PROCEEDINGS

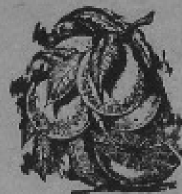
of

THE FIRST ANNUAL

LOWER RIO GRANDE VALLEY

CITRUS INSTITUTE

1 9 4 6



Weslaco, Texas *Dec. 3 to 5, 1946*

Published by the Rio Grande Horticultural Club

PROCEEDINGS

of

THE FIRST ANNUAL

LOWER RIO GRANDE VALLEY

CITRUS INSTITUTE

1946

Weslaco, Texas *Dec. 3 to 5, 1946*

Published by the Rio Grande Horticultural Club

PROCEEDINGS

LOWER RIO GRANDE VALLEY CITRUS INSTITUTE

First Annual Meeting 1946

Price $3.00

MESSAGE TO SUBSCRIBERS

The funds received from subscriptions were used in large part for the publication of the Proceedings, for the hiring of extra clerical help in connection therewith, and for other expenses in connection with the meetings. The balance is being held as a reserve fund to facilitate further meetings and publications. It is probable that the subscription price can be reduced for subsequent volumes.

CONTENTS

ADDRESS OF WELCOME

RIO GRANDE VALLEY CITRUS INSTITUTE

By

A. L. RYALL, *President—Rio Grande Horticultural Club*

Mr. Chairman, ladies and gentlemen of the citrus industry, visitors from other areas, and amateur horticulturists. It is gratifying to me, as I know it must be to all of those who have been concerned with the arrangements for this meeting, to see such a fine attendance at this first session.

We are met here this morning for two specific purposes: First to acquire some new ideas from the scheduled speakers each of whom is an expert in his particular field; Second for an exchange of ideas between growers, field men, handlers, and technical men. The latter purpose is in my opinion of equal importance with the first. To this end I urge your full participation in the open discussions which will follow each group of formal papers.

The citrus industry during the past few years has often reminded me of a man leaning into a tremendous wind. A wind of such magnitude that it supported him while at the same time preventing his forward motion. That wind is the wartime economy. It supported the industry by supplying a tremendous market for our citrus fruits and products at profitable prices. At the same time, due to shortages of equipment and skilled labor and lack of competitive incentive, it slowed our technical advance. I would remind you that there is abundant evidence that this wind of wartime economy is subsiding. When you as an individual or as an industry are leaning on the wind and the wind dies there are but two choices; Either you go forward or you fall flat on your face. It is to the purpose of going forward that these meetings are dedicated.

In behalf of the Valley Citrus Industry I welcome the staff members of A.& M. College who are largely responsible for the planning of this program and who will individually participate in the formal program and discussions. May their visits become more frequent and the scope of their Valley work increase as the years go by.

As a citizen of the Rio Grande Valley and the State of Texas I welcome also our distinguished visitors from California who have traveled so far to participate in our program. I trust that they will come to know our valley, its citrus industry, and its people and carry back with them some pleasant memories of Texas hospitality.

As a representative of the Rio Grande Horticultural Club I welcome all of you in attendance here. I hope and believe that you will find the program interesting and instructive and well worth the time you are taking from your regular occupations.

PHYSICAL PROPERTIES OF SOILS WHICH AFFECT CITRUS PRODUCTION

H. E. HAMPTON, *Dept. of Agronomy, Texas A. & M. College*

Citrus growers, like all farmers, must have a through understanding of soils to secure maximum production. In a consideration of soil fertility and soil management, we are often likely to give little attention to those properties of the soil which are really most evident to us. We hear a lot about the chemical properties of soils, about chemical tests for nutrient ions, about fertilizers and green manuring crops, about salts and irrigation. We seldom understand, or even consider, the influence of the physical conditions on the chemical properties exhibited by soils, on fertilizer response or on the effectiveness of irrigation practices.

THE PHYSICAL FEATURES COMMONLY CONSIDERED

Physical properties, as you know, are the properties which may be detected or perceived by the senses. Color is perhaps the most obvious as well as one of the significant characteristics of the soil. Although color in itself may be of minor importance, it is frequently a significant criterion of other soil conditions of extreme importance.

Another soil property which considers the size of the individual soil grains is called texture. Likewise, the combinations of particles of different sizes to give the several textural names such as fine sand, silt loam, clay, etc, must be treated under the heading of texture.

Soil structure refers to the grouping of the individual soll particles into aggregates. Several structural conditions are recognized which are related to water movement, aeration, and root growth. Also of importance in soils work is a knowledge of the adhesive and cohesive properties of particles and aggregates, greatly influenced by the moisture content of the soil, and designated by such consistency terms as sticky, plastic, friable, hard, and the like.

Because water movement and root extension and penetration is almost entirely channeled through the spaces between the particles, soil porosity is an important physical property.

In a pit which has been excavated several feet deep, an examination of the vertical face of the soil column will reveal several soil layers deffering morphologically from each other. Such a section is called a soil profile. In any attempt to interpret soil characteristics, the nature of all of these layers must be considered. A study of the surface layer alone usually results in erroneous conclusions. Sound recommendations must be based on a through examination of each of the soil layers to a total depth somewhat beyond that of maximum root penetration.

THE SIGNIFICANCE OF SOIL COLOR

Four principal soil colors are recognized—gray, yellow, red and brown. These may be modified by appropriate terms to describe the particular soil coloring encountered. Soil layers may be uniformly colored, or they may be streaked or mottled in many ways. Coloration and color patterns are indicative of soil conditions. Shades of red and brown are associated with proper aeration and drainage and desirable soil conditions at least in so far as physical conditions are concerned. Brown soils are nearly always higher

in organic matter than red, gray or yellow soils. Light colors indicate soils of low productive capacity due to the total lack of nutrients, or to the presence of salts or large amounts of lime, gypsum or similar materials. A dark grey soil may be fertile, but especially in heavy soils, the color calls attention to the possibility of a condition of restricted drainage. A condition of imperfect drainage is also indicated by mottling, particularly if the soil layer is medium to dark gray mottled or flecked with yellow. Soil layers which tend to remain wet and to retard root and water penetration usually present a bluish- or steel-gray appearance. Although organic matter tends to darken soils, materials other than organic matter may also cause a dark coloration. Some dark gray soils contain less organic matter than soils of lighter colors.

SOIL CONDITIONS AS INDICATED BY THE TEXTURE

A very evident feature of soils is the variation in the size of the particles composing them. Soil particles are divided into groups called separates on the basis of size. The various separates and some of their characteristics are given in the following table:

Name of Separate	Diameter of Particles	Surface Area in sq. cm per grain of material	Other Properties
Fine Gravel	2.00-1.00 mm.	90	Principally quartz. Hard and inert chemically. Constitutes framework of soils. Cause of large pores. Makes soils more workable.
Coarse Sand	1.00-0.50 mm.	722	
Medium Sand	0.50-0.25 mm.	5,777	
Fine Sand	0.25-0.10 mm.	46,213	
Very Fine Sand	0.10-0.05 mm.	722,074	
Silt	0.05-0.002 mm.	5,776,674	Quartz and weatherable minerals. Primary source of soil nutrients
Clay	Below 0.002 mm.	90,260.853.860	
			Presents great surface energy active chemically. Ability to absorb ions, swell and shrink, is plastic and sticky.

A soil is not made up of a single separate, but at least small quantities of nearly all of the separates are present. The proportions of the different sized particles in the soil determines to a great extent both its physical and chemical properties, and it therefore is desirable to group soils according to the relative amounts of each separate present to give the several textural names. The principal textural names are arrived at in the following manner:

(1) A soil which contains over 80% total sand is called a sand, but the term sand may be modified by one of the terms coarse, medium, fine, or very fine according to which one of the sand separates is present in the highest percentage.

(2) Soils which contain over 30% clay particles are known as clays.

(3) A clay loam contains 20 to 30% of clay.

(4) Soils which have less than 20% clay but less than 80% sand are loams.

(5) Clays, clay loams, and loams which contain from 50 to 80% sand are designated as coarse, medium, fine, or very fine, as in (1).

(6) Over 50% silt modifies the names clay, clay loam, and loam to silty clay, silty clay loam, and silt loam respectively.

Nearly all sands and many sandy loam soils are low in fertility because of the predominance of quartz, a mineral which does not contain nutrient elements. If the sandy material extends to a depth of several feet these soils are excessively permeable and have low water-holding capacities. Nutrients added as fertilizers leach readily, but the soils are not likely to become salty.

Soils which contain a large proportion of the clay fraction are likely to be more fertile. They have a high water-holding capacity, but water and roots tend to penetrate slowly, and they are more likely to accumulate salts.

The silt fraction of many soils is composed of minerals such as feldspars, micas, calcite, apatite, etc., in addition to quartz, which upon decomposition release calcium, magnesium, phosphorus, and potassium. Since these nutrient elements are needed in large quantities by plants, silty soils are likely to be of high fertility.

Considered from the standpoint of physical as well as chemical conditions, soils made up of about equal amounts of sand, silt and clay, such as loams, silt loams, clay loams, and silty clay loams, are likely to be most productive.

SOIL STRUCTURE AND ITS SIGNIFICANCE

A consideration of the manner in which the soil grains are arranged into clumps or aggregates is referred to as soil structure. Structural terms likewise may indicate the size or shape of the aggregates. Although the textural nature of soils influence drainage and the root growth of plants, considerable variation can be observed in the permeability of soils of the same textural name. This is particularly true of soils in which fine particles predominate, such as the clays and clay loams.

The structural conditions which may exist in any soil are influenced by a number of factors, Among the more important are (1) the relative amount of coarse and fine particles, (2) the nature of the colloidal (very fine) particles, (3) the nature and quantity of the organic matter, (4) the drainage condition which has existed, (5) the vegetative condition, (6) the presence or absence of excessive amounts of lime or salts, and (7) the weather factors.

The particles of coarse-grained soils, such as the sands and sandy loams, show little tendency toward aggregation, They are described as single-grained or structureless. As the amounts of fine particles in soils increase, structural elements are more likely to be manifested. The particles of all heavy-textured soils, however, are not aggregated. Although the particles are predominately very fine, they exist in a deflocculated, single-grained condition. Such soils (or perhaps single layers of soils) are said to present a dispersed or massive state; and because water and root penetration is retarded, they are undesirable as agricultural soils.

The structural or secondary units in certain soils may be roughly cubical, prismatic, or columnar in shape, having rather clearly defined angular edges; and they may be large or small in size. These secondary units originate as a result of fracturation along planes of weakness, which is essentially a breaking down process. Under certain conditions of weather, vegetative growth or cultivation the fragmentation can result in the formation of aggregates which become increasingly smaller with time. The term fragmental structure is used to designate these types which occur frequently in the subsoils of red soils of the humid regions and in salty or in alkali soils of the arid regions. Structure of the fragmental type, although a condition much superior to the massive state, does not present the most desirable structural condition for irrigation and the growth of crop plants. Roots and water can move rather freely through the spaces between the aggregates, but the aggregates themselves are rarely of a permeable nature.

A very different structural condition is found in many soils, especially in those of high productive capacity. An examination of the arrangement show the individual particles to be highly flocculated and the floccules weakly cemented to form small, more or less rounded, porus aggregates. These secondary units in turn are weakly held together to form a still larger aggregate. The entire soil mass is permeable to roots and water and presents a desirable physical condition. In handling the aggregates do not break up along distinct cleavage planes, but crumble into smaller units having very similar properties. This type is called a granular structure.

The incorporation of decomposable organic materials is essential for the maintenance of the granular type of structure. As cropping results in the depletion of the organic matter, in time soils lose their desirable granular structure unless they are well managed. In fact, the addition of organic matter is the most practicable way we have to improve or maintain the physical condition of the soil.

PORE SPACE AND ITS IMPORTANCE

Soil porosity may be defined as that portion of the soil volume which is not occupied by solid particles. About 50% of the total volume of the original soil is solid matter, and the remainder is made up of pores or voids between the solid particles. The pores of moist soil are filled with both air and water, and such a condition is essential for the growth of most crop plants. The relative amounts of air and water in a soil depend largely upon the size of these pores.

The textural and structural conditions, and the nature and quantity of organic matter are the principal factors which determine the amount of total pore space in a soil, as well as the relative sizes of the individual pore spaces or cavities in the soil mass. For high water-holding capacity, soils must present a large amount of rather fine pores, but for maximum infiltration and desirable movement of water and unrestricted penetration of roots large pore spaces are essential. Soils in which coarse particles predominate all through the profile, permit almost unrestricted intake of rainfall and irrigation water, but little of the water is retained in the root zone. On the other hand, soils composed chiefly of fine particles have the capacity to hold large quantities of water but infiltration is slow and root extension may be restricted. The permeability of fine-grained soils, however, vary within limits. The amount of organic matter present, the structural condition, and the nature of the clay particles themselves influence the permeability of heavy soils.

The importance of porosity in soil fertility and management must be emphasized. In an ideal soil the pore space would be about equally divided between large pores through which roots and water can penetrate readily and fine pores through which root extension is difficult but which would give the soil a high water-holding capacity. Many soils in the Rio Grande Valley appear to present poor conditions for plant growth because of the relatively large amount of very fine or capillary pore space in the soils or, frequently, in certain soil layers. The air capacity in these soils is limited and drainage is restricted, resulting in the development of a high water-table in some cases and in the maintenance of a dry subsoil layer in others. Studies to evaluate the relationships between these conditions and root distribution, growth and welfare of citrus trees are now underway.

ORGANIC MATTER AND PHYSICAL PROPERTIES

A discussion of the physical properties of soils would not be complete without a consideration of the influence of organic matter. The systematic utilization of animal manures, green manuring crops, and crop residues is paramount to a permanent type of agriculture. The processes of organic decomposition release intermediate products such as organic acids which render available the nutrients contained in minerals or fertilizer materials. The simple end-products of decomposition provide nitrogen, phosphorus, sulphur, calcium and other nutrient elements for plants. Complex residues of organic decomposition aid materially in promoting desirable structural conditions, increase the power of the soil to hold nutrient ions against leaching, and make soils more porous which favors the movement of roots and water.

Organic materials have the capacity to absorb large quantities of water for plant use. The droughty nature of many soils is due to their lack of organic matter. Decomposing organic matter also buffers the harmful effects of soluble salts. The growing of green manuring crops is one of the most practical means of remedying the unfavorable conditions of saline soils. The maximum benefits from commercial fertilizers can be secured only if the supply of decomposable organic matter in the soil is maintained.

Soils which are well supplied with organic matter are crumbly and mellow, and are readily worked into a desirable seed bed. Better stands of seeded crops can be secured where the physical condition of a soil is favorable, and the young plants get off to a better start. Many irrigated soils become lifeless, tight and run-together because the additions of water and better conditions of aeration brought about by plowing, rapidly deplete the natural supply of organic matter. The problems of irrigated soils are many, but we are definitely aggravating the conditions by neglecting to maintain the supply of vital organic materials.

THE NATURE AND PROPERTIES OF CLAY AND THEIR INFLUENCE ON THE PHYSICAL PROPERTIES OF SOILS

Clay particles are so small that they are not visible under the highest power of the ordinary microscope. Because of their small size, clay particles exhibit pronounced surface activities. Many of the physical as well as the chemical properties of soils are associated with the colloidal nature

of the clay minerals. Among other characteristics of clay particles are their sticky property and their ability to swell when wet and shrink when dry. The cracking of heavy soils is due to the total shrinkage which takes place when each tiny clay particle loses much of its water film during dry weather.

The clay fraction of soils may be made up of one or more kinds of secondary clay minerals. The nature of the clay minerals as well as the total amount of clay present influence soil properties. Some clay minerals exhibit more stickness than others, are subject to greater swelling when wet, or show greater capacity to adsorb or attract positive ions.

The properties of clay minerals and their effect on soil character is further influenced by the kind of positively-charged ion associated with the colloidal particles.

In general, one of three ions dominates the colloidal complex of soils, although other ions, of course, are present. Hydrogen ions are most likely to be adsorbed on the colloidal particles of the depleted soils of the humid region, and these ions account for the acidity of such soils. Calcareous soils, found in both humid and dry regions, contain an excess of calcium carbonate, and these soils have calcium as the principal adsorbed ion. In both saline and alkali soils the dominant ion is sodium.

Calcium saturated clays are flocculated, and soils which contain appreciable quantities of calcium usually exhibit desirable aggregation. The effect of the hydrogen ion is similar to that of calcium, hence, acid soils seldom present poor physical conditions. Root and water penetration is expedited in these soils by the more favorable porous state resulting from the high degree of aggregation.

Clay particles which are dominated by sodium ions, on the other hand, are deflocculated or dispersed unless a great excess of sodium salts is present in the soil. When sodium salts are in the soil in amounts sufficient to bring about favorable physical conditions, the salt content is high enough to inhibit or even entirely prevent plant growth. Sodium saturated soils are therefore troublesome and undesirable.

Because of their environment and nature of origin, the soils of the Rio Grande Valley contain more or less salt even in the virgin state. The use of impure irrigation waters adds to the original salt content of the soils. Sodium salts, especially the chlorides, are most common in the soils and in the irrigation waters. Should we wonder then, why many soils of this section are unfitted for irrigation and the production of crops?

Three general soil profile conditions from the standpoint of permeability suggest themselves; (1) Soils that are naturally sandy, loose and excessively pervious are common. The pore spaces in these soils are large and water percolates freely. Such soils are not likely to develop a troublesome water table or to become salty. They are of low natural fertility, but may produce successful crops if properly managed. The colloidal particles may become saturated with sodium, but because of the limited amount of colloidal material present, unfavorable conditions are not likely to arise.

(2) Many soils are found in which colloidal particles are abundant in all layers. In the virgin state, these soils usually contain appreciable quantities of salts, and the colloidal complex is sodium saturated. The soils are

tough and gummy when wet, are difficult to work, and root growth and water movement are retarded. With additions of irrigation water and the decomposition of organic matter, the physical conditions of these soils deteriorate, a water-table develops, nutrient uptake by the plant is hindered, and the trees decline in vigor.

(3) The most desirable soils of the Valley contain enough sand all the way down, to render them pervious to roots and water, but sufficient clay to give them a high water holding capacity and the power to retain nutrient cations against leaching. The silt fraction is likely to be made up of minerals which upon chemical weathering release nutrients for plant use. The good physical conditions is further enhanced and the nutrient supply increased by an appreciable quantity of organic matter. Drainage is complete but not excessive, because the soils are naturally well-drained, salts do not accumulate and the colloidal complex is not highly saturated with sodium. Such soils are highly productive, and should remain so indefinitely if wisely managed.

However, considerable evidence has been accumulated to show that the desirable characteristics of these soils can change over a period of time. Applications of irrigation water bring in sodium salts. Little by little, the sodium replaces the other ions attracted to the colloidal particles. As a condition of sodium saturation is reached the particles become dispersed and tend to be carried downward by the percolating water. Inasmuch as colloidal particles are large in comparison to ions and molecules, their downward movement is slow and restricted. They appear to concentrate several inches below the surface and along with the sand and silt particles form a dispersed, impermeable layer through which roots and water penetrate with great difficulty. Under such conditions citrus roots are limited to the upper 6 to 12 inches of soil. Root surface for the absorption of water and nutrients is not sufficient to permit unlimited, healthy growth. Loss of vigor follows, and the affected trees are undoubtedly more susceptible to disease and insect attacks.

CHEMICAL PROPERTIES OF SOIL WHICH AFFECT PRODUCTION OF VALLEY CITRUS TREES

By

M. K. THORNTON, *Extension Agricultural Chemist, College Station, Texas*

Mr. Chairman, Ladies and Gentlemen:

The topic that brings about most discussion at the present time is of "soils and fertilizers", This is because of the fact that we have come to realize that there is such an intimate relationship between the chemical composition of the soil and its productivity.

In the production of crops of various types, however, there are many things to take into consideration other than the chemical composition of the soils. The physical properties of the soil and conditions surrounding crop production are often more important than the chemical composition. Dr. H. E. Hampton has ably discussed the physical properties of the soil in its relation to crop production.

Some of the factors that influence production are, light, moisture, temperature, aeration, and micro-organisms. The composition of the soil

will influence production if these external factors are not adverse.

Reviewing these briefly, there is little to be said with respect to the influence of light for there is little that can be done about it. It is well known however that the length of the day, intensity of the sunlight or the absence of light will influence different types of crops in different ways. To adjust for this, adapted crops are planted so as to grow under existing light conditions. In the case of vegetable crops and citrus crops, only those are grown that will adapt themselves to light conditions that prevail in this area.

The most important factor in the production of crops is moisture—both in the atmosphere and in the soil. Most of our listeners are well familiar with conditions of a hot, dry atmosphere in which the leaves of the plant will wilt down without regard to how much moisture there is in the soil. Any attempt under such conditions to pour more water onto the land in order to prevent the wilting results in an excessive amount of water in the soil whereby the land becomes waterlogged. This waterlogging is perhaps one of the greatest defects that can be found in the handling of water and soil moisture in this area. It has been my privilege to make soil borings at several places throughout this area, at different places and times. In some cases water standing from 12 to 14 inches below the surface has been found. This simply means that in our attempt to prevent the dry atmosphere from causing wilting, water has been applied to the soils in excessive amounts with the results that roots are suffocated and destroyed. There is actually a smaller feeding area for nutrients and moisture than there would be if the water had not been so close to the surface. Since citrus trees should have a reasonably deep root system, the water table should not be near the surface of the soil.

In some cases, siltation and gelling of the sub-surface may be responsible for this high water table.

The solution number one for the problems in the handling of the soils in this area, will of necessity involve the proper handling of the irrigating water onto the soil and the removal of surplus water from the soil. By proper handling of the irrigation water, a soil atmosphere will be maintained which will result in the maximum root development. This will provide a maximum soil zone in which roots may feed and will improve the physical characteristics of crops tremendously.

As mentioned previously, the temperature plays quite a large part in the production of crops. For vegetable crops, the time of planting will take advantage of the best temperature ranges for the particular crop concerned. In the case of the citrus trees which grow throughout the year, there is little that can be done.

Micro organisms play a part in crop production. There are two classes to be found, those in the air and those in the soil. Some of these micro-organisms are pathogenic,or disease producing, and others non-pathogenic. A rough distinction between these two classes might be that the pathogenic micro-organisms live upon living matter whereas the non-pathogenic organisms live upon decaying matter.

The distinction made above is of considerable importance to all farmers. Conditions which make for a high population of pathogenic micro-organisms in the soil apparently make for a low population of non-pathogenic micro-organisms. The converse of this is true. When conditions are favorable for a production of a large population of non-pathogenic organism the conditions are unfavorable for the productuion of the pathogenic micro-organisms.

When the pathogenic micro-organisms are in the ascendant, then we have soil-borne diseases and air-borne diseases that render maximum productivity of the land virtually impossible. For example, cotton root-rot, wilt, and other pathogens make it very difficult for a large crop to be grown upon the land. Recently diseases that affect the above ground parts of your citrus trees have been discovered. One of these is known as gummosis and the other psorosis. Either of these will make it difficult to obtain maximum production of fruit and will shorten the lives of the trees.

Where such conditions exist, the chemical characteristics of the soil will be submerged. Therefore, before the soil can develop the greatest possibility, these two diseases should be controlled, as well as others.

In the soil, these pathogenic and non-pathogenic organisms play a great part. When large quantities of rotting organic matter are present in the soil so that conditions are favorable for the growth of the non-pathogenic organisms, then conditions are unfavorable for the pathogenic. To that end, one of the first steps in improving the soil is the use of large quantities of organic matter for turning under or discing into the soil to furnish a stable medium for the growth of the non-pathogens. This decaying organic matter will improve the physical characteristics of the soil and there will be less likelihood of the soil caking. The soils are easier to work and the percolating waters passing into the soil from this decaying organic matter will aid in keeping the substratum open and to that end prevent much of the salt trouble that is taking place. As Dr. Hampton pointed out in the previous paper, the use of large quantities of organic matter will increase the buffer capacity of the soil whereby adverse soil conditions are not nearly so manifest as in the case of soils with low organic matter.

Step number two in handling of the soils will be the increase in the organic matter of the soil.

The soil reaction is another factor in production. By soil reaction we mean the acidity or basicity of the soil. This is usually known as the pH. A neutral soil has a pH 7. Less than a pH 7—the soil would be acid and with a pH of greater than 7, the soil would be basic. For example, the soil with a pH 5 would be acid, the soil with a pH 6 would be slightly acid. A soil with a pH 8 would be slightly basic, with a pH 9 would be alkaline and with a pH 10 would be extremely alkaline. Most commercial plants prefer a pH 6 or 7. However, in some cases, pH6.5 - 7.5 seems to be the most desirable pH. The soils of the lower Rio Grande valley in general are above 7 in pH. In some cases, the pH will be greater than 8. Since the optimum pH is nearer neutrality, considerable effort should be extended toward reducing the pH to a neutral condition, where the need for this change is evident. This may be accomplished in several ways. (1) The incorporation of large quantities of organic matter in the soil will have a tendency to reduce the pH. (2) The use of aluminum sulphate or iron sulphate in the soil will serve to reduce the pH. (3) The use of sulphur in the soil will have a tendency to acidfy the soil and thereby reduce the pH. Any or all of these methods may be used. Probably the most economical method for reducing the pH would be the incorporation of large quantities of organic

matter in the soil together with the use of agricultural sulphur. To that end, 500 to 1500 pounds of agricultural sulphur per acre per year should be used. This sulphur may be placed in bands along the rows in the case of row crops. For citrus trees, it may be placed in holes or furrows spaced around the trees. If desired, it could be broadcast and disced in. The use of sulphur or any other acidifying agent is not, however, to be considered a general recommendation; it is recommended only for special cases where it is obviously needed.

