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MAYAGUEZ, PORTO RICO
Under the supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 33

CITRUS CULTURE IN PORTO RICO

BY

HENRY C. HENRICKSEN
Agriculturist

Issued February, 1930

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By Henry C. Henricksen, *Agriculturist*

CONTENTS

The Porto Rico Agricultural Experiment Station has kept in close touch with the local citrus industry from the time of the planting of the first commercial groves. It has helped to solve many of the problems having a bearing on the industry and has had to delay the solution of others because of a lack of adequate facilities for doing research work. Thousands of replantings must be made following the loss of citrus trees in the hurricane of 1928, and many new groves are being planted by persons who have had no special training in citrus culture. It is important that all growers should know how they can avoid making mistakes which would defeat the purpose for which the plantings are made. Representative groves in the different districts were recently studied for the purpose of securing a foundation for a contemplated campaign of systematic research. Some of the data obtained are published in this bulletin and should be of value to fruit growers in general and particularly to those who are rehabilitating old groves or planting new ones.

EARLY PLANTINGS

Seedling citrus trees are found growing in Porto Rico, as in other islands of the West Indies. It is impossible to trace the various introductions, for the seeds usually were brought in as a matter of course, and no record was made concerning their origin. It is reasonable to suppose, however, that a great many different lots of seed were brought in from the various places where desirable fruit was found

growing, especially from around the Mediterranean Sea. This would naturally be the case with oranges, and to a lesser extent with shaddocks, grapefruits, lemons, and limes. The shaddock and perhaps the grapefruit also were probably planted as a curiosity only. The shaddock is seldom found growing wild in Porto Rico and the grapefruit only scatteringly in the different districts, the trees growing singly or in small groups. The so-called native grapefruit tree is characterized by tall, upright growth, in which respect it resembles the Triumph variety. Like it also, the native grapefruit tree is immune to citrus scab. The fruit is small to medium in size, and of rather insipid but slightly bitter taste.

The orange is growing wild or semicultivated more extensively in Porto Rico than elsewhere in the West Indies, partly because the tree has been found useful as a coffee shade, and partly because the fruit can be marketed profitably. In the New York market the fruit is known as the "Porto Rican wild orange," which is a misnomer, for it is cultivated as thoroughly as is coffee. The fruit might better be called the Porto Rico mountain orange. It varies in size, shape, and quality, but is generally characterized by thin rind, melting pulp, and extreme juiciness. The fruit varies from light to dark orange in color, and from seedless to very seedy. Especially selected trees which have been used for propagation from time to time have been found to transmit character of the fruit as well as growth habit of the tree. Unfortunately, a very large number of seedling trees were destroyed by the hurricane of 1928.

COMMERCIAL PLANTINGS

Local commercial citrus growing dates from about the year 1901. The first trees which were planted in commercial groves were introduced from Florida, and simultaneously with that introduction nurseries were started on the island. Rough lemon and sour orange from locally obtained seed were the first stocks to be planted in Porto Rico. Later the cultivated grapefruit was also used for stock, and during the past 15 years seedlings of the so-called native grapefruit have been used to some extent. The first groves were of oranges and grapefruit, with the former greatly predominating. Perhaps all the varieties of oranges grown in Florida at the time were introduced into Porto Rico either in the form of bud wood or budded trees. The buds were not selected as they are nowadays; in fact, they must have been cut frequently from nonbearing trees because many of the trees in Florida had not attained the bearing stage following the freeze of 1895. The result of this promiscuous cutting of bud wood became apparent as soon as the trees began to bear. Some varieties were not true to name, and most varieties bore fruit which in both quality and quantity was below expectation. Some of the varieties, moreover, were unlike the same kinds growing in Florida. The pineapple orange, for example, failed to produce its characteristic flavor, and the blood orange showed no color, whereas the navels were coarse and dry as they usually are in Florida. These variations and the slow growth of the orange tree as compared with tnat of the grapefruit tree, together with the then-prevailing low

price of oranges, caused many growers to make new plantings or to rebud the trees already planted; as a result, very few orange groves are to be found in Porto Rico to-day.

The introduced grapefruit varieties, like the orange varieties, comprised practically all that were grown at the time in Florida. Types resembling the Duncan seem to have predominated, and the Duncan and the seedless varieties apparently have been preferred in later propagation work. To-day only these two varieties are recognized. The seeded type is locally known as the Duncan regardless of visible differences, and the seedless, or nearly seedless type, is called "Marsh Seedless." The variation found in most of the groves is considerable, and would seem to point toward a profitable field for selection.

The first groves were started by continental Americans, only a few of whom had had experience in citrus growing. Their experience had been gained in Florida, and as a result an attempt was made to apply Florida methods to Porto Rico. Many of the methods, such as low budding, deep planting, and growing the trees without wind protection, proved to be great handicaps to a successful industry from the very beginning. Efforts to combat gum disease, scale insects, ants, leaf-eating beetles, and root-eating grubs were costly and discouraging. As experience was gained these difficulties were overcome, but many of the surviving trees have required constant attention ever since. Because of these early mistakes the annual loss of trees in Porto Rico has been abnormally high. During the past 10 years many of the most productive trees have died from root rot and from gumming induced by low planting. The life of some of these trees has been greatly prolonged by inarching and by the judicious use of tree surgery, but most of them were destroyed by the hurricane of 1928. Thousands of healthy trees were blown over. Those which were promptly set up and properly cared for usually recovered, but many trees in the mountain districts were lost as the result of neglect.

ANNUAL SHIPMENTS OF FRUIT

Production per tree is difficult to estimate, and the average yield per tree can not be stated because some trees yield 10 to 20 boxes of fruit, whereas others yield nothing. Of the latter kind, some may not have reached bearing age, and others may be nonbearers or practically so. The export figures for oranges can give no clue to the yield per tree because oranges from the mountain districts are shipped only when prices warrant, and the island consumption is always uncertain. The census report of 1920 showed that there was then a total of 1,300,000 orange trees on the island. A comparison of this number of trees with the number of boxes of oranges exported in 1918 reveals a yield of less than half a box of fruit per tree, and similar comparisons show that in other years the yield was one-quarter of a box of fruit or less per tree. Notwithstanding these facts, the seedling trees are usually very prolific.

Table 1 gives the annual shipments of citrus fruits from Porto Rico for the period 1910–1928, inclusive.

TABLE 1.—*Annual shipments of citrus fruit from Porto Rico for the fiscal period 1910–1928* [1]

Year	Oranges	Grapefruit	Canned grapefruit	Year	Oranges	Grapefruit	Canned grapefruit
	Boxes	*Boxes*	*Boxes*		*Boxes*	*Boxes*	*Boxes*
1910	296,058	48,441	----------	1920	336,625	419,629	----------
1911	349,442	96,189	----------	1921	162,395	667,637	----------
1912	277,422	118,937	----------	1922	388,882	360,530	----------
1913	353,690	216,247	----------	1923	732,973	460,951	----------
1914	348,927	206,200	----------	1924	192,363	666,657	102,143
1915	200,311	276,583	----------	1925	336,761	579,736	123,461
1916	404,451	296,645	----------	1926	463,709	809,038	201,888
1917	503,318	435,890	----------	1927	311,294	692,052	344,660
1918	603,226	549,125	----------	1928	546,463	891,940	334,207
1919	373,679	417,369	----------				

[1] According to United States customs figures.

A grove-to-grove census, taken shortly after the hurricane of September, 1928, showed that there were then on the island approximately 6,000 acres planted with 430,000 grapefruit trees of all ages. Table 1 shows that 891,940 boxes of grapefruit in the fresh state were exported in 1928 and that 334,207 boxes of the canned fruit were shipped. If 3,793 boxes of fruit are allowed for local consumption, the island will be found to have produced a total of 1,230,000 boxes of grapefruit that year. This production from 300,000 full-bearing trees would give an average yield of slightly more than 4 boxes per tree. The table also shows that while production has increased steadily fluctuation has been considerable from year to year.

NATURAL REQUIREMENTS

SOILS

That the citrus tree is not very exacting as to its soil requirements is well illustrated by the fact that the groves are found on soils covering a wide range from beach sand to heavy clay. A systematic study of existing groves reveals differences in growth of tree due to soils which were not readily discernible at the time of planting. This is true especially of the region between Bayamon and Arecibo, which is bordered by the ocean on one side and by the railroad and in places by the public highway on the other. The soils of this region vary from sand that is almost devoid of colloidal matter to clay containing less than 25 per cent sand. The growth of the trees furnishes information regarding the chief limitation of each soil type. The white sand is poor because it does not retain enough moisture and plant nutrients to supply the needs of the trees under existing conditions. The darker sand, containing 2 to 3 per cent colloidal matter, of which about 1 per cent is organic, is excellent, provided the subsoil is pervious and the water level is not too variable. The red sandy soils containing upwards of 10 per cent colloidal matter are suitable for tree growth, provided they do not cement. Cementation is caused by the high amount of iron and the colloidal state in which it is present in these soils, and it prevents the trees from developing properly. The clay soils in this region vary from 20 to 60 per cent clay and are similar to those found in other regions.

