THE IMPROVEMENT OF ROOT-STOCKS USED IN FRUIT PROPAGATION

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FOR many years it has been clearly recognized that the root-stock has an important influence on the scion and on the quantity and quality of the crop produced, yet very little experimentation has been devoted to root-stock problems or to the determination of the best stocks to use.

It is true that these matters are discussed at almost every convention of fruit growers and much information based on experience has been recorded. In general, the discussion and indeed all consideration has been limited to the effect on different varieties of certain root-stocks which are themselves usually very variable species. In citrus fruits, for instance, all consideration has been limited to a discussion of whether one should use sour orange (*Citrus aurantium*), sweet orange (*Citrus sinensis*), grapefruit (*Citrus grandis*), lemon (*Citrus limonia*) or trifoliolate orange (*Poncirus trifoliata*). These species are not composed of stable, uniform groups of individuals but are exceedingly variable, each containing many hundreds of different types. No attention has been given, however, to the reactions that may be expected from the use of different types within the species. The same statement applies equally well to the various stocks used for apples, peaches, pears and similar fruits.

It seems clear to the writer that this is fundamentally wrong, and yet before any generally accepted policy can be overthrown, evidence must be found definitely to show that it is wrong. The

writer for the last five years has been engaged in the study of this problem in connection with citrus fruits and the evidence obtained will probably apply just as definitely to other fruits as to citrus. The following is an outline of the experiments and results of a study of this problem with different varieties of citrus.¹

VARIATIONS IN NURSERY AND ORCHARD TREES

Citrus orchards show great variation in the yield of different trees in the same orchard. This variation is known to be universal even in orchards of the same variety that have been planted with the best obtainable trees. Some orchards are quite uniform, however, while others are exceedingly variable. Batchelor and Reed have shown² that the trees in the most uniform groves will vary from 30 to 40 percent of the mean.

Mr. A. D. Shamel and his associates of the U. S. Department of Agriculture have emphasized the relation of the character of the buds used in propagation to this variability in the orchard and have rightly urged the importance of choosing buds for propagation from uniformly high yielding trees known to produce only fruits of standard type.³ Is this the only factor involved?

It is a well known fact that nursery trees as they are normally grown when two years old and ready for sale exhibit great diversity in size, the trunks frequently ranging from $\frac{3}{8}$ inch to $1\frac{1}{2}$ inches in diameter. Does this variation in size of trees of the same age

¹Webber, H. J. Selection of stocks in citrus propagation, California Agricultural Experiment Station Bulletin 317, January, 1920.

²Batchelor, L. D. and Reed, H. S. Unpublished investigations.

³Shamel, A. D. *et al.* Citrus fruit improvement, U. S. Department of Agriculture Bulletin 623, July 22, 1918; Bulletin 624, July 25, 1918; Bulletin 697, Sept. 27, 1918 and Farmers' Bulletin 794.

WASHINGTON NAVEL ORANGE TREES

These are average-sized trees chosen from the test rows of large, medium and small nursery trees planted in the orchard in June 1917 and photographed May 1919. They have now been in the orchard three years and still retain their comparative differences in size, each grade, from the smallest upward, being about two years behind the next larger one in development. (Fig. 1.)

mean anything or is it purely accidental? All of these trees are ordinarily sold and planted. Probably these differences in size are due to the same or similar causes as those responsible for the differences in size in bearing orchard trees.

A nursery grown at the Citrus Experiment Station for experimental purposes was planned with the idea of producing as uniform trees as possible. The sweet seedling stock used was thus selected when it was planted in the nursery, many of the small trees being discarded. Through the kindness of Mr. Shamel, the buds used for propagation were taken from record trees of standard type in order to further insure uniformity. Valencia and Washington Navel oranges, Marsh Seedless grape fruit and Eureka lemon were the varieties grown. When this nursery was two years old and ready for orchard planting the trees were found to show the same variations in size of buds that have been referred to as being universally present in ordinary nurseries. Had buds been taken indiscriminately from ordinary trees this variation would have been passed by as normal. As it was, this fact lead to a test of the different sizes of trees to determine, if possible, whether these differences in a nursery were of any importance in growing an orchard. Eighteen large, eighteen small and eighteen intermediate sized budded trees of each variety were selected and planted in comparison rows in the variety orchard at the Citrus Experiment Station, Riverside, California. These trees were all dug "bare root" to see that the roots were normal and not injured or diseased. All trees used in the experiment were normal and thoroughly healthy so far as could be determined. They were planted in the orchard in June, 1917. The severe heat coupled with "bare root" planting injured so many of the Eureka lemons that this variety was eliminated from the experiment. The Navels, Valencias and Marsh Seedless grapefruit stood the transplanting very well.

