet orange wood will serve to prevent the rapid downward movement of the disease to the roots. In one orchard, tangerine had been used as the intermediate stock, but both the sour orange and the lemon top had overgrown the tangerine, and the grower was convinced that this was not a good combination. On the other hand a very fine tangerine orchard in the Ciacullo section near Palermo is made up of trees topworked on old lemon trees.

There is every indication that a good rootstock testing project for lemons in Sicily is indicated. While all citrus species can be inoculated with mal-secco, many are notably resistant; these could be tested for adaptability to local conditions, and also for compatibility with commercial lemon varieties.

Harvesting and Marketing

The fruit is in practically all cases "snapped" from the stem (as is

frequently done also in Texas). In some cases, especially with tangerines, a small piece of stem with one or two leaves is left attached to the fruit, but in commercial practice, a second worker cuts the stem close to the calyx. The packers carry baskets that hold about the same as a picking bag; these are well padded to prevent bruising of fruit, and are carried by means of shoulder straps. Pickers bring the fruit to a central shed in the orchard, where it is emptied in bins or on the floor, sorted, and placed in larger baskets, for transportation to the packing shed.

A common practice is for the grower to sell the fruit on the trees for a specified price per unit of weight, and the buyer then handles all harvesting and packing operations. Where the growers are organized in co-operatives, harvesting is done by crews sent out from the packing shed. In still other cases, the grove owner has his own packing house, and markets his own fruit.

In the packing house, there is seldom any mechanical equipment, such as washers. brushes, or belt conveyors. Fruit is graded and sized from the individual field baskets, and packed directly into the box. Nevertheless, the fruit is bright and clean and in one shed at Messina where lemons were beng packed for export, no better looking fruit nor package could be found anywhere. The pack in this case was 300 fruits to the box, ranging in weight from 85 to 90 pounds.

A considerable volume of the Italian citrus production goes into export trade. Central Europe was formerly a big market, but now fruit is moving only into Germany, Switzerland, France, and England, with smaller quantities into the Scandinavian countries. The blood oranges, as produced around Francofonte, Lentini, and adjacent areas, are in considerable demand in Germany, which was formerly a very important outlet for them. Some lemons are moving into the United States at the present time. (1949-50).

The marketing program is complicated by the multiplicity of small producers, most of whom are not organized, and who sell in the most expeditious way available at the time. There is a lack of uniformity in varieties, complicated by the fact that many growers propagate their own trees, from parent trees of their own selection. The value of cooperative organization is observed in the functioning of such as the Compagnia Agrumicoltori Francofonte, which not only handles the marketing of the fruit, but is able to provide some technical information, and also to encourage planting of uniform blocks of varieties of best commercial value.

Ctrus Products

The citrus products industry has been an important source of revenue from the time that the Italian growers pioneered in the production of citric acid. At the present time, this product is far down on the list of profitable enterprises, due to the competition of citrus acid produced by the biological process. A list of the various products, with figures on production, *for Sicily only*, for the past three years, may be of interest.

Table 1. Production of Citrus Derivatives in Sicily

	1947	1948	1949 (Prelim)
Essence of lemon (kg)	456,500	380,000	449,188
Essence of orange (kg)	15,850	18,000	13,700
Essence of tangerine (kg)	10,270	12,000	12,315
Essence of petitgrain (kg)	1,010	840	1,010
Essence of Neroly (kg)	72	60	60
Lemon juice concentrated (long tons)	45	37	48
Lemon juice concentrated (long tons)	45	37	48
Orange juice—natural (long tons)	198	242	137
Peel—fresh or dried (long tons)	8,350	7,500	7,821
Orange paste (long tons)	1.8	2	1.7
Pectin-liquid (long tons)	1.6	1.5	1.2
Calcium citrate (long tons)	2,167	2,000	—
Citric acid (long tons)	1,300	1,200	—

These figures do not include the tremendous production of Bergamot oil, pectin, calcium citrate, alcohol and other products from the Bergamot processing plants in and near Reggio Calabria, nor the production of orange juice, peel, pectin, and related products from plants at Gioia Tauro and other points in the province of Calabria.

Two of the largest plants in Sicily, Sanderson-Bosurgi, near Messina, and Arenella, at Palermo, were visited with the idea of observing equipment, methods and products. It is interesting to note that considerable equipment is being installed, to replace some of the hand operations. Juice extractors from California were being installed at Messina, but it was also of interest to see in the Palermo plant and several others, a juice extractor that was developed and is being manufactured at Giarre, Sicily (Indelicato). There are also several machines for extraction of oil from the peel, but in many places, the old method of hand pressing into a sponge is still in use. Similarly, some plants still use hand labor to halve the fruit, which is then pressed by hand against burr-type reamers. The Indelicato machine also uses a reamer of this type.

Lemon juice is prepared with single strength, sweetened, and preserved with SO2 or concentrated about five times (1/5 original volume). The latter product is most popular for export. Orange juice similarly is processed single strength with SO2 or concentrated. The unconcentrated juice is put in barrels for export, and several shipments for England and Ireland were observed in preparation. The sweetened lemon juice is most popular in Italy.

Peel for processing has the pulp removed by a hand operation with a small curved knife. Operators are very skilful in removing the pulp in one quick action, and the resulting peel is very clean. After brining is completed, peel is packed in hogsheads that are placed on the side, filled with brine and the bung left out for refilling until product is shipped.

Pulp from this process, in case of oranges, was used in one plant to

produce a paste used in confections. The pulp is ground, juice pressed, and residue passed through a finishing machine. Only a small amount of final residue is left, and this is sold for stock feed.

Bergamont oil is extracted from the surface of the whole fruit which passes through a rotary machine with an abrasive surface. The fruits are then ground and juice extracted to produce calcium citrate and later citric acid, the pulp is used for production of pectin, which is particularly abundant in the Bergamot, and the final residue is used for stock feed, which is dried in stack-type dehydrators. Some rotary dehydrators are being installed.

Citric acid is produced in only a few of the larger plants. The smaller plants, of which there are many in Calabria, produce calcium citrate which is shipped in coarse bags to the larger plants.

Detailed information on all of these products and processes in Italy as well as in other countries is included in two 1949 books: "Citrus Products," by J. B. S. Braverman, Interscience Publishers, Inc. New York; and "The Essential Oils", (Vol. III), by Ernest Guenther, D. Van Nostrand and Co., Inc. New York.

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Nutritional Studies on Citrus at the Texas A. & M. College Experiment Station Substation 15

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According to the "Marketing News" of the United States Department of Agriculture, 23,200,000 boxes of grapefruit and 5,200,000 boxes of oranges were produced in Texas in 1947-48, with estimated values of $10,241,000 and $7,800,000, respectively. Citrus production is thus a major industry in the Rio Grande Valley, and it is gaining rapidly in importance in Texas. With continued improvement of drainage and irrigation facilities in the Lower Rio Grande Valley, the importance of the crop is certain to increase.