The soil at Plantaje, both surface and subsoil, in which the first commercial grove on the island was planted, consists of shell sand. With the formation of land at this point, silt was deposited in the lower places, whereas the slight ridges remained practically pure sand. A heavy hammock growth developed, especially in the silt-covered areas, and after it was removed considerable humus remained. The difference between the poorest and the best soils in these groves is readily discernible by the color of soil. Analyses show a difference of 2 to 3 per cent in colloid content, practically all of which is organic matter. In the better grade of this soil tree growth is excellent, and even in the poorest grade the trees develop much better than they do under different conditions.

The water table in these groves reaches within 3 to 4 feet of the surface in the rainy season, and supplies abundant moisture most of the time to the citrus trees even on the poorer soil. On the other hand, the high water table is the main limiting factor in root formation. The depth of the root system is naturally limited by the water level, and although a distance of 3 feet is ample for root development it is not sufficient to allow for the changes in water level that take place periodically. For example, the water may not reach beyond the 3-foot limit in a certain section for several years, but during a period of heavy rain it may come to within 2½ feet of the surface. Unless this excess water is drained off, the immersed roots will decay and the trees may die. At times, especially during prolonged droughts when the water table subsides 12 inches or more below normal, the trees may suffer from a severe shortage of moisture. Evidently the pore space in the subsoil is too great to allow for much capillary rise of water. A lack of moisture can be remedied cheaply by irrigation; but since the water has an alkalinity equal to 0.16 gram $CaCO_3$ per liter and a pH of 8 to 8.4, it may not be suitable for the purpose. In the surface soil with a humus content of about 2 per cent, the pH seldom reaches above 7.4. Whether or not a pH of 8.4 through the entire soil mass would be detrimental is not yet known.

The sandy soils in all the other groves in the above-mentioned region consist of silica sand mixed with clay silt and organic matter. The poorest grade of this sand is exemplified by the narrow ridge west of Dorado, which broadens out into a plain of several hundred acres between Vega Baja and Lake Tortuguero. This sand is several feet deep and is so pervious that water percolates through it readily. It is practically devoid of clay and humus, and consequently all fertilizers applied leach out immediately following a rain. To maintain plant growth, such sand must be given frequent fertilization and irrigation. Even were this treatment practicable it could not be satisfactorily used because citrus trees do not thrive well in a soil that is entirely devoid of humus and soil organisms. Obviously this extreme type of soil is unsuitable for cultivation, and large areas of it can not profitably be made suitable. Often, however, small areas in citrus groves may be improved without great expense. Clay, when available, may be applied to good advantage at the rate of 50 tons per acre. The clay should preferably be dry and pulverized, or at least granulated, so that it will readily mix with the sand.

The addition of stable manure to the sandy soil at the rate of 1 ton per acre will supply the soil with organisms, and then cover crops can be grown, although fertilizers may be necessary for the first few crops. Ground limestone may also profitably be applied to such soils at the rate of 2 to 5 tons per acre. A rock crusher should be available for use on plantations where limestone is plentiful because most of the soils in which citrus trees are planted are greatly benefited by an application of lime. The poor sandy-clay soils may be improved by an application of both ground limestone and organic matter. Citrus trees should not be planted on areas where the subsoil is high in iron and much cemented.

The suitability of sandy soils containing small amounts of clay and organic matter depends upon the permeability and water-holding capacity of the subsoil, as well as upon the level of the water table and its fluctuations. Provided that the water table does not reach to within 10 to 12 feet of the surface at any time and the subsoil has great water-holding capacity and is sufficiently pervious for root formation, the citrus tree usually will not suffer much from lack of moisture in most of the citrus districts in Porto Rico. In such soils trees with a taproot are more likely to succeed than those without. In fact, the presence or absence of a taproot is probably often the cause of differences in tree growth in many such soils. Wherever the level of the water table varies within wide limits the root system will adjust itself to the highest level maintained for a considerable length of time; consequently, the trees may suffer from drought when the level falls. The cultivation practice suggesting itself under such conditions consists in the growing of cover crops during the rainy season and the maintenance of a dust mulch during the dry season.

In sandy soils the leaching of fertilizers may be a problem of some importance. Usually, however, it is of minor importance, as is illustrated by the following example: A soil which in situ weighs 40 kilograms per cubic foot and has a water-holding capacity of 15 per cent will retain moisture equal to 2.5 inches of rain per foot. If such a soil is fertilized after having been saturated by a heavy rain, the water-soluble salts will go into solution quickly, and if 2.5 to 3 inches of rain fall shortly after the soil is fertilized a great portion of the soluble salts will be leached below the foot of soil. The actual amount of salts so leached will of course depend upon the amount of colloidal matter present in the soil. Another rainfall of 2.5 inches will wash an additional portion of soluble salts from the topsoil and also some of the salts from the subsoil. When the root system of the tree is deep and the subsoil contains considerable clay, fertilizers are not so likely to be washed below reach of the roots except during periods of unusually heavy rains.

The differences in productivity of clay soils are difficult to describe and difficult to determine by analytical means. The terms "heavy" or "light," when applied to clays, do not refer to actual weight of the soil but rather to soil plasticity, which is not governed by the content of clay or by any other constitutent, but rather by the state of the entire mass of colloidal matter. A clay subsoil, for instance, is usually termed "heavy" because the colloidal clay and iron com-

pounds present are compacted. When brought to the surface such subsoil may become hard on drying and plastic on wetting or it may become crumbly. Crumb structure does not usually develop in such soils until after they have become thoroughly mixed with 2 per cent or more of humus. It may erroneously be inferred from this that the plowing under of 15 tons of dry grass per acre will result in the formation of a 6-inch layer of topsoil. Theoretically this is correct, but in reality only a small portion of the organic matter remains in the soil. In fermenting, the humus becomes thoroughly incorporated with the soil, and a crumb structure results. Several annual applications of dry grass each of 15 tons would be required to produce the desired effect and at the same time leave a deposit of 2 per cent of humus in the soil.

A 6-inch layer of soil is not sufficient for root formation, especially in groves where the topsoil is disturbed periodically by cultivation. Usually seedling trees the roots of which are not disturbed by cultivation are shallow rooted where the soil layer is thin and the subsoil hard. Hundreds of such trees when blown over by the hurricane of September, 1928, were found to have a very shallow root system. In cultivated groves having a shallow surface soil the subsoil must of necessity be pervious to the tree roots, or growth will be very slow. A great many of the groves were found to contain small and large areas having a shallow surface soil when the trees were planted. Holes for planting were dug in the subsoil and sometimes dynamite was used to break up the surrounding soil area, but the tree growth usually was very unsatisfactory nevertheless.

Before planting is done it is often difficult to determine whether the subsoil is permeable enough for the roots to penetrate, but after the trees are planted and have attained the age of about 10 years the suitability of a soil can readily be judged by the root development. Unfortunately an impervious subsoil can not readily be improved, and usually it is more profitable to discontinue cultivating a grove on such soils than to attempt to improve them. Improvement, when practicable, may be had by the practice of deep subsoiling.

The water table in clay soils is not usually high enough to interfere with root development, but often drainage is slow, and the soil remains saturated for prolonged periods. An excess of water will cause the roots to decay because the area occupied by them is then poorly aerated. In the deep, well-drained clay soils of the Manati Valley the trees do not suffer from an oversupply of water even when the rains are heavy and prolonged. These soils, because of their crumb structure, are in some respects similar to sandy soils. The water drains quickly from them and evaporates from the surface to such an extent as to make drought a problem unless the dust-mulch method of cultivation is practiced. The crumb structure in these soils is readily destroyed by cultivating when the moisture content is too high. This is true of all soils, but some are much more difficult to handle than others. One type of soil in the Cidra Valley retains its crumb structure much better than do the soils of the Manati Valley, and these again better than most of the soils in the Bayamon section.

LOCATION OF THE NURSERY

In selecting a location for the nursery the water supply should receive first consideration. An abundant supply should be available, and overhead irrigation is very desirable. Preparation of the soil should begin about a year before planting is done. The soil should be deeply plowed and harrowed and then planted with a leguminous crop. This should be plowed under when it has fully developed and left for about three months to disintegrate. During this period the soil should be harrowed frequently and any growth of Para grass (*Panicum barbinode*), or malojillo as it is locally called, should be removed.

FIGURE 1.—Grapefruit budded on rough lemon stock and planted on extremely hard soil

TREE STOCKS AND THEIR IDENTIFICATION

In all citrus-growing countries opinion differs regarding the kind of root stock to be used. This is natural in view of the fact that the problem is complicated. In studying the stocks in the older groves it was found that they consisted of lemon (fig. 1), sour orange (fig. 2), cultivated grapefruit, and some so-called native or wild grapefruit. They are growing in all the different types of soil and in some of the groves in adjoining rows.

