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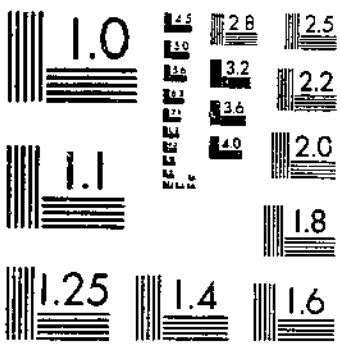

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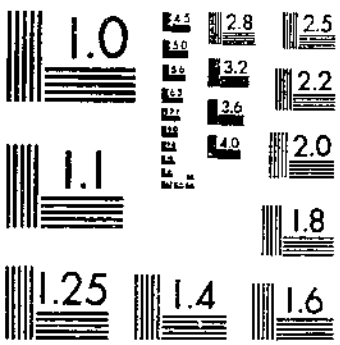

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BUD SELECTION IN THE WASHINGTON NAVEL ORANGE: PROGENY TESTS OF LIMB VARIATIONS

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INTRODUCTION

The Washington Navel orange (*Citrus sinensis* (L.) Osbeck) is one of the most important fruit varieties grown in the United States. Its commercial culture is largely confined to California, and the f. o. b. value of the crop shipped from that State in 1927 was approximately $40,000,000.

The importance of the Washington Navel orange industry is shown not only by the annual crop returns but also by several valuable contributions to horticultural practices which have been made as a result of scientific studies and commercial experience in connection with its development. Among these are improved orchard-heating devices, careful fruit-handling methods and special packing-house equipment, growers' cooperative-marketing organizations, systems for keeping and using individual tree-performance records for bud selection and crop improvement, and the demonstration of the economic importance of adopting and maintaining the fewest possible varieties in commercial fruit culture.

The Washington Navel orange was introduced into the United States from Bahia, Brazil, by the United States Department of Agri-

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culture in 1870 (*32*).[1] Twelve young trees were received at Washington by William Saunders, superintendent of gardens and grounds, and buds from them were propagated on sweet-orange seedlings grown for this purpose in one of the department greenhouses. These greenhouse-grown trees were distributed to various citrus districts of the United States, two of them being sent to Mrs. Eliza Tibbets, at Riverside, Calif., in 1873 (*5, 33*). When the Tibbets trees came into fruiting in the late seventies the valuable commercial characteristics of the fruit, including their quality, shape, size, color, texture, and seedlessness, were soon recognized by the citrus growers of this pioneer community. Local nurserymen obtained bud wood from these trees for propagation, and the resulting nursery trees were planted at Riverside and in near-by citrus districts.

The commercial success of these early orchards soon led to a widespread interest in this variety, so that it eventually became the most extensively grown citrus fruit in California, as shown in Table 1.

TABLE 1.—*Acreages of Washington Navel and Valencia oranges in the five leading citrus-producing counties of California, 1923–1927*

[Data from the annual numbers of the California Crop Report. In 1927 the seven next highest counties reported approximately 10,000 acres of the Washington Navel and 8,500 acres of the Valencia orange]

Year	Acreage	
	Washington Navel	Valencia
1923	90, 355	87, 407
1924	95, 205	87, 666
1925	90, 367	84, 010
1926	86, 817	92, 882
1927	85, 073	95, 892

The commercial shipments of this variety from California for as long a period as data are available are shown in Table 2, in comparison with the production of the Valencia orange, which is the other leading variety grown in that State.

TABLE 2.—*Total shipments of Washington Navel and Valencia oranges from California, 1916–17 to 1926–27*

[Data from Charles B. White, California Fruit-Growers' Exchange, compiled from monthly reports of the railroads]

Season, November to October	Total shipments (boxes)		Season, November to October	Total shipments (boxes)	
	Washington Navel	Valencia		Washington Navel	Valencia
1916–17 [a]	54, 268, 128	5, 305, 178	1923–24	12, 032, 036	8, 923, 601
1917–18	2, 468, 022	4, 234, 211	1924–25 [b]	9, 271, 540	6, 300, 943
1918–19	8, 390, 572	7, 235, 069	1925–26	10, 126, 506	11, 212, 419
1919–20	7, 544, 041	7, 301, 736	1926–27	11, 781, 539	12, 139, 682
1920–21	10, 803, 035	9, 437, 859			
1921–22 [b]	6, 596, 462	5, 111, 892	Total	102, 491, 256	86, 106, 329
1922–23	9, 918, 766	8, 897, 730			

[a] An extremely hot period in June, 1917, greatly reduced the Valencia crop that year and also the crops of both varieties for the following season.

[b] Both the Washington Navel and Valencia crops were affected by frost injury this season, and wind damage further reduced the Valencia crop in some districts in the season of 1924–25.

[1] Reference is made by italic numbers in parentheses to "Literature cited," p. 70.

The young navel-orange trees were distributed from Washington under the name Bahia (*32*), but when the Tibbets trees and others propagated from them came into bearing the name Riverside Navel was used to designate the variety. Later the growers decided to call the variety the Washington Navel in recognition of its introduction by the Department of Agriculture at Washington.