The action of sulphur on the soil is to reduce the pH and the products from this sulphur react with some of the limestone material in the soil, whereby gypsum is formed. This gypsum percolating down through the soil with the wash water will have the tendency to keep the soil open and porous, thereby maintaining the subsurface drainage.

The use of gypsum on the soil does not change the pH of the soil unless there is black alkali in the soil. In case black alkali is present which is evidenced by a pH of greater than 8.4, the use of gypsum will serve to reduce pH and at the same time open the soil up and make it a little more permeable to the wash water.

At certain seasons of the year, the Rio Grande River water has a high concentration of sodium chloride or common salt. The continued use of water carrying large quantities of sodium chloride will result in the interaction between the soil particles and the salt whereby the land will become gelled. This is particularly true when the land is poorly drained and waterogged.

This gelation of the soil will result in the land becoming tight and impervious making it difficult for irrigation water to penetrate and enter into the root zone or to drain out of the land. Such gelation stimulates waterlogging and high water tables. Usually the pH of the soil increases under such conditions. In order to offset the bad effect of salt in the irrigation water, the use of either sulphur or gypsum seems indicated. Probably sulphur will be the more valuable in this regard since it not only has the property of reducing the pH of the soil but the formation of the gypsum from the reaction with the soil will give gypsum in the wash water which will serve to neutralize the bad influence of the salts.

The use of iron or aluminum sulphates at the rate of 7 pounds of either to one pound of sulphur will have the same effect the sulphur will. In case iron sulphate is used, iron is being added to the soil. However, the soils of the valley have sufficient iron in them and if conditions are right the soil iron will be available to the plants.

This is step number three—the reduction of the pH to a more nearly ideal condition for growing plants by the use of the proper treatment or treatments.

Generally speaking, most of the soils of the Lower Rio Grande Valley are rather well supplied with the nutrients. Under forcing production such as takes place under irrigation in the valley, these nutrients are reduced rapidly. In order to offset this natural depletion by the crops, under these conditions of production, it is suggested that nitrogen and phosphate will probably be removed from the soil earlier than the potash will.

To offset this depletion and maintain high production, it is suggested that for a general fertilizer, 6-12-0 or 10-10-0 will perhaps be the best combinations for use. Quantities of this to be used per acre range from 500 to 750 pounds.

For some orchards, the use of 7 to 10 pounds of ammonium nitrate per tree will be satisfactory at the present time. This should be applied in two applications. One of these in January before blooming time and the other in May or June.

As stated in the early part of this paper, control of water is one of the limiting factors of production, if not the limiting factor. To that end, it is of little significance how much fertilizer you put on the land if the trees are standing in water. Therefore, before the fertilizer can develop its maximum benefit, it will be necessary to drain the land so that the root system is well developed. This drainage of surplus water will also drain off the salt, and permit washing the land to remove the accumulated impurities. When this takes place, the land will be highly productive.

When Correctly Balanced	When Too Much Or Unbalanced	When Not Enough
	NITROGEN	
Increases growth. Increases bloom. Increases total yields. Foliage dark green	Sappy growth. Tendency to lodge in grass crops. Susceptible to disease. May not set fruit. Plants may suffer in times of short water. Poor quality of fruit. sappy.	Foliage pale green Stunted growth.
	PHOSPHATE	
Accelerates fruiting. Encourages root action Strengthens the stem. Gives sounder fruit. Reduces tendency to disease. Makes for more nutritious plants. Gives body and stability to bloom. Hastens maturity.		Where phosphates are deficient it is rather difficult to recognize the symptoms until it is too late. The fruit does not set, the stems have a purplish cast, and the grain is scanty.

When Correctly Balanced	When Too Much Or Unbalanced	When Not Enough
	POTASH	
Increases sugar and starch. Increases root system. Improves bloom. Gives sounder fruit. Gives more weight to grain.	Delays maturity.	The edges of the leaves become brown without withering in the early stages. Grasses, corn, wheat, oats ,sudan and other long leafed plants will show brown tongues shooting from the base to the tips of the leaves. Legumes will show white spots on the under side of the leaves.
	IRON	
		Leaves pale with the veins dark green.

Recapitulating, may we suggest that the following steps in the production of crops on the soils of this area be listed:

1. Control of irrigation water and sub-surface water.
2. Control of disease so that the soil will be able to carry out its normal function.
3. Increase the quantity of organic matter in the soil so as to maintain its tilth, water permeability, and healthy growing conditions.
4. The use of soil amendments so as to reduce the pH of the soil when the pH is excessive. The soil amendment most adaptable will probably be sulphur at the rate of 5 to 15 hundred pounds per acre.
5. The use of commercial fertilizers for the stimulation of plant growth.

INFLUENCE OF SOIL CONDITIONS ON ROOT DISTRIBUTION OF CITRUS TREES

By—GUY W. ADRIANCE

Department of Horticulture, Agricultural & Mechanical College of Texas

Plants are made up of several sets of specialized parts, each of which has a definite function. Just as the leaves manufacture food from water and air, and transform it by the addition of mineral elements, so do the roots absorb the water and minerals from the soil and make them available for this process in the leaves. The efficiency of the tree is determined, therefore, by the growth and development of the root system in the soil.

In most plants, the roots branch repeatedly to form a network of small roots; from the smallest of these roots arise the root hairs, small, thin-walled cells that take up water and nutrients. In citrus, root hairs are not formed, except to a limited extent in acid soils, and they are not found at all in soils of alkaline reaction. Under such conditions as commonly prevail in this region, absorption is carried on by the small rootlets alone.

The root system of any plant, as a rule, receives very limited attention, for the reason that it is out of sight. Most people are not aware of the extent of the roots of the various plants, as evidenced by methods of watering and fertilization.

The root system of a citrus tree, or any other tree for that matter, will normally extend laterally beyond the spread of the branches. In an orchard, it is easy to ascertain that the roots are meeting each other and using all of the area, long before the branches begin to meet. This fact, once it is well established in the mind of the orchard operator, will have a considerable effect on his program of cultivation, irrigation, and fertilization.

The vertical distribution of tree roots is understood even less than the horizontal distribution. The common conception is that the roots grow downward, just as the top grows upward. Most trees do have some sort of a tap root that grows downward; the pecan tree has a very extensive tap root, while the peach has a very restricted one. Citrus trees are somewhat intermediate in this respect, but most of the commercial trees, budded on sour orange root, which is cut back twice in transplanting operations, show a two or three pronged tap root, extending possibly three to four feet downward.

The major portion of the root system of any tree, however, is found in the upper 18 to 24 inches of the soil. This condition is to be expected, because this area provides optimum conditions for root growth. The actual pattern of the root system will be influenced both by conditions of environment and by the natural habit of the species.

With regard to the latter characteristic, Dr. W. C. Cooper and his associates made some very interesting determinations recently in Florida. They have pictured the root systems of sour orange, bitter sweet, sweet orange, rough lemon, grapefruit, trifoliate, Cleopatra mandarin, citrange, sweet lime, calamondin, yuzu, and shaddock, as well as a sweet orange stock grown from a cutting. Because of the interest in rootstocks in the Valley at this time, this work is of the greatest importance.

ENVIRONMENT IMPORTANT

The influence of environmental factors on root growth is manifold. In the first place, roots will make a greater length growth in a poor soil, but will make a compact, densely branched growth in a fertile soil. Similarly, they will extend further in a dry soil, and branch more freely in a soil with an adequate supply of moisture.

As regards the downward penetration of roots, aeration is a very important determining factor. Plant food is made available under conditions of proper aeration, and consequently the feeding zone for most plants is rather limited. A large mass of roots of all sizes is to be found in this upper layer of the soil, and comparatively few roots grow beyond this area.

The mark of a good fruit soil, however, is that it permits tree roots to penetrate to greater depth than in ordinary soils. Even a small percentage

of roots penetrating to a depth of three, four, or even five feet, will exert a great stabilizing influence on the tree, making it less susceptible to fluctuations in moisture in the upper levels.

HIGH WATER—POOR AERATION

The condition of poor aeration in the soil is due to the presence of a high water-table, indicative of poor drainage. Where the water-table remains at five or six feet most of the time, it may rise at intervals much nearer the surface, and keep this part of the soil at too high a moisture level for satisfactory root development. Associated with this water-table condition is the salt content of the water; soil which has been saturated with water high in soluble salts may remain in a condition detrimental to root growth.

Aside from aeration, which is limited by poor drainage, another factor limiting root penetration is an impervious layer of some kind. Many soils are underlaid with a clay stratum, which is almost impervious to tree roots; while in other soils a layer of rock or shale may occur. A soil which clearly shows an impervious layer of any kind should not be considered for an orchard.

The soils of the Lower Rio Grande Valley have been formed from deposited material, most of which has been brought down by the river, and some of which has been shifted by wind action. Such soils are quite in contrast to those that have been formed in place, through the weathering of the rock and other parent material underlying them.

In the latter case, the soil is made up of distinct layers as a result of soil formation processes, and when a vertical section is made, well defined profiles can be observed. These layers are usually referred to as horizons, with the "A" horizon the surface soil, used for cropping; the "B" horizon a mass of material enriched by materials leached from the surface; and the "C" horizon the parent layer itself.

In this region, however, the soil does not show the same horizons as mentioned. Distinct layers are often found but they are depositional and not a result of natural development. In the best soils of the region, there is a very gradual change from the somewhat light medium textured surface soil which has been in cultivation, with only a slightly heavier and more compact condition in the lower levels, but no definitely impervious layers.

In a series of investigations now in progress in the Valley, a careful study is being made of the root development of trees under different soil conditions. Since the root development of a tree is one of the principal factors in determining its growth, survival, and yield of fruit, the information obtained in these studies should be of interest to all persons engaged in tree care. The investigations should give basic information upon which to plan management studies.

All studies up to the present time have been made with Marsh grapefruit, in order to avoid the variability introduced by different varieties. Persumably all of the trees are on sour orange rootstock, since it has been used almost universally, at least until quite recently. The trees selected for study have been of varying degrees of vigor and size, but are all of bearing age, ranging from eight to fifteen years old, in the orchard.

In order to get a clear picture of the root development of these trees in relation to the soil, an excavation has been made in each case so that complete observations could be made. The excavation is made two feet wide and eight to ten feet long, just at the edge of the branches, and at right angles to a line from the trunk of the tree. This places most of the excavations just inside of the line where irrigation borders have been set up, and gives a clear picture of the distribution of the roots as they come out from the tree.

The face of the hole next to the tree is cut smoothly, so that soil layers and tree roots can be seen clearly. The soil layers are then described carefully, and the cut ends of the roots are marked on a chart, according to their size and location. All of this information will be made available in graphic form at the conclusion of the work, but at the present time, a few preliminary observations may be made.

The most apparent observation to be made from all of these studies is that all trees in poor condition, and many that are still in good condition, have comparatively shallow root systems. This is true not only of trees on heavy soils, where it might be expected; but it occurs also on soils of light textures, where the roots might be expected to penetrate to a much greater depth.

Since the nature of the soil itself does not appear to limit the downward penetration of the roots, it is evident that some factor of the environment is unfavorable for their growth. In a few cases, dead roots in the lower levels indicate that conditions were at one time favorable, but that a change, most likely a rise in the water-table, killed them out. In most cases, however, not even dead roots are found in the lower levels of the soils.

The most apparent answer to this condition is that lack of drainage has been responsible for such shallow root growth. Many of the orchards studied showed excessive moisture in the zone from two to four feet below the surface, and in a few cases, there was an undesirable accumulation of salts. Most of these soils are of a nature that would permit the removal of excess water, and to a great extent the harmful salts, through any adequate system of drainage.

Another condition was observed in a few places which may account for poor root growth in the lower soil levels. Observations made only a few days after an irrigation, when the top soil was still wet, showed that the water had penetrated only to a depth of 12 to 15 inches. In order to confirm this observation, tubes were set up and filled with water. Even in the top soil layer which appeared to be in excellent condition, the water went into the soil very slowly, and did not go down more than a few inches in two to three hours. It is possible that a combination of excess sodium salts and a deficiency of organic matter, may be responsible for this condition of poor penetration. In any event, roots will not grow in a dry soil any better than in a wet soil. It is always advisable to check the penetration of water after each irrigation.

The foregoing observations do not mean that there are no good soils for citrus in the Valley, nor do they mean that all trees with shallow root systems are doomed to early death.

In the first place, most of the work on this project has been done in orchards where some unfavorable condition was apparent. For comparison, Some excavations have been made in orchards that are apparently in fine condition, and many of these good soil conditions and root growth down to five feet.

There is a great deal of land of this nature in the Valley, and care must be exercised to irrigate and drain it properly, to prevent a rise in water-table there.

In the second place, many of the orchards where the tree roots are only two feet deep are producing good crops, and will continue to do so under proper conditions of management. If it is known that all of the tree roots are in the upper two feet, and a high proportion of these in the first foot, the orchard operator will not want to destroy a considerable part of them through deep cultivation. Even the continued use of a deep cutting border machine will prevent the roots from extending beyond the spread of the tree, where they would normally obtain a considerable portion of their water and nutrient supply.

It is recommended that in all orchards where the depth of rooting is inadequate, proper provision should be made for drainage, in an effort to make a permanent improvement in the condition of the orchard. At the same time, the shallow root system should influence the practices of the orchardist with regard to method of culture and irrigation, in order that he may keep the orchard up to the maximum efficiency, under existing conditions.

THE NUTRITION OF CITRUS TREES IN RELATION TO DISEASE OCCURRENCE IN FLORIDA

By

E. M. HILDEBRAND

The opportunity to appear on this program was welcomed even though I have never before had personal contact with citrus growing in the Rio Grande Valley of Texas. However, two years of active participation in work on citrus diseases in the Research Department of Food Machinery Corporation in Florida prompts me to discuss the nutrition of citrus trees in Florida, the sand-culture state, from the viewpoint of a plant pathologist.

The citrus growers of Texas should be interested in the nutritional methods or practices being developed and used in Florida for the reason that such practices have practically doubled production of citrus fruit per acre in the past few years. Good scientific nutritional practices also have been largely successful in controlling the non-pathogenic diseases.

FLORIDA PROVIDES GUIDE

Florida, with a sand-culture agriculture for much of its citrus industry, has soils deficient in the major (nitrogen, potassium etc.) and minor (zinc, manganese, boron, iron, etc.) elements. Although the soil situation in Texas is far different from that in Florida the nutritional studies in Florida should serve as a guide for work to be done in Texas.

Heavy summer rainfall in Florida causes rapid loss of fertility by leaching. Thus, their cultural methods have been designed not only to supply, but also to conserve, the plant nutrients. In attempting to correct the unfavorable nutritional conditions encountered in the groves, it has been found important to time fertilizer applications to coincide with the time that the elements are used by the trees for setting and producing high quality fruit. Because drought may occur in the winter season water sometimes proves a limited factor. This lack can be corrected by irrigation supplemented by mulching. Some of those with good irrigation equipment during the war obtained very significant increases in yields both in size and quality of fruits. In one case the increased value of a single crop paid for the entire cost of an irrigation installation.

TWO SCHOOLS ON NUTRITION

To the observer, there are two schools of thought on the correct nutrition of citrus trees in Florida. The first school centers around the state-supported work of Dr. A. F. Camp and his colleagues at Lake Alfred. Their's might be called the Complete Fertilizer Program involving all major and minor elements necessary for good growth of the plants and their fruits. However, this program, in the opinion of some critics, may possibly involve shortages of some nutrients and excesses of others by virtue of the marked variations in the fertility levels encountered in the different grove soils.

One interesting outcome from the use of minor elements is that the fruit quality has been definitely improved for oranges grafted on rough-lemon rootstock grown on the Ridge of Central Florida and also for oranges grown on sour-orange rootstock in the Indian River and other sections. Still, minor elements do not bring orange quality produced on the rough-lemon rootstock up to par with that produced on the sour-orange rootstock.

Considerable valuable literature or contributions on the nutrition of citrus made at Lake Alfred, Florida can be obtained by writing to the State Citrus Experiment Station at that address. The literature on minor elements is well illustrated with color pictures that serve well in identifying the deficiency or toxicity symptoms. Time is too brief to give further details on the other types of work being done at Lake Alfred.

STRESS FERTILIZER NEEDS

The second school centers around the work of Dr. Bryan of the soil Science Cooperative at Lakeland, Dr. DeBusk of the Florida Extension Service, and the U.S.D.A. Citrus Laboratories at Orlando. This school stresses a Fertilizer Needs Program rather than the Blanket Program. Their essential idea is to have the soils analyzed for determining the needs to be supplied. Recently Roy and Gardner of the U.S.D.A. Citrus Production Laboratory at Orlando have been exploring the seasonal uptake of the various major elements with the view of improving the timing of applications in field practice. While far from complete these and other studies indicate that certain phases of plant nutrition can be learned by the use of sand-cultures.

By soil analysis, Dr. Bryan has frequently found that the soil may already be adequately supplied with phosphorus. Thus to supply this element would make the program more expensive than the needs warrant. Needless to say, the rivalry between the two schools has stimulated more

in the way of advance and achievement than otherwise. All seem imbued with the idea of obtaining more support for the kind of work that will count most for the citrus industry of Florida.

CALIFORNIA NITROGEN PLAN

In California the nutrition program stresses nitrogen fertilization plus minor elements. The fact that California oranges seem to have been becoming smaller over a period of years, certainly raises a question as to the possibility that somehow the decrease in fruit size may be correlated with some deficiency of the other major elements. However, the series of cool seasons in recent years should be borne in mind before drawing conclusions.

The citrus nutrition program in Florida has been characterized by some of the packing house managers as a boon to disease control because of the much lower percentages of culls that are now removed in grading before sizing and packing for shipment. What this really means is that the proper nutritional program enables them to get rid of the losses from imperfect fruits resulting from improper fertilization. Despite the good work on the control of the physiogenic diseases, the pathogenic disease problems still remain to be solved. The stem-end and mold rot market diseases of Florida citrus take a heavy toll on the fresh fruit markets. Much work is being done at the Lake Alfred Experiment Station, supported by the state and the Citrus Commission, on the control of these and other diseases. In the past year their research staff has been increased by about 10 trained investigators accompanied by the necessary buildings and facilities. Such increased state support practically doubles an already substantial research staff in the experiment station devoted to citriculture.

NUTRITION PLUS DISEASE CONTROL

Proper nutrition can only function in the control of the physiogenic diseases, that is, those caused by mineral deficiencies, excesses, unbalances, or other conditions causing abnormalities of non-pathogenic origin. No one will question that nitrition is one of the basic programs that will require adequate support if the citrus industry is to thrive in Texas or anywhere else. However, the use of the proper nutritional practices in fertilization, watering, and drainage cannot alone insure healthy citrus trees and fruit because of the pathogenic diseases. Therefore, the second essential unit in a sound basic program for citriculture is the study of the pathogenic diseases and their control.

At this point it would seem to be in order to give a good definition of a plant disease, even though several of my A. and M. students are here in the audience to check on me. The definition: "A plant disease is any abnormality in function (physiology) or structure (morphology) which makes the plant of less use to itself or to man." Thus all abnormalities from whatever cause are diseases.

STUDY TEXAS DISEASES

In Texas there are a number of important pathogenic diseases of citrus which are of vital concern tc the growers in the Rio Grande Valley. Psorosis, which is caused by a virus, will be discussed later on this program by Dr. J. M. Wallace, our guest from California. Gummosis, another important disease, the cause of which is now being studied, will also be discussed later on this program by your pathologist, Dr. G. H. Godfrey. The threat of the Tristeza virus disease, which is now on a rampage in South America, is of concern to us here because it attacks citrus trees on sour-orange rootstocks, the principal rootstock used in this Valley. For that matter, the sour-orange rootstock is the principal one used on citrus in the United States and the Federal Government has already sent one of its leading plant pathologists, Dr. C. W. Bennett, to Brazil to establish a laboratory in cooperation with the Brazilian government for the joint study of Tristeza where it is decimating the industry. Of course, there are also other orchard and market diseases in Texas similar to those in Florida and in other places where citrus trees are grown that deserve attention, but I am stopping at this point.

From the viewpoint of the pathologist, we should strive to produce disease free fruit of high quality. The greatly expanded programs in California and Florida on citrus and other subtropical fruits and vegetables sets the pattern for the expanding Texas citrus industry to emulate and adapt to local needs.

METHODS OF MAINTAINING ADEQUATE PLANT FOOD LEVELS FOR MAXIMUM PRODUCTION OF CITRUS FRUITS

By

W. H. FRIEND, *A. & M. College Experiment Station*

The average Valley grower shows a tendency to overly simplify his tree feeding problems; on the other hand, a number of well-informed growers seem to be laboring under the impression that maintaining nutrient levels for citrus trees is a very exact procedure.

The amounts of the various elements removed from sand cultures by growing citrus trees can be determined with considerable accuracy; and it is possible to analyze the fruit and determine approximately what quantities of nitrogen, phosphorus, potassium, calcum, magnesium and other minerals are being removed from the soil through the annual sale of fruit. It would seem that the logical procedure would be to add enough plant food each year to make up for that removed by the fruit crop and to take care of the increases in the size of the trees. However, chemical analysis may reveal that average Valley soil contains sufficient reserves of practically all of the elements necessary for the production of maximum crops of fruit throughout the life of the orchard, except nitrogen—an element which has a way of disappearing from the soil. Most of the other elements are present in the soil in a fixed or semi-fixed state and removal by plants is about the only avenue of escape.

A twenty-ton crop of grapefruit will remove nitrogen equivalent to that contained in about four hundred pounds of ammonium nitrate, phosphorus equivalent to that contained in one hundred firty pounds of 20% superphosphate and potassium equivalent to that contained in two hundred pounds of sulphate of potash. Calcium and magnesium are removed in quantities almost equivalent to that for potassium.

Experience of the average grower would seem to indicate that it is unnecessary for him to make annual applications of any element except nitrogen. At the Valley Experiment Station, however, we have found that nitrogen in combination with phosphorus (ammonium phosphate) gives higher yields of grapefruit over a period of years than nitrogen alone. The

average grower, though, is quite well satisfied with the results obtained through the use of nitrogen alone applied in split applications.

Experiments conducted by scientists at the U.S.D.A. Subtropical Station at Orlando, Florida show that citrus trees remove larger quantities of water and major nutrients during the spring and summer months than during other seasons of the year. On the other hand, applications of nitrogen fertilizers applied in November (under Florida conditions) were more effective in setting a fruit crop than similar applications made during December, January or February. Here in the Valley we do not worry very much about getting a crop set, but we do worry considerably about the matter of bringing the individual fruits to marketable size relatively early in the crop year. California orange growers have not been able to solve their small fruit problem through the use of fertilizers, even though their growers use on the average three times as much nitrogen as is used by our Valley growers.

Feeding a citrus tree is not as simple a matter as feeding a dairy cow. Balanced formulas cease to be balanced when they are mixed with alkaline or slightly saline orchard soils such as we use for the production of citrus fruits in this region. Availability of phosphorus and other mineral elements may also change with the seasons and with the management of the soil. Minor element deficiencies, particularly iron and manganese, will sometimes show up during the late fall season, soon after the onset of the fall rainy season. These deficiency symptoms are more acute when the rains are preceded by a long drouth period such as we experienced in the Valley during the summers of 1945 and 1946. Drouth causes soluble salts to accumulate in the surface soil and concentrations may reach such high levels that the trees are not able to absorb sufficient quantities of all the elements they need. Also, the leaching of saline soils with rain water may bring about physical and chemical changes in the soil. The chemical changes may inhibit the intake of certain mineral compounds which are insoluble in alkaline water, and the physical changes may slow up the movement of water through the soil.

This all sounds very complicated, but it serves to show why our Valley citrus growers cannot compound a perfectly balanced fertilizer that contains all of the elements known to be removed by crops of citrus fruits, apply it to their orchard soils in quantities sufficient to make up for all nitrogen and minerals removed by each crop, and then forget about nutrition problems.

The fertilizer needs of a citrus orchard should be determined by each individual grower, under his own special conditions, by trial and error methods. We can make general suggestions concerning the use of fertilizer materials, but each grower must do some experimenting on his own initiative, as soils vary considerably in the way they respond to fertilizers and to different systems of management. Clay soils are not as responsive to fertilizer as sandy and loamy soils, and soils devoid of humus are not as responsive as those containing adequate amounts of organic matter. Likewise, alkaline-saline soils are not as responsive as those having a lower salt content and lower pH.; and waterlogged soils cannot be expected to respond to any kind of fertilizer treatment until the soil has been properly drained.

Nitrogen has generally given satisfactory results wherever it has been properly used. Timing and the method of application are just about as important as the source and the amount used. Ammonium nitrate was a life saver to citrus orchardists in all parts of the country during the war-created shortage of other nitrogen fertilizers. However, thousands of trees have been killed by the improper use of this highly concentrated fertilizer. We believe that single applications of this material should probably not exceed three hundred pounds per acre (about 100 pounds of nitrogen).