Since the different stocks could not be identified except by means of the sprouts (fig. 3) which arise from below the bud union and are seldom present, it became necessary to find a chemical method permitting of readily differentiating one kind from another. The method found is simple enough for planters to use. The following directions will serve for field use: A piece of root from a tree carry-

ing sprouts emanating from the stock should be used as the standard with which to compare the unknown. A piece of this root should be washed and wiped, and the bark should be scraped from it. A

FIGURE 2.—Grapefruit budded on sour orange stock. Trees are the same age as is that shown in Figure 1 and are planted adjacent to it

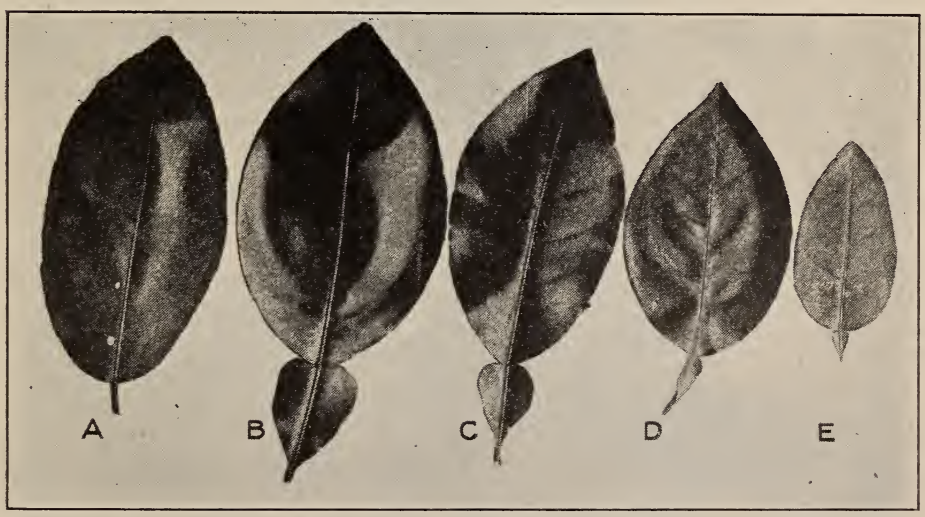

FIGURE 3.—Leaf forms of citrus: A, Lemon without apron; B, grapefruit with apron overlapping leaf blade; C, sour orange with apron not overlapping leaf blade; D, sweet orange with small apron; E, lime, very small leaf with very small apron

1-gram sample should be macerated in a morfar with a few cubic centimeters of water, after which about 20 to 30 cubic centimeters of water should be added. One cubic centimeter of a 5 per cent

ferric chloride solution should next be added. The mixture should then be poured into a measuring cylinder and thoroughly stirred, and water added to make 50 cubic centimeters. The color produced by the ferric chloride when mixed with the root bark of sour orange is very black. With cultivated grapefruit it is much lighter, and with native grapefruit it is still lighter, whereas with lemon practically no color develops.

The roots should preferably be taken from trees that are growing vigorously, as dormancy may interfere with results. When the color is not distinct enough, the following laboratory method may be satisfactorily used: Add a small portion of aluminum cream to the mixture and filter by means of vacuum. The depth of the color of the different solutions can then be determined in a colorimeter in comparison with a standard solution of naringin to which ferric chloride has been added. Lemon shows practically no color change; native grapefruit has a color equaling 4 to 6 milligrams naringin in 50 cubic centimeters of water; cultivated grapefruit has a color equaling 6 to 10 milligrams naringin, and sour orange has a color usually much deeper than 10 milligrams.

The rough or goat lemon, locally known as limón de cabra, has been and still is used extensively for stock. Unfortunately the method of identification does not permit of differentiating between the different varieties of lemons, but growth characteristics indicate the probable use in some instances of a variety other than rough lemon. The visible characters of trees which have been budded on lemon stock are (1) comparatively vigorous growth regardless of soil type, and (2) an uneven bud union, with the trunk usually enlarged below the union. (Fig. 4, A.) Frequently the enlargement is visible on trees 5 to 10 years old; after that time it may be obliterated. Trees having received little cultivation and small amounts of fertilizer up to 10 years of age may not show enlargement. (Fig. 4, B.) On the other hand, grapefruit trees on lemon stock may be decidedly constricted below the bud union, a condition which would indicate the probable use of some variety less vigorous than the rough lemon.

The sour orange (*Citrus aurantium*), commonly called naranja in Porto Rico, was used considerably as budding stock 25 years ago, and trees budded on it can be found in most of the older groves. Trees on sour-orange stock usually are (1) smaller than those on lemon or grapefruit stock, and (2) where grapefruit was used, constricted below the bud union. (Fig. 5, A.) In one grove having a loose, friable loam soil, trees 25 to 28 years old on lemon and sour-orange stocks were found to be of practically the same size. In another grove having an extremely light sandy soil, 25-year-old trees on sour-orange stock were dwarf in comparison with those on lemon stock. The same was observed in several groves having an extremely heavy, poorly aerated soil. Constriction below the bud union develops especially when the trees are well cultivated and fertilized. With no cultivation and scant fertilization, the growth is slow, and the top may develop no faster than the stock. When sweet orange is budded on sour-orange stock, the bud union usually is smooth, and constriction does not develop.

FIGURE 4.—Grapefruit budded on rough lemon stock: A, Typical bud union; B, occasional bud union

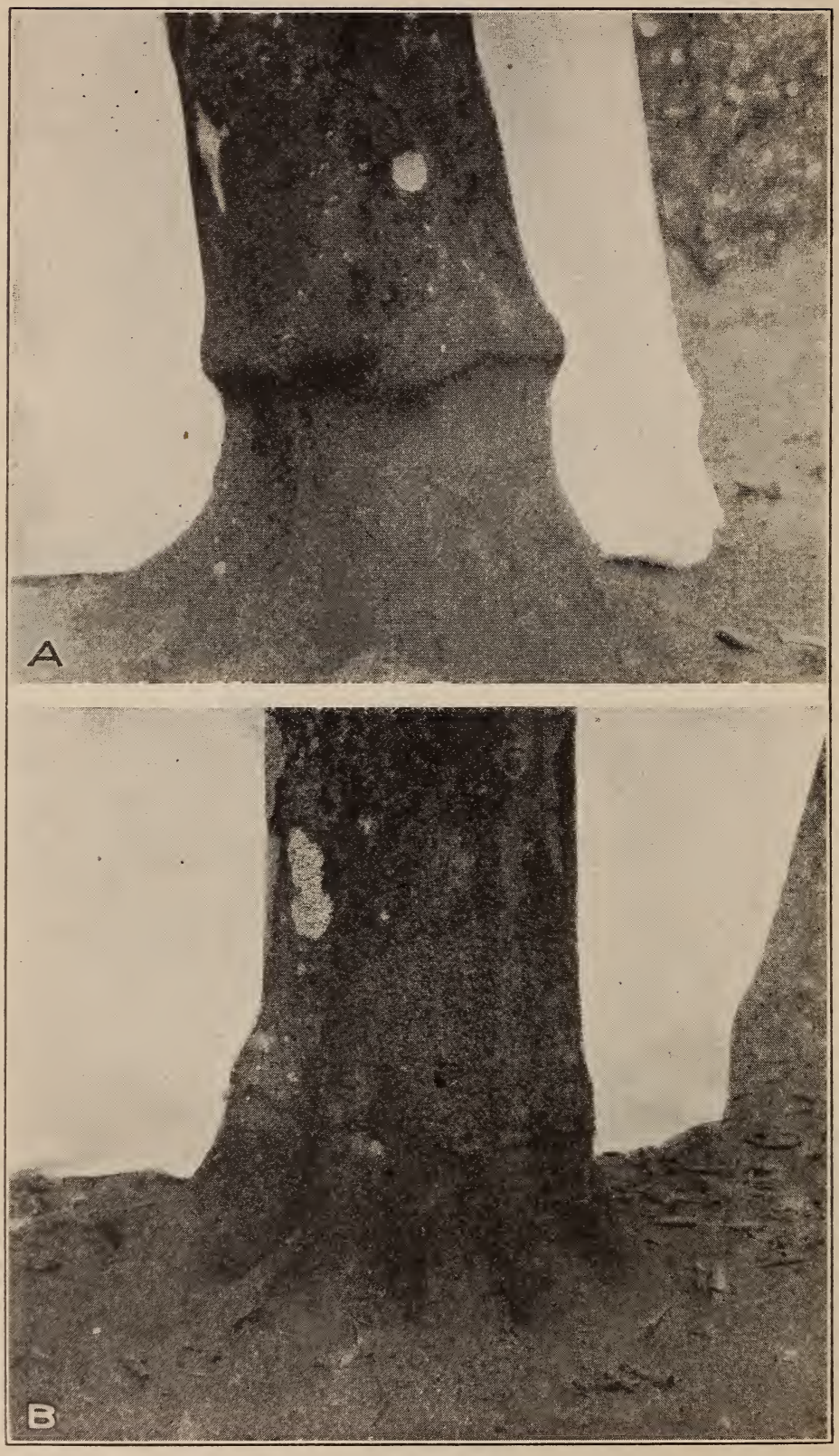

FIGURE 5.—Grapefruit budded on sour-orange stock: A, Typical bud union; B, occasional bud union

Apparently grapefruit was not used for stock in the island's first nurseries, and perhaps none of the trees of the early introduction from Florida were budded on grapefruit stock. That it soon became popular is attested by the fact that many of the grapefruit trees in 20-year-old groves are budded on grapefruit stock. Field studies did not show that grapefruit has been used as a budding stock for orange.

Some years after grapefruit began to be extensively used as a stock, a few growers started to use the seedling or so-called native grapefruit. No differences could be detected between the trees budded on this and other grapefruit stock in two small groves, 12 to 14 years old, which were observed. The growth of the seedling tree indicates that it may prove to be a desirable stock. In addition to having vigor and health, it is immune to scab. Grapefruit when

FIGURE 6.—Grapefruit budded on grapefruit stock. Typical bud union

budded on grapefruit stock and grown in good soil is characterized by (1) vigorous growth and large size, indistinguishable from trees budded on lemon stock, and (2) a smooth bud union and a trunk which is seldom constricted below the union like the sour orange or enlarged like the lemon.