Producers of citrus use heavy applications of fertilizer. Fertilizer consumption in the Lower Rio Grande Valley represents about one-seventh of the total fertilizer consumption in Texas. Citrus, cotton and vegetable production together account for this large consumption, but definite figures as to the relative importance of the three types of crops in this respect are not presently available. A great deal of work needs to be done with citrus in order to secure reliable data upon which to base fertilizer recommendations.

The primary use to be made of the results of the work now underway will be the formulation of definite fertilizer recommendations on different soil types and under varying irrigation and management practices.

Section 1

Experimentation with citrus fertilizers presents many difficulties which are not encountered in annual crops. Previous fertilization and management practices may greatly influence the response to current and future treatments. Only a relatively few plants are used on a given area, and fertilizer treatments must be based on the individual plant rather than a definite area in which many plants occur. Planning, on one hand, is confronted with the necessity for a considerable number of plants and, on the other, with the fact that the inclusion of many plants will involve a considerable area over which heterogenity of soils, irrigation, and management practices may overshadow or reduce the reliability of the effects of the treatment or treatments under special study.

An outline of the work being conducted on fertilization on citrus at the present time, is covered by project 746 of the Texas Agricultural Experiment Station in cooperation with Rio Farms, Inc. at Monte Alto, Texas, and E. M. Goodwin, Inc. at Mission, Texas. Table 1 gives the treatments over a five year period at Rio Farms, Inc., and Table 2 presents the treatments over a five year period at E. M. Goodwin, Inc.

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1. Design
   A randomized incomplete block design replicated three times.
2. Locations
   One location on fine sandy loam near Mission on land controlled by E. M. Goodwin, Inc.
   One location on fine sandy loam near Monte Alto on land owned by Rio Farms, Inc.
   Additional locations will be developed as personnel and facilities become available.
3. Plot size
   The gross plot consists of twelve trees, in a 4 x 3 block, with yield records being taken from the inside two trees in order to completely eliminate any cross feeding by the roots.
4. Fertilization
   A. Nutrient Levels
   Nitrogen: O, .65, 1.3, 2.6 pounds of nitrogen (N) per tree from ammonium nitrate on Rio Farms location. 0, 1.0, 2.5, 5.0 pounds of nitrogen (N) per tree from ammonium nitrate on E. M. Goodwin location.
   Phosphorus: 0, 2.0 pounds available phosphoric acid (P2O5) per tree from 20% superphosphate on Rio Farms location
   0, 4.0 pounds available phosphoric acid (P2O5) per tree on the E. M. Goodwin location
   Potassium: 0, 2.0 pounds of potash (K2O) per tree from 60% muriate of potash on Rio Farms location. O, 4.0 pounds of potash (K2O) per tree on the E. M. Goodwin location
   B. Application
   One-half of the total nutrients the last two weeks in January
   One-fourth of the total nutrients in June
   One-fourth of the total nutrients in September
   The fertilizer will be broadcast under the trees and worked into the soil with the usual tillage operations.
5. Tree records
   A. Diameter of the tree six inches above the bud union twice a year.
   B. Foliage diagnosis for nitrogen, phosphorus, and potassium three times a year.
6. Fruit records
   A. Yield and size of fruit
   B. Quality of the fruit

TABLE 1 Pounds of nutrients per tree for the five year period starting with five year old trees

Rio Farms Location Near Monte Alto

	Ist. Year	2nd. Year	3rd. Year	4th Year	5th Year
N	0 .65 1.30 2.60	0 .90 1.80 3.60	0 1.15 2.30 4.60	0 1.40 2.80 5.60	0 1.65 3.30 6.60
P2O5	0 2.00	0 3.00	0 4.00	0 5.00	0 6.00
K2O	0 2.00	0 2.50	0 3.00	0 3.50	0 4.00

Treatments for the First Year

Nutrients in pounds per tree	Fertilizer
N -0. .65 1.30. 2.60	Ammonium Nitrate 32%
P2O5 -0, 2.00	Superphosphate 20%
K2O -0, 2.00	Muriate of Potash 50 or 60%

TABLE 2 Pounds of nutrients per tree for the five year period starting with five year old trees

E. M. Goodwin Location Near Mission

	1st Year	2nd Year	3rd. Year	4th Year	5th Year
N	0 1.0 2.50 5.00	0 1.25 3.00 6.00	0 1.50 3.50 6.00	0 1.75 4.00 8.00	0 2.00 4.50 9.00
P2O5	0 4.0	0 5.0	0 6.0	0 7.0	0 8.0
K2O	0 4.0	0 4.5	0 5.0	0 5.5	0 6.0

Treatment for the First Year

Nutrients in pounds per tree	Fertilizer
N - 0. 1.0. 2.5. 5.0	Ammonium Nitrate 32%
P2O5 - 0, 4.0	Superphosphate 20%
K2O - 0, 4.0	Muriate of Potash 50 or 60%

Section 2

Papers presented at previous sessions of the Rio Grande Valley Horticultural Institute have discussed the various phases of salt and boron accumulation and injury to citrus trees. (Hayward, 1947, a, b; Maierhofer, 1947; Schulz, 1947; and Wilcox, 1949). Work by Dr. W. C. Cooper and his colleagues (1949, 1950) has been directed toward evaluating several root stocks as they affected salt and boron accumulation of scions. A Salinity and Boron Survey of the Lower Rio Grande Valley of Texas made in December, 1948 studied the extent and causes of salt and boron damage in the Valley (Wilcox, 1949).

Chemical analyses of soils in one form or another have been used for several decades in an attempt to evaluate the nutrient status of soils and to give guidance for fertilizer applications. Because of the possibility of a high percentage of error, as evidenced from experience with such soil tests, analyses of leaves and other plant parts have been studied in recent years as a method of measuring soil fertility and the limits of toxic ions. (Chapman, 1949; Hoagland, 1947; and Shear et al, 1948).

Because of the need for further studies of the salt and boron problem and for a more accurate method of evaluating the nutrient requirements for citrus in the Lower Rio Grande Valley, Texas Agricultural Experiment Station Project No. 783 was developed. The objectives of this project are as follows:

1. To establish minimum and optimum levels of soil nutrients required for economical and sustained production of citrus.

2. To establish by foliar analysis the minimum and optimum levels of nutrients and salts in citrus leaves that are associated with high production of quality fruit.

3. To determine toxic limits of injurious salts which occur in irrigation water and citrus soils.

Research in Progress

Work that is being carried on in an effort to achieve the objectives of the above project are:

1. A resampling of the soil, leaves, irrigation water, and ground water of the sites studied in the 1948 Salt and Boron Survey. Trees sampled in December, 1948, were marked so that the exact trees and soils can be resampled. In an effort to evaluate the leaching effect of fall rains, a set of samples was taken last August and another set will be taken in December, 1950. It is anticipated that a correlation between tree condition and salt and boron content of leaves or soil can be used to develop practical standards of value to citrus producers.