For young trees, the rate per unit area remain the same (about 1 ounce per square yard) but the area treated would be greatly restricted (9 ounces on 9 square yards of soil) in the case of the year old trees. The amount used would be increased year by year up to 81 ounces or about 5 pounds for old trees set 9 x 9 yards apart.

We believe that late December or January, April and June are the best times of the year for making applications of nitrogen fertilizers. Early winter fertilization makes it possible for trees to store up sufficient reserves of nitrogen to enable them to set maximum crops of fruit. The April and June applications should supply nitrogen when it is being used at the greatest rate by the trees and the cover crop. Fall fertilization, especially with nitrates in clean cultivated orchards, has occasionally resulted in severe winter killing of the succulent wood.

There seems to be no conclusive evidence that one source of nitrogen is sufficiently better than any other to justify a premium being paid for that material; with the possible exception of ammonium phosphate, which supplies both nitrogen and phosphorus in an available form. Nitrogen can be purchased at the lowest cost per unit of nitrogen in the form of urea (42%N) and ammonium nitrate (32.5%N.) Both of these fertilizers have given excellent results under a wide variety of conditions where they were intelligently used. Ammonium sulphate, cyanamid, and calcium nitrate are other nitrogen fertilizers which are occasionally used in this region.

Phosphorus is second in importance in the nutrition of Valley citrus trees; not because it is removed in excessive quantities by the fruit crops, but because it seems to become insoluble and unavailable under certain soil conditions. Experience at the Valley Station indicates that ammonium phosphate is a better source of phosphorus under our conditions than is 20% superphosphate. Arizona investigators report similar results on their alkaline-calcareous soils. Ammonium phosphate (11-48-0 and 16-20-0) disappeared from the market during the war years, but they are now being manufactured at Houston, Texas, and should eventually be offered for sale in the Valley.

Fertilizers which supply potash in addition to nitrogen and phosphorus are not required by most Valley citrus trees. Chloride salts contained in some of these fertilizers may actually cause damage where the mixtures are applied in sufficient quantity to supply the full nitrogen requirements of large trees, especially on soils which already contain appreciable quantities of chlorides.

Minor elements such as iron, manganese, zinc and copper are most economically supplied in the form of corrective sprays. However, it has been demonstrated that iron deficiency can be temporarily corrected by adding ferrous sulphate (green vitriol) to the soil at the rate of 1 ounce per square yard or 300 pounds per acre. The use of finely ground sulphur in conjunction with the ferrous sulphate tends to prolong the period of ef-

fective control of a form of chlorosis (yellowing of the leaves) which is quite common in the Valley at certain seasons.

Zinc sulphate at the rate of 5 pounds per 100 gallons of spray and manganese sulphate at 2 pounds per 100 gallons, along with half these quantities of hydrated lime or sodium carbonate (soda ash) can be used before the spring flush of growth starts or before it hardens. In some instances these materials are mixed with the fixed copper spray which is applied for the control of melanose disease. Growers who contemplate the use of these corrective sprays should obtain full information concerning their use before starting spraying operations. There is a definite way in which the zinc and manganese compounds should be mixed with the "neutralizing" agents (lime or soda ash).

Citrus trees under five years of age on good virgin soil should not require any fertilization. Trees on depleted farm lands will probably need moderate amounts of fertilizer from the start (4 to 16 ounces of ammonium nitrate per tree or its equivalent). This should be applied in two applications (April and July).

Trees in full bearing should probably receive an application of 300 pounds per acre of ammonium nitrate or its equivalent prior to the blossoming period (December or January). In orchards where a heavy set of fruit is secured, an additional 300 pounds of ammonium nitrate or its equivalent may be applied during April or early May. This should supply an abundance of nitrogen for normal crop production but an additional application of nitrogen at about the same rate may be justified in special cases (in orange orchards or in orchards where the grass cover crop is especially heavy.) This third application should probably be made in late June or early July. When 16-20-0 or 10-10-0 grades are used, they should be applied at rates of two or three times the quantity suggested for ammonium nitrate.

Fertilizer is a valuable aid in producing maximum yields of citrus fruit, but it must be intelligently used, along with a sound irrigation program, and on good trees which are growing in good, well drained soil.

NEW IDEAS IN ORCHARD SOIL MANAGEMENT

By

DR. J. B. CORNS, *Professor of Horticulture, Texas A. and I. College*

Orchard soil management is a most important consideration in the management of citrus groves and upon it depend for a very large part the returns from the grove. The length of the productive life of the trees is very largely dependent upon soil management practices. A survey of the groves of the Rio Grande Valley will show that large numbers of groves have gone out of existence many years before their normal time due to faulty soil management practices.

There are many systems of soil management practiced in the Valley. Some of these work well under some conditions and soil types whereas the same system would not work equally well under other conditions and on other soil types. It is safe to say that there is no one best method which will work best under all conditions. Sod culture may work well for some groves, but it could certainly not be recommended for all groves. These systems must be studied, tried, and evaluated and then the best one found which will be best fitted to the particular soil and to the other conditions peculiar to that grove and to that locality.

In evaluating soil management practices the following points should be considered:

(1) Maintain a high content of organic matter in the soil.

(2) Secure good penetration of irrigation water.

(3) Maximum utilization of applications of commercial and organic fertilizers.

(4) Cultivation practices with a minimum destruction of citrus roots.

(5) Minimum compacting of the soil.

The new ideas of orchard soil management should be sized up to see how nearly they come to fulfilling the 5 points as given above.

During the last few years several methods of soil management for the citrus grove have come to the front. Three of the most important of these will be considered in this paper, namely; (1) Sod Culture for Citrus Groves, (2) Herbicidal Sprays for Weed Control, and (3) Oil Spray for Weed Control.

SOD CULTURE FOR CITRUS GROVES

The sod culture system of soil management is not new here in the Valley, but no extensive use has been made of it until the present time. The sod has been used in orchards near large open canals where the area was subject to severe damage from seepage. There sod culture was the only system possible since the soil was generally too wet for use of the disk and other orchard implements. Interestingly enough this sod system was used in the Banker Grove near Brownsville for at least 25 years with very good success. This grove was located on the Resaca Type soil, and was well sodded with Bermuda Grass, Johnson Grass, and many species of weeds. High permanent borders and cross borders were used for the flood or border system of irrigation. These high borders precluded the use of disks or mowers to control the grass and weeds, and conventional sprayers for the control of the insects and diseases. Insect control was limited to applications of sulfur made with the knapsack duster. Little attempt was made to control the weeds and grass, so it was not uncommon to see grass and weeds growing to a height of 5 or 6 feet. Many growers classified this as a neglected culture rather than a sod culture.

To the surprise of most growers this grove with the sod culture or non-tillage system produced good yields for many years despite the unkept appearance of the grove as compared to the almost weedless groves of the neighboring growers. There were some reports from packing plants that some of the best quality of fruit of the district came from this grove. While this system of sod culture worked well for this grower it attracted little attention from other growers of the Valley since the general opinion was that although it worked well on this particular soil it would not work equally well elsewhere in the Valley.

The modern version of sod culture has little resemblance to the previously described system which was at best little better than a neglected system of culture. The present system is being tried in a number of groves in the Valley with success; however, a trial over a period of years will be necessary to really judge its value as compared to the conventional system of cultivation. In this system the weeds and grass are allowed to form a good sod, but are always kept under control, and are never allowed to get more than a foot or a foot and a half high. The weeds and grass under and next to the tree rows is controlled by mowing and those in the "middles" by a stalk-cutter. In some cases the mower is used altogether instead of the stalk-cutter. The mower very effectively controls the vegetation under the skirts of the trees while the stalk-cutter chops up the vegetation in the "middle," between tree rows.

This system can best be adapted to groves which use the sprinkler system of irrigation, as there are no borders and ditches over which the mower and stalk-cutter must run. By this method a level system of culture is used, so the whole grove is level which is a real advantage for all operations of grove management from dusting on through the harvesting of the fruit. This is a great improvement over the first described system in which permanent borders were left in the sodded orchard. The system is being tried out on a rather extensive scale by Rio Farms and by San Roman Nursery at Bayview as well as by some other growers in the Valley.

The system is best adapted to use with the sprinkler system of irrigation but can under some conditions be used with the flood irrigation. The sod culture is used in the Stugard Groves at San Juan and on the R. C. Smith Grove north of Weslaco. The weeds and grass are kept down by means of a Gravely Mower which is a walking type tractor with the sickle-bar mounted directly in front of the tractor. This mower with its 4-foot sickle-bar works very well on the Smith 10-acre grove, but it is questionable if such equipment would be practical for large groves and for use by common labor. While the Smith Grove has permanent borders they run only lengthwise in the direction of the water flow with no cross borders to interfere with mowing, dusting, or harvesting of the fruit. Unlike the conventional system of bordering the permanent borders are under the trees instead of being in the center of the middles. This method might work satisfactorily where the irrigation can be done without the need for cross-borders and when the borders are prepared before the trees reach maturity. The sod culture is being successfully used in some groves with the flood system of irrigation, but it is much better adapted to those groves on which the sprinkler system is used.

In evaluating the sod culture with the 5 points heretofore cited for maximum returns from a grove it is found that a high content of organic matter is maintained. A relatively high tonnage of grass and weeds is grown per acre and all is left on the soil for decay and incorporation with the soil. This sod and vegetative matter on the ground also affords shade for the soil which is effective in lowering the soil temperatures by at least 15°F. This is important in obtaining good root growth during the periods of high summer temperatures.

Another consideration is that of securing good penetration of irrigation water. Work on penetration has been done on the Rio Farms at Monte Alto on the Willacy Fine Sandy Loam. By this sod culture and the use of sprinkler type of irrigation increased water penetration has been obtained.

The system should secure good utilization of chemical and organic fertilizers; however, there is some question as to the maximum utilization of the phosphate fertilizers. Unquestionably this could be used by the shallow rooted grass and tree roots, but due to limited solubility and rapid fixation in the soil it is doubtful if appreciable quantities would be found below the surface soil. Understand that some experimental work is being conducted to determine depth of phosphorus penetration and availability in sod which should produce some much needed results for application to sod culture.

The sod culture should give a minimum destruction of citrus feeder roots allowing greater accumulation of roots in the upper foot of soil. This is an important consideration and certainly should be given stress in choosing a system of soil management. Root pruning should be kept to a minimum. Furthermore in addition to reduced root pruning there would be reduced compacting of the soil with the use of a sod. The compacting would be further reduced by full use of the mower in the tree middles as well as under the trees. However, after the sod is well formed there is a limited amount of packing with a stalk-cutter. The stalk-cutter does effectively cut the vegetation for a more rapid decomposition.

The sod of this system of culture will be made up for the most part of Bermuda and Johnson Grass along with some weeds; however, the weeds may ultimately be killed out with continued cuttings. St. Augustine Grass has been recommended by some as the best grass for sod. This grass may be found to be very satisfactory although more experimental work should be done before a general recommendation is made. General observation of this grass as a sod around trees in yards has been very satisfactory.

One of the real objections to use of the sod culture is that there is a fire hazard. There have been some orchard fires in sod culture, but with proper precautions it is believed that this danger can be kept to a very minimum. One precaution to be used is to mow before the grass and weeds get more than a foot high which will reduce the amount of hay on the ground. Another precaution as used on Rio Farms is to irrigate a few days after mowing and when the grass cut has dried out.

This system of sod culture appears to have considerable promise here in the Valley and certainly is worthy of attention and additional trials over a longer period to determine its real value.

WEED CONTROL IN ORCHARDS WITH HERBICIDAL SPRAYS

A problem of increasing importance in the Lower Rio Grande Valley has been the control of the Morning Glory and Clematis vines which have become a real problem in all parts of the Valley. It is reported that in some groves the cost of controlling these vines under the trees by hoeing is excessive. In addition to this labor cost the vines withdraw considerable quantities of soil nutrients and water from the soil at the expense of the trees. In addition to this the vines by their shading effect on the trees reduce photosynthesis or the manufacture of carbohydrates in the trees resulting in decreased growth of trees and fruit.

During the last year a new type of active ingredient for controlling weeds and vines was introduced by several commercial concerns. This material is the organic compound 2,4-dichlorophenoxyacetic acid, which is now generally abbreviated to 2,4-D. Such herbicides or weed-killers containing 2,4-D appear to have fewer objectionable features than those containing such materials as sodium chlorate, arsenicals, and more recently introduced dinitro compounds. Such herbicides are reported to be non-poisonous to animal life when used at herbicidal concentrations. Furthermore, they do not create a fire hazard as does the sodium chlorate. with the 2,4-D spray the roots of perennial species are more effectively controlled and if properly applied the subsequent germination of seeds in treated soils is not so greatly inhibited as with other herbicidal sprays.

This 2,4-D compound oddly enough belongs to a group of plant regulation substances known as plant hormones. These hormones have been used for the stimulation of roots of cuttings and on transplanted plants, stimulating the setting of fruit, and in preventing the premature dropping of fruits. Such stimulating effects were obtained by the use of dilute solutions. It was later found that greater concentrations would exert a toxic effect on plants. The concentrations were found to have a selective killing ability, killing many species of broadleaved weeds whereas but few of the grasses were affected.

This weed killer and others of similar nature are being given trials to further determine their killing powers and their effects on citrus trees. The Texas Experiment Station, the California, and Florida Experiment Stations are all conducting experiments with these herbicidal sprays and some reports are already being issued from these stations. There seems to be little question but that they are quite effective against our common weeds and vines, particularly the Morning Glory and Clematis vines, but much caution must be used to prevent excessive use of the material and to prevent it from getting on the citrus tree foliage, especially the new growth. The spray should be applied while the Morning Glory vines are only a few inches high and never sprayed on vines which are climbing on the trees.

Here in the Valley most of the applications of 2,4-D so far have been with knapsack sprayers; however, some large grove owners expect to use power sprayers with the boom hooded to prevent the spray from coming in contact with the tree foliage. Indications are that increasing amounts will be used the coming year. but that more experimental work is yet needed before there will be general use of the material for the control of weeds and vines growing under the trees. Additional work is needed to determine the correct dosage to use under Valley conditions.

According to Ethelbert Johnson, District Supervisor of the Bureau of Rodent and Weed Control and Seed Inspection, California State Department of Agriculture, the following precautions are recommended in order that injury to citrus trees will be minimized when treating of weeds in orchards with 2,4-D:

"1. Avoid treatment near the rainy season to prevent chance leaching into the root zone.

2. Avoid treatment during periods of active tree growth. New growth is particularly sensitive.

3. Time the treatment so that maximum results on the weeds can be expected. Generally speaking, this will mean treatment in an active state of growth, avoiding days of excessively high temperatures and low humidity.

4. Use the lowest dosage which can be expected to kill the weeds. For actively growing morning-glory, 500 parts per million (0.05%) is sufficient, adding a wetting agent if necessary to insure thorough coverage.

5. Avoid treatment in windy weather to prevent drift.

6. Keep the pressure at a minimum, 50 to 75 pounds is enough.

7. Use a fan-shaped spray in preference to cone or "gun" types. It is more easily controlled.

8. If a boom is used, it should be hooded to prevent spray and fog from coming in contact with tree foliage.

9. If the spray rig is later to be used for tree spraying, prompt and thorough cleaning cannot be stressed too much.

For water-soluble salts of 2,4-D, several washings with clean water should be sufficient. For the acid and oil-soluble esters, the rinse water should be alkalized with lye, sal soda, baking soda, trisodium phosphate, or other alkalizing agent."

USE OF OIL SPRAYS FOR WEED CONTROL

In California there are some 20,000 acres of citrus groves in which no tillage practices are used. The weeds are controlled by various methods including the use of oil, fire, chemicals, and hand hoeing. Of these methods oil is the most extensively used and seems to be gaining in importance. This system of culture is most revolutionary and is redically different from practices of soil management heretofore used. This system consists of eradication of vegetative matter in the orchard, whereas the conventional system of culture is to grow large quantities of cover-crops and weeds in order to increase the organic matter content of the soil.

This non-tillage system has given some very good results in California and from reports these growers who are using it are very enthusiastic, whereas the majority is still skeptical and are cautiously waiting for further experimentation, Growers report that growth responses and fruit quality are perfectly satisfactory and it is generally accepted that fruit in non-tilled orchards matures from one to three weeks earlier, which is probably due to higher soil and air temperatures.

This oil spray is applied by many different mechanical means including the small knapsack sprayer and other types of portable sprayers. The cost for this system of weed control will be rather high for the first two years and after that, lower, depending upon the local situation and the type of weeds to be controlled. It is reported that growers use on the average about 240 gallons per acre the first year down to about 90 gallons in the fourth year. According to B. E. Yarrick of the Agricultural Extension Service of Los Angeles County, California, "The least oil will be required if the weeds are hit when less than four inches in height. A correct application need not drench the soil, since a light mist will kill the weeds. Smudge

oil is generally used. It is very volatile and leaves only a stain. Chemical tests have not been able to show the presence of oil in the soil and no growers have complained of any ill effects."

The application of this non-tillage method through weed destruction by oil appears extremely questionable for use in the Rio Grande Valley. Our conditions are much different including higher soil temperatures and higher air temperatures, flood type of irrigation as compared to furrow type in California, different chemical content of irrigation water, and irrigation water containing large quantities of weed and grass seed which readily re-infest the soil. The system may possibly work here in the Valley, but considerable experimental work should be done before it could be recommended.

SUMMARY:

1. No one system of soil management is best under all conditions.

2. Sod culture in itself is not new here in the Valley.

3. Latest version of sod culture is new and consists of sod maintenance, but with grass and weeds controlled by mowing under the trees and use of stalk-cutter in the tree middles. Sprinkler system of irrigation used.

4. Sod culture in some cases carried on with flood system of irrigation and a Gravely mower used to cut weeds and grass. Sod culture more readily adapted with sprinkler irrigation than with flood irrigation.

5. Sod culture appears to have definite possibilities, but should have further experimental work before definite recommendations are given.

6. Weed control with 2,4-D is a late development and considerable experimental work is being carried on for its use in controlling morning-glory and Clematis vines under citrus trees. The 2,4-D seems to be an effective weed killer, but much caution must be used to prevent contact with citrus leaves especially new growth. Nine precautions are cited in this paper.

7. Oil sprays are effectively used for weed control in California. A radical departure from theory that large quantities of organic matter should be added to soils by growing cover-crops or addition of manure.

8. In California non-tillage groves with the oil sprays for weed control have given sustained high yields with earlier maturity.

9. Questionable if such non-tillage methods with oil spray weed control will work equally well here in the Valley under very different conditions. It is, however, worthy of consideration and some experimental work should be done on this system.

WATER REQUIREMENTS OF CITRUS TREES

By
J. ELIOT COIT, *Fallbrook, California*

During the course of evolution the different species of plants have adjusted themselves to the various environments in which they find themselves. They may vary widely in water requirements from water lilies and willow trees at one extreme to cactus and mesquite trees on the other.

Our citrus trees developed in or near tropical rain forests of Southern Asia and Indonesia where rainfall is plentiful and atmospheric moisture is relatively high—they therefore have broad leaves which remain on the trees throughout the year. The leaves have to be many and large in order to pump up from the roots sufficient sap, which holds mineral plant foods in solution, to permit growth and fruit bearing.

When we transplant these trees from their native habitat to this Valley, the environment is so different that they cannot thrive unless irrigation water in addition to the rainfall is provided. The question of just how much irrigation water is needed here for optimum growth and fruiting cannot be answered categorically, because even here rainfall and other elements of climate vary in different parts of this Valley. Also there is much variation in soils and in sizes and ages of trees. Each grower should understand the way his particular trees are using water and determine the optimum amount of water for his particular orchard. With this in view, it is well for each grower to have a good working idea of the physiology and anatomy of the citrus tree.

Practically all the water used by citrus trees is obtained from the soil. It is absorbed by the small fibrous roots and carries in solution certain chemical plant food elements required for growth. This solution is known as sap and is pumped up by the leaves. In the green leaves, raw sap is digested and made ready for the nutrition of the tree. Excess water, of which there is a large amount, is evaporated from the leaves, thus maintaining a suction in the sap vessels in the wood, which provides a continuous supply of necessary mineral matter. The upward path of raw sap is in the wood and the downward path of digested sap is in the bark. The two streams are separated more or less by what is known as the Cambium layer. That layer is represented by the plane of cleavage when green bark is stripped away from the wood.

Roots possess only partial selective powers, and in addition to necessary food elements, they also take up some unwanted items. Also the proportion of the food elements is seldom just right, and after digestion, excess and unused materials accumulate in the leaves. In the final shedding of the leaves the tree relieves itself of these excess and waste products.

Water evaporates from leaves principally through very small openings known as stomata, which in the case of citrus trees are all in the under side of the leaves. These, in most plants open and close to regulate water loss. Citrus stomata are fairly efficient in young leaves, but as the leaves grow older this power of regulating evaporation decreases. The evaporation of water through leaf stomata is technically known as transpiration.

The water requirements of citrus trees is very closely related to the rate of transpiration, and this is of sufficient importance to discuss in some detail.

Citrus transpiration rate varies with at least five factors: humidity, temperature, light, air movement, and soil moisture.

The more moisture or humidity there is in the air surrounding a leaf, the less the pull is exerted by the air on the leaf for moisture. This slows the transpiration rate and in turn reduces the amount pumped from the soil.

In dry desert areas trees require more water.

The higher the temperature the greater the transpiration rate. In hot weather, trees require more water than in cool weather.

Transpiration is increased by bright light, especially by the actinic rays at the short wave-length end of the Spectrum of sunlight. These rays are partly absorbed by atmospheric moisture even though invisible as fog. Thus, we find the high humidity of this Valley reducing that part of the sunlight which stimulates transpiration. In this connection there is a lot of detail with respect to the effect of sunlight on sap digestion and hence transpiration, which for the sake of brevity, we will pass over.

Air movement has a profound effect on transpiration. If the same layer of air remains in contact with a leaf, it has its moisture content increased by water from the leaf until it is sufficiently saturated to slow down transpiration. If a breeze or wind is blowing, fresh and dryer layers of air are constantly brought into contact with the leaf surface, and to this extent transpiration is increased. In California, we have occasional dry, hot desert winds at which time each of the four factors just enumerated operates at a maximum. Then the transpiration rate mounts so high that the water conducting vessels in the wood are inadequate to the demand. No matter how much water is in the soil, the leaves on the windward sides of the trees wilt and blow away. The trees cannot stand the strain of such extreme conditions.

The last factor to affect the transpiration rate is soil moisture. This is of less importance than the others and only operates perceptibly when the moisture of the soil is near or below the wilting point.

This Valley is 150 miles south of the center of the citrus district of Florida. It is 500 miles south of the California citrus district. The only thing which prevents tropical agriculture here is the lack of a mountain range barrier to shut out occasional blizzards from the north. Perhaps I should not mention the cold spells. It is an unpopular subject around here. Normally the mean temperature at Brownsville is 73 degrees while at Mission it is 74. In winter it is from 2 to 4 degrees colder than at Brownsville where the proximity of the Gulf affords a protecting influence. The length of the growing season is 332 days at Brownsville and 318 at Mission. The mean humidity of 74 percent at Brownsville decreases inland to 59 percent at Del Rio, and 37 percent at El Paso. Thus, we see that several of the factors discussed operate together to increase the transpiration rate as one progresses from the Gulf toward the interior desert country.

Due to the environmental complex described above citrus trees grow very fast here and produce abundantly. In general, I think that a five year old tree here is about the size of an eight year tree in California.

The average rainfall is 27 inches at Brownsville and 21 inches at Mission. It is inadequate for such fast growing trees and is not distributed so as to be most efficient for tree use. I presume that here at Weslaco we are at about the middle of the citrus area. As I said in the beginning, I have made no personal investigation here to find out the optimum amount of water required by citrus trees here. If I should hazard a guess, based on my experience elsewhere, I should say for full grown and bearing trees in a clean cultivated orchard, a total of 40 inches at San Benito, increasing to 45 or more inches at Mission. This includes both rain and irrigation. I feel quite sure that in past years much harm has been done in this Valley by unnecessary and excessive irrigation. In assigning me this subject, I am not sure that Prof. Adriance intended me to stick my neck out quite that far!

Now we come to some of the more practical aspects of this subject. Too little water is indicated by reduced growth, smaller leaves, smaller fruit sizes, and in extreme cases actual wilting of foliage and dropping of fruit. Too much water is indicated by slower growth, pale color of foliage, dying off of root fibers, and various root and crown diseases such as gum disease. and foot rot. Citrus roots require some air or oxygen in the soil. They profit by a certain amount of drying out of the soil between wettings. This permits air to enter the soil.

How may one determine the optimum moisture content for his particular soil? The experienced farmer has learned how to use a soil auger and judge the soil moisture by its look and feel in his hand. I cannot tell you how to do this as the art is acquired only by practice. For those less experienced, however, it is well to become familiar with a few terms used by soil technologists.