As a result of observations made in many groves, it is concluded that the rough lemon may be used as stock for both orange and grapefruit. It may be planted in any soil that is suitable for citrus growing, and is preferable to other stocks in extremely light sandy and in very impervious soils. The indications are that time of fruiting may be controlled more readily with trees budded on lemon stock than on sour-orange stock. Trees which are budded on lemon stock are said to be more likely to produce coarse fruit than are those budded on the other stocks. This was not found to be the case, but may be in a more extensive study when more fruit is available. The

longevity of trees which are budded on lemon stock is said to be less than that of those budded on the other stocks, but this fact was not established.

Lemon is said to be more severely attacked by foot rot than is grapefruit, whereas the sour-orange stock is reputed to be practically immune. This fact could not be substantiated in field studies because all the older trees were budded too low to permit of learning whether gumming started in the stock or in the bud. In most of the groves gumming of various kinds is as prevalent on trees budded on sour-orange stock as on those budded on lemon stock, although in one grove those budded on lemon stock were found to be the most affected.

The sour orange may be used as stock for sweet orange, but is less desirable for grapefruit than is grapefruit stock. The sour orange may be planted in any good grade of loose loam, but should never be planted in extremely light or in extremely heavy soils.

The sweet orange as a stock has not received a thorough trial in Porto Rico, and may be worthy of consideration. The growth of the seedling tree in all types of soil indicates that it may prove to be a desirable stock, at least for the orange.

The grapefruit may be used as stock for grapefruit, and undoubtedly for orange as well, although it has not been used for the latter in Porto Rico. It may be planted on any fair grade of soil, but does not thrive as well as the rough lemon in very light sand or in very heavy clay.

PROPAGATION

SELECTION OF SEED

In commercial citrus growing the foundation of the tree is the seed. The seedling is planted either for the purpose of producing fruit as such, or for use as stock. Seedling trees may produce desirable fruit in abundance, as is well illustrated by the thousands of seedling orange trees grown in Porto Rico. The fruit is variable, however, and therefore not so valuable as that from budded trees. The difference in value may be too small to warrant the planting of budded trees in coffee plantations, especially where cultivation other than weeding is impracticable. In cultivated groves, on the other hand, where intensive culture is practiced, the cost is too great to risk the planting of seedlings. The seed should be carefully selected regardless of whether the seedlings are wanted for fruit or for use as stock. Seed selection always pays notwithstanding the fact that the seedlings do not always reproduce the desirable characters of the parent tree.

If the seedling is to serve as stock, the selection may be confined to tree characters only, in which case the primary requirements of the mother tree are vigor and size. Health may well be considered also and perhaps shape, but prolificacy and fruit characters are immaterial factors. If, on the other hand, the seedling tree is to bear fruit, the mother tree must be selected for fruit as well as for tree characters. The tree must be large, vigorous, well shaped, healthy, prolific, and produce fruit of such color, shape, and quality as the market demands.

After the tree has been selected all fruit below medium size should be discarded. Likewise, after the seed has been removed from the fruit, the abnormally small ones should be discarded. This may be accomplished partly by washing the pulp away from the seed, when the very light ones float off, and partly by hand picking. After having been cleaned the seed may be dipped in any of the organic mercury preparations which are sold especially for seed disinfection. The seed may be planted without having been dried, or it may be dried in a drafty but shady place and stored in a tight container for some time and then planted. It should preferably be planted immediately when possible, however.

SEEDLINGS

In Porto Rico, where the nurseries are comparatively small, germination boxes should be used in preference to seed beds. The boxes may be of any convenient size, but should not be less than 6 inches

FIGURE 7.—Germination box with seedlings 8 weeks old. Note perfect stand due to disinfection of seed and planting in soil free from organic matter

deep. Holes one-half to 1 inch in diameter should be made about 6 inches apart in the bottom of the boxes to provide for drainage. The boxes should preferably be placed on racks of convenient height and be partly shaded. An open shed with boxes placed near the sides will afford a suitable location, or a frame having a covering of slats so spaced as to provide half shade may be used. Pieces of rock should be placed over the drain holes and the boxes filled with soil to a depth of 6 inches. Any kind of soil that is not too heavy may be used, although pure sand is unsuitable and much organic matter is undesirable for the reason that it may harbor damping-off fungi. A friable subsoil may be used because it is nearly sterile. Commercial fertilizer consisting of inorganic matter should be applied and mixed with the upper layer of soil; about an ounce per square foot of a 4–8–8 mixture will do. The seed bed

will then be comparatively free from damping-off fungi, growth will be rapid, and the plants stocky. (Fig. 7.) The seed should be scattered on top of the soil at the rate of about four per square inch and covered with a thin layer of soil. This in turn should be topped with a thin layer of fine coconut fiber. The soil should be kept constantly moist until the plants are ready for transplanting.

If fresh seeds are planted the resulting seedlings will be large enough for removal into other boxes in three months. All seedlings below medium size should be discarded. The young plants should be set one-half inch apart in boxes containing 8 inches of preferably a rich loam soil. They may be left in the boxes for six months, during which time they will require less attention than would similar plants in the nursery.

In the nursery the seedlings may be planted 12 inches apart in rows 3½ to 4 feet apart. When the soil is clayey the plants should be set at least 18 inches apart in the row to permit of removing a ball of earth with the tree in transplanting. Preparatory to the removal of the plants from the propagating boxes a shovel should be run along the bottom to loosen the earth. After this they can be taken up with less likelihood of breaking the roots. All undersized plants should again be discarded. It is a good practice to remove only a few trees at a time, dip the roots in a slurry consisting of clay and cow dung, and place them in a covered basket from which they can readily be removed for transplanting. Holes large enough to accommodate all the roots without cramping should be made in a straight line across the field. The plants should then be set and the soil firmed around the roots. Water should be applied immediately.

After planting is done the soil should be kept constantly moist, mellow, and fertile. It is well to use fertilizers two weeks after planting and then at intervals of two months; applications of 1 ounce per plant of about a 4–6–6 mixture will produce stocky plants which should be ready to bud in about 12 months from seed.

BUD SELECTION

In bud selection the main points for consideration are the tree and the fruit. The tree should have a branching habit with a spread as great as, or greater than, the height. It should be large in order that the bearing area may be large, and free from imperfections that may be attributed to inheritance. The fruit produced should be large and evenly distributed and advantageously placed. Grapefruit, for example, should hang singly, or nearly so, rather than in large clusters.

The most essential points to be considered in regard to fruit are time and degree of maturity, form, size, weight in proportion to size, color and smoothness of rind, thickness of rind, flavor and consistency of pulp, number of seeds, fiber and number of sections, and finally uniformity of all these points in a large number of fruits. Special attention should be paid to uniformity of characters. The fruit from a certain tree may be generally desirable, but when individual specimens differ much in regard to any one character the indications are that the character is not stable and may not be

uniformly transmitted through the bud. The fruit from some particular branch may prove to be more desirable than that from the other branches on the same tree, in which case the buds should be taken from the one branch only. Of course the records for one year will not be as reliable as data covering a period of at least five years. There are many tree records now on the island, and a comparison of them may yield valuable data leading to the establishment of a foundation for future work. Planters who have not yet adopted the system of indexing their trees individually should do so at once. They will soon learn of the benefits to be derived from such a system and the importance of selecting bud wood from trees whose records have been kept for a number of years. Two numbers should be painted on each tree, one to indicate the row and the other the number of the tree in the row.

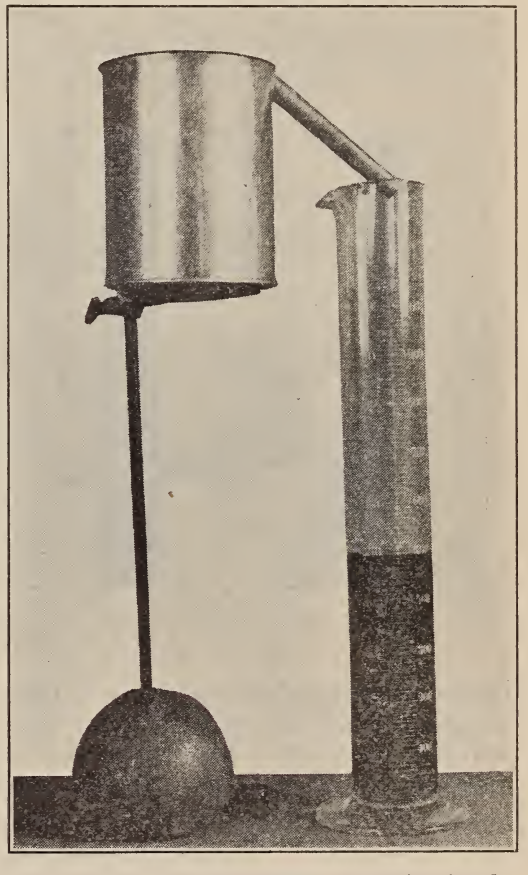

FIGURE 8.—Can and measuring cylinder for determining volume weight of fruit

DETERMINING THE VOLUME WEIGHT OF THE FRUIT

In bud selection the grower usually judges the desirability of the fruit without regard to weight, measurements, or other accurate tests, which is unsatisfactory. The acidity may be determined by titration and the total solids by means of a hydrometer, the methods of determining which are well known to most planters. The weight should preferably be ascertained by means of scales that are correct to within the limit of 1 gram. The exact size may be ascertained by means of a container shown in Figure 8. The container is filled with water until a few drops escape from the spout, when the measuring cylinder is set under the spout. The fruit is immersed in the water and is held down by means of the point of a nail. The number of centimeters of water escaping from the container may be learned from the cylinder and indicate the volume corresponding with that of the fruit. The weight in grams, formerly ascertained, divided by the volume in centimeters will give the density, the variations of which are governed mainly by the thickness of the rind. An orange having a density much below 1 has a very thick rind, judging from Porto Rican standards, and a grapefruit having a density below 0.85 has a thick rind. It is well to peel the fruit and weigh the rind.