2. Analysis of soil and leaf samples from the fertilizer plots described previously under Section 1. Sampling of leaves and soils of the plots will be made just prior to fertilizer applications. Because this project was developed some months after the fertilizer experiment was start-

ed, only two sets of leaf samples have been taken to date from the Rio Farms plots at Monte Alto, and one set of leaf samples from the plots on the Goodwin tract at Mission.

Nitrogen, phosphorus, potassium, calcium and magnesium determinations will be made on both the soil and leaf samples and these results will be compared with tree growth, tree condition, yield, and fruit quality.

Additional Research

Other studies of a similar nature will be undertaken as time and personnel permit. Comparisons of different soils, fertilizer practices, and systems of water management in groves of owner cooperators have proved helpful in Florida and California and it is hoped that similar comparisons will be useful in Texas. In this type of work, the cooperation of the Extension Service is locating suitable groves will be solicited.

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Consumer Preferences for Fresh and Processed Citrus

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The consumer, during the last decade, and particularly during the past year, has exhibited a keen interest in citrus fruits. Two factors were particularly responsible: higher retail prices which resulted from a reduced volume of production; and the widely publicized birth and growth of the new frozen citrus concentrate industry. Undoubtedly, consumers have had to pay a higher price for fresh and canned citrus during the past year. Consumer purchases of citrus, however, have continued to be large in spite of the higher prices. Such buying behavior shows the high regard consumers have for citrus as an essential requirement in their diets.

Citrus production has increased until it is now a major fruit crop of the United States. In terms of fruit tonnage, oranges ranked first and grapefruit fourth during the 1948-49 season. During the period 1943-1947, citrus accounted for 44 percent of the total tonnage of the leading fruits while citrus juices represented 60 percent of the total fruit and vegetable juice pack.

Citrus production and marketing play an important role in our national economy. Agriculture and industry are interdependent. The progress of one is closely related to the progress of the other. This relationship has been recognized by Congress in the passage of the Research and Marketing Act of 1946. Appropriations under this Act have made possible expanded research in production, utilization and marketing of agricultural products. Researchers from the State Experiment Stations and the United States Department of Agriculture are now working on many problems confronting the citrus industry. The primary objectives of this research is to provide information which will enable growers, shippers, wholesalers and retailers to do a better job of production and marketing. One of the important fields of marketing research is consumer demand and consumer preferences. Consumption is the aim and end of all production. Therefore, it is logical that research be conducted on consumer buying behavior as an aid in guiding groups in their production and marketing practices and policies.

Problems Under Study

Consumer preferences for citrus are being studied by two groups, the Agricultural Experiment Stations of Texas and Florida and the research agencies of the United States Department of Agriculture. The state agencies are studying consumer preferences and buying behavior in various southern markets. The USDA is obtaining records of purchases of citrus fruit by a national panel of households, with regional comparisons.

Objectives of Studies

The objectives of these studies are:

1. To determine the influence of changes in prices on changes in quantity of sales for each citrus product.
2. To determine competitive relationships between fresh citrus and processed citrus products, and between citrus juices and non-citrus juices such as tomato and pineapple.
3. To determine the factors which affect consumption and non-consumption.
4. To determine consumer preferences in merchandising methods.
5. To locate areas of limited consumption and to study possible methods of improving the situation.
6. To evaluate advertising and promotional methods for expanding consumption.

Research Results to Date:

Although the findings of all the studies are not complete, a summary of the major results to date provides helpful information which can be used for promotional work. It appears that most households, both urban and rural, use some type of citrus product. However, the type of product used and the frequency and amount of use vary considerably. The extent of use of citrus products seems to be determined by the interaction of several factors such as taste, habit, price, and availability. Taste is probably the most influential. Cost and unavailability appear to restrict the use of citrus more in rural areas than in urban areas (Anon. a., 1950).

It appears that homemakers generally prefer to buy citrus in bulk rather than in bags. Consumers complain that bags often contain spoiled fruit or fruit of uneven quality and size. If consumption is to be expanded through the merchandising of fruit in bags, steps must be taken to insure uniformly high quality fruit.

A report on consumers' preferences for both fresh and processed citrus in Houston, Texas has recently been released by the Texas Agricultural Experiment Station. This study was a joint project of the Texas Agricultural Experiment Station and the United States Department of Agriculture (Fugett et al, 1950). This project included a study of both consumer attitudes and consumer purchases.

The study shows that practically all homemakers in Houston use some citrus products. At the prevailing level of prices for citrus and competing products (May 15-June 15, 1949), the consumers were more sensitive to changes in quality of citrus products than to changes in price.

The consumers, both in their buying behavior, as revealed by retail store sales, and in their stated preferences, as obtained from the household survey, make a distinction in their evaluation of the various citrus products. The primary distinction is between fresh citrus and processed citrus juices. Consumers apparently are convinced that fresh citrus excels in health and taste properties. This was evident when the consumers spent twice as much for fresh citrus as for either processed citrus juices or fruit juices other than citrus.

According to the household survey phase of the study, 95 percent of all homemakers reported using both fresh oranges and fresh grapefruit. However, the retail store data show that they spent approximately four times as much for fresh oranges as they did for fresh grapefruit. Sales were obtained from stores selected in a manner that would show the influence of income. The proportion of sales among fresh citrus, processed citrus juice and non-citrus juices did not vary greatly among stores serving low, medium and high-income consumers. Sales of fresh grapefruit were relatively less in low-income areas than in the medium and high-income areas, while sales of canned orange juice were relatively more important. Sales of frozen orange juice were relatively greater in the stores representing high-income customers than in the stores representing medium and low-income customers.

Frozen orange concentrate was preferred over canned citrus juices, primarily because of taste, by those who had used both products; however, many homemakers had not used frozen orange concentrate as of June 15, 1949. This survey showed that citrus is a distinct class of fruit to most consumers. Because of this many people indicate some reluctance to shift their purchases to competing fruits and fruit juices. The retail store data show that during May when the quality of fresh citrus declines, fresh citrus sales also decline, while sales of processed citrus juices increase and sales of non-citrus juices do not change. The household survey indicated that shifts are also made from fresh citrus and citrus juices when other fresh fruits are in season. The household survey showed that homemakers prefer pink grapefruit over the white or red; white grapefruit juice over pink; unsweetened juices over sweetened; large-sized cans of juice over small; bulk fresh citrus over packaged, and pricing by count over pricing by the pound.

Consumers are constantly seeking high quality fresh citrus. If citrus growers are to expand sales of fresh citrus they must provide consumers with the qualities desired. The maintenance of quality is important as expansion of sales must come largely through increased sales to consumers already using fresh citrus but on a limited scale. Grapefruit "sweeter and less bitter" in taste is the quality most desired. This should be considered when growers and shippers are inclined to market early shipments of immature fruit which may be lacking in acceptable taste attributes. This fact should be of particular significance to citrus growers in Texas because of their specialization in grapefruit production.