The executor of the estate which later controlled the Tibbets homestead disposed of the two California parent Washington Navel trees. One of them was given to the city of Riverside and was moved in the spring of 1902 to the head of Old Magnolia Avenue, where it still stands in an attractively planted setting, as shown in Figure 1. The other parent tree was given to Frank A. Miller, master of the

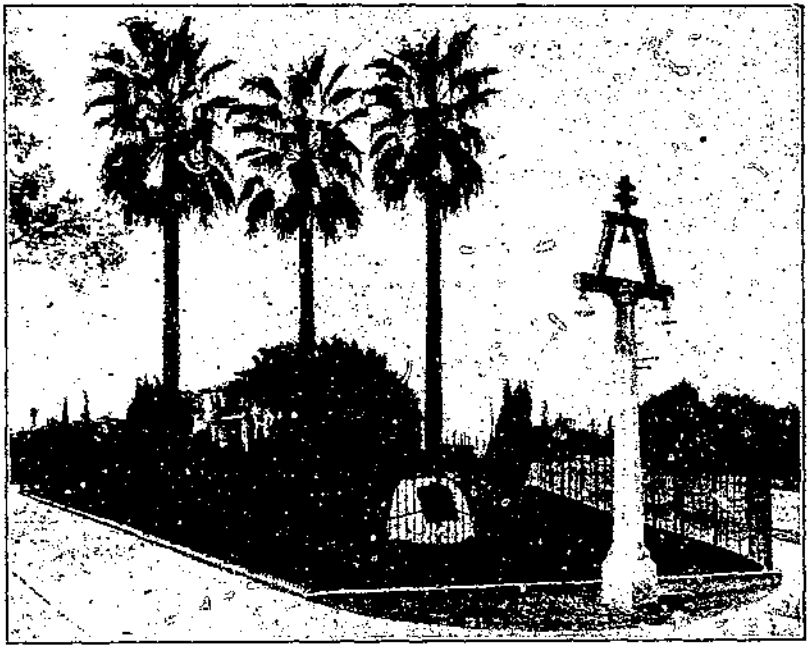

FIGURE 1.—One of the two trees of the Washington Navel orange that were sent to Mrs. Eliza Tibbets, at Riverside, Calif., from the United States Department of Agriculture at Washington, D. C., in 1873. The navel-orange industry of California has been developed from this tree and its companion which died in 1921. Photographed in January, 1928

Glenwood Mission Inn at Riverside, and was planted in the courtyard of that hotel May 8, 1903, by President Roosevelt. It died in 1921 and was replaced March 20, 1923, by an 11-year-old tree which had been propagated from the old one.

BUD VARIATION IN THE WASHINGTON NAVEL ORANGE

The inception of these bud-selection studies resulted from a visit by the senior writer to the packing house of C. E. Rumsey, at Riverside, in April, 1909, when several strongly ribbed Washington Navel oranges were observed in the cull bin. No explanation could be obtained for their occurrence or their source, but a walk into the orchard from which the fruit had come disclosed a limb on one of the first trees examined which bore the same type of abnormal fruits.

Following this discovery a systematic search for limb variations in trees of this variety was begun in extensive orchards belonging to the National Orange Co., and L. V. W. Brown, of Riverside; W. H. Jameson and R. B. Hampton, of Corona; J. S. Edwards, of East Highlands; and in other very successful commercial plantings. During this study more than 100 striking limb variations were found, as well as many individual fruit variations, and a still greater number of entire trees bearing fruits and foliage typical of that borne by various ones of the limb variations.

A statement of the early phases of this investigation was made in Bureau of Plant Industry Circular 77 (*7*), and further reports of the progress of the work have been presented from time to time (*1–4, 6–14*). The 6-year performance records and observations of the trees of the Washington Navel orange which were given detailed systematic study were presented in United States Department of Agriculture Bulletin 623 (*27*).

Propagations of striking limb variations in the trees under investigation were made in 1915 and during subsequent years. The performance records of these progenies, together with a description of the results of these tests, particularly with respect to their bearing on the phenomenon of bud variation [2] and the importance of bud selection in the Washington Navel orange variety, are presented in this bulletin. Progress reports giving partial performance records of some of these progenies have previously been made (*15, 16, 18–24, 26*). Similar investigations are being carried on with the other leading citrus varieties grown in California, and some of the results of these studies have already been published (*25, 28–31*).

The bud variations described in this bulletin can be classified from the economic standpoint as desirable when superior to the normal [3] and as undesirable when inferior to the parent forms for commercial use. In these investigations fewer desirable than undesirable bud variations have been discovered. One reason for this condition may be the fact that undesirable variations are more easily recognized than the desirable ones on account of their more distinctive and readily observed characteristics. Another explanation is that most of the effort used in looking for bud variations in these studies has been devoted to finding those that are decidedly undesirable, so that they might be eliminated from the present and future orchards.

A further classification of the bud variations found in these studies would include those that have been inherently stable when propagated and those that have proved to be inherently unstable in progeny propagations. The degree of inherent stability of the progenies has been found to be about the same as the condition of uniformity in the characteristics of the parent bud variations. If the fruit or foliage of these limb or tree variations was uniform their progenies have been found to be uniform; on the other hand, if there was marked variability of the fruit or leaves in the parent limb variations the progenies have usually been relatively variable.

The bud variations under investigation have been identified largely by their fruit characters. The observed variations include both

[2] The term "bud variation" as here used may be defined as a somatic variation of fruit or foliage which differs in one or more clearly recognizable characteristics from the normal and which is capable of perpetuation through bud propagation.