Macerate the pulp and squeeze the juice out through a piece of muslin and weigh the two separately. A tabulation of the data obtained in this manner will yield valuable information.

BUDDING

The nursery trees are ready to bud when they are large enough, at 6 inches from the ground, to hold a bud. About 6 inches is the proper height to insert the bud; by budding lower the tree may become increasingly susceptible to foot rot, and budding higher is of no advantage.

The operation of budding is familiar to most growers. The main points to be remembered are that the knife must be sharp, and the bud must be cut at a slant from the base to the tip of the knife blade in order that the wood may not split. (Fig. 9.) Adhesive budding tape which readily sheds water should be used instead of

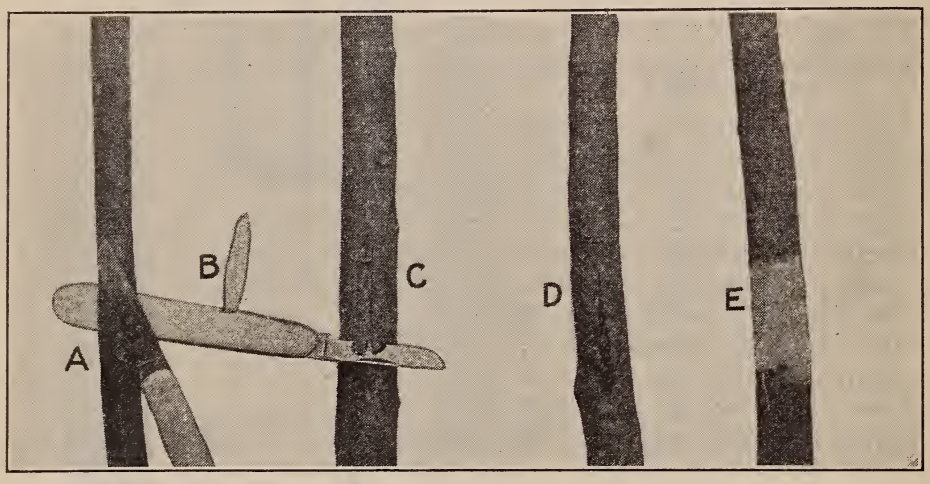

FIGURE 9.—Method of shield budding: A, Cutting the bud; B, bud; C, making the incision; D, bud partly inserted; E, bud wrapped

twine in wrapping the buds. The wrapping is usually partly removed a week or 10 days after the operation, and the bud if alive will be ready for forcing a few days later. Forcing consists in girdling the stock 2 or 3 inches above the bud, or cutting the stock partly off and lopping the top over. Some growers prefer to cut the stock partly off and lop the top and others prefer to sever the whole stock a few inches above the bud. The whole stock should be removed only when the seedling is growing vigorously, however. As soon as the bud starts growth it should be fastened to a stake placed beside each tree. Frequent tying is needed to insure straight growth. After two or three months the stock should be cut off smoothly, slanting from the bud downward. All these details are very important. As a result of their having been neglected in the past, many of the nursery trees on the island are undesirable. Given proper attention as regards irrigation, cultivation, fertilization, and all other details, a first-class budded tree may be produced in less than two years from seed. Abnormally small or defective trees should be

discarded in the nursery. The trees may be transplanted when they are 3 feet high. Old, overgrown nursery trees are not as desirable as young, vigorous ones. About two months before transplanting is done, watering and cultivation of the nursery should be discontinued in order to allow the young growth to mature. Frequently the weather is rainy and growth continues, in which case transplanting can be done without loss of the immature growth.

PREPARATION OF THE FIELD

The present-day field practice is based upon the experience gained during the first few years of commercial citrus growing in Porto Rico. Some of the growers who have come to the island within the past 15 years are prone to deviate from this practice, and others who are starting to plant now are not always convinced that it is right under all conditions. Nevertheless, with some minor changes, the earlier practice will continue to prevail because, as was shown by the data collected in field studies, it is built upon correct premises.

The two principal facts to be borne in mind are that (1) the trees must be planted on mounds, and (2) wind protection must be provided before planting is done. Preparation should therefore be started several months in advance of planting. The field should be measured off and stakes placed where the trees are to be planted. Usually the trees are planted at distances of 25 or 30 feet each way. The latter distance is not too great to accommodate grapefruit trees after they reach the age of about 20 years, but until that time 25 by 25 feet is sufficient, and budded orange trees do not usually need more room at any age. Planting 25 by 25 feet will permit of the growing of 69 or 70 trees to the acre. A mound of soil with a diameter of 4 to 6 feet is usually built up around each stake to a height of 18 inches or more, and the trees are planted on top of these to safeguard them from foot rot. On heavy soil where the water table is high the following practice is recommended for trial: Plow as deep as is practicable and follow the plow with a subsoil breaker. Make the beds to extend across the slope of the land, and use each line of stakes as the center of a bed. This may be done most economically by using a road scraper, proceeding in the same manner as when building a road. If this practice is followed the size of the mounds can be greatly lessened.

WINDBREAKS

Protection against wind may be provided by planting annuals or biennials broadcast in the field, and tall-growing perennials in strips at suitable intervals so that they will cross the field at a right angle to the prevailing wind direction. Leguminous plants are desirable for planting in the field because they supply the soil with nitrogen. The crotalarias make efficient windbreaks, and especially *Crotalaria juncea* because of its tall growth. The pigeon pea or gandul (*Cajanus indicus*) is perhaps the second choice among the legumes although *Tephrosia candida* seems to be equally desirable. The gallito (*Agati grandiflora*) grows well wherever the soil is not too dry, and is an excellent nitrogen gatherer. (Fig. 10.) The seeds

FIGURE 10.—Gallito trees planted on the windward side of a young citrus tree

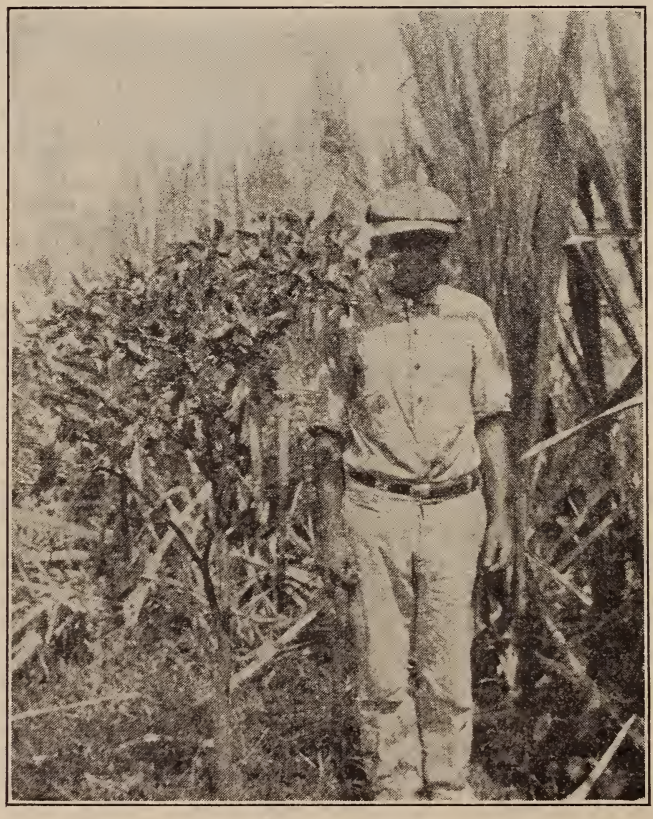

FIGURE 11.—Sugarcane planted for local wind protection

may be sown thinly or broadcast, and the trees will develop similarly to annuals. If they are planted 2 to 3 feet apart these trees will attain good size and serve as windbreaks as long as they are needed. The main drawback is the poor wind resistance of the gallito, which may result in damage to the citrus trees during heavy winds.

Several nonleguminous crops may also be used as windbreaks in Porto Rico. Sugarcane makes a desirable windbreak in places where the crop can be disposed of at a profit. (Fig. 11.) The banana is another economic plant that may be used for wind protection wherever the soil moisture is ample for the development of later crops. Corn is not as extensively used as it might be, at least during the first year. A combination of either corn or sunflowers and climbing peas or beans is desirable. Pigeon peas, planted thinly so as to produce stout plants, will provide a good support for velvetbeans, and afford one of the best combinations both for wind protection and for soil improvement. The latter factor is very important. The soils of citrus groves in Porto Rico can all be greatly improved by the addition of humus, which must be added while the trees are small enough to allow crops to be grown in the grove.