The MOISTURE EQUIVALENT is the percent of moisture left in a soil after having been subject in a centrifugal machine to a force of 1000 times gravity. This test has to be made in a laboratory and, having been made once for each soil type on your property, remains practically unchanged. The range is from about 5% in a course sand to 35% in stiff clay. The wilting point is figured by dividing the moisture equivalent by 1.84. The water holding capacity, commonly known as field capacity is gotten by saturating a known weight of dry soil and, after draining, compute the gain in weight in terms of dry soil. The OPTIMUM MOISTURE for growth is usually about 60% of the water holding capacity. It is a good idea to have some of these tests made at a soil laboratory. Ask for a sample of each of your soil types at optimum moisture in covered soil cans. Go to the same spot in your orchard where they were taken and with a soil auger bring up a fresh sample. Open the can and compare the two by feeling with the hand. After doing this a few times you will come to know your soil as you should.

It is a good idea also to take irrigating water through a meter or weir and keep a record, even if not scientifically accurate, of the amount of water you put on your land in a year. Keep a good rain gauge on your place and keep a rain record. Add the irrigation to the rain and compare the result with the optimum figure of 40 to 45 inches I suggested. You may find that you are irrigating too much for best growth and yield, to say nothing of leaching away your plant food or raising the water table.

Because it is the leaves which remove water from soil, the more leaves, the more water is needed. Young trees are often over-watered while very large full bearing trees, if closely set, may possibly be under-watered.

The amount of water varies also according to the soil type. It is difficult if not impossible to irrigate land which has an open gravelly subsoil without wasting some water by leaching and this must be allowed for. On the other hand, land which has a stiff clay subsoil requires very careful irrigating in order to avoid damage from what is known as a "perched" or temporary water table.

Your period of heaviest rainfall comes in the fall (just the opposite of California) and it is especially important to pay close attention to weather forecasts and avoid watering, or shut off the water when rain comes. During the short cool days of winter the transpiration rate is quite low and trees do not need much water.

If rain happens to be light in fall and you are in a quandary as to whether or not to irrigate, compromise by irrigating lightly every alternate middle. Then, each tree will have some of its roots in wet soil and can get along very nicely.

Less water is needed, of course, under clean culture than where there is a permanent cover crop of weeds and Johnson grass, which is not kept short by mowing.

In conclusion, I may say that water requirements vary so widely according to local conditions in this Valley that no fixed recommendation can be laid down. It is up to each grower to become familiar with the principles involved in the use of water by trees, and then do his best to apply them to his peculiar set of conditions.

APPLYING IRRIGATION WATER TO CITRUS ORCHARDS ON RIO FARMS

By

S. B. APPLE, Jr., *Rio Farms, Inc.*

In every irrigated area you are now faced with a choice of one of two distinctly different methods of applying irrigation water—the flood or surface method with its many modifications, and the sprinkler or overhead method. It is my purpose to briefly discuss each of these systems and in doing so tell you which of these two systems we prefer on Rio Farms, Inc., and why.

With all methods of surface irrigation the soil itself is the final medium for distributing the water which you either flood over the surface or run in furrows spaced close enough together so that most of the soil can be moistened. Unless you properly grade your land and lay out your irrigation system very carefully, uniform distribution is difficult and sometimes impossible to obtain. We have found it no simple matter to get uniform distribution and otherwise control our water in an orchard that has been planted in the regular manner on a relatively steep slope. Erosion has been severe on some of our groves and we more often than not get too much water on part of the row while we are trying to get enough on the remainder of the row.

CONTOUR IRRIGATION

Contoured plantings and subsequent surface irrigation on the contour is at lease a partial answer to water management on such sloping land. There are many variations of the contour system but basically the idea is the same. Initial costs are higher but I understand that costs of contour irrigation have been less than flooding straight rows on the same topography and soil. Some of our young trees are being planted on the contour now.

The sprinkler system differs fundamentally from surface irrigation in that it distributes water to the soil independent of the soil itself. Uniformity of sprinkler application depends primarily on the ability of the system to apply equal amounts of water to all parts of the area. Uniformity of surface irrigation, on the other hand, depends upon the surface condition, the uniform permeability of the soil, and the ability of the system to distribute water uniformly to all parts of the area.

The sprinkler system does not give you the same penetration as surface irrigation with less water being used. A definite amount of water is required for a given penetration on a given soil regardless of the application method. Where you apparently get better penetration with lighter applications, the water is simply more uniformly distributed and less water is wasted—loss by run-off can be avoided and heavy amounts are not applied in low spots.

On Rio Farms, Inc., we have both systems of irrigation—the major acreage at present under the flood or surface system. If pressed for a choice of one or the other our Citrus Department without hesitation would choose the sprinkler system. We have found that on the soil types on our farm and with our relatively steep-sloped orchard sites that the sprinkler system is the best of the two, to date. To us the following advantages can be derived by using the sprinkler system:

1. USE OF COVER CROPS

We have found that cover crops can be more successfully grown under sprinkler irrigation than under surface irrigation. Thus we can fit an important humus and nitrogen supply system with all its attendant advantages in our management program. In the past one of the main objections to summer cover crops has been the difficulty of supplying moisture for both tree and cover crop. With the sprinkler system we have the opportunity of alternating the middles for the portable pipe and using the other middles for a good legume cover crop.

2. CONTROL OF SOIL MOISTURE

On any given acreage of our citrus groves we find areas of well drained soil and areas of poorly drained soil, soils that vary from shallow to deep and soils that vary from relatively heavy to light. These different types of soil require different rates of application and amounts of water. By making careful studies of these areas and determining their moisture penetration rate we have with the use of the sprinkler system avoided over-watering some areas and underwatering others.

LOWERED WATER TABLE

We have definitely lowered the water table on one block of trees from three to eight feet. This past summer these trees were chlorotic, heavily defoliated and in very poor condition. The Citrus Department switched from surface to sprinkler system and today these trees are recovering.

Sheet and gully erosion are quite common in our area. On mature established orchards contouring is of course impossible and we have turned to the sprinkler system. By not discing and using only a stalk cutter and mower plus the sprinkler system we have checked erosion.

3. REDUCTION ON OPERATIONAL COSTS OF IRRIGATION ON RIO FARMS (1946)

A. SPRINKLER IRRIGATION—DIESEL POWER

Depreciation	$ .75 per acre
Fuel	.31 per acre
Labor	1.20 per acre
Total	$2.26 per acre

B. SURFACE IRRIGATION

Labor (varies 90c to $3.00)	$1.50 per acre average
Bordering and connecting	2.00 per acre average
Extra discing	1.50 per acre average
Total	$5.00 per acre

4. REDUCTION OF COST OF GROVE MAINTENANCE

a. No bordering and heavy equipment used

b. No extra discing or no discing at all under a cover crop system

c. Smaller equipment can be used with less initial cost and maintenance cost.

5. OTHER ADVANTAGES

a. Smaller equipment means less tree breakage and fruit loss.

b. Pruning, picking, and hauling easier—smooth grown surface.

c. Ground machinery for dusting used easily with no border interference.

Sprinkler irrigation is *NOT* a cure-all. Irrigation, whatever the method, is the complicating factor in soil management of citrus orchards. There is a real need for careful and accurate soil and soil moisture studies on every orchard site, whether it is ten acres or five hundred acres. Research points the way but recommendations resulting from research must of necessity be general. In the end, each of you must solve the problem for your own particular acreage.

VARIETIES OF CITRUS FRUIT FOR PLANTING IN THE LOWER RIO GRANDE VALLEY

By

W. H. FRIEND, *Superintendent, Substation No. 15,*

Texas Agricultural Experiment Station, A. & M. College of Texas

The opening of the planting season for citrus trees always creates a demand for information pertaining to the various types and varieties of citrus fruit. Fortunately, the citrus expositions such as the Citrus Fiesta and the Midwinter Fair are held at such a time that grower interest is stimulated just at the proper time. These citrus shows have done a great deal to popularize worthwhile varieties, and they have also been a means of showing up the undesirable features of the older types. Grower interest in varieties is always a favorable sign, as it shows that the prospective planter of trees is aware of the benefits to be derived from using better adapted varieties for commercial planting.

The benefits that come from standardizing on a few commercial types are not to be taken lightly, but it would be extremely unwise to continue using inferior varieties merely because the nurserymen and shippers have "standardized" on these old reliable varieties. There was nothing much wrong with the Marsh variety when the Pink Marsh was discovered, and we still find little to complain about in the Pink Marsh, now that the superior (Redblush) grapefruit is available. However, those growers who ten years ago followed station advice in regard to the planting of these pink fleshed improvements over the standard Marsh grapefruit are now reaping their reward.

In the Lower Rio Grande Valley of Texas, citrus growers are principally interested in sweet oranges and grapefruit. None of the varieties of pummelo or Shaddock are commercially desirable, and all varieties of lemon and lime are quite tender to cold. There is limited interest in tangerines, but merchandizing difficulties always act as a check on the popularity of this species of citrus. Some of the tangelo hybrids involving tangerines and grapefruit are well adapted to Valley conditions. Thornton, Lake and Mineola tangelos are the three outstanding varieties. Grower interest is now based on salability of the fruit as well as productive capacity of the trees, and this interest is reflected in the demand for nursery stock. The big demand is now for Hamlin, Joppa and Valencia oranges and Redblush grapefruit. This is not to be interpreted as convincing proof that these varieties are the acme of perfection in their respective classes, as better varieties may already exist, or may be developed by plant breeders. It is this changing situation which makes citrus production appeal to the new arrival in the business, and tends to keep the old timers constantly on the alert. Like many other horticultural enterprises, citrus fruit growing is somewhat speculative in nature, and the grower who uses good judgment in selecting the varieties he puts his money into, is most likely to win.

In the developmental stages of the Valley's citrus industry, planting stock was imported from many sources. Due to the brisk demand for trees of certain varieties, shortages developed and substitutions were made sometimes without the purchaser knowing anything about the matter. For example, many orchard developers thought they were getting Hamlin (Norris Seedless) oranges, when in reality they received some inferior type

of seedless orange that eventually failed to measure up to the performance normally expected from trees of the Hamlin variety. This substitution accounts, in part, for some of the reports about Hamlin oranges splitting and drying out early in the season. Nurserymen, who grow citrus trees for sale, owe it to the people they serve to familiarize themselves with the best strain of each variety they propagate and then use every precaution to insure propagation only from tested and proven trees of that strain.

Since standardization is a highly desirable factor in citrus fruit production, it is unnecessary for nurserymen or growers to burden their minds with more than half a dozen varieties.

Orange varieties of the early, midseason, and late types are available for commercial planting. The Hamlin orange is the outstanding early variety because of the smoothness and fine appearance of the nearly seedless fruit, and because of the exceptionally high productive capacity of the trees. When grown on good orchard soils, and properly cared for, there have been no appreciable losses from drying or splitting. Its principal faults are its relatively small size and its poor keeping quality as compared with thick skinned varieties such as Joppa Seedless or Valencia. It does not readily stand the rough handling usually given Valley citrus fruits in harvesting, packing and shipping.

Joppa Seedless is a midseason variety worthy of commercial recognition because the trees are only slightly less productive than those of the Hamlin variety, and the fruit is definitely superior in flavor, keeping quality, and size. A good demand for this variety is likely to develop during the next few years.

Valencia is the standard late variety, but early seedless strains of this fine variety are now available. The cold hazard is the principal factor limiting the popularity of the Valencia variety.

Navel oranges are not popular with Valley growers, but there is a limited demand for the large, mild flavored fruits of this variety. Because of the exceptional vigor of the trees and also because of the excellent interior quality of its fruit, Texas Navel is recommended above other strains of the Navel orange. When planted along the borders of an orchard, the gigantic trees of the Texas Navel strain make excellent wind break plants and produce fair yields of fruit.

There are many other varieties of oranges which thrive in this region, but the Station does not feel justified in recommending any but those mentioned.

Grapefruit are not as popular with Valley growers as they were back in the good old days, when good Marsh fruit sold for forty dollars per ton. The trend is now definitely toward the pink or red fleshed varieties, and there seems to be little justification for increasing the acreage of standard Marsh grapefruit. It seems highly desirable to reduce the acreage planted to seedy varieties and acreage on marginal lands.

Redblush grapefruit is decidedly the most popular fruit of this type, and its popularity is well deserved. The trees are highly prolific, the fruit is very attractive in appearance, both inside and out, and the quality of the pulp is exceptionally good. Better varieties may be produced, but the discovery of the Redblush grapefruit will probably go down in citrus history as a high water mark in variety improvement. There should be a steadily increasing demand for planting trees of Redblush grapefruit to replace trees of obsolete types.

Tangerines can hardly be classed as a commercial type of citrus, as the demand for them is very limited. Due to their highly perishable nature, it is not likely that there will ever be a heavy demand on the part of growers of trees for tangerine, tangelo, Temple orange, or Satsuma. Clementine is the best early tangerine for Valley planting, but the fruit are small and must be moved before December 15. Dancy tangerines are poor in quality and the trees are not long lived. Warnurco, a large fruited variety of tangerine, has few qualities to recommend it for commercial planting. Some of the new tangelo varieties such as Mineola, Lake and Thornton and two of the new King orange hybrids are fine fruits for the home garden but have no commercial value.

Limes and lemons are the species of citrus which are most tender to cold, and as few growers care to risk this extra hazard in the production of fruit, the acreage planted to these crops is not likely to increase rapidly. The good prices received for lemons has encouraged persons who are financially able to afford heater protection to enter lemon production on a limited scale. Eureka is still the leading commercial variety of the standard type, while the Meyer cold resistant lemon, grown from cuttings, is the most dependable acid fruit for the average Valley grower to produce.

There are many varieties of citrus fruit which could be grown in the Valley, but since most of the fruit is produced for sale, it pays to confine commercial planting to a few varieties which are known to be popular with shippers and handlers of citrus fruit.

NEW ROOTSTOCK NEEDED BY CITRUS GROWERS

By

WILLIAM C. COOPER, *Physiologist, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture, Weslaco, Texas*

THE SOUR ORANGE PROBLEM

The sour orange has always been considered to be a very good rootstock for sweet oranges, grapefruit, and tangerines in all of the citrus growing States of the United States. It has been especially valuable for use on the heavier, wetter, and relatively poorly drained soils. In Florida the famous Indian River groves consisting of approximately 25 percent of Florida acreage are nearly all on sour orange. In California half of the citrus is grafted onto sour roots. In the Lower Rio Grande Valley it is practically the only rootstock used.

The chief reason for the sudden interest in new rootstock is the failure of sour stock in many other parts of the world. Since the beginning of the century in South Africa, it has been impossible to grow sweet orange, grapefruit, or tangerines on any strain of sour stock. The same has been true in the Island of Java. In 1930 a disease, now called "Tristeza" of oranges, grapefruit, and tangerines broke out in Argentina. It is now in Brazil and it kills all trees grafted onto sour root.

Very recently a disease known as "Quick Decline" has developed in California. Like Tristeza, it kills only trees on sour stock. The root of sour orange is apparently starved in both Tristeza and Quick Decline by a failure of food material to pass from the top to the root. The stopping point is apparently near the graft union.

Recent studies at the Citrus Experiment Station at Riverside, California, (1), have shown that Quick Decline can be transmitted to healthy plants by graft inoculation and can therefore be considered an infectious disease. This discovery plus the fact that investigations have revealed no bacterial or fungus organisms as the cause, lead the California workers to the conclusion that Quick Decline is a virus disease.

With such an insidious disease as Tristeza appearing in many parts of the world and getting closer to the United States' citrus growing regions, the U. S. D. A. has launched an investigation of this disease from funds appropriated by Congress and made available on July 1, 1946. Since Florida, Texas, or California would be vitally affected by the disease, the problem is not simply that of one State, but is of concern to the entire citrus industry.

Because the trouble has the characteristics of a virus disease, the U. S. Department of Agriculture selected a virus expert, Dr. C. W. Bennett, to undertake the investigations on the Tristeza disease in South America. Dr. Bennett is now in Brazil and has set up his labroatory at the Instituto Agronomico, Campinas, Sao Paulo, Brazil.

In addition to the virus disease studies in Brazil, the U. S. Department of Agriculture is working cooperatively with the Instituto Agronomico on rootstock investigations to determine what stocks are susceptible and what ones are immune to the disease. Many different citrus species, varieties, and hybrids will be sent to Brazil to supplement what they already have for trial as rootstocks and these will be exposed to the Tristeza disease to test their susceptibility.

Concurrently with the Brazilian rootstock studies, the U. S. Department of Agriculture has initiated an investigation in the Indian River section of Florida and in the Rio Grande Valley of Texas to find stocks that can be used to replace sour orange and that, as determined by tests in Brazil, will be resistant to Tristeza.

The seventy-five or more different citrus species, varieties, and hybrids that are being sent to Brazil and tested for susceptibility to Tristeza there are now being grown in the nursery at the Valley experiment station in a citrus rootstock project conducted cooperatively by the U. S. Department of Agriculture and the Texas Experiment Station. The stocks include a wide variety of limes, lemons, shaddocks, sweet oranges, mandarins, tangelos (tangerine-grapefruit hybrid), citranges (trifoliate-sweet orange hybrid), citrangedins (trifoliata-sweet orange-calamondin hybrid), citrangequats (trifoliata-sweet orange-kumquat hybrid), citrumelos (trifoliata-grapefruit hybrid) and other citrus species, varieties, and hybrids. These rootstocks, when budded to several orange and grapefruit varieties, will be tested in the nursery for susceptibility to root rot, cotton root rot, and salt tolerance. The salt tolerance tests will be conducted in well-drained artifically salted soil pots where the concentration of salt will be carefully controlled. By this procedure, it is hoped to determine salt tolerance as differentiated from high water table and other soil factors which induce decline in citrus grown in the Valley.

After these preliminary tests in the nursery, the most promising stocks will be used in field plantings made in six or more commercial orchards in different soil types. These plantings will be extensive and carefully laid out so as to gain information to serve the Valley not only in the present emergency but in other emergencies to come.

These studies necessarily require years of close attention before definite results are known. Many Valley growers want to know what rootstocks to use **NOW**. Should you continue to use sour rootstock a while longer or should you turn to some other stock? In view of this question, let us consider what is already known about other rootstocks. Sweet orange, rough lemon, grapefruit, trifoliata, and Cleopatra mandarin have been sufficiently studied and used commercially in Florida, California and other parts of the world for us to know in general what each type of stock is fitted for. Commercially grown nursery stock is practically limited to these varieties for rootstock.

Other stocks that have been used on a limited scale or have been studied experimentally include sweet lime, Rangpur lime, Sampson tangelo, citron, Cuban shaddock, Ponderosa lemon, Dancy tangerine, Calamondin, bittersweet orange, and certain citranges, citrangequats, and citrangedines.

FLORIDA ROOTSTOCKS

The citrus industry in Florida is roughly divided into two distinct regions; the Indian River and the Ridge. In the Indian River region the soil is relatively heavy, wet, and poorly drained. Sour orange is used as exclusively here as a rootstock as it is in Texas. On the Ridge, however, the rough lemon predominates. The soils are very light, well-drained, dry, and very deficient in mineral nutrients. On such light and poor soils, the rough lemon stock has the ability to make a satisfactory growth, produce standard size trees while trees on sour stock grow slowly and tend to be dwarfed. The fruit on the rough lemon stock, however, is coarser and has a lower solids and acids content than fruit produced on sour orange stock.

Cleopatra mandarin and sweet orange seedlings are used to some extent as stocks in the Ridge section. Both have grown well and have produced fruit of quality approximating that produced by the sour orange stock. These two stocks, however, are not used in the Indian River region. Up to now, the growers along the Indian River have been quite satisfied with the sour orange stock. The sweet orange was eliminated as a rootstock in this region many years ago because of its susceptibility to gummosis and foot rot. Thus, it is seen that in the region of Florida that is most comparable to Texas, that is, the Indian River, the sour orange is used as exclusively as in the Rio Grande Valley.

The U. S. Department of Agriculture citrus station at Orlando, Florida, has had a comprehensive rootstock experiment in progress during the past four years on the light, high, dry soils in Lake County on the Ridge. The results of these tests, although not applicable to the major portion of the Rio Grande Valley soils, may be of some interest to growers in selecting rootstocks for use on some of the lighter soils now being planted in the region north and west of Mission.

In this Florida experiment the rough lemon, sour orange, sweet orange, Cleopatra mandarin, grapefruit, and Rusk citrange were used as rootstock for Parson Brown and Valencia scions. The results after the first four years in the field are as follows:

(1) Rough lemon produced the most vigorous top growth and the sour orange the least top growth of both scion varieties.

(2) The Rusk citrange produced a tree almost as large as the rough lemon while the Cleopatra, sweet orange, and grapefruit were intermediate between rough lemon and sour orange.

(3) Trees on rough lemon, sour orange, and Rusk citrange all came into bearing one to two years ahead of those on Cleopatra, sweet orange, and grapefruit.

(4) The quality of the first crop of fruit produced on Rusk citrange stock appeared to be of nearly as good quality as that on the sour orange and of better quality than on rough lemon. It will, however, be several years more before differences in yields and fruit quality can be definitely established.

CALIFORNIA ROOTSTOCKS

On the heavy but well-drained soils of California (2) before the advent of quick decline, sweet orange and sour orange roots were used about equally for the Washington navel and Valencia varieties, and to the exclusion of all other stocks except for a few trees on rough lemon and trifoliata. Gummosis or foot rot on the sweet root has been kept under control by (a) maintaining the general health of the tree with ample fertilizer applications, (b) irrigating by the furrow system, thus keeping the water away from the trunks of the tree, and (c) planting the trees high with only the roots in contact with the soil.

The Citrus Experiment Station at Riverside, California, started an extensive rootstock experiment as early as 1922 which is now far enough along to furnish information of interest to Texas growers.

The experiments consisted of over 5,000 trees on 49 different rootstocks planted in six orchards of different soil types. Unfortunately for the test none of these test orchards was located in a region where quick decline has become evident.

In the case of the Washington navel and Valencia experiments, the sweet orange and sour orange stocks produced about the same yield and fruit quality. Sweet orange, however, was more susceptible to gummosis. Sampson tangelo produced a yield and fruit quality equal to sweet orange and was found to be resistant to gummosis. The rough lemon yielded as well or better than the sweet orange, but the fruit quality was inferior to that from sweet orange rootstock. Cleopatra rootstock gave as high yields as sweet orange and had greater resistance to gummosis. Grapefruit rootstock was inferior with respect to yield to the sweet orange. Trifoliata in most instances produced smaller trees but when planted closer the per acre yield was equal to sweet orange rootstock. Trifoliata was resistant to gummosis.

In the case of the five different citranges tested as rootstocks. the results were variable. The Rusk and Savage were a failure while the Morton was an outstanding success; it produced a larger and more productive tree than the sweet orange. The poor record for Rusk citrange is in contrast to what was observed in the Florida experiments.

In the case of experiments with the Marsh grapefruit variety at Riverside, there appeared no choice between sweet orange, sour orange, rough lemon, Sampson tangelo, and Cleopatra mandarin rootstocks in the matter of tree size and yield. Cleopatra was found to be more resistant to gummosis than sweet orange. The Sampson tangelo stock appeared to be highly resistant to gummosis. Cuban shaddock and Tresca grapefruit were promising as rootstocks for grapefruit while the Cunningham and Savage citranges were a failure. The Rusk and Morton citranges were not used for Marsh grapefruit.

Some idea of the susceptibility of various rootstocks to quick decline has been obtained from observations made on 300 commercial groves in the quick decline region in California. It was found that sour orange was susceptible and sweet orange was highly resistant or immune and, on the basis of these findings, sweet orange rootstocks have come into general use for new plantings in the affected area.

Grapefruit stock was not widely used in the affected area. In five orchards in this area, comprising 38 acres and 2779 trees on grapefruit stock, none has shown quick decline, while 514 trees on sour stock intermingled in these orchards have shown 23% to be infected.

In 23 acres (1351 trees) of trifoliata stock with 336 sour orange stock replants, none on trifoliata showed decline, while 15% on sour were affected.

In the case of rough lemon, 170 trees were located on this stock intermingled with sour orange and none of those on the rough lemon has shown quick decline.

No Cleopatra stock was found in the affected area.

Only Washington navel and Valencia orange trees were found in the affected area. There were no grapefruit orchards found.

BRAZIL ROOTSTOCKS

Fortunately for the citrus growers in the United States, the Instituto Agronomico at Campinas, Estado Sao Paulo, Brazil, started an extensive citrus rootstock experiment in 1938. (3) The "Baianinha" (navel) orange, "Pera" (Valencia) orange, and the Marsh seedless grapefruit were budded onto sour orange, bittersweet orange, two varieties of sweet orange, Rangpur lime, sweet lemon, rough lemon, Ponderosa lemon, citron, grapefruit, Cravo tangerine, and trifoliata rootstocks. These budded trees are now six years old and are located in the heart of the tristeza-infected region of Brazil. Dr. Bennett of the U. S. Department of Agriculture is now working cooperatively with the Instituto in Brazil and the results of the Brazilian rootstock tests will be of considerable value both in the virus work and the expanded rootstock investigations.

A recent report on these Brazilian tests has shown that all three scion varieties when grafted onto sour orange and bittersweet orange were definitely susceptible to Tristeza and that the grapefruit root was suspected of being susceptible. The combinations with Ponderosa lemon and citron rootstocks did not grow well, but they did not appear to have tristeza.