[3] The term "normal" is used here and elsewhere in this bulletin in the sense of "having the characteristics of the parent Washington or Thomson strains."

quantity and quality differences, and the following quality characteristics have been given primary consideration: Size and shape of fruits, color, texture and thickness of peel, number and arrangement of the pulp sections, size and arrangement of the navel, amount of rag, quality and composition of the juice, and the development of natural blemishes.

Certain vegetative characters of the individual trees have also been studied which for the most part have been found to be correlated to a greater or less degree with observable fruit variations. The rate of tree growth and the natural arrangement of the branches have been found to be rather definitely related to certain fruit characteristics in some cases. The characteristic shape, size, color, and quantity of leaves have also helped in the finding of bud variations both in the case of limb sports and in entire-tree variations.

Washington Navel orange trees are grown from buds inserted in seedling orange root stocks. These root stocks if not budded produce tops bearing seedy oranges of types depending upon the kind of root stock used. Therefore, the occurrence of off-type Washington Navel trees in established orchards can not be explained, as has been attempted in other fruits, as due to the growth of buds from the stock. Furthermore, the similarity of the fruit and foliage produced by the entire tree variations to those of some of the limb sports early led to the conclusion that the off-type trees were the result of the unintentional propagation of similar limb variations.

Certain conditions of the fruit and foliage of Washington Navel orange trees probably result from environmental influences. The local climatic, soil, and cultural conditions affect the quantity and commercial quality of the crop, but such variations are not inherent ones and are not transmitted through budding. In this bulletin only those heritable variations which have been proved to be perpetuated through bud propagation are described, together with an account of their relation to commercial fruit production.

FREQUENCY AND SIGNIFICANCE OF BUD VARIATIONS

The term "undesirable" is here used to mean variations that bear fruits having one or more characteristics that are less desirable than the normal for the variety.

Individual-tree estimate studies in more than 100 representative Washington Navel orange orchards during the period 1909 to 1915 showed that an average of about 25 per cent of the trees in these groves consisted of individuals of very abnormal and inferior strains.[4] Among the undesirable variations that have been found are those that are consistently light in production and those that bear oranges maturing out of the normal season, particularly where the oranges ripen about two or three months later than the normal. Other undesirable characteristics that have been studied include fruits of abnormally large or small size, irregular shape, coarse and unsightly texture of the rinds, unusually thick peel, an excessive proportion of rag, and a small quantity or poor quality of juice.

The tree-estimate studies showed that the proportion of trees of inferior strains was larger in the younger orchards than in the older

[4] The term "strain" as here used designates a group of individuals of a horticultural variety differing from all other individuals of the variety in one or more constant and recognizable characteristics and capable of perpetuation through bud propagation.

groves. This condition was responsible for a rather general belief that the Washington Navel orange variety was running out and becoming unproductive and unprofitable, with the result that for a considerable period there was little further planting of this variety.

An illustration of the manner in which the proportion of trees of undesirable strains was being rapidly increased in young orchards is shown by studies in an old orchard and those made later in a young grove the trees of which had been unintentionally propagated from some of the undesirable variations in the older orchard.

The studies in the older orchard, which was considered to be the most uniformly productive one of that district, showed that 3.5 per cent of the trees were of a particularly undesirable strain. While these records were being obtained two men were observed cutting bud wood for commercial-nursery propagation from some of the very inferior trees. As was the common practice then, no attention was being given to the fruiting condition of the trees, and buds were being obtained from these particular trees because they contained an abnormally large proportion of the vigorous-growing vegetative type of wood which was then considered the most desirable for nursery use.

Several years later a study was made of a young orchard where it was found that approximately 90 per cent of the trees were of the same rank-growing, unproductive, and inferior fruiting character as those which had been observed previously in the older orchard. An investigation of the history of these trees showed that without question they had been grown from some of the buds that were being cut from the undesirable trees in the older orchard at the time the tree-estimate studies were made.

The undesirable trees in the younger orchard were subsequently top-worked and brought into normal production. However, the lack of crops for several years and the expense of the top-working resulted in a large loss to the owner. This occurrence indicates the way in which inferior trees were increasing in the younger orchards through unintentional propagation from undesirable parent trees in the commercial-nursery practice and shows the significance of these variations to commercial fruit culture.

Bud variations in the Washington Navel orange are also important on account of the occurrence of desirable variations of commercial value. Several striking and apparently valuable variations are being grown in progeny-performance record plots, and some of the most promising ones have been selected and propagated for commercial tests of their value.

In studying the progenies of selected parent trees of the best strain of the Washington Navel orange it has been found that some progenies are uniformly more desirable than others. This characteristic has now been perpetuated through two bud propagations, and it seems apparent that in these progenies the uniformity of the growth of the trees and the size, shape, color, and other characteristics of the fruits are above the average for the original strain. The indications are that these superior progenies have originated from desirable bud variations, and they illustrate the importance of bud variation in the improvement of the variety and to the Washington Navel orange industry as a whole.

PROGENY TESTS OF LIMB VARIATIONS

In order to determine whether or not the characteristics of the striking limb variations could be perpetuated through budding, some of the early discovered ones were top-worked on normal Washington Navel orange trees in bearing. These tests proved conclusively that without exception all of the limb variations that were propagated did perpetuate their leaf and fruit characteristics.