For permanent windbreaks the bamboo has been used extensively. It is objectionable because citrus trees do not thrive in proximity to a bamboo hedge. A bamboo windbreak, therefore, entails the loss of two or three rows of citrus trees but is a fairly good insurance against heavy winds. Most of the tall tropical trees are too slow growing for use as windbreaks, and they are usually less wind resistant than the citrus trees. The so-called Australian pine (*Casuarina equisetifolia*) is promising for the purpose since hedges of it and isolated trees generally withstood the hurricane of September, 1928. (Fig. 12.)

PLANTING AND CULTIVATION

The method of planting citrus trees with a ball of earth surrounding the roots is especially desirable where nursery trees are not shipped long distances. Young, vigorous trees taken up with a ball of earth survive the shock of transplanting without the loss of foliage and with very little loss of roots. If the trees are not removed with a ball of earth adhering to the roots, all the leaves should be cut off, the branches should be cut back to within a few inches of the trunk, and a portion of the longest root and all broken ends should be pruned off. Immediately after the roots are pruned they should be dipped in a thin slurry consisting of clay and cow dung and wrapped in wet sacking. The trees should then be kept in a shady place until they are wanted for planting. The method of planting on top of a mound involves the difficulty of conserving the soil moisture. The mounds should, therefore, be mulched with trash cut in the field, or brought from without, if necessary. (Fig. 13.) The soil surrounding the tree should be well watered at the time planting is done, and then often enough to maintain a high soil-moisture content until root growth is well advanced. An examination of transplanted trees usually shows that on young vigorous trees with thin roots the root scars heal over in a few months and new roots form rapidly enough to support the leaf growth; and, on the other hand, that on old trees with dormant and thick roots the root scars do not heal quickly.

FIGURE 12.—Double windbreak consisting of bamboo and Casuarina

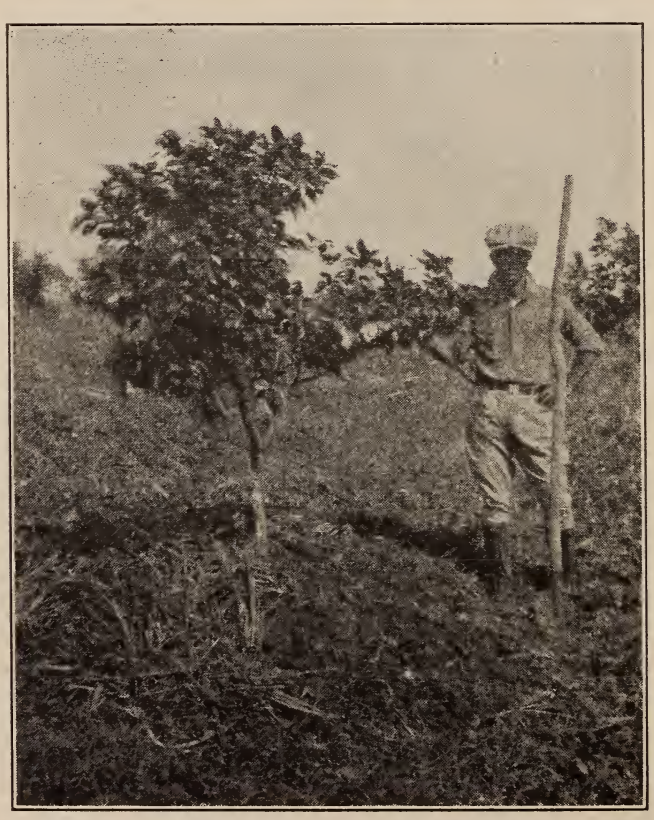

FIGURE 13.—Young tree planted on mound with the soil well mulched. Note mulch has been removed from one side

Decay may set in before the scars heal, continue into the trunk, and eventually cause the death of the tree. The root growth of such trees is frequently too slow to permit the sap to reach the leaves rapidly enough to prevent wilting, especially when the air is dry and moving fast.

The value of wind protection for young trees is mainly that of maintaining a humid atmosphere. With the checking of excessive air movement the tree may survive under conditions which would make growth impossible without wind protection. The checking of excessive air movement also promotes the growth of beneficial fungi.

FIGURE 14.—Two-year-old tree which was planted on mound. The mound has practically disappeared and the crown roots are exposed

This was noted in the groves first planted on the island. Most of the trees in these groves were severely attacked by the purple scale, which was not kept in check by beneficial fungi until after wind protection was established. Nowadays newly planted trees which are similarly exposed do not suffer from scale to such an extent, because the beneficial fungi, especially the red-headed fungus (*Sphærostilbe coccophila*), seem to be able to maintain themselves under more adverse conditions than formerly. Planting tall-growing plants for cover crops among the young trees has nevertheless proved to be a most economical and time-saving practice in the establishment of citrus plantations. Under this practice cultivation during the first few years consists in plowing under as soon as it matures each crop of

plants grown for wind protection and planting another as soon thereafter as possible. In establishing a grove the first point needing consideration is the maintenance of such wind protection as will afford the most favorable conditions for tree growth and eliminate the necessity of spraying. The second point is determining the best method of improving the soil so that it will continue to support growth during the many years the trees are expected to produce profitable crops.

The only treatment required by the tree mounds is that of keeping them free from weeds and sufficiently well supplied with trash to maintain a high degree of soil moisture. The soil will gradually level down and after a few years will leave the trees with the

FIGURE 15.—Tree which was planted on mound. Crown roots are well exposed and trunk is free from gum disease

crown roots entirely exposed. (Figs. 14 and 15.) These roots should be carefully protected from injury. No implement of any kind should be allowed in the proximity of the trees, and weeding should be done by hand. Plows and harrows may be used 4 to 6 feet from the tree trunk. Annual deep plowing is advisable, but intermittent plowing is inadvisable. If plowing is deferred for several years the large roots within reach of the plow are likely to be cut, and the tree may thus be seriously injured.

The time and necessity for cultivation and the kind of implement to be used vary with the different local conditions. In one 20-year-old grove where the medium heavy clay soil is kept moist with water from surrounding springs, plowing and cultivation have not been practiced since the trees were young. Para grass (*Panicum barbinode*) grows luxuriantly in the grove and is cut at intervals. Most of

it is left to serve as a mulch. This practice is not advisable where soil moisture is not abundant at all times. The general practice is to plow or to cultivate, or to do both, although in some heavily fertilized groves the soil seems to retain its moisture well under a luxuriant growth of Para grass. Disk plows pulled by tractors are being used successfully, but the area that can be plowed naturally decreases with the spread of tree growth. In the older groves plowing is usually confined to two or three furrows in the spaces between the rows of trees. Disk or cutaway harrows are used almost entirely for cultivation.

FERTILIZING

A study of the practice followed locally in fertilizing citrus trees showed a lack of uniformity in the mixtures used, the quantities applied, and the number and times of application. The quantities applied differ greatly in the various groves, but applications are usually made in excess of 50 pounds per tree annually. In some instances 60 to 80 pounds are applied and in others 100 pounds annually are applied to each large bearing tree. Such large quantities may not always be necessary for maximum tree growth and fruit production, but the practice has undoubtedly much to recommend it, inasmuch as many growers seem to find it profitable. The number of applications varies from two to three or more a year. Many growers apply half the fertilizer in November or early in December and the other half in June. Some who question the desirability of this practice apply fertilizer three to six times a year. The practice of making four to six applications seems to have nothing to recommend it, but three applications are undoubtedly preferable to two. An application in December has a tendency to bring on bloom not later than February. However, since the fertility of the soil may not be sufficient for the development of the fruit, it may be well to make a second application about March 1 and a third application about June 1.

For present purposes the question of fertilizing may be summarized as follows: With few exceptions the aim is to ship most of the crop before October. This can be done provided the bloom appears in January. Often it does not appear until toward the end of February, in which case the fruit has only six months or slightly more in which to develop. Such fruit is not usually very palatable, even though it may pass the Government maturity test, and can be improved in quality by being left on the tree six to eight weeks longer. In other words, the bloom should appear in early January in order that the fruit may have a chance to mature early in September.

Although no infallible method is known at present for inducing the trees to bloom in early January, the following practice, if consistently employed from the time the trees are young, may produce the desired result. Apply fertilizer about December 1 and follow with plowing and cultivation. If a bloom is induced about the latter part of January or the first part of February, apply fertilizers again the latter part of February and continue cultivation until about June 1. Then apply fertilizers again and cease cultivation until the first of December. If the trees are far enough apart to permit growing

other plants, a cover crop may profitably be planted at the time cultivation ceases.

In regard to the kind and amount of fertilizer to be used, the following suggestions may be helpful: Suppose a planter has found by experience that it pays him to apply, say, 60 pounds per tree annually of a 6–8–10 mixture (3.6 pounds nitrogen, 4.8 pounds phosphoric acid, and 6 pounds potash). Rather than divide the mixture into three equal parts, let him use 20 pounds of a 3–2–2, or 10 pounds of a 6–4–4 mixture in December, 20 pounds of a 2–3–3, or 10 pounds of a 4–6–6 mixture in March, and 20 pounds of a 1–3–5, or 10 pounds of a 2–6–10 mixture in June. The reason for this suggestion is obvious. The aim is to have the fruit mature early and the tree attain as high a stage of dormancy as possible by early December; hence the minimum amount of nitrogen in the June application and cessation of cultivation during the summer. In December the aim is to break the dormancy of the trees as quickly as possible; hence the large amount of nitrogen in the application, followed by intensive cultivation.