Undesirable taste is the major objection to canned citrus juices. This may explain why approximately half the homemakers do not use canned orange juice and canned blends. This large proportion of non-purchasers is significant because the expansion in sales of citrus juice must come largely from the homemakers who are now not purchasing processed citrus juices. The Houston study revealed that consumers in all income levels are "fresh citrus" conscious during the winter and spring months. This is clearly supported by the large share of the consumers' citrus dollar which is spent for fresh citrus in all income groups. The household survey also corroborated the retail store findings. Homemakers emphasized fresh citrus as an important health-promoting item from the points of vitamins and prevention of colds. For this study, the sales of citrus was obtained weekly from retail stores by volume and price per unit. This provided total dollars of expenditure and an indication of the relative shift in purchases from month to month.

The share of the consumer's citrus dollar spent for canned juices and frozen orange concentrate was very stable on a monthly basis. Thus, it appears that if consumers buy a larger quantity at one time they will reduce subsequent purchases. During the period of this survey, many of the stores included in the study sponsored "special sales" for canned citrus juices and frozen orange concentrate. Such sales may prove conducive to increase "traffic" to a specific store, but it appears doubtful whether they sustain purchases of canned citrus juices over a period of time.

Consumers preferences are strongly guided by sales promotion. Therefore, the expansion of the frozen citrus juice concentrate industry is of much concern to all interested in the citrus industry, especially the marketers of fresh fruit. High-powered, and sometimes questionable advertising has aided in expanding consumer acceptance of this new product.

It is interesting to note the existing capacity and size of firms processing frozen citrus juices. Florida has 30 plants representing an investment of $18,000,000 while California has 10 plants representing $8,000,000. Texas has one plant but to date no investment figures are available. The Florida and California plants have a total capacity of 37 million gallons and during the 1949-50 season they processed 27 million gallons of frozen citrus juice concentrate. The long time influence which the frozen concentrate may have on fresh fruit and single strength juices is unknown at this time. However, records of purchases obtained during the past year seem to indicate that sales of fresh fruit and single strength juice have been reduced equally. Thus, it is apparent that packers of fresh citrus and processors of single strength juice face considerable competition, particularly on oranges (Anon., 1950).

Since Florida citrus production has a vital influence on the production and marketing of Texas citrus, comparative statistics should be of interest.

Table 1. Production of Citrus by States

	Grapefruit (Boxes in 000)		*Oranges* (Boxes in 000)	
	Texas	Florida	Texas	Florida
1949-50	6,500	24,200	1,659	62,800
1950-51 Est.	12,000	32,000	3,500	62,500

The following tables are presented to show the changes in the production and utilization pattern for Florida citrus during the past year. This utilization pattern is extremely important because it has a strong influence on the degree of competition which each citrus product will face.

Table 2. Utilization of Florida Citrus, 1949-50

Grapefruit		*Oranges*	
	Percent		*Percent*
Fresh fruit	44	Fresh fruit	40
Frozen concentrate juice	8	Frozen concentrate juice	34
Single strength juice	37	Single strength juice and sections	26
Sections	11		
	100	Total	100

The relative importance of each type of single strength juice packed in Florida for 1949-50 was as follows: orange juice 52 percent, grapefruit juice 24 percent, blended juice 20 percent, and tangerine juice 4 percent.

The unprecedented expansion in the production of frozen citrus concentrate helps to explain the changing consumption pattern for each type of product.

Table 3. Production of Frozen Concentrate Citrus Juice in Florida, 1948-49 and 1949-50

	1948-49 (Gallons in 000)	1949-1950 (Gallons in 000)
Orange	10,000	21,000
Grapefruit	100	1,600
Blend	100	1,300

Summary:

The studies of the Agricultural Experiment Stations of the consumers' views on citrus shows the need for more emphasis on:

(a) maintenance and improvement of quality
(b) improved merchandising
(c) reasonable prices
(d) greater availability

The research to date on consumer preferences, purchases and buying behavior on a national basis show that areas of limited citrus consumption appear:

(a) in the Southern and Southwestern states.
(b) in farm families and households in cities having 10,000 or less in population.
(c) in low-income groups.

Thus, the evidence shows that it is within these areas and groups that exploratory methods should be devised for expanding consumption.

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Present Status of Citrus Trees Damaged by the Freeze of January 30, 31, 1949*

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A Review of the Freeze Conditions

The weather conditions which existed at the time of the January 1949 freeze were not unusual as such conditions may be expected in this delta region, and occur to a greater or lesser degree every few years.

Most of the citrus trees in the Valley were growing vigorously; when the freeze came, many of the trees were in blossom and had many new shoots eight inches to a foot or more in length with leaves nearly half grown. Most of the young trees were severely damaged because they were in a state of vigorous growth. The older trees which were in a flush of growth had most of the branches less than two inches in diameter killed. The freeze killed large patches of bark in the crotches of many trees, especially in the younger orange and grapefruit trees.

Reviewing Practices in Connection with the Freeze

Trees which were dormant at the time of the freeze showed less freeze damage than those trees which were growing vigorously. Cultural practices which produce a vigorous flush of growth during December and January should be avoided. If trees are allowed to go into the winter in a dry condition, then when we get winter rains, the trees will be forced into vigorous growth. If the orchard soil is kept fairly moist, the trees may produce some growth, but usually they will not throw a heavy flush of growth.

The damage to the trees was not caused entirely by the cold weather. Sunburn killed additional bark on many trees. This was particularly true on trees which were heavily pruned so that their trunks were exposed to the direct sun during the hot summer months. White-washing, used in other areas to prevent sunburn, might have saved many trees from further damage. If a large part of the leaves are removed, as by a freeze or pruning, the trunk or large limbs will sunburn much more easily.

Most of the trees set out in the six or eight years before the freeze were orange or red grapefruit. The larger limbs and crotches of these trees were, in general, very badly damaged. While pictures of this age trees are not shown, the same pruning principles apply. Remove all dead wood wherever possible. Do not leave too many branches at the crotch, and keep wounds sealed with pruning compound.

Banking of Trees

Most growers in the Rio Grande Valley make a practice of banking their young trees by piling soil around the trunk during the winter months to protect the trunk during a severe freeze. This is a standard practice in the Rio Grande Valley for at least the first three winters after setting the

*For previous reports on the freeze of January 30, 31, 1949, see Proceedings of the Third Annual Rio Grande Horticultural Institute, pp. 174-194, and the Proceedings of the Fourth Annual Rio Grande Horticultural Institute, pp. 19-21.

trees, while it is advisable to continue this practic as long as possible. Usually by the fourth or fifth winter, it is difficult to bank the trees because the low growing branches interfere with the banking operation.

Observations 21 Months After the Freeze

All of the pictures shown in this report were taken about twenty-one months after the freeze.

Figures 1-A and 1-B, show young trees which were killed back to the banks. These trees were pruned about six months after the freeze. They have made a good come-back and probably will become satisfactory trees.