These top-working tests led to the propagation of a larger number of limb sports by budding on sour-orange seedling root stocks, as is now commonly done in commercial citrus-nursery practice. One purpose of these experiments was to determine the behavior of the limb sports under ordinary nursery propagation, and another object was to compare the relative tree growth and the quantity and quality of the crops produced by the progenies of limb variations with that of progenies of normal limbs from the same parent trees. The limb-sport propagations in every instance were from unquestioned variations in parent trees which had been grown from a single bud on sweet-orange seedling rootstocks and where the history of the propagation, planting, and care of the orchards were fully known. All these variations showed foliage or fruit characteristics closely resembling those of certain off-type trees in established orchards. These progeny tests have made it possible to study the relation of the occurrence of limb variations to the presence of trees of abnormal strains in bearing orchards and to obtain evidence regarding the importance of the bud variations in relation to the maintenance of the variety, its improvement through the isolation of superior strains, and the possibilities for a more economic production of the Washington Navel orange for the welfare of this industry.

This first general propagation of a number of limb and tree variations, typical of the most important strains of the Washington Navel variety that had been studied up to that time, was made in the spring of 1915. Buds from these variations were inserted in sour-orange rootstocks in a commercial nursery in cooperation with the Citrus Experiment Station of the University of California, and the resulting progeny trees have been grown on the station grounds at Riverside.

The progeny trees were transplanted from the nursery in July, 1917. They were set 10 feet apart in rows spaced 24 feet apart, the close planting in the rows making possible the testing of twice as many progenies as would have been the case had the ordinary spacing been practiced. The planting is arranged so that when the trees reach such a size as to interfere with cultural practices every alternate tree may be removed, thus leaving what is considered to be a normal spacing for this variety in this district.

This orchard was planted on virgin land where nothing but winter-grain crops without irrigation or fertilization had been previously grown. The trees have been given ordinary cultivation, irrigation, and other cultural care. Winter cover crops have been grown and plowed under each year for the purpose of soil improvement. Summer cover crops have been grown occasionally, but have not been particularly successful. Very little fertilizer of any kind has been applied up to the present time, although it is believed that the use of additional fertilizer is now necessary in order to provide favorable soil conditions for future tree growth and crop production. The

trees have made a normal growth thus far and have not suffered serious frost damage at any time, orchard heaters being used at critical periods for frost protection. Little or no injuries from scale or other insect pests of the citrus tree or from citrus-tree diseases have occurred, and the trees may be considered to have made a somewhat better development than is usually the case in this region.

The progeny planting has served two purposes: (1) To prove the transmissibility of certain bud variations of tree and fruit characters and (2) to provide for citrus growers and other persons interested a demonstration of the importance of the work for the improvement of the Washington Navel orange through bud selection. Each year since these progeny trees came into fruiting the planting has been visited by many citrus growers, scientists, and others, not only from California and other near-by sections but also from several foreign countries. In this way the progeny orchard has become of wide interest and value in furnishing living evidence of the fact of bud variation and the importance of studies in bud selection in vegetatively propagated crops.

PROGENY PERFORMANCE RECORDS

The performance records of the progeny trees propagated from the various limb variations of the Washington Navel orange have been obtained by counting the fruits borne by each tree. The oranges have also been classified according to strain characteristics, and for the last five years the weight of the fruits has also been obtained.

The number of trees in each progeny was limited by lack of orchard space. When possible and desirable, progeny trees propagated from a normal limb of the same parent tree have been included with those propagated from the limb variation, so as to make possible a closer comparison of the performance records of the normal with the variation progeny trees. A larger number of progeny trees would have been desirable in some instances, but the writers are of the opinion that enough trees have been studied so that from the data available for consideration reliable and sound conclusions can be drawn. The sets of progenies of the various strains will be considered separately, in order to show clearly the results of these propagation tests. All of the most important strains that have been observed are included in these descriptions.

The Thomson, Golden Buckeye, and Golden Nugget strains have been commercially propagated to a limited extent by nurserymen and growers and have been considered as distinct varieties. These terms are used in this bulletin as strain designations and not as varietal names.

WASHINGTON STRAIN

The term "Washington" is here used to indicate that strain of the Washington Navel orange which has been found to be the most valuable one for commercial culture in California. It is the strain which was first introduced to this country and upon which the reputation of the variety is founded. The trees of this strain, illustrated in Figure 2, are productive and tend to bear regular and successive crops of fruit. They have an open and somewhat drooping habit of growth and dense foliage with large, oval, dark-green leaves. They produce few suckers, in contrast with the large proportion of the

vigorous nonfruiting vegetative growth produced by the trees of the Australian and some other strains. Variations of fruits and foliage are less commonly found in trees of this strain than in those of most other strains of this variety. Under normal conditions no pollen is produced by the anthers of the flowers of the Washington strain.

The fruits, illustrated in Figure 3, are obovoid in shape and generally of medium to large size. The rind is of medium thickness, and the texture is smooth and grained. The color of the fruit is bright orange; the rag is tender and comparatively small in quantity; the juice is abundant and of superior quality, having a pleasing and sprightly subacid flavor. The fruits are seedless, and the navel usually is small, sometimes rudimentary, with no development except in the rind.