The sweet orange and rough lemon stocks were recommended as good rootstocks for the Baianinha variety; sweet orange, sweet lemon and Rangpur lime for the Valencia variety; and rough lemon and sweet lemon for the Marsh grapefruit. The Cravo tangerine as a stock was not susceptible to tristeza but produced a very shy crop during the first six years. Unfortunately for the Rio Grande Valley the Cleopatra mandarin was not included in these tests but will be included in a new series of tests started this winter. The trifoliata did not appear to be susceptible to tristeza but, as in this country, it produced a dwarfed tree.

THE CLEOPATRA MANDARIN

In the quick decline area of California the sweet orange stock was practically as plentiful in the nurseries as the sour stock, and it has been no great task for the growers to switch from 50 percent sweet stock to 100 percent sweet stock. The new rootstock experiments in the quick decline area may develop a more desirable stock than sweet orange, but for the time being, sweet orange is satisfactory.

In the Rio Grande Valley the only stock grown to any extent by the nurseries is sour orange. If it should suddenly become necessary to substitute another stock for sour orange, even if it were known what to use, it would take several years to develop the necessary nursery stocks. For this reason it is highly desirable for a number of the Valley nurserymen to be planting a reserve of Cleopatra mandarin even before it is definitely known that it is resistant to Tristeza or adaptable to the Valley soil conditions. This stock in the heavy soils of California has been found to grow as well, yield as well, and produce as good quality fruit as sweet or sour orange rootstocks. This appears justification enough to test it commercially here in the Valley. Two 15-year-old grapefruit trees on Cleopatra stock growing at the Valley Experiment station have exceeded the sour orange in tree vigor and yield. Nothing definite is known as yet about its salt tolerance and Tristeza susceptibility.

The Sampson tangelo is also worthy of a limited trial by nurserymen. It has performed as well as any stock in California and is resistant to gummosis. Its susceptibility to tristeza or quick decline is not known.

The rough lemon appears to be resistant to both tristeza and quick decline and has performed well in the light sandy soils of Florida. It should be tried on a limited commercial scale for a stock on the light soils west and north of Mission.

The sweet orange, which is definitely resistant to tristeza and quick decline, probably would not grow well on the heavy, poorly drained soils of the Valley, due to its susceptibility to gummosis.

The grapefruit has not proved promising as a rootstock in any citrus region and does not appear worthy of commercial trial here.

In general, most nurserymen will probably prefer to continue to use sour orange stock until the rootstock situation becomes clarified.

In the rootstock investigations here in the Valley we have several years' start on the Cleopatra stock, due to the foresightedness of the Valley Experiment Station in initiating a number of trials with commercial nurserymen in various regions of the Valley. In the plantings at Adams Gardens, Los Fresnos, Raymondville, Monte Alto, Weslaco, and McAllen, the seedlings have grown well and have produced a tall, unbranched seedling that buds easily.

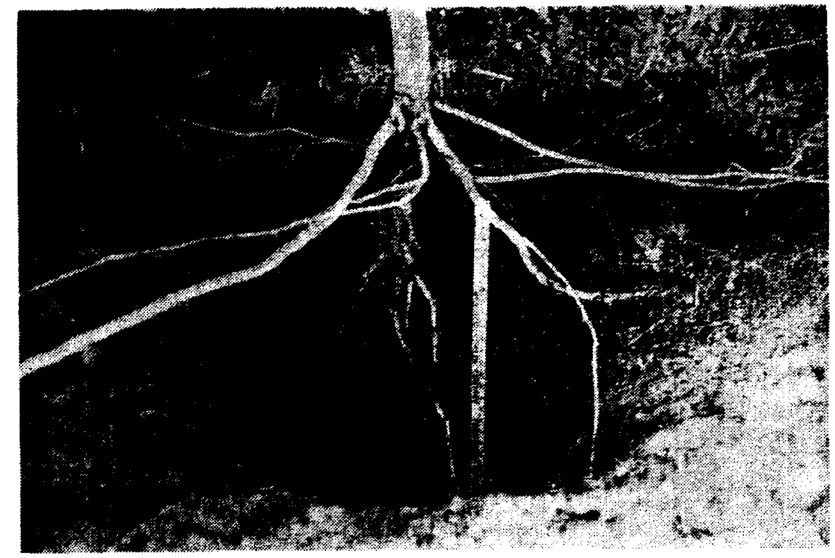
At Weslaco one cooperator has Cleopatra stock that has been budded with Red Blush grapefruit for a period of 20 months. These trees are as large and as healthy as Red Blush trees on sour stock. Several trees have been excavated and show a more fibrous root system than the sour stock. Where the sour stocks that were examined had six or eight lateral roots, the Cleopatra stock had about 20 smaller laterals. The tap root in both instances penetrated well into the subsoil. The Cleopatra tap root system, however, consisted of from 10 to 20 small, vertically growing roots, while the tap root system of the sour orange consisted of three or four larger, vertically growing roots.

LITERATURE CITED

(1) Fawcett, H. S. and J. M. Wallace. Evidence of the virus nature of citrus quick decline. Calif. Citrog. 32 (2): 50 and 88. 1946.

(2) Report of the California Agricultural Experiment Station for 1938-1940.

(3) Rootstock experiments with Citrus II. Bragantia 5 (10): 597-654. 1945.



The root system of scur orange seedlings budded with Red Blush Grapefruit in April 1945. Picture taken in November 1946.

The root system of Cleopatra mandarin seedlings budded with Red Blush grapefruit in April 1945. Picture taken in November 1946.

ESTABLISHING THE YOUNG ORCHARD

BEN CHAMBERS, *Horticulturist, Harlingen, Texas*

Establishing a young grove should be considered from two points of view. First, those plantings going on new land, and secondly, plantings on old land or land having been in cultivation several years and being materially depleted by heavy cropping and weather erosion, which has been given little attention. Nature has provided us with some very fertile soils, which are capable of producing excellent groves with high production over a long period of time if we take advantage of, and utilize available information and methods leading to maintaining the soils in as near original physical condition as possible. By proper analysis, then application or replacement of deficient elements and treatment for unfavorable conditions it is possible to restore old land to a fair degree of it's original state before planting, thereby enabling us to combine the discussion under one head, except for a few instances.

There are many soil types in the Valley, nearly all of which have been planted to citrus in the past with varying degrees of success, but generally speaking, the greatest success has been attained on the deep, light to mediun sandy loams having good surface and sub drainage. The selection of a tract of land for planting must be very thorough and every precaution taken to give young trees a fair chance before planting. Those desiring to plant land they have owned some time should check the soil carefully.

Desirable soil is of a sandy, porous type, well drained, high in organic matter and having a minimum of alkali and calichi content in the top three or four feet. A water table of less than six feet is considered dangerous and avoided unless it can be remedied with tile drainage or other means well in advance of setting. Any special treatments for alkali or heavy applications of organic matter should also be done before setting in order to work them in deeply.

The first step in preparation is deep breaking, eight to twelve inches deep, followed by disking. If any roots or stumps are encountered they may be removed at this time. Modern leveling equipment is now available, and should be used to properly smooth the land for irrigation. In most cases it is advisable for an engineer to check with instruments for ditch or pipeline locations and be certain of no irrigation difficulties. Lands having steep slopes will eventually wash badly unless handled properly. The soil conservation service has rendered a valuable service in some localities in assisting with contour and terrace plantings on steep slopes where necessary. Their services are now available in certain parts of the Valley at no cost to the grower.

Assuming that arrangements have been made for good thrifty trees of the varieties desired, a plan or chart for setting should be prepared accordingly. Dimensions of the tract must be known so a chart may be drawn to scale. Turn rows are left on all sides, which may vary in width depending on how spacings check out, but should not be less than twenty feet, preferably wider for proper tractor operation. The nearest standard tree spacing is 25x25 feet, however 25x30 feet has been popular for grapefruit, as well as 20x25 feet for oranges. Double planting 25x15, or other close dimensions for heavy production the first few years may be profitable if alternate trees are removed before crowding becomes serious, however the removal of these

trees is quite expensive and in most cases is not done soon enough. Grapefruit will crowd and production fall off much quicker than with oranges.

After the chart is prepared, or exact demensions are decided on, staking for each tree may be done. Outside lines should first be staked with steel chain or marked wire, after which inside stakes may be sighted in from two directions, or all put in with marked wire, which is accurate on smooth ground if stretched tightly each time it is moved. When individual tree stakes are in, planting stakes are set by each one with the aid of a planting board. The planting board is made from a 1x4 about four feet long, cutting a notch in each end and another in the center of one side. The board should be placed on the ground with the tree stake in the center notch, then a short one foot stake driven in the ground in each of the two end notches. The board is then moved and the tree hole dug between them with the tree stake as the center.

For the average sized ball, a hole about eighteen inches across by twelve to fourteen inches deep is dug, with some loose dirt left in the bottom of the hole. The tree is then placed in the hole, the planting board set back on the two planting stakes as they were driven, and the trunk of the tree placed in the center notch where the tree stake had been, but not leaning in any direction, unless slightly to the south-east. The top of the ball should be slightly above ground level. If not, dirt must be thrown in to raise it's level to that point. When the tree is properly adjusted, the planting board is removed and the hole filled about half with dirt. The twine around the trunk of the tree should be cut and the sack pulled down into the hole, after which filling of the hole with dirt is completed and packed lightly with the planting board. Loose top-soil should be used for filling the hole.

A border or basin three or four feet wide is then made around the tree sufficiently high to hold fifteen to twenty gallons of water. Dirt for the basin should not be pulled from inside around the tree. The basin may then be filled with water and watched for air pockets around the ball, which must be filled with dirt. Before the ground inside the basin gets dry on top a small amount of dry dirt may be scattered over it to prevent cracking. A second watering of the same amount should be given a week or ten days later to complete the settling of dirt around the ball after which the basin dirt is pulled in around the tree to hold moisture. Later watering may be given if necessary.

Trees may be successfully planted from early fall as soon as the summer heat begins to moderate, on through the winter until late spring. By months, most plantings are made from October first to May first, however both earlier and later plantings are made with good results by exercising more care in curing of the trees and watering more frequently if necessary. Dry, windy days at any time during planting are severe punishment to young trees, and setting should be held up during such weather. Many people prefer the months of October and November above all others as some root growth takes place before cold weather sets in to check growth, and there is sufficient time for two or three waterings before banking.

Banking of the young trees is generally done about the 15th to 20th of December for safety against early cold. The trees should first be painted with Bordeaux paint, which is prepared by mixing dry Bordeaux powder in water until a thick paint is prepared. Frequent stirring is necessary to prevent settling. The entire trunk of the tree from ground level up to head branches should be thoroughly painted to protect against fungus growths or bark rots due to contact with moist dirt. Loose dirt may then be banked around the tree until only the head remains exposed. In time some settling will take place in the banks and winds will cause enough move ment of the head to create an air space around the trunk. In event of freeze warning a quick round must be made to press the dirt back to the trunk and add necessary dirt to keep the bank sufficiently high. If banks become wet from rains and hot weather prevails, it may be advisable to open one side to permit drying cut which may be closed quickly if necessary. Banks should be left up until cold danger is passed, or about March first, at which time all dirt must be pulled down to ground level and scattered away from the tree. Any trees that may have died may be replaced at this time. and make necessary replacements each year for uniformity.

An early tank watering after banks are pulled down serves to push spring growth unless considerable rain has fallen. At no time during the growing season should the trees be permitted to suffer for water. Tank watering is done at the first signs of dryness the first year, but during prolonged dry periods, a general irrigation of all the ground may become necessary, or bordering on both sides of the tree rows and flooding a narrow strip may be sufficient. Tank watering may be economical the second year when needed, but the third year irrigation is advisable to give sufficient water. Heavy irrigations must be avoided to permit quick drying of the top soil. Surplus water should be drained off after irrigating as well as after heavy rains.

After waterings or rains the ground around the tree should be loosened by hoeing, to prevent heavy weed growths too close. Working of the middles may be done by disking frequently enough to keep down heavy weed growths. Clean cultivation is advisable during the dry season to conserve moisture, but heavy growths of weeds following rains are beneficial to the soil when disked under or chopped with the stalk cutter. However weeds must not be permitted to sap needed moisture from young trees at any time. A balanced system of cultivation should be carried out to produce and incorporate as much organic matter into the soil as is possible while trees are small, as little of this.can be done in later years. Leguminous cover crops are excellent, but as a general rule, native weed growths will produce equal or heavier tonnages of organic matter. Continued clean cultivation tends to reduce the organic matter rapidly.

Inter-cropping or growing of certain vegetables between young trees may be done if care of the trees is placed first at all times. Shallow rooted or light feeding crops, such as beans or peas, are the most desirable to use, while cabbage, a heavy feeder and one that requires frequent heavy watering often injures trees as well as soil. Favorable growing conditions for the tree must be provided, as well as prevention of soil depletion or water-logging of the land.

Young citrus trees are subject to the same insects and diseases found on old trees. Ants possibly do the most damage and must be watched for continually as they may kill small trees in a few days. Scale insects and aphids become serious at times and must be controlled. Other insects and diseases encountered are orange dogs, rust mite, red spider, sour scab and root rot.

Pruning of young trees consist mostly of keeping suckers cut from the trunks. Dead or broken limbs should be removed with clippers. Bark injuries must be painted with tree paint and long branches that tend to throw the tree out of balance should be cut back. In the second and third years a light pruning may be given to remove weak or interfering branches and cut back in places to balance the tree, but under normal conditions very little cutting of green wood is advisable, except in selection and development of strong scaffold branches.

The climate and soils of the Valley are conducive to rapid growth of citrus trees, yet these same natural advantages may be very destructive if not controlled. In simple terms, the establishing of a young grove requires the planting of thrifty trees on carefully selected soils, close observation, a fair amount of hard work and plenty of good practical horse sense.

PRUNING CITRUS TREES

By

C. R. HEATON, *Associate Horticulturist*

Extension Service, A. & M. College of Texas

It is a real pleasure to be here at your Citrus Institute or Short Course. The presentations thus far have not only been extremely interesting and instructive, but the principle involved are vital to the welfare of the citrus industry in Texas.

The subject that has been assigned to me "Pruning Citrus Trees," is one of great interest and importance. It is a practice that has been abused in many ways; all the way from no pruning to incorrect pruning and too drastic pruning.

In the early days of citrus work, pruning the trees to form a high head 4 to 6 feet to the lowest limb—was thought to be correct. Gradually this practice was followed by the other extreme—an extremely low-headed type of tree. Even though this latter system was distinctly better than the high-headed type, it had its distinct bad points, such as permitting heavily loaded limbs to reach the ground and produce skinned, bruised or otherwise, low quality fruits. Today, the modern citrus grove is pruned and trained to hit a "happy medium" between the two extremes just mentioned. This will be elaborated upon a little later.

Before any attempt is made by anyone to prune either a young or old citrus tree, a few of the fundamental principles should be clearly understood. First of all, the leaves of a citrus tree are to that tree what the digestive system is to our bodies. It is in those leaves that the photosynthetic processes, or carbohydrate elaboration takes place which is essential to fruit production and even to the life of the tree itself. Therefore, in any pruning job, it should be clearly borne in mind that if everything else is favorable, reduction of fruit or fruit losses, as well as dwarfing of the vegetative growth are both proportionate to foliage losses due to pruning or otherwise.

I'm afraid that if we keep talking we might easily find ourselves arguing that no pruning should be given. This is definitely not the case. There are some advantages in proper pruning that definitely mean more to the welfare of the tree, quality of the fruit produced as well as dollars to the grove owner than the reduction in production brought on by a correct pruning system.

I think at this point we might enumerate the advantages of correct pruning as well as briefly elaborate upon each.

First, in young, non-bearing trees we prune to properly develop and shape the main framework of the tree, that is, to permanent arrangement of the tree head.

Second, in old, producing groves we prune to:

1. Keep the tree shaped as desired.
2. Protect from sunscald, cold and wind.
3. For ease and economical harvesting of fruits.
4. For ease in heating, cultivation, fertilizing, irrigation, spraying, and many other orchard operations.
5. Conserve moisture.
6. Prevent limb congestion, reduce certain disease and insect troubles and removal of otherwise undesirable growth.
7. Removal of damage from cold, vermin, etc.
8. Renovate or revitalize neglected or sick trees.
9. "Skirt" pruning to keep fruit from low hanging limbs from reaching the ground.
10. Give strength to the tree.

From the above reasons for pruning one who is not familiar with the correct procedure might easily conclude that the job is a difficult and drastic one. This is not true. No fruit requires less pruning, normally, than citrus, once it is properly established.

Normally, the shaping, pruning and scaffold branch development of young trees is begun in the nursery. These young trees should be headed back to 24" to 30". From 3 to 4 lateral buds should be left on the upper 12" to 14" of the trunk, well spaced and each pointing in a different direction. This gives a well balanced framework that has strength. All other buds or branches should be kept removed. If the young tree to be trained is branched, leave 3 to 4 of the best branches, and remove all others. Then, cut these side branches back to spurs each having 2 or 3 good buds. All buds or sprouts below the bud union should be removed. By following the above procedure, normally, little or no pruning should be necessary for about a year.

Following the first year of training only light pruning is necessary to keep the tree to the desired shape for production, as citrus trees are inclined to do an excellent job of balancing themselves without our help. Subsequent pruning may involve the removal of new twigs from the trunk or below the bud, dead limbs, or in some cases, close growing twigs too thick for proper development. That's just about all.

Again, I would like to clearly emphasize the detrimental effects of im-

proper or over pruning. Aside from the ill effects of heavy foliage removal as mentioned before, there are other points that should be enumerated briefly. In young, bearing trees, the lower limbs bear the greater part of the fruit and should therefore be left if possible. Heavy pruning not only reduces the yield but does not apparently improve the grade and size of the fruit appreciably. In some cases pruning did improve the size and quality of the lemon. Again heavy pruning may leave limb areas endangered to sunscald or blister. Large wounds made by the removal of large limbs encourage disease troubles unless properly protected. This broad principle should also be clearly understood that for every pruning operation, be it large or small, there is a definite response. Drastic pruning means, normally an unfavorable response in the form of excessive sprouts or sucker growth. Heavy pruning has a decided dwarfing effect on the trees.

In the producing grove, some pruning should be done every season. If this is done, unless something unusual happens, little or no other pruning is either desirable or necessary. The pruning operation normally, should consist of: 1. The removal of all broken, dead, seriously insect infected, or fungus infected limbs, or twigs as these interfere with the set of inside fruit, proper tree development, fruit harvesting, and other field operations, as well as harboring the melanose and stem-end rot organisms. 2. The removal of suckers or sprouts not needed in maintaining a well balanced tree. They may often be used to an advantage, however. 3. Complete removal or heading back of limbs growing out of proportion to the main head of the tree. Often times long, spindly limbs, that do not side-branch readily, develop. These should generally be completely removed or at least headed back to conform to the rest of the head. At the same time such cutting back induces the desired side-branching. 4. Removal or heading back of rubbing or crossing limbs. 5. The "skirt" pruning of low-hanging limbs to prevent fruit reaching the ground. 6. Pruning to correct bad crotches that may be developing. This may be easily done by cutting back the least desirable limbs to give the others the advantage in growth. 7. In some instances some twig thinning may be desirable.

Under certain conditions heavy or drastic pruning is justified. Some of these conditions are:

1. ***Freeze injury:*** There are at least three routes to take with a grove damaged from cold. The severity of the damage should determine the best route to take. They may either be let alone, which seldom is advisable; they may be cut back to the ground and replaced with new trees, if injury is severe; or, the injury may be satisfactorily removed when its extent can be accurately determined. Often times the full extent of freeze injury can be determined in late spring following such injury. Prunings should be made well below outward evidence of cold injury. Short growth may begin well up injured limbs and later die.

2. *Neglected Trees:* Citrus trees in serious need of fertilizing, spraying and other practices that have been neglected and as a result have induced general unthrift may be pruned drastically, inducing new growth, a part of which may be used for a new head. Better results will be obtained if the operation is extended over two or three seasons rather than doing it all in one season or operation.

3. ***Pruning declining trees:*** Trees declining in production may sometimes be severely pruned and revitalized profitably. If the decline is due

to nitrogen starvation, even though drastic pruning will likely temporarily balance the nitrogen-carbon ratio, the application of fertilizer would be desirable. If, however, carbohydrate starvation is in evidence due to inefficient or insufficient foliage, heavy pruning may be justified.

4. *Other justifications for severe pruning:* These include those trees damaged from high water, rodent damage, or some other type of mechanical or chemical injury.

When we prune drastically, the response is drastic. The nitrogen-carbon ratio is out of balance—nitrogen is heavy and vegetative growth is rapid. The top is out of balance with its root system. Water sprouts and suckers appear. Careful removal and training must follow. This is a gradual process. Suckers should be removed before they are 12" long to prevent devitalizing the tree too severely; to prevent their interfering with the normal growth of those to be left, etc. A follow-through program of two or three years may be necessary.

Each type of citrus, as with other kinds and varieties of fruits has its own peculiar characteristics that the pruner should be familiar with. For example, leaves are inclined to grow upward with the limbs too thick. In pruning, heading back to side buds or branches that point outward will largely correct this trouble. Generally speaking, grapefruit requires less pruning than oranges; oranges require less than lemons.

Here, we've talked about how to prune, advantages and disadvantages of this system and that, and haven't said anything about *when* to prune. The removal of injured, dead or diseased branches as well as water sprouts may be done at any time. Producing trees should generally be pruned before the young fruits are ¾" to 1" in diameter, and preferably, immediately after fruit harvest. Pruning in late summer or fall should be avoided as new, tender growth is induced and subject to winter injury. Any necessary limb shearing around the skirt of the tree should be done in early spring. In removing limbs or twigs, close cuts should be made. If it involves the complete removal of a limb, make the cuts just as close to the limb to which it is attached as possible. It is also wise to make cut parallel to the limb to which it is attached. By observing these two principles, healing quickly follows. If the pruning involves only partial removal of a limb or twig, cut just above a side bud or branch.

Wounds ¾" to 1" or more in diameter should be disinfected within 48 hours after exposed to prevent the entrance of certain disease organisms. Such wound protectants should be of a plastic nature to prevent cracking or checking. A 1 to 1000 mixture of Bi-Chloride of mercury and alcohol is a good disinfectant followed by painting with an asphaltum paint; asphalt diluted to paint consistency with benzene is good. Carbolineum, and Bordeaux paste are sometimes used. Oily or Corrosive materials should always be avoided for painting tree wounds. Shellac applied to the Cambium is also good, followed by a complete painting after the wound dries. Painting should be repeated annually until the wound has healed. After the pruning job is complete, all prunings should be removed from the grove and burned.

It has been found that a crew of three men constitute a well balanced working unit. One set of tools should consist of: one 7" or 8" pruning shears, a 24" to 30" pair of lopping shears, one pole pruner, a 14" pruning

saw, a curved blade pruning saw, one curved blade pruning knife, a whetstone, leather hand and arm protectors and a stepladder.

In conclusion, I would like to say that even though citrus pruning is an important and even essential annual practice in the grove, it does not reduce the importance of other orchard practices.

HARVESTING METHODS AS INFLUENCING TREES AND FRUIT

By
ROBERT T. CORNS, *Horticulturist, Engelman Products Co.*

Up to this time the papers that have been given for the most part have dealt with soil maintenance, use of fertilizer, application of water, etc., all of which were for the purpose of sustaining the tree in a vigorous growing and fruiting condition. This was in order to produce citrus fruit which would pay the grower for the expense and labor required to bring that fruit to its final stages of production from blossom time to maturity. As all of you growers know, labor and other operating expenses are very high for bringing the crop of fruit to maturity.

Fruit that has reached maturity and is damaged in the harvesting process becomes a loss to the grower; for some of this fruit may have been knocked from the tree and never recovered or run over or stepped on. Again some fruits as a result of a bruise or skin-break decay rapidly so that they may be culled from the lot, or may be delayed in decaying and passed over by graders and be packed out. After being packed out and shipped, decay may develop in transit or at destination.

LOSS CUTS PROFITS

This, however, is still the growers loss in the long run. Such fruit upon reaching the market is inferior fruit and is sold at a lower price than if the fruit had reached the market in a sound and marketable condition. This means less return for the shipper and finally will mean less to the grower, as prices at terminal markets may be reduced if sufficient decay and consequently poor quality fruit continue to invade such markets. Then it would seem that to lose fruit which was perfectly sound, as a result of a handling or mechanical injury, would be losing a certain amount of profit which so justly belongs to the grower.

INTO FOUR CHANNELS

The question forthcoming now is: What becomes of fruit which is roughly handled and is injured during the process of harvesting? One of four things may happen:

1. The citrus may never reach the packing house—the picker, in his haste to make money as he is paid by the box, knocks fruit from the tree in picking or loses it by filling his bag too full or by overfilling the field box. Furthermore, in loading of field boxes on the trucks, the men may sling fruit from box or knock fruit from trees with trucks, all of which is usually never recovered.

2. Injured fruit which has no decay at the time passes the grading table is placed into a 3rd grade bin where it is conveyed on to canning plant for juice and dehydration. The fruit is thus diverted from the fresh fruit channel into the processed channel which usually means less returns.

3. Fruit that shows decay at time of grading is classed as cull and becomes a complete loss.

4. Citrus fruit that may be damaged at harvest may pass by the graders un-noticed and packed out with a result that diseases may develop in transit or at the market. Also hidden damage may result from rough handling at harvesting, which will later develop decay in transit or at the market. On the other hand the fruit may be damaged by the packing house machinery or packers, and consequently be packed un-noticed and later decay may set in. Such diseases will be referred to as "Market Diseases".