Figures 1-C, 1-D, 2-A, 2-B and 2-C, show trees which were cut back, but limbs have been left which are likely to cause trouble later. In figures 1-C, the two main branches at the left will always crowd each other and are already growing together. The same is true of the two main branches on the right in Figures 1-D. The center main branch in Figure 1-C and one of the right hand branches in Figure 1-D should be removed. Large branches, growing close together with only a small angle between the two limbs, bend back and forth in the wind and the rubbing damages the bark of the crotch. This gives an opening for decay or disease organisms. Such a crotch is a common starting point for Rio Grande gummosis, which is particularly bad in grapefruit trees. Too many branches have been left on the tree in Figure 2-A. The second branch from the left and the branch on the extreme right should have been removed. These limbs are crowding each other severely now and the larger they become, the more crowded they will be as their size increases. In Figure 2-B, three branches have been left which is often satisfactory. In this case, and in many others, one limb is much stronger and more vigorous. Often these smaller limbs do not grow appreciably as they are shaded out by the larger branch. If these two smaller limbs and the knob of the old trunk were cut off, and only the one large branch allowed to remain, the wound would soon heal over and a better tree would result. The same is true of the tree in Figure 2-C. If the smaller crooked branch on the right were removed, a much nicer looking tree would be obtained.

Many of the trees in the Valley were given a hurried preliminary pruning after the freeze. The majority of them have had no attention since. Figures 3-A, 3-C and 4-A, show trees badly in need of pruning although they were pruned following the freeze.

Figures 3-B, 3-D and 4-B, show the same trees after additional pruning. The central parts of these trees contained a large amount of dead wood which, if left, would have made an excellent place for disease organisms to enter. Four branches have been left on the tree in Figure 4-B. The left back branch should be removed.

Too many branches at the main crotch often cause troubles such as those shown in Figure 4-C. Three branches at the crotch make an ideal number. The height of the crotch is not of particular importance. Most people prefer a fairly low crotch, and it has several advantages.

Figure 4-D, is a picture of an old grapefruit tree which was inadequately pruned following freeze damage when it was younger. Crooked lower limbs have been shaded out and have died off. Diseases have now attacked the whole trunk. This is the result of leaving too many branches at the crotch.

Figure 5-A and 5-B, show old grapefruit trees which had their branches badly frozen. They were pruned back to limbs about two inches in diameter, leaving almost no leaves on the trees. The trunks were badly sunburned on the southwest sides of the trees. It will be difficult, or impossible, to ever heal these wounds. Such trees will inevitably be short lived.

Figure 5-C, shows an orange tree with dead bark in the crotch killed by the freeze. This wound should have been cleaned out and treated with a good pruning compound to keep out moisture, diseases, and ants. This was a young vigorous tree and if properly protected, would have had a good chance of recovery.

Figure 5-D, shows an orange tree, the main limbs of which were badly frozen. Large suckers, or water sprouts, have grown out at the crotch. These suckers are ten feet long without a branch. Suckers such as these should not be allowed to develop. As much as possible of the dead wood should be removed, and the remaining live wood protected with a good pruning compound. New branches can then be trained into a well shaped tree.

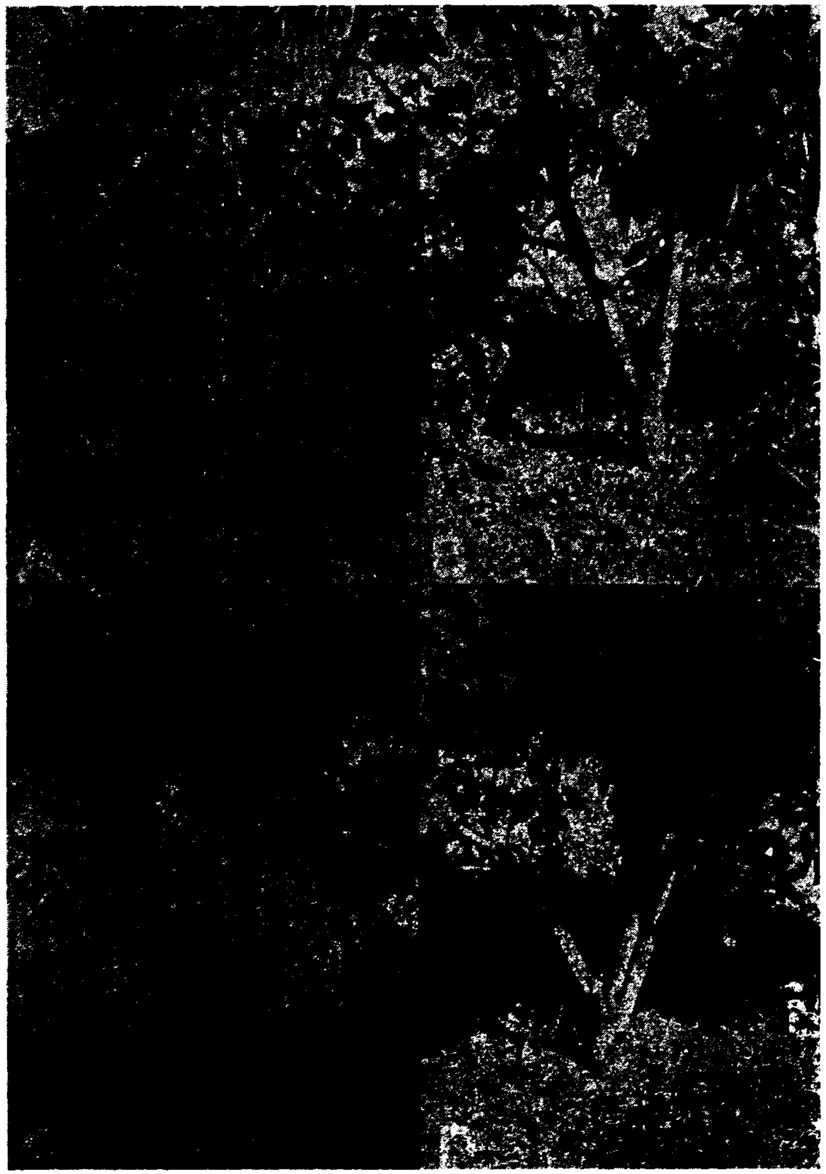

FIGURE 1—A & B show young grapefruit trees which were frozen back, but are now (21 months later) healthy, vigorous, well shaped trees. C & D show similar trees with branches which are too close and growing together.