The following observation will serve to emphasize some of the problems in citrus fertilization. It was found during the past year that small trees in 25-gallon containers continued growth even when the soil nitrogen content was very low. It was also observed that wild trees produce considerable growth and fruit in soil containing only small amounts of plant nutrients. This indicates that the citrus tree can supply its needs from very weak soil solutions. Field experience, on the other hand, seems to show that for quantity production and early maturity liberal amounts of fertilizers are necessary.

In regard to methods of application, most growers apply the fertilizers broadcast in groves 6 years old or more. Some claim to get better results by applying it in a narrow band around the tree, about as far from the trunk as the spread of the branches. Others who are now irrigating apply the fertilizers entirely under the tree, in a space radiating from the trunk to the tips of the branches. The results obtained from these different methods will soon show which is the superior one.

In regard to the kind and amount of ingredients in a fertilizer mixture, variations might be made to meet soil requirements. In very light sandy soils, for instance, there is loss by leaching of some nitrogen and perhaps some potash, but probably not much phosphate. A great deal of phosphate may be found in the upper few inches of such soils at any time during the year. An accumulation of phosphate under such conditions would seem to justify the use of fertilizers containing decreased amounts of the ingredient after a few years.

In clay soils both phosphate and potash may accumulate, but the phosphate is often present in a form that is not available to the tree. Whenever leguminous cover crops are used as a source of nitrogen the content of this ingredient in fertilizers may usually be diminished. The amount to be applied can be partly determined by the appearance of the tree. Applied in excess of needs, nitrogen will cause the rind of the fruit to be coarse and thick.

INSECT AND DISEASE CONTROL

In addition to gumming and various decays of the roots, the trunk, and the branches, the chief enemies of the citrus-fruit industry include scab, several species of scales, and the rust mite. The control measures used for these are not uniform. Some growers spray with Bordeaux mixture for scab, others spray with lime-sulphur, and still others follow the Bordeaux mixture with sulphur in the powdered form. Scale insects can usually be kept in check by means of beneficial fungi, provided that Bordeaux mixture is not used. The use of Bordeaux mixture entails the use of scale washes, and too much spraying is costly as well as harmful to the trees.

A comparison of the efficiency of the different control measures used in the different groves for the past several years fails to show that one is superior to the other. It is generally agreed that Bordeaux mixture is the most efficient remedy for scab, but some growers claim that practically as high a percentage of scab-free fruit can be had from the consistent use of lime-sulphur as from the use of Bordeaux mixture. This may be largely due to the fact that spraying can not be done as often and as efficiently as necessary. Dusting, being much the more rapid of the two methods, may overcome this difficulty, but it has not yet been in use long enough to warrant its recommendation.

The use of Bordeaux mixture is objected to principally because it kills the scale parasitic fungi. Scale insects can be kept in check by spraying the trees with oil emulsion; yet it is not unusual to find groves in which the trees as well as the fruit are very scaly. This may be due to ineffective spraying, or to poorly applied sprays, but usually it is due to neglecting to spray at the proper time. Such neglect is often inevitable, because even with a thorough equipment only a certain number of trees can be sprayed in two to three weeks, and during some seasons spraying must be repeated at two to three week intervals.

Scab attacks the leaves and the fruit of the lemon, the sour orange, and some varieties of the grapefruit tree. The Triumph and the native grapefruit have so far been immune to scab, and the sweet orange is seldom attacked by it. Grapefruit leaves are seldom so severely attacked as to necessitate spraying. However, it may become necessary at times to spray the nursery stock before budding is done unless, of course, the Triumph type is used for stock. When scab is kept out of the nursery it may likewise with great care be kept out of the isolated grove in which the scab-free trees are planted. When scab does attack the young trees spraying should be deferred until the fruit needs it. In fact, it is better to destroy the first year's crop, which consists of a small amount of coarse fruit, than to spray for the purpose of keeping it free from scab. When spraying is resorted to for the second and succeeding crops the following points should be kept in mind: Spray (1) before the bloom appears in order to cover all the foliage, (2) at the time the petals are falling, and (3) often enough to keep every part of the tree covered until the fruit is three-fourths to 1 inch in diameter. These directions apply whether Bordeaux mixture or sulphur is used and whether they are applied in the form of sprays or dust. After attaining a

diameter of about 1 inch grapefruit is not attacked by scab. In view of the fact that many trees have a habit of blooming over long periods, spraying for scab must be done almost continuously where attempt is made to keep all the fruit clean.

The formula for Bordeaux mixture is usually 3–3–50. Some growers use commercial calcium caseinate as a spreader, whereas others use a paraffin oil-soap emulsion, the quantity of which varies according to the hardness of the water.

After sprayings with Bordeaux mixture for scab have been discontinued, sprayings with oil emulsions for scale should be begun and followed with sprayings for rust-mite control. Failure to spray for rust mite has resulted in the shipment of very little bright grapefruit from Porto Rico. That which is called bright usually contains hundreds of rust-mite punctures. Sulphur is the best remedy for rust mite and does the least harm to the foliage and the fruit when applied dry. A dusting machine should be found in every large grove for covering the trees with sulphur after sprayings with oil have ceased. Only the pure sulphur should be used.

Lime-sulphur (1 gallon, having a density of 32° Baumé, to 30 or 40 gallons of water) should be applied for scab control when the trees are the most dormant. When they are blooming the strength should be reduced (1 gallon to 60 or 75 gallons of water), and after the fruit has set and the foliage has matured the mixture should be 1 gallon to 40 or 50 gallons of water. Lime-sulphur, although a fungicide, does not entirely destroy beneficial fungi but does probably injure them. It is also used as an insecticide against the various scales, and when used frequently enough is effective against the rust mite. In the powdered form sulphur can be applied more cheaply and more frequently.

The most common root diseases observed in field studies apparently are the results of cutting the large roots. Injured roots are the rule rather than the exception in cultivated groves, and it is readily apparent that if infection took place as the result of every injury the root system would be continually diseased. One form of root disease which attacks trees growing in certain areas and spreads from one tree to another is not caused by root injury. This disease has been studied by the pathologist of the station for the past two years, but the causal organism has not as yet been found. Fortunately the disease is not very prevalent.

Foot rot appears on the crown roots and lower part of the trunk and causes heavy losses in most of the groves. (Fig. 16.) Observations indicate that the disease can be prevented by planting the trees on mounds so as to expose the crown roots to the air. Such roots are not attacked, but may readily become infected after they are injured; hence the practice of planting on mounds involves a strict adherence to the rule of keeping all cultivation away from the tree. In some of the old groves diseased trees have been saved by removing the soil from immediately around the trunk to expose the crown roots. This practice, however, is successful in sandy soils only; the water accumulating in the excavation during rainy weather would be fatal to trees in clay soil. On land having a gentle slope the excavations could probably be advantageously connected with drainage ditches.

Rebudding which was done years ago has been the cause of much trouble. The large trunks were not always properly cut and the scars properly covered; as a result the trees started to rot and could be saved only by means of tree surgery. This consists in removing all dead wood and filling the cavity with some material such as Portland cement. Cement is not always satisfactory, because it usually shrinks away from the sides of the cavity. Once water gets between the cement and the tissue the decay proceeds more rapidly than ever. Asphalt has given better results than cement, but is satisfactory only when used by skilled workmen. The cavities may also be left open provided they are well cleaned out, waterproofed, and drained.

Some growers plant three or four seedlings around an old diseased tree and inarch them into the trunk. By means of this treat-

FIGURE 16.—Tree which was planted on level ground. Crown roots are not visible and the trunk is infected with gum disease

ment and the giving of proper attention to wounds, the life of the tree may be prolonged. Wounds should always be treated with Bordeaux paste, or some wood preservative that will not injure the live tissue. Of late years gas tar has been used by many growers. It is not always suitable, but the grade produced and sold in San Juan does not seem to injure the live tissue of the tree. In choosing a wound dressing it is well to keep in mind the fact that such materials as Bordeaux paste and other similar antiseptics do not make the wound water and air tight. They must be followed by an application of tar, asphalt, or some other preparation that will form a perfect permanent seal.

Wither tip or die-back of the small branches causes considerable loss in some of the groves. Like the various gum diseases of the trunk, wither tip is associated with fungi. Losses from it are small

unless the trees are suffering also from a lack of moisture or nutrition. The remedy is, of course, to keep the tree growing, which is not always possible because of climatic conditions. The tree, therefore, must be constantly watched and the dead tips and branches pruned off at the termination of a dormant period. New growth may start from the live tissue, and the dead parts may drop, but very frequently the decay continues unless the dead tissue is removed by pruning. Wounds following the removal of branches one-fourth inch in diameter or over should be dressed.

Two decays cause appreciable damage to citrus fruit in Porto Rico after it is picked. One decay is due to the blue mold (*Penicillium italicum*) and sometimes to the green mold (*P. digitatum*). These fungi do not usually enter the rind of the fruit unless it has been bruised or mechanically injured and do not seriously attack grapefruit because the rind does not bruise readily. They are a very serious pest of oranges having a thin rind, especially oranges grown in the mountain districts. The avoidance of bruises is not always possible under local conditions, and dipping bruised fruit in a borax or sodium bicarbonate solution is not very advantageous. Even cooling to a temperature of 40° F. or below does not prevent bruised fruit from decaying. The method suggesting itself for stabilizing the mountain-orange industry is that of handling without bruising, whenever that is possible, and precooling and shipping under refrigeration. The oranges of the mountain districts are of fine quality and can be grown cheaply and should therefore be entered on the market in competition with oranges from elsewhere.