DISEASES CHARTED

The next question which may be in order is: What Valley citrus fruit diseases are principally responsible for the decay, lowering of sales value and quality? I wish it to be known that these are the citrus diseases found in Engelman Products Co. study and may not necessarily be identical with those found elsewhere. The citrus fruit diseases are five which are briefly described as follows:

1. BLUE MOLD—begins with soft, watery, decolorized pinhole spot which enlarges rapidly; followed by fungus growth which is blue up to near the edge, then a band of water soaked rind.

2. GREEN MOLD—begins just as Blue Mold but fungus growth has olive-green color and is usually surrounded by a broad zone of white.

3. STEM-END ROT—is identified by a softening of rind and underlying pulp and usually begins at stem-end. (Fruit with stem parts left on are more susceptible than when pulled off.)

4. OIL SPOT—is identified by irregularly shaped yellow, green, or brown spots in which oil glands of the skin stand out because of sinking of tissues between them.

5. BROWN ROT—(Lemons) is identified by a slight discoloration of rind and on mature lemons the rind turns a drab and brown; does not soften rapidly and has a penetrating and rancid odor.

BRUISES START BACTERIA

To better emphasize that care should be taken in handling citrus fruit from time of picking to the time it reaches the final consumer, this statement is made from U. S. D. A. publication entitled: "Market Disease of Fruits and Vegetables—Citrus and Other Subtropical Fruits." "Citrus fruits like all other fruits and vegetables are susceptible to invasion by bacteria and fungi at bruises and skin breaks. Hence, it is of prime importance that they be handled as care fully as possible at all times." If this then be taken for granted, let's take a look into the picture and find out where these bruises and skin breaks take place.

Statements made are based on the harvesting operation observed and such observations were made from a critical standpoint as the purpose was to discover where injuries occurred. The general practice of harvesting citrus is understood by growers; however, it is briefly: Picking crews of 8 to 15 men are supervised by a picking foreman; Pickers are paid by the box and use picking bags to put the pulled fruit into until the bag is filled;

then it is dumped into field boxes, placed along harvest rows; then filled field boxes are placed on the trucks which enter the harvest rows; a truck being filled, goes to the packing house where unloading follows and the truck is ready to return to the field again.

PICKERS' DAMAGE

As an observer, a picking crew was watched and here are some steps where bruises and skin breaks of fruit and injury to trees take place:

1. LADDER DAMAGE

(a) As no trail leg appears on most picking ladders, they are pushed against twigs, branches, and fruit with the weight of the picker, plus that of the fruit in picking bag. This results in the knocking off or bruising of fruit, and the tree, twigs and branches are partially or completely broken, and if not broken, then scarred.

(b) Ladder with picker often slips and crashes against other twigs and fruit with results same as given above.

2. PICKER DAMAGE

(a) The picker is paid by the box, so the greater the number of field boxes that are picked, the higher his wage is for the day. Speed then often results in neglect in carefully handling the fruit.

(b) Where a picker must fully extend his arm to reach a high fruit, there is unnecessary pressure exerted by the hand and a bruise or nail injury may follow.

(c) Fruit picked around drip of tree is sometimes knocked off or bruised and twigs and branches also may be broken.

(d) In climbing about the inside of tree, new and small growth is knocked off which might have been potential fruit-bearing twigs.

(e) On main branches of the tree may often be seen scraped areas on the bark caused by the picker climbing from branch to branch.

(f) Frequently a picker falls from a limb or branch which fails to sustain his weight; injury is to the limb in that it may be partially or completely broken, and the fruit knocked off.

3. DUMPING DAMAGE

(a) Pickers often hold their picking bags 2 or 3 feet above the bottom of the box, then open their bags and allow the fruit to drop to the bottom of the box. This often results in bruising of the fruit or breaking of skin.

(b) When fruit is piled above the handle ends of a field box, the pickers often throw excess fruit into the bottom of an adjoining empty box which again results in either bruising or breaking of the skin.

(c) Pickers in stacking field boxes filled with fruit often miss the end cleats and allow the edge of the field box to rest on the top fruit in the box below.

(d) Another damaging step by the picker is to pile fruit into a field box so that some fruit protrudes above the end cleats. This procedure often results in the loss of the top fruit, and if not lost, it is bruised by other boxes being placed on top of it.

4. LOADING DAMAGES

(a) To load field boxes of citrus from the ground to its place on the truck, the fruit undergoes 2 jolts. First, from the ground to the truck platform as the picker picks up the box from the ground and places it on the platform. To do so, it is necessary for his to sling the box onto the platform. The second jolt comes when the loader picks up the box from the platform and stacks it with the other boxes. In the first jolt, fruit is frequently lost as it is slung up to the platform, and if it is recovered, it is often times bruised.

(b) A loading truck with its wide bed in moving down a harvest tree row knocks much fruit off, bruises others, and scars, tears and partially or completely breaks limbs, twigs and branches—especially so when the truck must turn around among the trees.

(c) Pickers may often be seen riding on top of loaded trucks, which naturally will bruise some fruit on which these pickers are sitting.

5. FIELD BOX DAMAGE

(a) Where field boxes become splintered on the bottom and inside sides of box, fruits which are emptied into such boxes are subject to puncture by these splinters.

(b) A bottom slat which has a split in it, often breaks away from the box when filled with fruit. This again will result in the bruising or puncturing of fruit.

6. TREE SHAKING DAMAGE

In recent years some growers toward the end of the harvest season after the ring picking period, shake the trees to make fruit drop to the ground to facilitate gathering. Such fruit is primarily used at the cannery. Such a procedure is not only damaging to the fruit, but also to the tree.

(a) The fruit is damaged by puncturing or bruising from the fall at the time of the shaking of the tree, or it is often stepped on by the pickers. If such fruit is canned immediately, it is possible that no infection may take place; but if for some reason it must lay over, it is subject to decay.

(b) The tree is damaged in several ways. Twigs, limbs and branches may be partially or completely broken, but mainly blossoms or even newly formed fruit are knocked to the ground which affects next year's yield.

7. PACKING HOUSE DAMAGE

These damages are briefly given as follows:

(a) It has been noticed that when the plant is operating at a fast speed, Mexicans with their wheel trucks rapidly bring to the conveyor the stacked boxes of fruit. This speed in handling may cause one or more boxes to slip from its cleat seating onto the top of the fruit in the box beneath.

(b) Packers often bruise fruit (especially mature fruit) by throwing the fruit into a box or into a sack.

(c) The mechanical lid machine in placing a lid on a box with a high pack may frequently bruise the top fruit.

(d) Boxes in which fruit are to be packed may occasionally have a nail exposed which may puncture the fruit, and in the case of the Bruce Box, the wire end in fastening the lid may also occasionally protrude and puncture the fruit.

Now we have just finished a discussion on where many of the damages in the harvesting of fruit take place. We are then interested in correcting some of the harvesting procedures, or better still, to improve some of the harvesting techniques.

But it should be borne in mind that in improving harvesting techniques, there are two factors that are involved. First, it must be an economical improvement in harvesting technique. That is to say, there may be many things which could be done but the cost would be prohibitive to the grower. For example, it is possible that Americans who would know how to carefully handle the picking of fruit, could be hired for the job of picking if 40-50c were paid per field box, but it is easily seen such would be foolish and far too costly for the grower. Second, improvement of harvesting techniques must be adaptable. For example, in California in most cases the pickers wear gloves and to a great extent use clippers, and likewise, the packers in the packing house use gloves to pack fruit. But this practice is hardly adaptable to the Valley as our fruit is capable of taking rougher treatment than that of California, primarily because, as a California horticulturist once stated, California citrus fruits have a greater per cent of oil in the rind as compared to that of Texas; therefore their fruit must be handled more gently.

CORRECTIONS CHARTED

If corrective measures to improve the present harvesting techniques are both economical and adaptable to the Valley, then they are worthy of consideration.

These suggestive corrections are:

1. Close and constant supervision by picking foremen of their pickers may reduce the per cent of injured fruit which enters the packing house.

(a) Picking foremen should make it understood to the pickers the precautionary measures to be taken to prevent the rough handling of the fruit.

(b) If a picker continually violates such precautionary measures, the foreman should call his attention to such violation.

2. Another means which may reduce the loss in the injury of fruit is the pruning of harvest rows. At Engelman Products Co. it was found that by directing harvest trucks into the same harvest rows from year to year, the loss and damage to both fruit and trees was reduced. Such harvest rows were pruned back and kept that way from year to year so as to allow the passage of a wide bed harvest truck at harvest time.

3. Thorough pruning after harvest season discourages infection of both fruit and tree. The removal of dead limbs and branches retards the possibility of stem-end rot of fruit at a later period nearing maturity as dead limbs and branches harbor the stem-end rot fungi. The pruning of broken limbs and branches is a means to prevent the beginning of gummosis and the harboring of ants and other insects. Likewise, the painting of scarred twigs and trunks of trees will also prevent or retard further infection.

4. In conclusion, constant repair of field boxes during harvest season prevents fruit damage from splinters, broken slats, and protruding nails. Also in connection with field boxes and worthy of mention, is the immersing of the field boxes in a disinfectant to prevent the spread of citrus disease organisms which may have become present in the box. This is practiced by a shipper in Harlingen.

THE PSOROSIS DISEASES OF CITRUS IN CALIFORNIA

By
J. M. WALLACE, *Associate Plant Pathologist, University of California, Citrus Experiment Station, Riverside, California*

In California, the term "psorosis" is used to designate a group of virus diseases of citrus all of which have certain characteristics in common, particularly from the standpoint of the symptoms produced on young leaves. There are, however, striking differences when the symptom picture is considered as a whole. At present, "psorosis" includes five distinct diseases caused by what we believe to be related strains, or varieties of viruses. These five diseases are known as psorosis A, psorosis B, concave gum, blind pocket and crinkly leaf.

Inasmuch as these diseases have been described and illustrated in detail in a recent publication by Fawcett and Bitancourt, **1** some of the descriptive details of the individual diseases will not be presented in this paper.

Psorosis A and psorosis B cause the bark condition commonly known as "scaly bark". Orange, grapefruit and tangerine trees infected with these two psorosis varieties commonly develop the bark symptoms but lemon bark never shows them.

1 Fawcett, H. S. and A. A. Bitancourt. Comparative symptomatology of psorosis varieties on citrus in California. Phytopath. 33:10, 837-864. 1943.

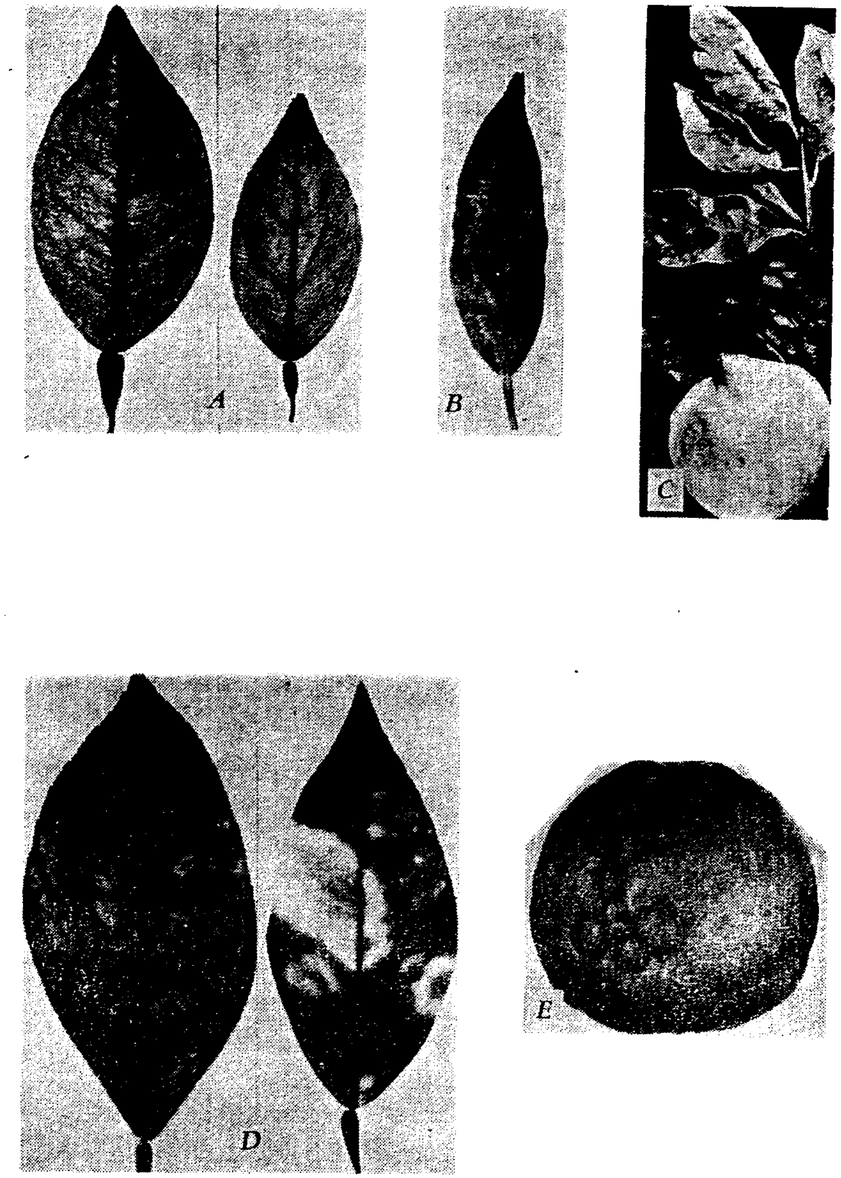


Figure 1. (A) Typical young-leaf symptoms of psorosis. (B), Oak-leaf pattern found commonly on spring flush of trees with concave gum psorosis. (C,) Leaves and fruit of crinkly leaf affected lemon. (D), Mature-leaf symptoms of psorosis B on orange. (E), Fruit symptoms of psorosis B on grapefruit.

YOUNG-LEAF SYMPTOMS COMMON TO ALL PSOROSIS VARIETIES

Young-leaf symptoms make their appearance during the growth flushes but there is much variation in the extent and degree to which they manifest themselves. This variation occurs between individual trees at a given time as well as between different seasonal growth flushes.

Small, elongated, cleared areas, distinctly lighter than the rest of the leaf blade occur in the region of the veinlets. These areas are usually about 1 to 3 mm. long and 1/4 to 1 mm. broad and the long axis is, for the most part, parallel with the main side veins. (Fig. 1A). They may be numerous and scattered over the entire blade or they may occur on only certain portions of the leaf. At times a majority of leaves of suitable growth will show symptoms but at other times relatively few leaves have symptoms. It is not uncommon to find strong symptoms on one leaf while an adjacent leaf of almost identical age will be symptomless.

Often some of the small flecks are quite indistinct, while others coalesce to form large streaks or blotches. A characteristic pattern known as the zonate, or oak-leaf pattern is sometimes present (Fig. 1B). This pattern occurs on nearly all leaves of the spring flush of trees affected with the concave-gum psorosis but is seldom found on leaves of later flushes.

As the leaves mature, the cleared areas gradually disappear. Large, soft leaves frequently show symptoms until they harden or become almost mature and as a rule the oak-leaf pattern is retained longer than the ordinary flecking or stippling symptom. Caution is necessary to distinguish between faint psorosis symptoms and leaf injuries caused by thrips, red spiders or mechanical injuries. Careful examination of both sides of the leaves will usually distinguish between these injuries and psorosis. Symptoms are seen most readily when the leaf is shaded from direct sun and viewed with the transmitted light of the sky coming through the blade.

PSOROSIS A AND PSOROSIS B

Bark, twig and mature leaf symptoms.

Psorosis A and psorosis B are the common bark-lesion producing psorosis varieties. They appear to be caused by closely related strains, differing perhaps only in virulence. Psorosis B produces more deleterious effects and in addition to the young-leaf and bark symptoms it also induces symptoms on mature leaves, twigs and fruits. On mature leaves the symptoms consist of circular spots or rings of varying sizes usually comprised of a yellowish green central portion surrounded by a light yellow circular or irregular border (Fig. 1D). Other spots consist of small, corky, raised areas which may coalesce to form pustules of varying sizes. Some fruits of psorosis B affected trees show surface rings bordered by sunken grooves varying in size and pattern. Young green fruit sometimes has circular spots similar to those found on mature leaves. In other cases, especially on grapefruit, large circular grooves, partial rings, or irregular circles occur on the ring and result in a rough, lumpy condition (Fig. 1E).

On trees infected with psorosis B the bark of green twigs and small limbs often shows raised, corky areas similar to those occurring on mature leaves. As the twigs become older the bark develops reddish brown color and these areas split and flake off somewhat like the scaling that takes place on lesions that break out on old bark of the large limbs and trunk.

Psorosis B is not encountered often in the field. Probably because affected trees react earlier and more strikingly to it, propagators for the most part have been able to avoid trees with psorosis B.

Psorosis A is by far the most common variety of psorosis. The fact that affected trees seldom develop bark symptoms before 8 or 10 years after budding in the nursery no doubt accounts for the use of many affected trees as bud-wood sources with the resultant distribution of diseased trees.

The symptom expression on the bark of psorosis A-affected trees sometimes appears on orange trees within 6 years from time of budding. Some trees first develop bark lesions after they are 20 years or more old. The average time required for bark symptoms to appear on trees grown from diseased buds is probably around 15 years. There is no explanation for the long delay in appearance of bark lesions nor for the wide variation between individual trees in this respect.

The bark lesions begin either as erumpent pustules or pimples, or as small scales or flakes of the outer bark, under which the tissue is brown (Fig. 2A). The scales of outer bark are dry, irregular flakes 1/12 to 1/8 inch thick which loosen and break away from live bark underneath. These scales occur first on localized areas of the trunk or limbs (Fig. 2B). As the scaling advances (Fig. 2C) the deeper layers of the bark become disorganized in growth and some of the tissues become impregnated with gum or gum-like materials. Scaling is more or less continuous and the lesions increase in size. Gum sometimes exudes to the surface of the bark.

Mature-leaf and twig symptoms have not been definitely associated with naturally occurring psorosis A infections.

Wood Symptoms.

Symptoms induced in the wood by psorosis A and psorosis B show no differences except that in the latter, wood symptoms may appear within a shorter period of time after bark lesions develop.

Soon after a bark lesion becomes visible, gum layers begin to be formed in the wood underneath. At certain seasons of the year the embryonic layer of woody tissue immediately beneath the cambium is acted upon in some way so that the cells between the medullary rays are forced apart and partially broken down and these inter-ray pockets become filled with a colorless, watery, gum-like substance. Normal wood is then laid down for a period of time before another gum layer develops This process continues until there are numerous bands of normal wood alternating with thin layers of gum. The older gum layers become buried deeper in the wood with each successive period of wood growth, and with aging, the gum hardens and acquires a yellowish, brown color. A longitudinal section of wood beneath a bark lesion showing the gum layers is pictured in figure 2D. In later stages, wood staining makes it appearance (Fig. 2E). At first only small areas of stained wood are present but in wood underneath old, well-advanced lesions all of the wood excepting narrow bands nearer the bark become stained. Top deterioration begins after wood staining makes its appearance. Impregnation of the wood blocks the vessels through which water moves and top decline results largely from a shutting off of the water supply.

CONCAVE GUM AND BLIND POCKET

The young leaf symptoms induced by these two viruses are indistinguishable from those found on trees affected with the other strains of psorosis. No mature leaf or twig symptoms are associated with these two viruses.

The most distinguishing features of concave-gum psorosis are the concavities of various sizes that develop on the trunks and larger limbs. For the most part, a fairly normal bark covers the surface of the concavities. In the center part of the concavity, or around the margin, cracking of the bark often occurs and gum appears on the surface. Occasionally there may be typical bark scaling but this may be due to the presence of psorosis A in the trees in addition to concave gum. Symptoms in the wood are usually limited to gum development in a local area immediately under the concavity. As long as the concavities remain few the trees appear not to be seriously handicapped but when the concavities become numerous, dwarfing and decline may occur. Large limbs sometimes show concavities and flattened areas which give the appearance shown in figure 2F.

The bark and wood symptoms of blind pocket are similar to those of concave gum except that the concavities are usually deeper and more narrow. It appears that a smaller area of wood is affected so that the depressions may become very narrow or almost closed. In older blind pocket lesions the wood beneath the central portion of the blind pocket concavity shows more alteration than in the case of concave gum and is composed of a rather loose wood parenchyma, often impregnated with a waxy or gummy substance. The apparent point of origin is often found quite deep in the wood beneath the bottom of the pocket. Only rarely is gum exuded to the surface. Figure 2G shows an external view of a tree with numerous blind pockets on the trunk.

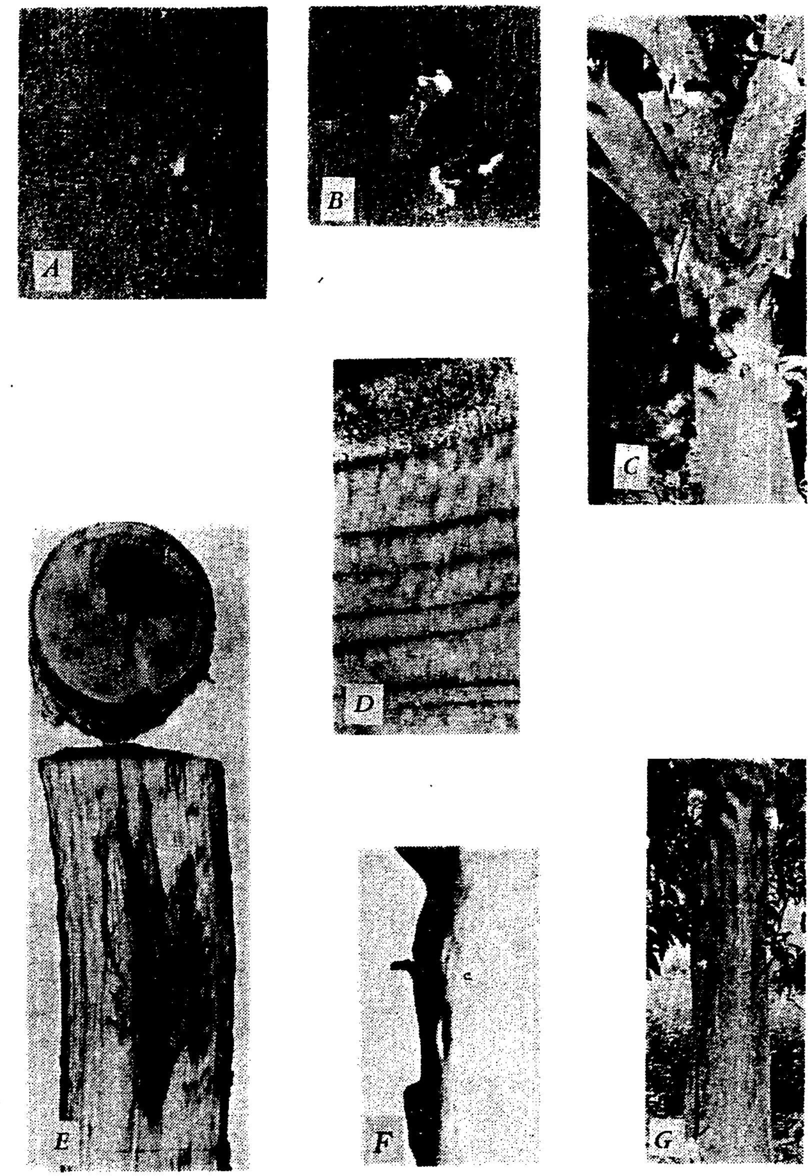


Figure 2. (A), Early stage of bark sumptoms of psorosis A. (B), Early scaling stage of psorosis A. (C), Advanced scaling of psorosis A. (D), Gum layers in wood beneath psorosis bark lesion. (E), Wood stain of orange in advanced stages of psorosis. (F), Concavity and flattened areas on limb of orange affected with Concave gum psorosis. (G), Numerous blind pockets on trunk of tree affected with Blind pocket psorosis.

CRINKLY-LEAF PSOROSIS

Crinkly leaf, seen principally on lemons, induces typical young leaf symptoms and in addition the old leaves become pocketed and warped. When transmitted to orange it causes similar young leaf symptoms and some puckering or cupping of old leaves. If sweet orange rootstocks carry crinkly leaf lemon tops, the rootstock will develop bark symptoms of psorosis A. Although it has not been established definitely it appears that the crinkly leaf disease may result from a mixture of two viruses, one of which is the psorosis A virus. Crinkly leaf is not found commonly. Its symptoms are so striking on lemon that propagation from diseased trees has been easily avoided. Leaves and a fruit with crinkly leaf symptoms are shown in figure 1C.

INCREASE AND DISSEMINATION OF THE PSOROSIS DISEASES

There are no known insect vectors of the psorosis viruses and there is no definite evidence that insects are a factor in their spread. From the standpoint of the citrus grower this is an extremely fortunate circumstance. It is equally fortunate that the viruses of these diseases are not transmitted through seeds to any detectable extent. While it is possible that either one or both of the above might account for an occasional diseased tree, it is quite well established that these means of spread are of no economic importance.