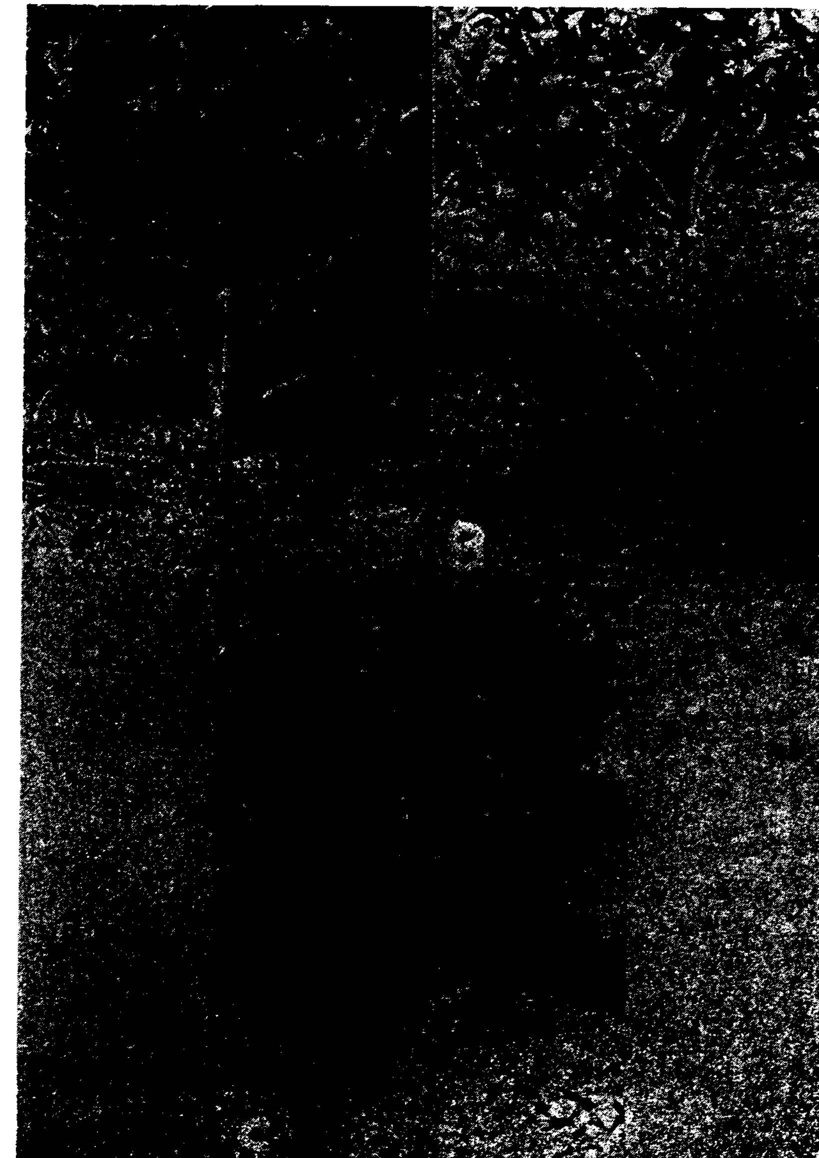

FIGURE 2—A, B, and C show trees which are inadequately pruned. A, this tree has too many branches at the crotch. B, this tree has two small branches being shaded out and a long stub of the old trunk. C, this tree would be better with just the one strong trunk.

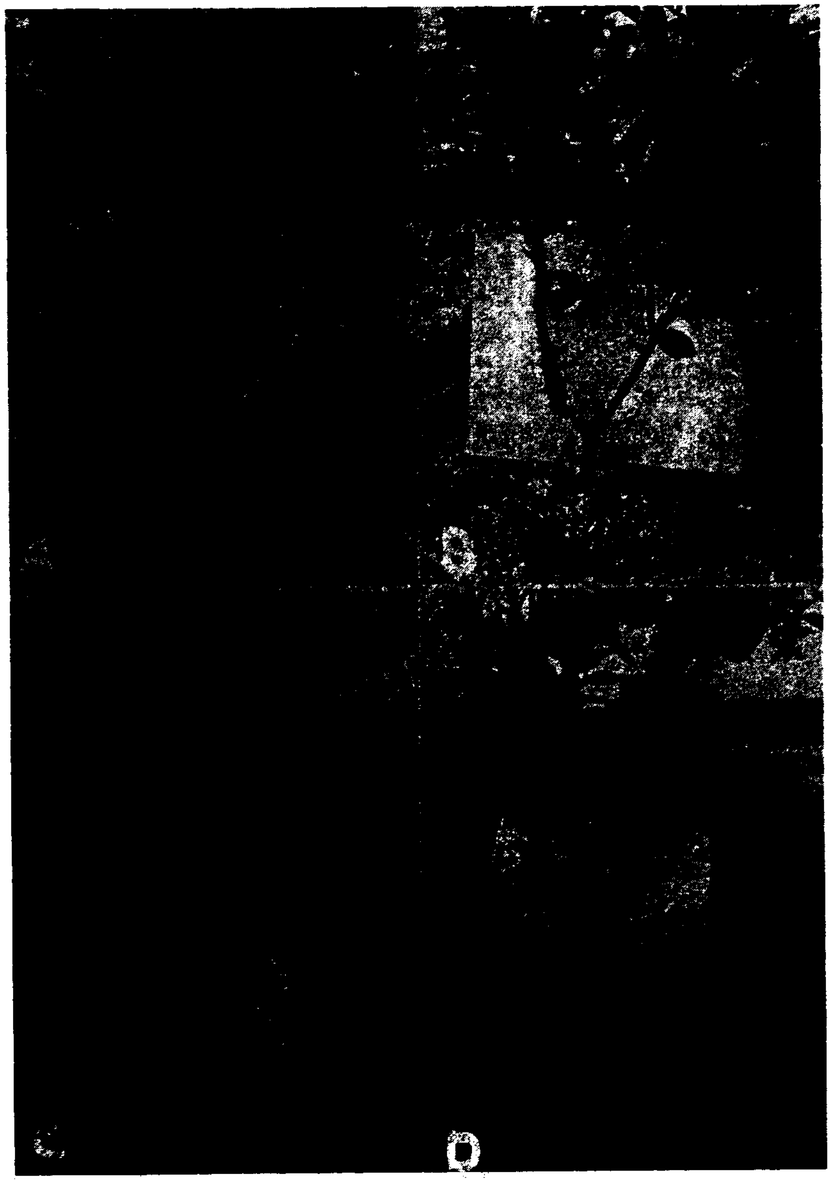

FIGURE 3—A and C, show trees inadequately pruned. B and D, show the same trees after pruning, but before applying pruning compound.