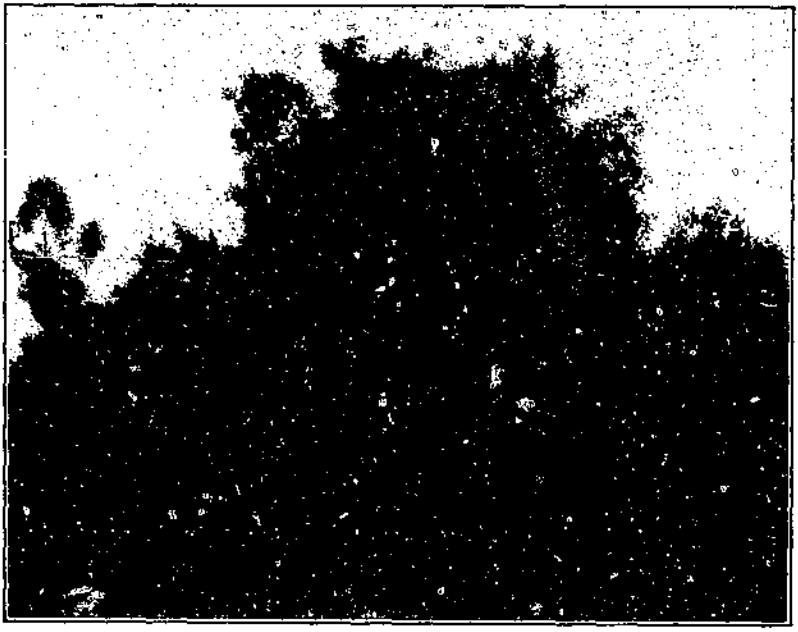

FIGURE 2.—A typical tree of the Washington strain of the Washington Navel orange variety, Corona, Calif. Planted in 1903; photographed in January, 1927

The Washington is the most important of all the Washington Navel orange strains on account of the high productiveness of the trees and the superior commercial quality of the fruit, which is not equaled by that of any other strain grown in California.

Limbs of the Washington strain sometimes occur as reverting variations in trees of other strains of the Washington Navel orange. The performance records of three trees of the Washington strain which were propagated from two limb variations in Thomson strain trees, compared with the records of three trees which were propagated from normal Thomson branches of the same parent trees, are shown in Table 3. Each of these trees has produced only fruits typical of the strain that was propagated.

TABLE 3.—*Records of annual production of progeny trees propagated from limb variations of the Washington strain occurring in trees of the Thomson strain of the Washington Navel orange compared with records of trees propagated from the Thomson portions of the same parent trees*

[All these progeny trees were planted in July, 1917]

Progeny tree No.	Source of buds		Fruits produced by progeny trees									
	Parent tree No.	Limb	Character	Number								
				1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28	Total
7–31	16	Washington limb variation in Thomson tree.	Washington	15	95	98	277	179	249	539	252	1,704
7–32				25	140	104	253	243	278	352	192	1,787
7–35	16	Normal part of same Thomson tree.	Thomson	18	70	73	247	215	235	338	201	1,403
7–43	22	Washington limb variation in Thomson tree.	Washington	9	70	94	428	331	224	327	145	1,628
7–45	22	Normal part of same Thomson tree.	Thomson	22	107	127	296	281	352	545	235	2,025
7–46				7	103	103	269	298	201	466	200	1,647

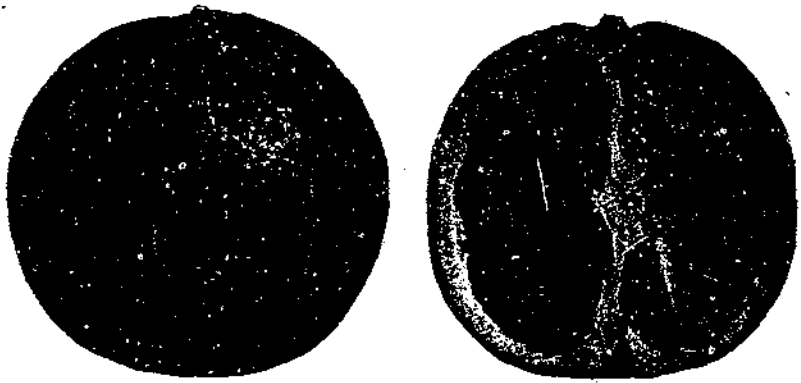

FIGURE 3.—Fruits of the Washington strain of the Washington Navel orange, Riverside, Calif., January, 1912

These performance records show a total production of 5,119 oranges for the three progeny trees of the Washington strain, whereas the three trees of the Thomson strain produced 5,075 fruits. The difference in productivity of trees of these strains is usually greater than is indicated by the comparative yields of these few trees, and such differences are in accord with the yields in commercial orchards under comparable conditions, where, as a rule, the trees of the Washington strain are somewhat more productive than those of the Thomson strain. The fruits of the Washington strain are of better quality and have a higher commercial value in most markets than the fruits of the Thomson strain, and for these reasons the Washington strain is preferred in California.

THOMSON STRAIN

The Thomson strain of the Washington Navel orange has been grown commercially in California for a number of years and has been recognized as an established variety. Recently, however, the commercial propagation of the Thomson strain has been largely discontinued in southern California, and there seems to be little likelihood that it will again be propagated extensively in that district. Indi-

vidual fruits, limb variations, and entire trees of this strain have been commonly found in orchards planted to trees of the Washington strain. The writers have observed more than 100 Thomson limb variations in otherwise normal trees of the Washington strain in California orchards. The late A. C. Thomson, of Duarte, Calif., who introduced this strain commercially about 1891, acknowledged having found it as a limb variation. Because of the proved bud origin of the strain, no propagations of limb variations of this character were included in these progeny tests.