The absence of insect and seed transmission plus the fact that psorosis cannot be transmitted from diseased to healthy trees by pruning or other cultural practices leaves only one chief source of infection. That source is the parent tree, from which buds are taken. Like all known plant virus diseases, transmission takes place and healthy trees become diseased when virus-bearing tissue is grafted to them. When natural root grafts occur between a diseased and a healthy tree the latter becomes diseased but since root grafting takes place only infrequently the amount of disease resulting in that manner is probably not very great. In the case of psorosis, the use of cions or buds from psorosis affected trees for top working old trees or for growing nursery trees results in diseased trees and accounts for nearly all of the naturally occurring psorosis.

CONTROL OF PSOROSIS

Preventive measures

Absolute control of psorosis lies in prevention. The absence of any significant amount of natural spread of the disease in the field makes prevention effective. Citrus trees are free of psorosis and remain so if psorosis-free bud-wood parent trees are used for the production of nursery trees. However, the long delay in the appearance of bark lesions on affected trees, and the inexperience of nurserymen or propagators in detecting young-leaf symptoms, has resulted in the production and sale of a great many diseased trees.

In California a service has been inaugurated by the State Department of Agriculture by which prospective parent trees are thoroughly and repeatedly inspected over a period of a year or more. When trees are considered free from psorosis they are registered by the Department and the progeny from such trees are sold as registered, psorosis-free stock. It has been left to the option of the nurseryman as to whether or not he wishes to grow and sell registered nursery trees but in California, more and more

producers of citrus stock are realizing the value of this practice. At present about 1,000 parent trees have been registered by the State Department of Agriculture.

Curative measures.

There is no known cure for psorosis affected trees. However, the productive life of diseased trees can be prolonged by certain procedures. For many years it has been the practice of growers and tree surgeons to remove the bark lesions by what is known as the "scraping" treatment. By means of a specially designed "bark scraper" the disorganized and discolored bark of the lesion area is removed by scraping to the necessary depth. Injury to the cambium is avoided except in small, localized areas where the affected bark extends completely to the cambium. If trees are carefully inspected annually, over the entire framework so as to detect bark lesions in their early development, treatment is much more effective and the amount of labor greatly reduced. On trunks and larger limbs the lesion proper and a 4-inch surrounding margin of bark should be scraped. On small limbs the usual procedure is to remove the limb completely, making the cut several inches or a foot below the lower limits of the lesion. A good practice is to reinspect the treated lesions each year and to rescrape where reactivity such as roughening, scaling or gumming has occurred. At the same time any new lesions should be treated.

The treatment of old, well-advanced lesions is usually of doubtful value. This is particularly true if there is evidence of staining in the wood or if the tree shows signs of top deterioration. Also, if trees show many active lesions generally over the trunks and limbs it may be that too much attention and labor will be required to warrant treatment.

A recent development which shows promise of providing a satisfactory treatment of psorosis lesions is chemically induced bark scaling. **2, 3** This treatment consists of brushing the lesions and marginal bark with a one percent solution of dinitro-o-cyclohexyl-phenol in kerosene. This solution, known as DN 75, is prepared and distributed by the Dow Chemical Company. This treatment is giving good results, particularly on lesions in early stages. It is inexpensive and easily and quickly applied but the directions as to its use and application must be cautiously followed. Improper use of DN 75 will result in serious injury to the treated trees. This chemical treatment, like the standard scraping, is not a cure; it is merely a way of prolonging the commercial usefulness of the tree. It is not recommended for trees that show a marked top deterioration nor for trees already showing wood staining. Until further investigations are completed it is not being recommended for use on previously scraped areas.

ECONOMIC IMPORTANCE OF PSOROSIS

Psorosis, primarily the bark-scaling type, psorosis A, is widely distributed over the California citrus growing areas and is known to be present in most, if not all of the citrus areas of the world. The economic importance

---

2 Fawcett, H. S. and L. C. Cochran. A method of inducing bark-shelling for treatment of certain tree diseases. Phytopath. 34:2, 240-244, 1944.
3 Rounds, Marvin B. Pest control circular, Calif. Fruit Growers Exchange. Subj. Series 4. June 1946.

of this disease in California varies in individual plantings. The percentage of diseased trees varies from negligible in some groves to as high as 75 percent or more scaling trees in groves not more than 25 years old. Data obtained in 1943 and 1944 in a survey conducted in California by the Emergency Plant Disease Survey **4** covered 18 different groves totaling 14,320 trees. These groves ranged in age from 16 to 50 years. The percentages of trees with bark symptoms ranged from a low of less than 1/2 of one percent to a high of approximately 30 percent. Replants, thought to have been necessary because of psorosis, sometimes ran as high as 15 percent in the older groves. The surveyed groves were perhaps an average representation of the California plantings of that age range. There are, however, many plantings with a much higher percentage of diseased trees than was shown by those included in the survey. In the older groves, yield estimates showed that the affected trees were yielding on the average about 1/3 less than healthy trees of the same age. As the disease effect increases, the yields become proportionately less. An additional reduction in total yields also results from the loss caused by the necessity of replanting.

It is perhaps unnecessary to point out the disastrous potentialities of a disease such as psorosis if control measures are not put into effect. Failure to provide proper instruction of citrus nurserymen and propagators with regard to psorosis, and to inaugurate some system of aiding them in producing and distributing psorosis-free trees can, in time, result in serious financial losses to growers and to the citrus industry as a whole. This loss, occurring gradually over a long period of time, although less alarming and less dramatic than that caused by certain other plant diseases, is none theless real.

INFECTIOUS WOOD NECROSIS AND GUMMOSIS OF CITRUS

By: G. H. GODFREY, *Plant Pathologist, A. and M. College Experiment Station*

In the Lower Rio Grande Valley of Texas we have a citrus tree disease that apparently is not known in California. This is infectious wood necrosis and gummosis. This rather complicated name is given it to distinguish it from other types of infectious gummosis such as the brown-rot gummosis or foot rot, more or less common in both California and Florida (and occasionally occurring here) which affects only the bark and the cambium layer. Wood necrosis means wood dying or wood death; and that is the distinguishing character of the Texas disease. It is the most common kind of branch and trunk gummosis in the Valley. It is constantly taking its toll, bringing about the gradual death of thousands of trees in all parts of the Valley. The disease has been referred to as "Rio Grande gummosis".

Milder forms of gummosis also occur, completely different in origin. There is, for example, plain "bleeding" resulting in gum formation, arising from large or small wounds in the bark or from pruning wounds. This type usually ceases spontaneously when callus formation connected with healing is well started. Another type is a physiological gumming associated with some temporarily adverse growing condition such as a temporary rise in the water table, excessive salt in the soil, and even sometimes a mineral deficiency. Physiological gumming may occur in a tree every year for a brief period, after which natural recovery occurs and the tree resumes normal growth without serious damage. Still another type is a foaming gummosis on the branches, which, while it may kill a small area in the bark, is really only "skin deep". This disease has a characteristic sour odor. It sometimes heals from the bottom up, with new bark beneath the old, not even leaving a scar. None of these is serious and natural cessation usually occurs. There is also a gumming associated with scaly bark disease, but it is rarely as profuse as it is with our Rio Grande gum disease, and the typical bark scaling is its distinguishing feature. Then there is the foot rot or brown rot gummosis referred to in the first paragraph.

With the Rio Grande gummosis, rather than a bark scaling, one sees a distinct crack or blister in the bark from which gum exudes, and a general darkening of the color of the bark in that region. One can be certain of this disease only by cutting well into the wood at the bleeding point. Here he finds that not only is the cambium discolored, but that there is a band of discolored wood sometimes well beneath the cambium. By chiseling still deeper it is found that the diseased band has spread both sideways and lengthwise in the branch—more extensively lengthwise, and both upward and downward in the branch. A cross section of a typical infected branch made above or below a bleeding point shows the discolored band of wood usually 1/4 to 1/2 inch beneath the bark, a half inch more or less thick, and 2 or 3 (or more) inches wide. A longitudinal section shows the extent of spread upward and downward in the branch, often 2 or more feet. Where the advancing band has come outward to the cambium layer, it kills the cambium there, and brings about another blister in the bark and another gum spot.

This meandering band of diseased, discolored wood has been produced apparently by the active spread of a wood-penetrating infection. The true nature of the causal agency is not fully understood and it will not be considered in this paper. Much additional work is required before it can be described.

As evidence of the infectious nature of this disease, however, inoculations into healthy branches, made by inserting small chips of infected wood from the advancing edge into slits cut through the bark and into the wood beneath, produced typical wood death (necrosis) in spreading bands. Typical gummosis was caused. When small branches were inoculated the usual result was the complete killing of the branch beyond the point of inoculation in only a few months. Any broken branch, any break or bruise in the bark, any unprotected pruning wound may be the site of entrance of the disease into the tree. Once inside, it spreads within the wood, and it may grow there for a long period before its presence is detected by an outbreak of gummosis. The disease has been destructive in the Valley for many years. There can be little doubt but that extensive new infections occurred at the time of the hurricane in 1933, and that still further increase occurred in splits in the bark in the serious freeze of 1934. By 1937 the disease was rampant, and it was then that active investigations as to its nature were started. There is still much to be learned by further study; but gradually accumulating information has indicated certain control measures that are of practical value.

4 Joseph S. Tidd. California citrus psorosis survey. The Plant Disease Reporter. 28:20, 638-640. 1944.

PREVENTION

Prevention consists of the use of sanitary measures to prevent new infections. These are: (1) the removal of broken branches by making a smooth clean cut in proper relationship to a side branch; (2) the disinfection of pruning wounds; (3) avoiding any bruising or breaking of the bark by cultivation implements, by ladders, and by hard-soled shoes of the pickers and pruners; (4) removal of the dead and discolored wood extending into the branch to which was attached a dead limb that has been removed.

A good disinfectant is important. Bichloride of mercury 1 to 1000, potassium permanganate 1%. or carbolic acid 2% in water, all may be used. Another material that has been found to be outstandingly good is carbolineum stepped up to 2% phenol content but never exceeding that. It is somewhat oily in consistency, and will repel water, whereas the other materials mentioned will absorb water and the disinfectant properties will gradually be eliminated. A material practically identical with a good grade of carbolineum consists of anthracene oil with phenol (carbolic acid) added up to 2% by volume. Anthracene oil is purchasable in drum lots at a relatively low cost per gallon, and dealers would do well to stock it and add the required amount of phenol, as a pruning wound disinfectant.

However, disinfection of the larger wounds is not enough. Needed in addition is a coating material that will prevent drying out and checking or cracking of the exposed wood. Without such additional protection, new infections may start deep in the cracks in the wood. A very efficient pruning wound coating material may be made by mixing a relatively low melting point asphalt with carbolineum in about equal proportions. The asphalt must be melted first and then the warmed carbolineum poured into it, with thorough stirring to make an even mixture. When cool it should have the consistency of a slightly thick paint. To this mixture should be added enough phenol to give a total of 2%. This material will adhere well, will not injure the bark or the cambium, and will harden sufficiently to give a somewhat flexible but long-lasting and completely water-repellant coating. On large wounds it is desirable to make a periodic check, giving a renewal coating if necessary. Asphalt emulsions are not recommended as they do not adhere to green wood and they are not as persistent as the asphalt-carbolineum mixture.

In practice, it is not necessary or practical to apply the preliminary disinfecting treatment on newly made pruning wounds that show healthy wood on the surface. The coating material, being itself an adequate disinfectant, may be applied directly. In cases where diseased wood has been removed, however, it is advisable to use the more liquid disinfectant first. It is more penetrating and therefore more likely to kill any trace of infective material that may have been left in the wood. As soon as this has been absorbed, which, if properly applied should require only a few minutes, the coating material may be applied.

CONTROL

Attempts to control already existing cases of infectious gummosis require judicious consideration. Where the disease is not too far advanced, tree surgery methods may be applied to good advantage. For example, a case may be found with gumming started at or near some obvious wound or broken branch. With a chisel or curved gouge and a mallet, an exploratory

cavity is dug to determine the extent of the region of affected wood. If it is not too deep or too wide, the operator will proceed to excavate all discolored wood, advancing as far as necessary above and below the original point. The important thing is to remove *all* diseased wood. To leave any of it is to invite further progress of the disease, which would mean wasted effort up to this point. The shaping of the cavity is an important consideration. This will be dealt with in connection with cavity filling.

For another case, picture a tree with a fairly large branch gumming badly near its base, and the trunk gumming also, just below. The chances are that the two gumming spots are connected internally by a rather large band of diseased wood. Usually it is desirable to cut off the branch close to the trunk, and then proceed to clean out the diseased wood in the trunk. This may leave a rather large cavity, even as much as 6 inches deep, several inches wide, and two or more feet long. Often the affected wood in the trunk extends all the way to the bud-union line, but there it usually stops. This again leaves a cavity that must be filled.

When two or more branches are obviously affected, and also the trunk, it may be taken for granted that tree surgery methods will be of no avail. Inevitably an attempt to excavate all diseased wood would leave nothing but a shell, and the tree would inevitably break down in the first heavy wind. Such a tree should be left to bear a crop as long as its space in the orchard justifies its gradually decreasing yield. When it is no longer profitable, it should be removed and another tree planted in its place. As the sour orange root stock appears to be immune, the new tree will not become diseased from the remains of the old tree roots.

CAVITY FILLING

We have left off with our cavities in the trees that have been treated. Obviously they require surface disinfection of the wood, just like any pruning wound. And it is best to apply also the coating material. To leave the cavity in even this condition would be dangerous to the welfare of the tree, as inevitably, as the healing callus forms at the edge, it develops a lip at the lower end and the cavity becomes a pocket to collect falling leaves and dirt, and rainwater. After the potency of the coating material wears off, the hole often becomes a nest and breeding place for ants. And in every case we have observed, decay has again started and has spread several inches farther into the tree. The cavity should be filled.

Before starting the fill, and indeed before the tree-surgery job as such may be considered complete, the cavity should be properly shaped. The cavity should be wider inside than at its opening. This is necessary to make it retain whatever material is used for filling. It should be pointed at both ends, rather than left with either rounded or squared ends. The pointed ends play a very important part in promoting rapid healing. Only after the cavity is properly formed, the disinfectant treatment is given. It is now ready for the fill.

The cavity may be filled with any filler desired. Cement may be, and often is used. Blocks of wood coated with asphalt may be inserted and arranged. Asphalt combined with any of several different materials may make a good filler. Asphalt mixed with the rock-asphalt used extensively in road repair work in Texas, if used in just the right proportions may make a better fill than cement, in that it is more apt to be slightly flexible. At the Experiment Station we are testing a number of different mixtures, and we are not yet satisfied that the "ideal" has been obtained, though we are getting pretty close to it. The field is an open one for any operator who wishes to experiment for himself.

A good fill, when finished, will be flush with the cambium layer, and will have a fairly smooth surface It should be firm enough to hold its form and not flow or bulge out, even in hot weather. (Cement of course, will fill this requirement). If in a branch that is capable of movement, the fill should have some flexibility. (Cement will not fill the bill here).

Within a very few weeks callus growth will begin at the cut edge of the cambium, will proceed over the edge of the fill, and eventually the entire surface will be covered, leaving only a scar, where the work was done.

IS THE TREE SURGERY JOB WORTH WHILE?

It is evident, of course, that a thorough job of tree surgery as described is an expensive one. It may cost several dollars a tree. Is it worth while? I can recount one example out of several that would make it appear that it is. Two comparable trees in a grove near McAllen, both with severe gummosis, were treated. One had a complete tree surgery job, ending with concrete fill. The other was only surface-scraped and treated with carbolineum. Four years later the surgery case showed the cavity fill almost completely covered, the tree was healthy in appearance, and not a trace of gummosis was showing. The other tree was practically dead. The yield on the healthy tree every year probably paid the cost of the surgery, and it will do sc for years to come.

This would be a good point at which to stress the importance and value cf *individual tree care and attention*. Some people can't see the tree for the forest, (or in this case, the orchard) It is better to look upon the individual trees as the units that make up the orchard. Keep the individual trees healthy and the orchard will be healthy.

A PEST CONTROL PROGRAM FOR VALLEY CITRUS

By: RAYMOND ROBERTS, *Entomologist, Texas A. & M. College Experiment Station*

The Lower Rio Grande Valley has the advantage of other citrus growing areas, in enjoying a degree of isolation. A limited number of citrus pests have been introduced into the Valley but it is still free of many of the common and serious pests found in other locations. The Valley has some pests peculiar to this area.

The principal insect pests of citrus in the Lower Rio Grande Valley belong to two orders and three families. The first group which is important is the order *Homoptera*. Of this order there are twc important families, the scale insects, including the mealy bugs, soft and armored scales (*Coccidae*), and the aphids or plant lice (*Aphididae*). The second order is the *Hymenoptera*. The ant family, *Formicidae*, is the important group in this order. In addition to these two groups of insects, there are two types of mites which do damage. These are the rust mites and purple mites or red spiders.

The insects injurious to citrus trees are not closely related though their biology brings them together as a unit for control practices. The aphids and scale insects are specialized degenerate insects while the ants are highly developed.

All of the scale insects, mealy bugs, white flies and aphids belong to a group of insects which excrete a sweetish, sticky substance known as "honey-dew". This material is very attractive to the species of ants which are known to be sweet feeding ants. As a result of this attraction of ants to "honey-dew", many species of ants gain almost their entire living from these insects. But they have learned through hundreds, probably thousands of years of partial dependence upon this "honey-dew" for food, to care for the somewhat helpless insects which are the principal source of their food.

An example of this association which has been thoroughly studied is that of the cornfield ant (*Lasius niger alienus americanus*), with the corn root aphid (*Anuraphis maidi-radicus*). The ants collect the aphid eggs in the fall and take them into their nests where the aphid eggs are cared for just as carefully as those of the ants. Very early in the spring these eggs are carried to cells near the surface of the ground on warm days and back deeper when it is cold, so that the eggs hatch early. The young aphids are then taken out and placed on the roots of host weeds, long before corn has been planted. When the corn begins to come up, entire aphid colonies, which by this time have became large, are transported by the ants to corn. Thus, if the ants did not enter the picture, field corn would not be attacked by one of its more severe pests.

While no such an association of ants with aphids has been worked out for the species here in the Valley, it is logical to assume that ants do regulate the activity of the aphids to a certain extent, and that similar association exist with some of the scale insects, especially the soft scales and mealy bugs. It is impossible to find a tree heavily infested with aphids which is not visited in more or less abundance by ants. On the other hand, it is easy to locate an aphid colony by trailing the ants. One species of ant, the Acrobatic ant (*Crematogaster laeviuscula clara*) goes to a great deal of trouble to build shelters around terminal twigs on citrus trees. If these shelters are broken away, a number of soft scales will usually be found, lined up along the twig, with a dozen or more ants working diligently over them. All "honey-dew" excretion is taken away by the ants as food for their colony which may also be located in the same tree.

Since there is a true association of the ants with their "honey-dew" producing guest, it may be possible to work out a satisfactory control for both groups by striking at either in its most vulnerable spot. The mealy bugs and soft scales are very difficult to control, since they produce a waxy covering for the body which is almost impervious to insecticides. Aphids are not difficult to kill but they reprcduce rapidly and a severe infestation may be developed before the grower is aware of their presence in his grove These insects are all fcund on the trees. The fire ants on the other hand, usually nest in the ground and cnly visit trees to feed. Acrobatic ants which do live in the trees have permanent nesting sites. The fire ants may be destroyed in their nests in the ground by the use of recommended synthetic organic insecticides. These same insecticides can be dusted or injected into the nests and tunnels of the Acrobatic ant. If the ants are controlled, that leaves the aphids and scale insects to shift for themselves and leaves them open to attack by the several predacious and parasitic species which are relatively efficient in their control at present.

There are two species of ants involved in this association; one, the fire ant (*Solenopsis geminata*) is quite familiar to everyone who has nursed a grove from its infancy. It is a small reddish ant found nesting in large nests thrown up in grass land or quite generally where food is available. The second species is one which has not heretofore been associated with this type of injury in the Valley. It is the red and black acrobatic ant found so common in citrus trees.

fire ant

S. W. Clark reported work done on the control of the fire ant in T. A. E. S. Bulletin No. 435 (1931). According to this bulletin, it was found that the most promising control was thallium sulphate bait. Since the publication of Clark's work, war has made thallium sulphate a scarce and expensive item. This material was recognized by Clark to be too expensive for wholesale use. Thallium is a highly poisonous material and a number of deaths resulted from careless use of the syrup and improper handling. With these objections to thallium, it appears desirable to search further for insecticides which are effective in the elimination of fire ants.

Fortunately the insecticides known as synthetic organics have been developed. Several of those tried have proven satisfactory for the control of fire ants. A thorough application is important. Place a quarter to a half teacup full of 5 to 10% benzene hexachloride or Dianisyl Trichlorocthane on the nest and rake it in with a small hand cultivator. If the treatment is properly applied, no further work should be necessary. However, it is well to inspect the treated nests after 24 or 48 hours and if any new activity is seen in the vicinity of the nest, another application should be made. These materials, at the concentrations suggested here, have not injured test tree. If preferred, wettable dusts can be prepared into sprays. Individual ant nests should be eliminated, including those in or near the trees and those in open ground.

acrobatic ants

The acrobatic ant nests in many places, choosing advantageous locations. They are often found nesting in old birds nests, tree crotches where they build a cover for the nest, in broken or decaying limbs, or trunks of trees. They will also build shallow nests in the ground. Unlike the fire ant, this ant does not sting, but will bite on occasion. They work through hollow weed stems and may enter trees at the skirts through weeds, which have been allowed to grow up into the tree. The most difficult problem in control of the acrobatic ant is the location of their nests.

The acrobatic ants can be controlled by dusting with the same materials suggested for fire ants. Where they have entered a decaying limb or trunk, a spray or wash at the rate of 4 pounds of a 50% wettable benzene hexachloride dust suspended in 100 gallons of water thoroughly injected into the nest will kill them out. Complete eradication of nests in old heavily infested trees, has been accomplished. The 5% benzene hexachloride dust has proven satisfactory for their control and is better than the other materials mentioned.

Two other pests have been mentioned, the rust mites, and red spider

or purple mite. The mites are satisfactorily controlled by an adequate program of dusting with sulphur. Two sulphur dustings are normally satisfactory for this purpose, one in late March or early April and a second in June. If the first dusting is followed within a week by heavy rains which wash off the sulphur, it should be reapplied. If on inspection of the orchard, russetting of the fruit indicates the presence of rust mites, additional applications should be made.

The red spider or purple mites are easily seen on the foliage of trees. Most of them are bright red or green with black spots. They work under a web, but may be seen moving about on the leaves. Their injury may be recognized by a "salt and pepper" appearance of the leaves. Sulphur dust, in order to give control of these mites, must be put on under pressure to penetrate the webbing.

If ants and mites are kept under control, the predators and parasitic insects found in abundance on the trees most of the year will keep aphids, scale insects, white flies and thrips pretty well under check. These beneficial insects include the lady bird beetles and their larvae, the lace-winged flies and their larvae, and a number of small wasp parasites too small to be noticed by the casual observer. Sulphur applied for the control of the mites will not affect these beneficial insects, but DDT, rotenone, pyrethrum and other such insecticides will kill many beneficial insects. Some of these insecticides are not effective in the control of the injurious species and should not be applied as a general procedure unless some specific infestation calls for such an application.

PROCESSING AS AN ADDITIONAL OUTLET FOR CITRUS FRUIT

By
W. CLIFFORD SCOTT, *In Charge*
U. S. Fruit and Vegetable Products Labroatory

Processing of citrus fruits has, within the past few years, assumed a place of economic importance in the citrus industry of South Texas. In 1930, growers were forced to bury their cull fruit at a cost of approximately $2.50 per ton. By 1937, they received a million dollars per season from canners for their cull and surplus grapefruit. In the 1945-46 season, the growers received between nine and ten million dollars from the canners. By this time the processors were well enough established to compete with fresh fruit shippers for the crop, with the result that they handled 45% of the grapefruit produced. It is of interest to note that the same year Florida processors handled 67% of the grapefruit produced in that state.

FOOD PRODUCTS

The greatest importance of citrus juice lies in its food value. Canning of juice makes available its full food value to all people at all seasons. While the canned juice may perhaps lack something of the flavor of fresh juice, the loss in food value in processing is insignificant from the nutritional standpoint.

Agricultural Chemical Research Division Contribution No. 201.

Grapefruit juice is comparatively easy to preserve and processors of the Lower Rio Grande Valley have cashed in on the fact that consumers accepted canned grapefruit juice more readily than canned orange juice.

It is entirely possible that this advantage is soon to be lost. Good canned orange juice is now being produced in large quantities. It may be well to introduce a few statistics comparing the production of canned grapefruit juice with that of orange juice in the past few years. In 1944, 21.4 million cases of grapefruit juice were produced in Florida and Texas, while only 6.3 million cases of orange juice were produced. In 1946, the production of grapefruit juice had increased only to 24.7 million cases, while the production of orange juice increased to 18.5 million cases. It is of further interest to note that practically all of the orange juice was readily absorbed by the trade, while approximately five million cases of grapefruit juice were carried over past the beginning of the new season.