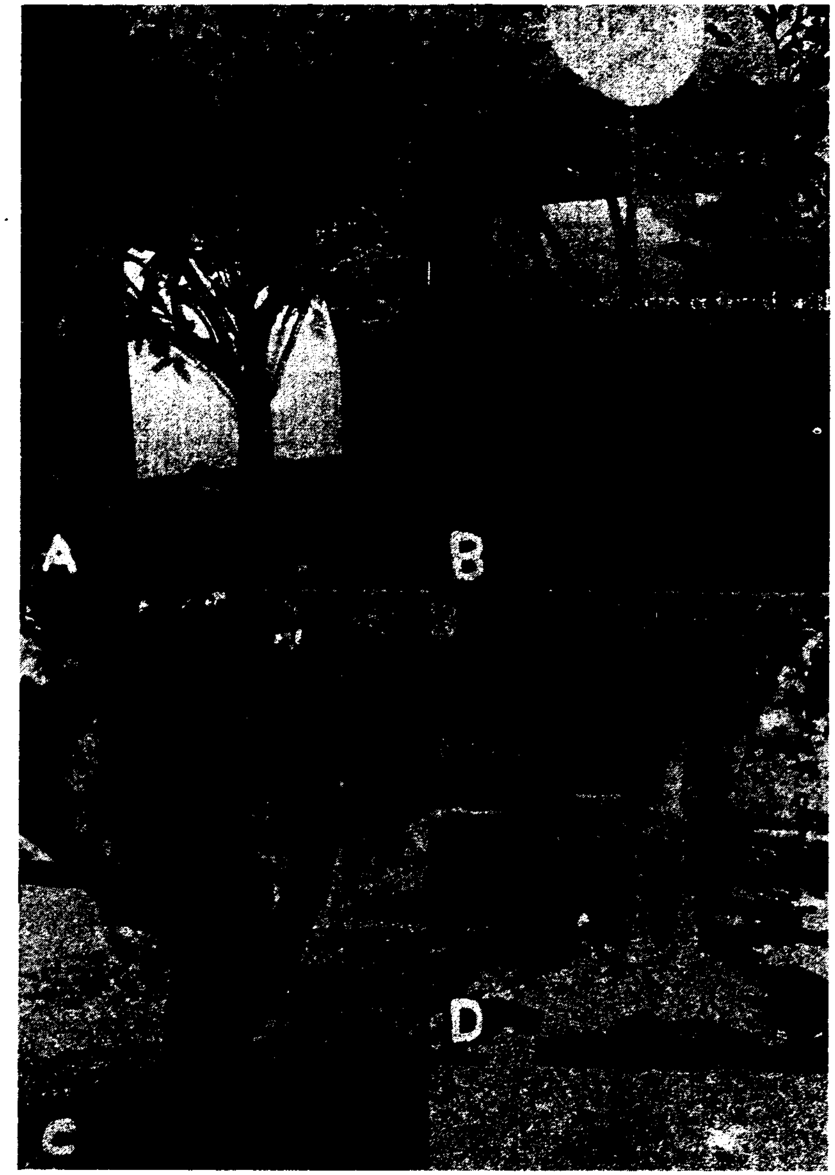

FIGURE 4—A, shows a tree inadequately pruned. B, shows the same tree after pruning. The limb at the left should also be removed. C, an old tree which shows what happens when a tree is not properly pruned. D, this picture also shows how diseases attack trees which are not properly pruned.

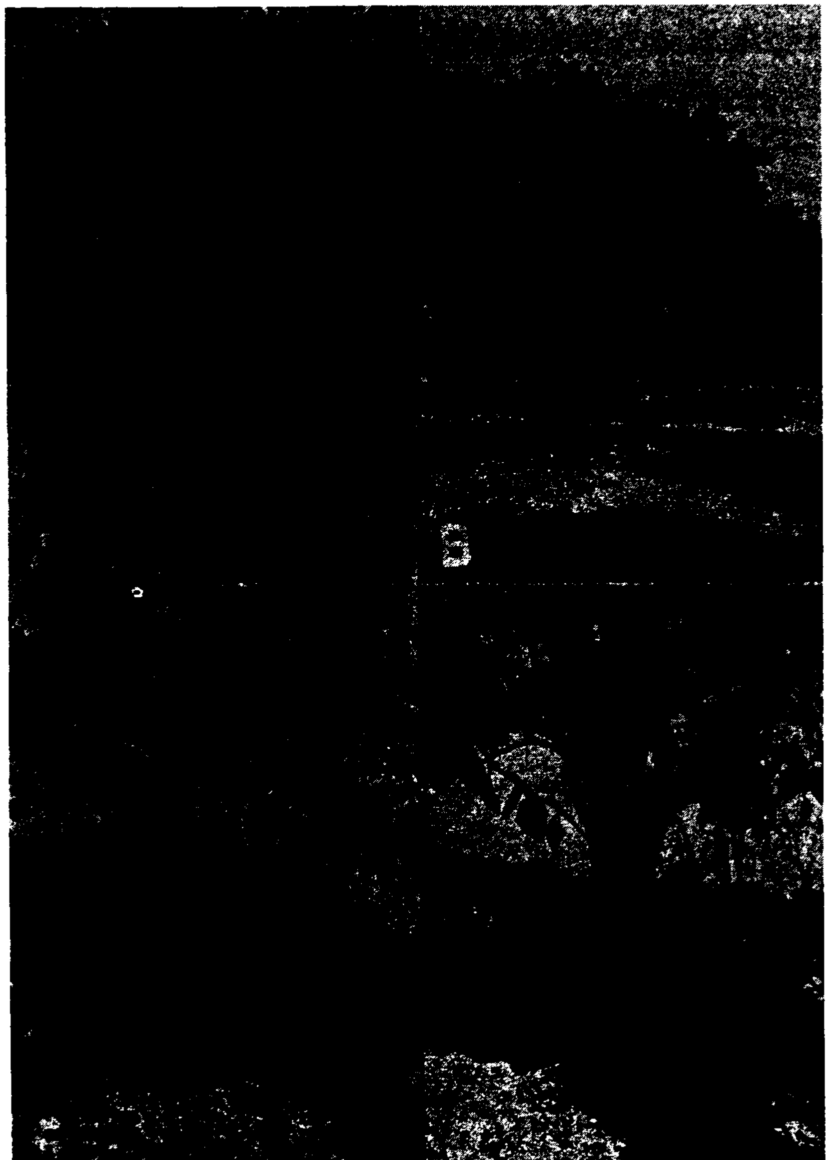

FIGURE 5—A and B, show trees which were badly sunburned before they had leaves to protect them. C and D, show orange trees which have not been cared for since the freeze.

Symptoms of Freeze Damage in Citrus Fruit

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The general symptoms of freeze damage to citrus trees are well known since they are easily observed, but the symptoms of freeze damage in citrus fruit are much less apparent. This is especially true in the early stages and thus often very misleading. Most of the information in this report was obtained after the freeze of December 7, 1950, and the severe freeze of January 30-31, 1949, in the Rio Grande Valley. The latter freeze was undoubtedly the most costly in the entire history of citrus.

Apparently ice crystals must form in citrus fruit before damage is done. This means that temperatures below the freezing point of the internal juices must be present. This temperature varies with the total soluble solids and is very close to 28°F. for mature fruit. Citrus fruit juices also exhibit a common phenomenon called super-cooling, which means that temperatures below the actual freezing point may exist before crystal formation. However, a slightest motion of the fruit will induce crystallization under such conditions. So for all considerations this is of no practical significance. It should be pointed out that the temperature of freezing fruit will not drop lower than the freezing point until it is frozen solid.

Many factors determine the extent of damage such as, variety, size of fruit, maturity of fruit, total soluble solids, condition of tree, location on tree, duration of low temperatures, minimum temperature reached, etc.