The trees of the Thomson strain are similar to those of the Washington strain except that under comparable conditions they are not quite as vigorous growers and consequently are somewhat smaller in size, sometimes presenting a rather dwarfed appearance. They are more variable than trees of the Washington strain, in both foliage and fruit, one tree frequently bearing several distinct strains. Fruit vari-

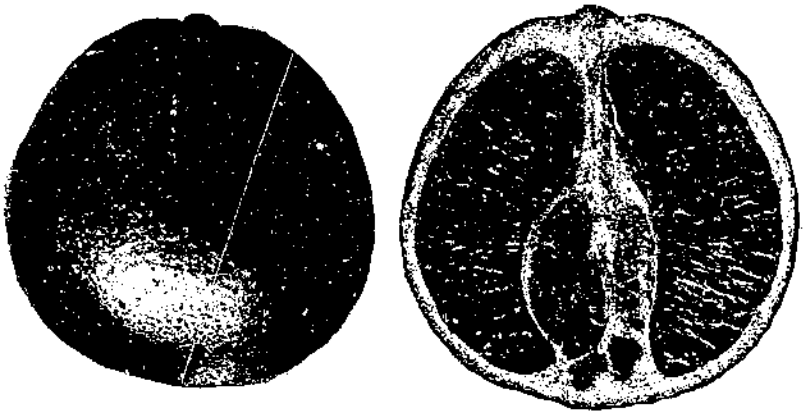

FIGURE 4.—Fruits of the Thomson strain of the Washington Navel orange, Riverside, Calif., January, 1915

ations in established orchards of this strain are so common as to be distinctly detrimental to the value of the crops.

The fruits illustrated in Figure 4 are similar in shape and size to those of the Washington strain. They differ from them mainly in having a very smooth rind of bright reddish-orange color. The rind of the Thomson fruits is usually thinner and the rag much more abundant, coarser, and tougher than that of the fruits of the Washington strain. The fruits mature somewhat sooner, as is shown by the earlier coloring of the rinds and the higher sugar-acid ratio of the juice, making it possible in many instances to harvest them at an earlier date than the fruits of the Washington strain. The smooth texture of the rind as well as the reddish color is of distinct market value, but the juice is less acid than that of the fruits of the Washington strain and is lacking in flavor. The undesirable characteristics of the rag and the inferior flavor of the juice are detrimental to the reputation of the fruits of this strain and are the main reasons for the almost entire abandonment of the further commercial planting of trees of the Thomson strain.

The comparative performance records of five progeny trees of the Thomson strain and five of the Washington strain are shown in Table

4. This shows that the five progeny trees of the Thomson strain have produced a total of 8,914 oranges as compared with a total of 9,359 oranges for the five trees of the Washington strain. These data are fairly typical of the yields of these strains obtained in commercial orchards in California wherever accurate comparable records have been available for consideration.

TABLE 4.—*Records of annual production of progeny trees propagated from normal Thomson limbs in trees of the Thomson strain of the Washington Navel orange compared with records of trees propagated from normal Washington limbs in trees of the Washington strain*

[All these trees were planted in July, 1917, and have borne only fruits typical of the strains that were propagated]

Progeny tree No.	Source of buds	Number of fruits produced by progeny trees								
		1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28	Total [1]
7–40	Normal limb in Thomson tree No. 20	18	115	121	511	334	270	380	122	1,871
7–41		22	39	74	453	325	268	405	230	1,816
7–53	Normal limb in Thomson tree No. 26	2	106	90	247	182	201	354	315	1,497
7–54		22	116	113	234	230	326	531	227	1,799
9–40	Normal limb in Thomson tree No. 105	30	157	93	233	238	315	484	381	1,931
7–11	Normal limb in Washington tree No. 4	30	125	127	505	148	300	522	171	1,928
7–27	Normal limb in Washington tree No. 12	13	98	27	532	249	316	630	163	2,028
7–28		1	91	78	355	131	154	416	143	1,369
9–21	Normal limb in Washington tree No. 78	12	54	116	457	169	324	653	190	1,975
9–22		28	76	141	490	207	387	531	199	2,059

[1] The total production of 5 Thomson trees was 8,914 and that of 5 Washington trees was 9,359.

UNPRODUCTIVE STRAINS

The limb and tree variations of the Washington Navel orange that have been strikingly and inherently unproductive have been segregated into three groups: (1) Those of very light production, but bearing fruits apparently identical with those of the parent strain; (2) those having a very low production of small, wrinkled fruits; and (3) those bearing somewhat larger crops of rather coarse fruits as compared with the other two groups.

These strains are important ones to the Washington Navel orange industry, because the presence of trees of these strains has been proved to be largely responsible for the very low production of several commercial orchards where individual-tree studies have been carried on and is doubtless the cause of low yields in many other unprofitable orchards.

In 1910 the senior writer found a very unproductive limb in a tree grown from a single bud of the Thomson strain in an orchard planted in 1903 at Riverside, which is typical of the occurrence of similar limb variations that have been found in trees of both the Thomson and the Washington strains.

This Unproductive-strain limb is one of the main branches of the tree arising from a point about 3 feet above the bud union, and at the present time constitutes about one-half the growth of the tree. This tree was mentioned on page 25 of United States Department of Agriculture Bulletin 623 and was illustrated in Figures 7 and 8 of that publication (*27*). It was also described and a progress report made on the performance of its progeny in the Journal of Agricultural Research for November 17, 1923 (*15*).