Another food product that is gaining widely in popularity is blended orange and grapefruit juice. This product is acceptable to many who do not care for straight grapefruit juice, and who still are not pleased with the quality of orange juice offered in the markets. The production of this blended juice increased from 5.6 million cases in 1944 to 17.9 million in 1946.

Another food product of increasing economic importance is canned grapefruit sections. This product has been packed in Florida for a number of years, but its production has not been attempted on a large scale in Texas. The reluctance of Texas canners to pack this product has been based on two factors: high labor costs and the comparative tenderness of Texas Marsh Seedless grapefruit. Fruit with large, comparatively tough sections, high in acid flavor, are more readily adaptable to this process than the mild, soft fruit produced in this area. However, in response to the demand of brokers for mixed shipments, the majority of Texas canners are planning to produce limited packs of sections this season. It is anticipated that a million cases will be packed in this area.

A fairly popular food product is frozen sections. Such a product is usually a very high quality, and commands a premium price. For this reason, it will probably not become so important as to replace the canned sections. Although frozen single-strength citrus juices retain much more nearly the flavor of fresh juice, it is not believed that the consumers will be willing to pay for the high cost of freezing, transportation and storage of a product containing 85% water.

Vacuum-concentrated orange juice was widely used before and during World War II. Domestic consumption was largely limited to soda water and fountain drinks. During the war, large quantities of concentrated orange juice were exported to Great Britain to be used as a source of Vitamin C. The babies of England were not critical of the flavor of the concentrated orange juice supplied them. Today, the consuming public is considerably more quality-conscious than those babies. It is therefore fortunate that an improved method of producing and distributing a high-quality orange juice concentrate has been developed by our Florida laboratory. In this method, orange juice is vacuum-concentrated to about 5-fold, and reconstituted with fresh juice to 4-fold. This addition of fresh juice replaced much of the flavor lost in the vacuum-concentration process. This 4-fold concentrate is then quick-frozen and marketed through frozen-

food channels. At the usual zero storage temperature, the product is little harder than a slush and can be mixed readily with three volumes of tap water to quickly prepare a cold drink hardly distinguishable from frozen juice. This is perhaps the best of the orange products thus far developed.

A very good dehydrated orange powder has been produced on a pilot-plant scale, and a plant is in process of construction for its commercial production. The process used is similar to that used for the drying of penicillin and blood plasma, and is a comparatively expensive method for production of food products. Use of the powder, therefore, will probably be limited to remote areas where high transportation charges offset the cost of production.

In the past, grapefruit juice has not lent itself well to vacuum concentration; however, our laboratory is working on a flavor recovery system that may help overcome some of the difficulties in preparing this product.

PROCESSING BY-PRODUCTS

So far we have mentioned only the primary products. These may conceivably become so important that you will be growing citrus primarily for processing. When that time comes, a reconsideration of desirable varieties will be in order. For instance, pink-fleshed varieties look good in sections, but poor in juice and concentrates. Some authorities claim that seeded grapefruit varieties have more juice, better flavor and higher food value than the seedless. Hamlin oranges leave much to be desired in any product.

Stock feed is first among the by-products in volume and dollar value. This product is prepared by dehydrating all the solid waste from canning operations. A by-product from the preparation of stock feed is citrus molasses. Juice drained or pressed from the canning plant waste prior to dehydration is almost as rich in carbohydrates as is the fruit juice itself. This may be concentrated in multiple-effect evaporators to yield a product similar to blackstrap molasses which at present brings a very high price when sold to feed manufacturers. It may also be used for the production of ethyl alcohol for beverage use, or for the production of feed yeast. The latter may some day prove to be a valuable source of a vitamin-rich, high-protein ration for stock feeding.

Probably second in dollar value nationally among the by-products are the essential oils obtained from the rinds of citrus fruits. The primary use of these oils is for flavoring of beverages, desserts, confectionery and other foods. While grapefruit flavor is rather extensively used in Great Britain, its use in this country has not become popular. The demand for grapefruit oil is, therefore, considerably less than for lemon, orange, and lime oils. We are hoping that industrial uses for grapefruit peel oil may be developed that will make its recovery in this area economically feasible.

Another valuable by-product, but one which also has limited demand, is citrus pectin. Pectin can be prepared from grapefruit as readily as from oranges or lemons, and the quality is equally high. The one plant in South Texas equipped to produce high-grade pectin operates only part-time on this product. A by-product from the manufacture of pectin may be crystalline Vitamin C. Methods have been developed for the recovery of Vitamin C from wash-waters used in the manufacture of pectin from canning-plant waste.

Occasionally a processor will develop specialty products from peel which he promotes individually. The demand for citrus peel preserved in brine is fairly constant, but quite limited. Such peel may be used for manufacture of candies, fruit cakes and the like. Excellent marmalades can be prepared from Texas fruit, but Americans are not generally marmalade eaters.

Very good citrus-flavored table syrups can be manufactured from the various citrus juices or from canning-plant waste. The latter material is probably better adapted for the manufacture of a bland syrup which may be used in competition with bland apple syrup.

Manufacture of citric acid from citrus fruits other than lemons and limes is not necessary, and is therefore of little interest to South Texas.

Considerable publicity has been given in the national press to the production of oil from grapefruit seed. Several years ago a plant was established in Florida for the manufacture of grapefruit seed oil and produced considerable quantities of oil which were sold in tank-car lots at 5c per pound. Several explanations have been given as to why this processor later went out of business.

Attempts have been made from time to time to develop a plastic from canning-plant waste. The plastics so prepared have not exhibited sufficiently outstanding characteristics to warrant their competition with plastics made from more abundant and inexpensive raw materials. Our laboratory is, however, continuing research upon this project.

It is to be hoped that increases in processing of many of the food products and by-products will help to minimize problems of growers faced with the threat of over-production.

In order that the greatest benefits to the citrus industry may be derived from the manufacture of products and by-products, there must be continued and improved cooperation between research agencies, the processors, and the growers. In order for research agencies to lead the way, they should be adequately staffed and equipped. The processors must be more quality-conscious than was necessary during the war, and the growers must supply the processors with the best raw material that can be produced.

DEVELOPMENTS IN THE PACKAGING, TRANSPORTING AND STORING OF TEXAS CITRUS

By
A. LLOYD RYALL, *Horticulturist, U. S. Department of Agriculture*

I assume that most of you are citrus growers rather than handlers or shippers of citrus. As growers of citrus you may feel that having grown a crop of good quality grapefruit or oranges your responsibility ends when your fruit is sold on the trees or harvested and delivered to the packing house. Let me assure you that such is not the case for in a free and competitive market the quality of fruit which the ultimate consumer receives is reflected in the price which he will pay and the quantity he will consume, So in the final analysis the consumer determines the price and that priee is certain to influence the returns to you as a grower. I suggest therefore that you make it your business to know the developments in packaging, handling, transporting, and storing of citrus and to determine that your marketing organization or your independent shipper is adopting the newer methods as they are proven to be economically sound.

COMPETITION TO INCREASE

There is no question but that the citrus market will be increasingly competitive in the next few years. Only a great natural disaster in one of the three main citrus producing areas could prevent a materially increased production of citrus fruits each year for a number of years. In addition competition from bananas, other tropical and sub-tropical fruits and deciduous fruits will inevitably increase. It is not within the purpose of this paper to give you a mass of figures on production trends but a glance at any production statistics will convince the sceptic. This does not mean that the citrus industry faces disaster. It does mean that both production and marketing will have to be geared to optimum efficiency in order to maintain a profitable industry.

CITRUS INDUSTRY

I am not an economist but in a number of years experience in the fruit and vegetable industry I have observed two general and opposed methods of meeting increased competition. The first is to compete on a quality basis by growing the best possible product, harvesting it carefully and at the proper stage of maturity, grading it to the demands of the market, handling and packaging it so that a minimum of damage is done, transporting it under conditions whereby it will reach the market with as little deterioration as possible, and then, by means of advertising, letting the public know that a high quality, appetizing, and nutritious product is available to them The second method of meeting competition is on a price basis. Using this method the product is grown, harvested, packaged, and transported by the cheapest possible methods at the expense of quality and appearance. It then can undersell other products which are competitive and thus finds a certain market among consumers who buy wholly on price. Of the two methods I prefer the former and I believe that a study of the record on districts which have tried the latter method would convince any of you that underselling by furnishing a cheap product is not the economic way.

PACKAGING TRENDS

There are at the present time three major trends in packaging which I will discuss individually. There are: (1) The swing to individual consumer packages; (2) The increased importance of gift packages; and (3) The trend from standard boxes to wirebound boxes.

Most of the consumer package business at present consists of small mesh bags containing eight to ten pounds of fruit. According to figures compiled by the Federal-State Inspection Service the total output of 10 pound bags from Texas during the 1940-41 season amounted to only 253,500 for grapefruit and 107,700 for oranges.

By the 1945-46 season the use of this package had increased many fold with the Texas totals at 3,605,100 packages for grapefruit and 2,933,300 for oranges. Shown as percentage increases the figures are very striking. From 1940-41 to 1945-46 total shipments of grapefruit from Texas increased 82 percent while shipments of the 10 pound bag increased over 1300 percent. Total orange shipments increased 71 percent during the same period while the amount packed in 10 pound bags increased over 2400 percent. As carload equivalents the 10 pound bag accounted for approximately 1800 of the total of 33,500 cars of grapefruit and oranges shipped from Texas during the 1945-46 season. This is a relatively small proportion of the total shipments but it is becoming increasingly important each season. The principal objection to the consumer size package comes from the shipper who claims, and correctly, that more labor is involved in filling and handling the small bag than with half box or box size bags or wirebound boxes. This objection will be overcome as mechanization is increased. Definite progress is being made in automatic fillers and tiers for the small bags and in master packages to reduce the amount of labor involved in moving the consumer bags into and out of the refrigerator cars. It appears probable that as mechanization is perfected the trend will be to smaller size consumer packages.

DEMANDS FOR SMALL PACKAGES

Market surveys have indicated a greater demand for 4 to 5 pound packages of oranges than for the standard 8 to 10 pound packages. It is quite possible that some of our more tender citrus varieties such as tangelos, Temple oranges, and lemons will eventually be packaged at shipping point in consumer size trays or window cartons. There is now a rapidly growing demand among self-serving stores for such a package and distributors in almost every large market are equipping themselves to meet this demand.

There is reason to believe this consumer packaging might be more ecnomically done at shipping point than at market distribution points and there should be some interesting developments by wide awake shippers in this field in the next few seasons.

GIFT PACKAGES NEW

Another relatively new phase of citrus marketing is the gift package business. In 1940-41 this amounted to 214,115 individual shipments or the equivalent of 403 carloads of 640 bushels each. By the 1945-46 season this had grown to 648,138 individual shipments equaling 1084 carloads. The gift package business has grown steadily for several years past and appears to be destined for greater development. This method of marketing performs a double service to the industry as it not only sells a sizable tonnage of fruit at top prices but also introduces Texas citrus into many homes and communities which it would not otherwise reach. This gives it a certain promotional and advertising value. For this reason it is extremely important that the fruit going into these gift packages be of a quality which will result in favorable consumer reaction. It is encouraging that the package shippers themselves, with full realization of their responsibility, have recently organized to control the quality of their products.

FAVOR WIRE BOUND BOXES

The trend from the standard, two compartment nailed box to the naked pack, wire-bound box is also striking during the past five years. In the 1940-41 season almost equal amounts of grapefruit were shipped in standard 1-3/5 bushel boxes and wirebound 1-3/5 bushel boxes with about 2-1/2 million units of each. During the 1945-46 season approximately 31 times more wirebound boxes than standard boxes were shipped with only about 1/3 million standard boxes and over 11 million wirebound 1-3/5 bushel boxes. The same trend is apparent in oranges with the proportion of wire

bound to standard boxes during the 1945-46 season even greater than that for grapefruit.

There are several reasons for this trend away from the standard box most of which are related to the period of wartime economy of the past few years. Shortages of sawed box shook, shortages of paper wraps, a greater amount of labor required for assembly of the standard box, and shortages of skilled labor for packing the standard box have all tended to increase the proportion of the pack going into wirebound boxes. In addition a sellers market during much of this period eliminated much of the pressure normally applied by the buyer for certain desired packages. Whether this trend to the wirebound box will continue as the wartime economy changes gradually to a post war economy is subject to some doubt. It seems probable that as we return to a more competitive market the trend may be reversed with a relatively higher proportion of the pack going into standard boxes.

PRECOOLING IS IMPORTANT

No discussion on the transportation of citrus fruits would be complete without some mention of precooling. While not an integral part of the transit period, precooling is so closely associated with transportation as to make it a part of the same problem. The term precooling, as used by the fruit and vegetable industry means simply the rapid removal of heat from the commodity prior to shipment. It is usually accomplished after packaging and can be done in refrigerated rooms prior to loading into the car or by any one of a number of methods after loading into the refrigerator car. This is not the place for a detailed discussion of precooling methods as few of you are directly involved in the shipment of your fruit. However, I do want to impress upon you the importance of precooling when fruit is being handled at high temperatures or under conditions conducive to decay development. Precooling has never been extensively used in the Texas citrus industry and yet there are periods in almost every shipping season when it could be used to good advantage.

It is generally known that high fruit temperatures are favorable to decay development, shrinkage, and quality deterioration but it is not so generally known that warm fruit (at an average of 80°F. or above) loaded in the top layer of a standard car and shipped under standard refrigeration requires from 4-1/2 to 6 days to cool to 50°. In fall picked fruit stem-end decay often develops rapidly at temperatures above 50° and fruit harvested in the spring often develops substantial amounts of green mold when held at temperatures of 50° to 90°. The best insurance against decay development in transit is a thorough removal of heat from the load before the car begins its journey together with effective transit refrigeration. Furthermore precooling does not necessarily add to total costs. The transit refrigeration service can often be modified with precooled fruit so that the total cost of precooling and transit refrigeration is no greater than the cost of transit protection to the non-precooled load. We have conducted a number of experiments in this area which indicate that fruit precooled to 45° and shipped with initial ice only, carried to Chicago with better temperatures and resultant better arrival condition than fruit which was 80° or over when shipped and moved under standard refrigeration. The difference in charges between initial ice only and standard refrigeration amounts to approximately $35.00 on a standard 525 box load moving between the Valley and

Chicago This amount is sufficient to pay for a good precooling job under normal economic conditions.

TRANSPORTING METHODS IMPROVED

The greatest single advance in refrigerator car design in a number of years is the incorporation of air-circulating fans so that a positive circulation of air is obtained inside the car instead of the rather sluggish air movement obtained by natural convection. These air circulating fans, which operate by means of a friction drive from the car wheel while the car is in motion, were in the experimental stage for some years but for several years how have been in commercial operation on a limited number of refrigerator cars. A great many tests by the U. S. Dept. of Agriculture and the car-lines themselves have proven the value of forced air circulation both under refrigeration and heater service. As a result the more progressive refrigerator car lines are incorporating circulating-fans in all of their new equipment for fresh fruit and vegetable movement. The fan equipment is also being installed in many of the older refrigerator cars as they come into the shops for rebuilding. There are at the present time approximately 10,000 fan-equipped cars of a total of around 135,000 operating refrigerator cars of all lines. Reliable estimates indicate that by the summer of 1947 the number of fan cars will have increased to about 20,000 which means that about 1 out of each 7 cars in operation will then be equipped with air-circulating fans. As the number of fan cars increases it is increasingly important that the shipper familiarize himself with this development so that he can be prepared to make the best possible use of such cars. It is unfortunately true that at the present time many shippers are not even aware that such equipment exists and therefore are not in a position to take advantage of the occasional fan car spotted in at their sheds.

VENTILATING, ICING IMPROVES

Another development in the transportation of citrus fruits is the increased knowledge gained from experimental work with respect to ventilation practice and modified icing practice. A considerable amount of experimental work with the winter transportation of oranges from California has indicated that the ventilators can safely be left open, during the first few days of the transit period, when outside temperatures fall to as low as 20°F. instead of closing at 32°F. as required under the present tariff. It now appears that the tariffs will be modified in this respect during the coming season.

Other methods of transporting citrus fruit are also of interest to those of us concerned with research and to you as growers and handlers. Refrigerated trucks will undoubtedly be of increasing importance as new and improved equipment becomes available. That trend is already appearing in increased truck movement this season over that of several seasons past.

It appears that there should be a place in the transportation picture for refrigerated ships particularly for the movement of citrus to east coast ports. We have had no opportunity to determine the efficiency of such equipment as is now becoming available but it would seem that there is a place for some investigational work in that field.

Air freight does not show important promise for the movement of fresh citrus fruits. Rates will continue at a level above that which is economic

for the vast bulk of citrus fruits for some years to come. It is quite possible that some air-borne business may develop in relatively perishable and high priced specialty lines such as fresh frozen juices and fancy, consumer packaged tangelos, tangerines and mandarins.

STORAGE TO INCREASE

As most of you know there is practically no commercial storage of Texas grapefruit or oranges at the present time. It appears possible, however, that with increased production it may become desirable to store a certain proportion of the spring harvest to supply demand through the summer months when freshly harvested local grapefruit and oranges are not available. The storage of grapefruit has never been practiced widely in any citrus area largely because grapefruit, like many other tropical and sub-tropical fruits is subject to low temperature injury.

When grapefruit is held at 32°F. for a month or more the chances are good that the rinds will develop an unsightly pitting. Storage at a temperature of 50° or above practically eliminates the possibility of pitting but at this temperature decay may develop in serious amounts. Thus under present conditions it becomes a choice between two evils:—store at 50° and chance decay or store at a lower temperature and chance physiological disorders.

DEVELOP KEEPING QUALITIES

Oranges are ordinarily stored at about 38° but experimental evidence has indicated that for relatively long storage a temperature of 32 to 34° is more satisfactory. Some low temperature pitting may develop at the lower temperature but the damage from this is apt to be less than the losses from decay at the higher temperature. Our project expects to be equipped for controlled storage studies before the completion of the present citrus season. In the event that this expectation is realized we will attack the problem of grapefruit and orange storage on a considerable scale. There is reason to believe that with recent advances in knowledge on fungicidal dips, sterilizing fumigants, chemically treated wrapping paper, and moisture proof packaging materials it may be possible to store both grapefruit and oranges at temperatures optimum with their physiological processes and yet without the decay development expected at such temperatures. At the present time this is only within the realm of speculation but such a development would permit the year around marketing of Texas citrus and should be a real contribution to the citrus industry.

CORRECTING UNFAVORABLE UNDERGROUND WATER CONDITIONS IN THE LOWER RIO GRANDE VALLEY

By

P. EARL ROSS, *Agricultural Engineer, Soil Conservation Service*
U. S. Department of Agriculture

This excellent presentation, unfortunately, is not available for inclusion in the Proceedings. The speaker, who was substituting for another man, prepared his talk on short notice, and there was not sufficient time to get the formal approval from Washington, D. C. that is necessary for publication by any Government employee. The paper dealt, in general, with the source, effects, preventive measures, and corrective measures for unfavorable underground water in the Lower Rio Grande Valley. It is to be expected that, another year, with increased knowledge on the subject, this important field of study will again be adequately covered, and that the material will be available for the Proceedings. (Editor's note.)

THE FIELD DAY EXHIBITS

The third and final day of the Citrus Institute was devoted to Field Day Exhibits. These were conducted at Engelman Gardens, a few miles north of Elsa, and at Rio Farms, a few miles farther north, near Monte Alto. There were an estimated 500 people in attendance at the various exhibits and demonstrations. The crowd was divided into three sections, in order to facilitate the giving of demonstrations. A portable loud speaker was used to convey special messages and instructions. At noon a barbecue dinner was served at the Rio Farms headquarters buildings.

Exhibit No. 1. Methods of applying water to citrus orchards. Rio Farms.

Grady Foster and Cordell Edwards, employees of Rio Farms, showed the five different methods, told of the advantages and disadvantages of each, and something about the relative costs of each method. The five methods were; (1) High pressure rotary sprinklers; (2) Low pressure perforated pipe; (3) Basin irrigation; (4) Flooding; and (5) Furrow irrigation.

Exhibit No. 2. Soil problems in citrus orchards. Rio Farms.

J. F. Oswalt, Hidalgo County Agent, and M. K. Thornton, Agricultural Chemist, Texas A. and M. College Extension Service, showed the use of the soil auger in sampling soils, and the correct methods for collecting representative soil samples for chemical analysis. Dr. H. E. Hampton, Agronomist of A. and M. College, showed examples of different soil types to illustrate his talk given on the first day of the Citrus Institute, on the physical properties of soils. Dr. G. W. Adriance showed by actual demonstration the method necessary for studying the root system of a tree, and the differences that occur between different soil types in the type of root growth obtained.

Exhibit No. 3. Pruning bearing citrus trees, and tree diseases. Rio Farms.

Mr. J. F. Rosborough, Extension Horticulturist of Texas A. and M. College gave demonstrations of correct methods of pruning citrus trees. Dr. G. H. Godfrey, Plant pathologist of the Valley Experiment Station, assisted by Mr. C. W. Waibel, showed an exhibit of the best types of pruning tools, showed specimens of citrus wood affected by the Rio Grande wood necrosis and gummosis disease, demonstrated cavity filling, and explained proper pruning-wound treatment, with materials used and their application. Dr. J. M. Wallace, visiting plant pathologist from the Riverside, California, Citrus Experiment Station, showed the nature of the psorosis or scaly bark disease and the methods used in its control.

Exhibit No. 4. Orchard Equipment. Engelman Gardens.

Robert Corns, Orchardist at Engelman Gardens, assisted by Frank Brunneman, Cameron County Agent, gave a demonstration of the principal heavy tools and equipment used at Engelman Gardens. Included were:

(1) ***The Border Machine and Connector***, used for both basin and strip types of flood irrigation. Used in connection with these machines are the plow

and push, for the construction of laterals for irrigation.

(2) ***The Disk Harrow.*** Two irrigations are usually made with the same borders, after which the disk harrow is used to control weeds and knock down borders. The harrow shown was the offset type, with disk shields, and it also had a 12-inch disk at the end in the rear set, to throw the dirt back into the middles.

(3) ***The Fertilizer Distributor*** was a home-made type with fertilizer hopper and moving parts for actual distribution, the rate of distribution being determined by the hopper valve and the speed of the tractor.

(4) ***Stalk Cutter***, used primarily at Engelman Products Company where the sprinkler type of irrigation is used.

(5) ***Orchard Grader***, which pulls the accumulated soil from under the tree back to the middles, thereby allowing level surface irrigation again.

(6) ***Sulphur Drill***, a home-made type mounted on a two-wheel chassis, with a sulphur hopper and a pipe leading down behind a middle-buster plow. The sulphur is distributed in the furrow and covered by a heavy iron rail that drags behind.

Exhibit No. 5. Pest Control in Citrus Orchards. Engelman Gardens.

A beautiful demonstration was given of the use of the airplane for applying sulphur for rust-mite control in citrus groves. William Hester gave an excellent demonstration of the use of the Bean Sprayer for liquid applications to citrus trees. He was using oil emulsion for the control of scale insects. Mr. Raymond Roberts, Entomologist of the Valley Experiment Station, demonstrated ant control in citrus orchards with benzine hexachloride.

Exhibit No. 6. Preparing Young Citrus Trees for Cold Weather. Rio Farms.

Dr. Joe Corns, assisted by Cordell Edwards, demonstrated the painting and banking of young trees for protection against freezing. The purpose of the painting was to protect the trees, during the period they are banked, for invasion by soil fungi.

Exhibit No. 7. Planting Young Citrus Trees. Rio Farms.

Mr. C. H. Beasley, Willacy County Agent, assisted by Grady Foster, demonstrated the correct method for planting young citrus trees.

Exhibit No. 8. Herbicidal Sprays for Orchard Use. Rio Farms.

Cordell Edwards of Rio Farms, assisted by Mr. John Gibson of the Dow Chemical Company, demonstrated the use of 2,4D sprays for the control of vines and weeds in citrus groves.

ACKNOWLEDGEMENT

The officers of the Rio Grande Horticultural Club gratefully acknowledge the contribution of the following organizations and individuals toward the success of the recent Rio Grande Valley Citrus Institute:

To Texas A. & M. College and its staff members who conceived the idea, made the preliminary plans, largely arranged the program, and participated so ably in the various sessions.

To Rio Farms and its officers and directors for supplying facilities and personnel for the successful Field Day, and for underwriting the expenses of Dr. J. M. Wallace of the California Citrus Experiment Station.

Tc Engelman Products Co.

To Mr. Carl Hoblitzelle and the Hoblitzelle Ranch for bringing Dr. J. E. Coit from California to participate in the program and to contribute so much from his vast experience in the citrus industry.

To the committee Chairmen and committee members of the Rio Grande Horticultural Club (listed below) who gave generously of their time and effort toward the success of the Institute.

Auditorium Committee
Morris Allen—Chairman
W. J. Bach
Ben Chambers, Jr.

Field Day Committee
W. H. Friend—Chairman
Cordell Edwards
Grady Foster

Food Committee
J. A. Oswalt—Chairman
J. R. Padgett
Art Shull

Publicity Committee
W. H. Hughes—Chairman
E. W. Linnard
Ray Goodwin

Proceedings Committee
G. H. Godfrey—Chairman
W. C. Cooper
D. J. McAlexander

By A. LLOYD RYALL,
President, Rio Grande
Horticultural Club