These trees have now been in the orchard three years and are five year old buds. They still retain the same comparative difference in size just as markedly as when they were transferred from the nursery. The large trees retain their lead and are still large. The intermediate are still intermediate in size and the small are still small. After two years in the orchard the small trees were about the same average diameter that the intermediate trees had when they were transplanted and the intermediate sized trees after two years in the orchard were about the same average diameter as the large trees when they were transplanted. Each grade is thus about two years behind the other in development. (Compare Frontispiece and Figs. 1 and 2.)

To get some indication of the comparative average size of the tops of the different groups, the top diameter of each tree was measured east and west, north and south and the height from the lowest branch to the top of the foliage. These measurements for each tree were multiplied together to give the volume of the cube that would enclose the top. The averages of these figures for each group in each variety are given in the following table.

Average Comparative Size (in cubic inches) of Tree Tops, as Indicated by Product of East and West Diameter x North and South Diameter x Height from First Branch to Top.

	Large	Intermediate	Small
Navels.....	54,174	20,185	12,541
Valencias	29,003	15,606	12,953
Grapefruit.....	26,343	15,827	10,642

While admittedly such figures are not exact measures of the top volume, they are believed to represent fairly accurately the comparative sizes of the trees in each group.

FACTORS CAUSING VARIATION

To what factors could this variation be due and is it of any importance in citrus propagation? A difference in the soil or in the nutrition available might cause variation in size but this cannot be the main cause of the varia-

tion in size of these trees as they showed the difference in the nursery and continue to show it three years after transplanting into the orchard. In the orchard they are planted close together on uniform soil and are treated alike, so the difference cannot be attributed to local soil condition or nutrition.

Is the difference due to the character of the bud union? The buds seem to have healed nicely in all trees used and exhibit no characters indicating that the formation of a poor union could be considered as causing the difference.

Is it due to the roots having been injured thus resulting in dwarfing the tree? The roots were all examined when the trees were transplanted and all were found to be healthy and uninjured. Any injury or disease contracted since the trees were transplanted could not be limited to the small tree rows only.

Is it due to the kinds of buds used? All that can be said regarding this is that the buds were carefully selected from trees of known record and standard type. It does not seem that the difference is to be explained in this way although this possibility cannot be entirely eliminated.

IMPORTANCE OF SEEDLING STOCKS

The only other factor that is likely to be the cause of the variation is the influence of the stocks used. The sweet orange stock used was merely ordinary sweet orange seedlings grown from unselected seed, the only extra precaution taken being merely to discard the smallest seedlings when transplanting from the seed bed. About 15 percent of the total number of seedlings were discarded at that time. The universal custom pursued at present is to use either sweet, sour, grapefruit, lemon or trifoliate orange stock without reference to any particular kind within these great groups. Are the variations within the ordinary lots of sweet and sour orange seedlings sufficiently great to be assumed to account for these variations in size of nursery trees? Fortunately some evidence has been secured bearing on this point.

In 1915 the writer, with the help of Mr. W. M. Mertz and Mr. E. E. Thomas, made an examination of one sour orange nursery and selected sixteen seedlings that appeared to show different characters. At the same time in the same nursery four different types were selected in a bunch of sweet seedlings. A more detailed examination would doubtless have revealed many more types but the only object in view at that time was merely to add "freaks" to our variety orchard. Buds were cut from each of these seedlings and two sour orange stocks were budded with each type. The trees from these buds are now five years old from the bud and have been set in the variety orchard for three years. All of the types selected present marked differences in size, foliage, character of branching and the like. The good vigorous types in the case of the sour orange selections are five times, or more, larger than the slow growing dwarf types. An indication of this great difference can be obtained by comparing the photographs of three typical trees shown in Figure 3, A, B and C. A represents a fine, vigorous, growing sour orange type while B and C represent slow growing, probably dwarf types. Similar differences in leaf size and shape are also exhibited. Compare for instance the size of leaves in A with those of C, which are both healthy trees. Two trees out of 16 of the sour orange types selected have lost the typical aroma of the sour orange, so far as the leaves are concerned. The four types of the sweet orange also differ in similar way in size and foliage characters.