Immediate Effects

Certain symptoms are immediately apparent to identify damaged fruit. Both oranges and grapefruit develop wet or water soaked section membranes immediately. Fruit must be completely dissected and inspected before a true estimate of damage can be made. This is most simply done by making cuts or slices parallel to the equator of the fruit about every one-half inch. The center slices are then cut in half so the peel can be rolled back and thus separate the section membranes. The cores or central vascular bundles and the albedo layers should be inspected on all slices for evidence of wetting. Normal fruit will present a dead white appearance, while frozen fruit will show a dull grayish wet translucency. Core and albedo wetting may be found at any level, that is, at the stem end, center, or blossom end. The juice sacs should be carefully noted at each slice for evidence of dryness and translucency. In freshly cut sound fruit the sac walls will show distinctly, while in damaged fruit they will be much less distinct. Frozen section membranes are wet or translucent and this is by far the most readily recognized symptom of damage in grapefruit immediately following a freeze. The observance of ice or slush should remove all doubt as to fruit damage. Normal section membranes are dry, whitish and opaque and separate easily. They are not even readily wet by repeated wiping with a moist finger, or the application of pressure produced by stretching against the juice sacs. Seeds often take on a darkened coloration which likewise is due to a wetting of the seed coats. The symptoms so far described appear to be due to actual rupture or weakening of the cell walls with the resultant release of enzymes, mainly pectic enzymes.

Microscopic examination reveals a rapid destruction of the pectin-supported cellular structures has taken place throughout the fruit. This destruction is most obvious in the core network. The cell walls show fractures and disfiguration in severely damaged fruit. Staining is necessary before such an examination can be made. Methylene blue followed by an alcohol or dilute acid wash is very satisfactory. Mangin (1888-1892) has thoroughly investigated this phase of pectin chemistry and the application of his findings should greatly facilitate future research on freeze damage. Juice extracted from freeze damaged fruit generally shows disintegrated core cells and the fragmented cell walls. Plates thought to be pectic acid are likewise often found in freshly extracted juices.

In slightly damaged fruit most of the wetted portions dry up within a couple of days so they are no longer apparent. While in severely damaged fruit, especially grapefruit, the wetting gradually extends until the water marks are clearly visible through the outer peel. If the water marking is limited to a small area on the surface only slight damage has been done. The color is generally lighter following recovery on the tree. Such fruit is more apt to show abnormalities in the coloring process. Since water marking and wetting produce translucency they can often be detected long before visible through the peel by "candling" just as is done with eggs. Wetted fruit will take on a glowing appearance in all portions showing wetting when tested.

Glucoside Crystal Formation

Hesperidin crystals appear to be formed within all radial section membranes of oranges that have been frozen. Crystallization of hesperidin apparently is induced by nuclei resulting from freeze damage in the membranes. Hesperidin crystals are not visible to the naked eye during the first four or five days. The most probable explanation is that very minute deposits are formed during the low temperatures since hesperidin is quite insoluble at low temperatures. These crystals then grow until they are easily identified as small four pointed stars, or crosses. Fast ageing can develop visible crystals within two hours. It is quite common to find only one or two section membranes showing hesperidin. This is readily explained since it is well known that the total soluble solids and thus the freezing point of fruit varies from section to section. Then too, various sections of fruit can easily be subjected to different cooling or freezing conditions. All tests made to date have indicated that, once the crystals are formed, they increase in size and do not disappear. In cases of severely damaged oranges, hesperidin crystals will often extend throughout the cores. In most cases these cores are also showing gelation. Hesperidin crystals are readily found in dehydrated citrus pulps made from frozen oranges.

Definite correlation has been found between hesperidin crystal formations and freeze damage. This is most readily seen in drying or granulation which is more severe in those sections whose membranes are showing crystal formation. Hesperidin is a naturally occurring glucoside and obviously harmless when eaten.

Naringin, the glucoside of grapefruit corresponding in the hesperidin of oranges and other citrus varieties, is rarely seen in frozen fruit. Naringin, unlike hesperidin, forms in small spherical clusters of needle-shaped crystals between the outer section wall and the albedo layer and only then in severe cases of water marking in the albedo.

Naringin, like hesperidin, is a naturally occurring glucoside and harmless when eaten in grapefruit. Naringin and hesperidin crystals can be produced experimentally in grapefruit and oranges respectively. Present information available supports the belief that freeze damaged citrus is harmless for human consumption.

After Effects

Severely damaged fruit infected by microorganisms begins to ferment the third day after the freeze, and is most active the fourth and fifth days. This fermenting fruit drops from the trees. Most damaged fruit will drop, along with the leaves, from the fifth to the tenth day. Fruit hanging on trees showing less than about twenty-five percent defoliation will generally remain on the tree but will continue to show drying. On the other hand, fruit may be damaged when the trees show no defoliation.

Apparently frozen citrus will hang on to trees longer in dry weather than in wet weather. The weather conditions following the freezing temperatures determines to a large extent the severity of fruit drying as well as the length of time the fruit hangs on the tree, which may last two or three months. Drying is most obvious at the stem end, but is most extensive, at least in the early stages, at a point about mid-way between the stem and the equator. After approximately two weeks the damaged fruit has either become soft and mushy or tough and leathery. The former is very similar to the normal softening and withering seen in citrus fruit following picking. In the latter case the epidermal layer shows signs of deterioration and the entire surface is open not only to evaporation but also to invasion by microorganisms. In severe cases of drying the following sequence of events is observed: the fruit juices tend to thicken as do the juice sac walls; the outer juice sac walls pull away from the outer segment or section membrane; the shrinking juice sacs separate from the inner section membranes and form large air spaces. These exposed surfaces are ideal for fungi growth. Considerably more water is believed to be lost through these stiff dry feeling peels than is reabsorbed by the tree through the stem. As drying progresses in slightly damaged fruit the peel thickness increases, while in cases where damage is limited to the peel, the peel thickness actually decreases.

Respiration of frozen fruit is greatly increased (Gonzalez, 1948). Respiration rates might well serve as a reliable measure of freeze damage. Transportation of such fruit is hazardous. Increased respiration rates probably account for the rapid increase in naringin content and the decrease in citric acid content in the juices. The former occurs quite rapidly and then returns almost to normal, while the latter continues to decrease throughout the life of the fruit. Large decreases in the total sugar content of fruit have been reported (Thomas et al 1919). The total soluble solid content of extracted juice does not show much change, however, the total juice content decreases rapidly, due to drying and granulation—as much as 40% in two weeks.

Juice sacs which are severely damaged by the presence of ice crystals generally present a lighter color than the surrounding regions which are less damaged. This is most obvious in the pink-and red-meated grapefruit. Areas around seeds generally show this discoloration. Gelation is first seen in the areas adjacent to the seeds and later in the cores. Grapefruit appears to be more susceptible to gel formation than oranges and the seedy varieties more so than the seedless ones. Gel formation occurs after about one week in most cases and is believed to be due to an enzymatic degradation of pectin to low methoxylpectins which are capable of forming clear gels in low sugar content solutions. Fast ageing can produce gelation in damaged fruit in approximately two hours.

Dried and granulated fruit shows a decreased density. Thus frozen oranges can be satisfactorily separated on a commercial scale from sound fruit by means of gravity separators. The problem of separating dry grapefruit is more complicated since the density is normally less than that of water.

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