The other decay is the so-called stem-end rot caused by the fungus *Diplodia natalensis*, which results in great loss to grapefruit growers in Porto Rico. Like the Penicillium fungi, the Diplodia fungus does not usually enter the rind of fruit unless it has been bruised. Since it is usually found about the stem the name stem-end rot has been given to it. The fungus may enter through the stem end before the fruit is picked, in which case it almost invariably drops soon after. Usually very little fruit drops because of Diplodia infection in Porto Rico. After the fruit is picked the fungus enters through the stem scar or through the stem cavity after the button loosens. The latter is the usual mode of entrance because the space under the calyx always harbors dirt and fungus spores. Two remedies have been tried to control stem-end rot in Porto Rico. One consists in disinfecting and sealing with shellac the cut end of the stem at the time the fruit is picked, but it did not prove to be efficient for the reason that respiration of the fruit is very high in the usual air temperature in Porto Rico. When respiration is vigorous the gas exchange is very much greater through the stem end than through any part of the rind; consequently sealing does not endure and infection readily takes place once the seal is broken. The other remedy tried consists in removing the button and sealing the stem cavity, but that has not been found successful locally, at least not with the early fruit. In removing the button from fruit that is not thoroughly mature the rind is torn on a great many specimens, and infection follows.

Diplodia will be much less of a problem in the future since precooling and a more efficient refrigeration are now available on the steamers.

HARVESTING AND HANDLING

The work of harvesting and handling the fruit in Porto Rico is better systematized than any other part of the industry. The fruit is picked by means of clippers, and generally it is carefully handled. It is transported from the field to the packing house in field crates, of which several suitable kinds are to be found on the market. Most of the packing houses are equipped with standard machinery, and use standard methods throughout. Packing-house problems awaiting solution include coloring, cleaning and grading, and decay.

Coloring the fruit artificially is necessary early in the season because citrus fruit does not change color from green to yellow as soon as it reaches the stage of maturity at which it is edible. Coloring is induced by keeping the freshly picked fruit in an air-tight compartment for varying lengths of time, at varying temperatures, and with varying amounts of ethylene. Variations in the above-mentioned factors are due to variations in the coloring quality of the fruit. These have been studied by the writer for many years, and some of them may profitably be discussed at this time.

One set of variations is due to differences in dormancy of the rind tissue. Starvation of the tree or prolonged drought causes the rind of immature fruit to turn yellow, after which irrigation and fertilization with nitrogen may cause it to turn green again. Fruit which has turned partly yellow because of tree dormancy is readily colored by means of ethylene even when very immature; whereas fruit which has again turned green because of renewed growth is very difficult to color by any method. This helps to prove that the trees should not be fertilized and cultivated later than about June 1 if they are to produce marketable fruit in September. Of course adverse weather conditions may upset all calculations, and some trees may remain in a vigorous condition long after others have become dormant. The desirable state of dormancy or colorability of the rind can be determined by measuring the catalase content. This has not as yet been correlated with the amount of gas needed nor with other coloring-room conditions.

Rind blemishes and covering of various kinds cause differences in colorability. For example, the rind of fruit which is attacked by scab can not readily be colored artificially, probably because of a change in the surface tissue which practically inhibits respiration. The effect of the purple scale (*Lepidosaphes beckii*) is similar to that of scab. Fruit which is infested with scale may color perfectly when left to mature on the tree. However, when the fruit is picked green and colored artificially the spots underneath and immediately surrounding the live scale will be found to remain green and the green spots to contain more catalase than the surrounding tissue. The rufus scale (*Selanaspidus articulatus*) produces the very opposite effect. The spots covered by it are light yellow long before the fruit reaches maturity, and the colorability of the intermediate rind is not affected. Fruit that has been sprayed with oil emulsions shortly before it is picked is not readily colored by ethylene, probably because of the oily covering which inhibits respiration. The same effect is produced by any covering which leaves a thin film

on the rind. Coloring is greatly retarded by washing the fruit in soapy water, or by running it over the polishing brushes, during which process some of the oil cells in the rind may be ruptured.

Before it is packed the fruit is soaked in water usually containing some detergent, after which the extraneous matter is removed by brushing machines. The surface of the rind is often covered with various scales and scale-destroying fungi and also with dust and spray residues. This covering when dense is very hard to remove. Of the many different soaps, emulsions, and soap powders tried at the station for the purpose, a soft soap of the nature of shaving cream when mixed with water to the consistency of lubricating oil was found to give the best result.

After the fruit is washed and polished it is sized by mechanical sizers and graded by hand according to color and blemishes. For the latter kind of work standards of comparison have been generally agreed upon by the growers, but the agreement is not always adhered to.

Attack by decays such as blue and green molds and stem-end rot, which follow injury to the fruit, may of course be prevented by careful handling of the fruit so as to avoid bruising, by keeping it cooled to a temperature of 40° F., and transferring it directly from the refrigerator to an insulated, refrigerated hold of the steamer. Infection takes place in fruit the rind of which has been torn, especially when the fruit is placed in a hot, moist atmosphere such as prevails in the coloring room or in the hold of a nonrefrigerated steamer. The paper in which the fruit is wrapped inhibits evaporation and moisture conditions then favor fungus growth regardless of where the fruit is stored. The fruit should be thoroughly dried to eliminate as much moisture as possible from around the calyx. Fruit which is well dried and kept in dry air is not nearly so likely to decay as is that which is wrapped and packed. However, since wrapping and packing are necessary and since infection is induced by high respiration, the only remaining remedy is refrigeration. By means of refrigeration both respiration and the vitality of the fungus are greatly lessened.

Infection is likely to take place at any time between picking and refrigeration, and this period should therefore be shortened as much as possible. This matter seems to be understood by growers, and a modern precooling plant has been erected on the steamship wharf in San Juan. After the precooling system is put into practice brown spotting or cold-storage pitting of the rind may become a problem. However, it will not be serious unless the fruit is held at 40° F. or below for some time and can be partly prevented by careful handling. Spots always develop on parts of the rind which has been slightly scratched or squeezed.

SUMMARY

In a study made of the present practice of citrus growing in Porto Rico the origin of some of the methods now in use are traced and those giving promise of best results are discussed. Operations for

which no well-defined methods have as yet been perfected in Porto Rico are considered on the basis of practice successfully used elsewhere.

Commercial planting of citrus in Porto Rico dates from about the year 1901. The first plantings consisted mostly of orange trees, but these were generally rebudded to grapefruit a few years later. The more recent plantings consist almost entirely of grapefruit.

The area devoted to grapefruit approximated 6,000 acres in 1928, when the estimated yield was 1,235,000 boxes of that fruit. The quantity of oranges produced fluctuates from year to year. In 1924 less than a quarter of a million boxes of oranges were exported, whereas the previous year the exportation was nearly three-quarters of a million boxes. Most of this fruit was produced by trees growing in the mountain districts, where they are used as shade for coffee trees.

The commercial citrus groves are located mainly on soils ranging from light beach sand to heavy clay. The sandy type of soil is suitable for citrus culture, provided it contains a fair amount of humus and the water table does not at any time rise to within the soil area occupied by the larger portion of the root system.

In a preliminary study of tree stocks a chemical method was devised permitting of readily differentiating one kind of stock from another by means of the color produced when ferric chloride was added to an aqueous extract of the root bark.

The selection of seeds for the production of stock as well as of seedling trees is emphasized, and nursery methods suitable to local conditions are described. Bud selection, based upon recognized, desirable trees and fruit characters, is discussed.

Field methods, based upon practical experience in Porto Rico, are outlined. These include the provision of windbreaks for the citrus tree and the planting of the latter on raised mounds. Planting such permanent windbreaks as the bamboo or other similar tall, quick-growing plants is recommended. The use of smaller plants, grown among the citrus trees as windbreaks, also is advocated, especially for young plantings. The purpose of the latter is primarily that of maintaining as high an air humidity among the trees as possible. By this means scale insects, which are very destructive to citrus trees, are kept in check by scale-destroying fungi.

The planting of citrus trees on raised mounds is described. By the use of this method the crown roots become exposed after the mound subsides, which effectively prevents foot rot, a disease doing considerable damage to citrus trees planted too deep.

Fertilizing, based upon local field experience, is discussed. It is pointed out that most local planters apply 50 pounds or more of mixed fertilizer to each bearing tree annually, and that some apply as much as 100 pounds to large bearing trees. The formulas of the various fertilizer mixtures used are too variable to serve as a basis for standardization of fertilizer formulas. The number of annual applications is variable, but the practice of applying the fertilizer three times a year, the first part of December, March, and June, is desirable for bearing trees.

Mention is made of the destructive insects and diseases commonly encountered in citrus groves and after the fruit has been picked, and a brief description is given of the control measures commonly employed for them.

Harvesting and handling of citrus fruits is fairly well standardized, but some of the packing-house operations need further perfecting. Coloring of fruit artificially in the early season and the various factors affecting coloring have been studied and are discussed.

U. S. GOVERNMENT PRINTING OFFICE: 1930