A photograph of the structure of the parent tree is reproduced in Figure 5, in which the Unproductive limb is marked with a white cloth. The branches below the white cloth on all sides of the tree

FIGURE 5.—Trunk and main limbs of the tree of the Thomson strain orange from which the five trees listed in Table 5 were propagated. The limb marked with the white cloth is the Unproductive variation. Photographed at Riverside, Calif., in the spring of 1914

trunk are normal for the variety. A general view of the tree, as it appeared in December, 1922, is shown in Figure 6.

The growth of the Unproductive limb has been somewhat more vigorous than that of the other branches of this tree, and its leaves have tended to be smaller, slightly more pointed, more yellowish

green, and less abundant than the normal foliage. However, during recent years it has become more difficult to distinguish the growth of the Unproductive limb without close examination of the tree structure. There are no apparent differences in time of blooming or in the number or structure of the flowers borne by different branches of the tree.

The orchard in which this tree stands is favorably located, has been given ordinary cultural care, and the tree has never suffered from

FIGURE 6.—A tree of the Thomson strain containing a limb variation of the Unproductive strain, as shown in Figure 5. Progeny trees propagated from this parent are shown in Figure 7, and their performance records are given in Table 5. Riverside, Calif., December, 1922

frost injury, insect attack, or fungous diseases. The tree has been under observation each year since its discovery, but detailed performance records were not obtained from it because of its location some distance from the Washington Navel orange performance-record plots. Lack of time and assistance made it impracticable to obtain yield records from it, as was also the case with many other interesting isolated trees which have been closely observed for a number of years.

The yearly observations of the behavior of this tree, both before and after propagations were made from it, have shown that the Unproductive limb has been consistently unproductive or barren, never having produced more than 6 fruits in any year except in the 1922–23, season, when it produced 14 oranges, 13 of which were borne by one small branch, the foliage of which indicated that it might be a reversion to the original Thomson strain. Subsequent observations have shown that this fruiting branch has continued to bear a few fruits each year, and its performance and appearance have confirmed the conclusion that it is a reversion. The limbs of this tree other than the Unproductive one have produced normal crops each year. The fruits borne by the Unproductive limb are so like those produced by the normal branches that it has been impossible to distinguish between them.

The progeny plantings from this tree consist of three trees grown from buds from the Unproductive limb and two trees grown from a normal branch planted as part of a single row. Two trees of each progeny are shown in Figure 7. The trees have made a vigorous and

FIGURE 7.—Progeny trees of the Unproductive (right) and Thomson strains of the Washington Navel orange which were propagated from a limb variation and the normal part of the tree shown in Figures 5 and 6. The performance records of these trees and an additional one that stands at the right of them are given in Table 5. University of California Citrus Experiment Station, Riverside, Calif., January, 1928

healthy growth and began bearing three years after planting. No pruning or other tree treatments have been given any of these trees, and they have all received the same cultural care, every possible precaution having been exercised to provide uniform environmental influences so that the performances of the individual trees are fairly comparable.

The oranges borne by the progeny trees of the Unproductive strain have been similar in all their characters to those produced by the progeny trees of the normal Thomson strain, as shown in Figure 8.

The more vigorous growth of the progeny trees of the Unproductive limb as compared with the normal has been increasingly marked with each successive year until at this time they are much larger than the progeny trees from the normal part of the parent tree, both as regards size of tree trunks and volume of tree tops. The time of blooming, structure, and other characteristics of the flowers are the same for the trees of both progenies. The shape and size of the leaves are much the same for all of the progeny trees, but the foliage of the trees

of the productive strain, like the parent limb, is more yellowish and less abundant than that of the normal Thomson trees. The habit of growth of the normal progeny trees of the Thomson strain is much more drooping than that of the Unproductive trees. This condition, as well as the smaller size of the trees, may be explained as resulting from the continuous cropping of the Thomson progeny trees as contrasted with the very light yields of the Unproductive trees.

TABLE 5.—*Records of annual production of progeny trees propagated from a limb variation of the Unproductive strain of the Washington Navel orange compared with the records of trees propagated from normal branches in the same parent trees*

[These progeny trees were planted in July, 1917, and all the fruits produced by them have been normal in character]

Progeny tree No.	Source of buds		Number of fruits produced by progeny trees								
	Parent tree No.	Limb	1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28	Total
7–4	2	Unproductive limb variation	1	0	0	28	0	33	68	0	130
7–5			3	0	0	16	0	29	104	0	151
7–6			0	0	1	15	0	8	122	0	146
7–7	2	Normal limb of same parent tree	18	61	56	173	99	283	444	118	1,252
7–8			50	60	72	262	93	261	362	85	1,245

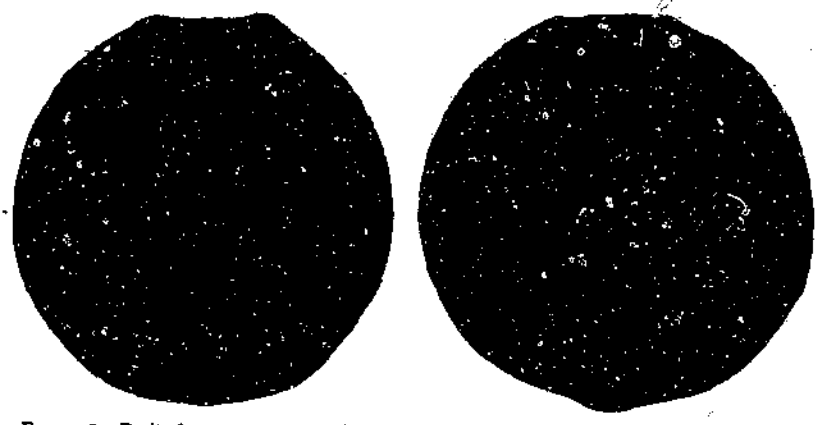

FIGURE 8.—Fruits from progeny trees of the Unproductive (right) and normal Thomson strains, showing their great similarity. These are from trees 7–6 and 7–7 shown in Figure 7 and listed in Table 5, which were propagated from different limbs of the tree shown in Figures 5 and 6. Riverside, Calif., December, 1922