The great extent of this range of variation within the different species is shown equally as well by the large number and range of the named varieties that are grown.

The sweet orange and sour orange seedlings grown for stock purposes are usually or at least frequently grown from seed, of unknown origin, and taken from different trees. We are not dealing with a homogeneous lot but with lots in which every individual differs from every other individual and

MARSH SEEDLESS GRAPEFRUIT TREES

Average-sized trees chosen from the test rows of large and small nursery trees planted in the orchard June 1917 and photographed May 1919. These, too, have continued to show the same comparative difference in size as they had when in the nursery. (Fig. 2.)

yet our policy has uniformly been to use all—good and bad alike—for propagation. Is it any wonder under these conditions that our trees though grown from the best selected buds should be variable in the groves?

The Eureka lemon on a trifoliolate stock is very markedly dwarfed while Valencias grow to good sized trees. The Florida rough lemon is usually a good stock while the Chinese lemon is commonly recognized as a poor stock. Different reactions on the bud caused by the influence of different stocks are well known to exist. When therefore such marked differences are found to exist in the sour and sweet orange seedlings that we are using as stocks, is it any wonder that the budded trees in the nursery, even when selected buds are used, should grow differently and produce large and small trees and that these differences should continue to

exist when the same trees are grown in the orchard?

The evidence now available very strongly points to the conclusion that the differences in size of nursery trees such as those taken for the experiment outlined are mainly to be attributed to the different nature of the seedling stocks used. If this is true, and it is entirely in line with the evidence as well as with common sense and judgment, it is certainly an element of fundamental importance in citrus propagation.

I would be remiss in caution if I did not call attention to the fact that one very important link in the chain of evidence is yet lacking, that is, the growing of good buds on known stocks of these various types to prove that certain ones give better growth than others. This evidence, however, is partially supplied by our known ex-

A

B

C

DIFFERENT TYPES OF THE SOUR ORANGE

A, a good, typical form with vigorous growth and excellent foliage and branching characters, selected as a good stock type; B, a type of medium size and rapidity of growth; C, a slow growing dwarf type with small leaves. (Fig. 3.)

perience of the reaction of buds on different stock such as referred to above.

DIFFERENCES INHERENT IN STOCKS

Will the small trees continue to remain small? Certainly the evidence thus far indicates that this is very likely. The probabilities are that they will. Dr. Reed of the Citrus Experiment Station carried out a series of experiments⁴ with a considerable number of sunflower plants that has a bearing on this phase of the problem. In this group of sunflowers, exact measurements of height were made of each plant every week from the time it was a few inches high until it reached maturity. The analysis of the data of growth obtained showed a well marked tendency of the plants to retain their same relative rank as to size throughout the period of growth. Plants which were small at maturity were generally small in the beginning and those which were large at maturity had a well marked superiority from the start. The evidence indicated that height and vigor of growth were determined not by chance but by some definite inherent factor in the plant itself. The same is doubtless true with citrus seedlings of the various species such as those used for stocks and if the cause of the different sized nursery trees is to be attributed primarily to the influence of these stocks as seems probable, then it is also probable that the difference is due to causes inherent in the different stocks and that the same relative rate of growth and size will be maintained in the majority of the plants.

While the evidence is yet incomplete, we are probably justified from what evidence we have in speculating somewhat as to what this means in our fruit industries. Frequently, almost every tree in an orchard will be a fine good grower and fruiter, giving a uniform orchard. Again, an orchard equally well handled may be very ununiform

having some good trees, some poor ones and some of intermediate character. This difference could be accounted for by assuming that the good orchard chanced to be from trees grown on stock that happened to come from seeds of good stock trees or that they had been taken from a nursery where in filling the order of size only the large trees had been dug, which would be the ones naturally on good vigorous stocks. The remaining slower growing trees from such a nursery would ultimately reach the required size and be sold and planted in another orchard which would likely give an uneven orchard with good and bad trees.

Some growers will be inclined at first to think that their experience is contrary to this and that the small tree is more likely to be fruitful while the largest trees are likely to spend their energy in vegetative growth. They must remember that this experience was gained before buds of selected type were used. Mr. Shamel has demonstrated that some types of our varieties tend to produce rapid growth and little fruit while others produce good growth and are fruitful. The results the writer is explaining, however, were obtained with the use of buds taken from the best fruiting types and it is not likely that this type will be changed materially by the stock other than in size of growth.

NEW NURSERY METHODS SUGGESTED

If the results of these experiments are correctly interpreted by the writer it means that our nursery methods in citrus propagation must be materially changed.

(1) We must no longer grow merely sour stock or sweet stock and the like. The process must be carried farther and good stock varieties of sour orange and sweet orange must be discovered and named as stock varieties and every nurseryman should then use seeds from these varieties known to produce good stock seedlings. The trees of these varieties from which seeds are to be

⁴Reed, H. S. Growth and variability in *Helianthus*. American Journal of Botany, Vol. 6, 1919, p. 252.

TWO TYPES OF FRENCH CIDER APPLE TREES

The tree at the left (Marechal) is a small, slow growing variety; the one at the right (Julien de Paulmier) is a large vigorous growing variety. Both of these trees are growing in the U. S. Department of Agriculture's orchard at Arlington, Va., and they are of the same age and on same stock, indicating that the same variation in size applies to other varieties than citrus. (Fig. 4.)

taken to grow stocks must be planted in isolated places so they will not be crossed with other varieties.

(2) Good policy will doubtless dictate that all small seedlings be discarded when transplanting from the seed bed into the nursery. Doubtless nearly 50 percent of the seedlings should be discarded at this time. The writer believes that a severe culling of the seedlings may unhesitatingly be recommended.

(3) In budding a nursery no inferior seedlings found in the nursery should be budded. Doubtless we will hereafter carefully inspect the seedlings just before budding and cut out all in-

ferior ones to save the expense of budding them.

(4) When the budded trees reach the age for transplanting into the permanent orchard only the good, vigorous, growing ones should be used.

The writer assumes that hereafter only buds from trees of known good record and of standard type will be used in propagation. This is already recognized as the only correct and safe policy.

VARIATIONS IN APPLE STOCKS

The evidence secured with citrus varieties discussed above doubtless applies equally well to other fruits such

as the apple. In Australia and South Africa Northern Spy roots have been found to be resistant to the woolly aphis, and apple varieties are now largely propagated on this variety.⁵ Professor J. K. Shaw has recognized the importance of this problem and has conducted extensive experiments in the attempt to grow apple trees on their own roots.⁶

Apple varieties are largely grafted on the French crab or cider apple stocks, the seeds or plants of which are obtained in large numbers from France. Several years ago a considerable number of the different types of these cider apples were selected in France by Professor Alwood and two trees of each of these different types are now growing in the variety orchard of the U. S. Department of Agriculture at the Arlington Farm near Washington, D. C. In November, 1919, the writer had the privilege of making observations on these different types in company with Professor L. C. Corbett and Dr. D. N. Shoemaker, horticulturists of the Department. The variations in the different types are fully as extreme as those found by the writer to exist in citrus fruits. These trees are of the same age and planted on comparatively the same soil and yet some of them are dwarfs while others are giants. As an illustration the two trees of the Julien de Paulmier are much larger and more vigorous than those of the Marechal.

Photographs, of the same comparative size, of trees of these two types were made at the writer's request by Dr. Shoemaker and are reproduced in Figure 4. Seedlings grown from fruits of the Marechal could scarcely be expected to give the same results when used as stocks as seedlings from the Julien de Paulmier. Yet if the writer is correctly informed the seed we use in growing apple stocks are likely to be taken from many different types which are probably as markedly different from each other as are these two. We may desire to use a dwarf stock in some cases and a giant stock in other cases but certainly we should know what we are using.

In the propagation of grapes the specialization has been carried much farther and here a great fund of information has been obtained showing that with certain varieties only certain hybrid stocks will give good results and that on some soils only certain stocks may be successfully employed.

In fruit industries where the trees may grow for many years, possibly even for a century or more, and where continued success depends as much on the stock used as on any other single factor, is it too much to require that the stocks used should be of known quality? The writer maintains that all trees should be propagated on selected stock varieties of known origin and kind.

⁵Cole, C. F., in *Journal Agriculture Victoria*, Vol. 9, 1911, p. 338.

⁶Shaw, J. K. The propagation of apple trees on their own roots. Massachusetts Agricultural Experiment Station, Bulletin 190, 1919.

FOR THE HARD-OF-HEARING

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