The performance records of each of the progeny trees are shown in Table 5, in which are recorded the number of oranges borne by each tree for each year since they began fruiting. This table shows that trees 7–4, 7–5, and 7–6, which were propagated with buds taken from the Unproductive limb variation, have been consistently low in production during the entire period of this performance record, producing totals of only 130, 151, and 146 oranges, respectively. On the other hand, trees 7–7 and 7–8, propagated from buds taken from the normal Thomson part of the same parent tree, have been normally productive,

producing totals of 1,252 and 1,245 fruits, respectively. The average production each season for the Unproductive and normal Thomson trees is shown graphically in Figure 9.

This striking difference in the productivity of progeny trees is a typical example of the transmission of the quantity-of-production character to progeny trees budded from a similar limb variation. This test also suggests that many of the low-yielding trees in established orchards have probably resulted from the unintentional propagation of similar limb variations where systematic bud-selection practices were not followed. It also illustrates the importance in commercial propagation of the careful selection of bud wood based on performance records and the individual tree studies, in order to avoid the perpetuation of trees of the Unproductive strain or limb variations in otherwise normal trees.

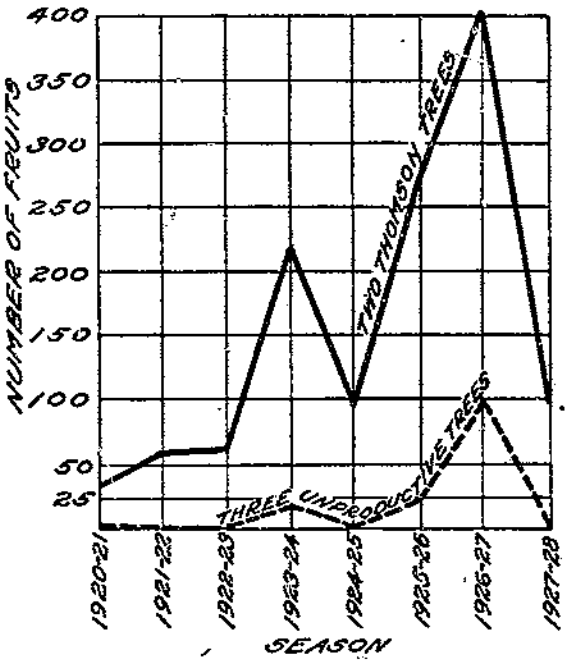

FIGURE 9.—Diagram showing the average number of fruits produced per tree each season by the progeny trees of the Unproductive and normal Thomson strains of the Washington Navel orange which are recorded in Table 5. Four of these trees are shown in Figure 7, and they were all propagated from buds from the tree shown in Figures 5 and 6

The number of fruits produced by all the trees has been considerably reduced in certain seasons by unfavorable climatic conditions. It will be seen, however, that during seasons of low yields the crops of the Unproductive strain trees have been more seriously reduced than have those of the normal-strain trees.

The production of trees of the Unproductive strain in this progeny test has been very unprofitable, whereas the yields of the normal-strain trees have been profitable under the conditions where these trees have been grown. In established orchards of this variety frequently more than 10 per cent of the trees have been of the Unproductive strain, similar to those in this progeny test. The economic loss from the presence of such trees has been large and has been an annual burden to the growers.

The performance records of progeny trees of the two other forms of the Unproductive strains with records of trees propagated from comparable normal-parent trees are shown in Table 6. Progeny trees

8–21 and 8–22 in this table are representative of the second group of the Unproductive strains, bearing very light crops of abnormal fruits. These two progeny trees propagated from an Unproductive limb variation in a tree of the Thomson strain have produced totals of only 112 and 22 oranges, respectively, for the 8-year performance-record period, whereas the comparable progeny trees 7–49 and 7–50 have produced totals of 1,493 and 1,948, respectively, for the same period. The fruits of the Unproductive strain trees have been small, somewhat elongated or pear shaped, with a coarse texture and slightly wrinkled surface of the rind.

TABLE 6.—*Records of annual production of progeny trees propagated from limb and tree variations of Unproductive strains of the Washington Navel orange compared with records of trees propagated from comparable normal parent trees*

[The first four progeny trees were planted in July, 1917, and the others in May, 1919]

Progeny tree No.	Source of buds		Fruits produced by progeny trees								
	Parent tree No.	Limb	Character	Number							
				1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28	Total
8–21	39	Unproductive limb variation in Thomson tree.	Long, coarse, wrinkled.	0	0	0	0	0	19	91	2	112
8–22				0	0	0	4	0	3	14	1	22
7–49	22	Normal Thomson limb in comparable tree.	Thomson	10	95	92	248	223	209	369	247	1,493
7–50				7	107	96	490	288	263	458	225	1,948
31–15	205	Unproductive Washington tree.	Coarse	---	---	4	8	32	166	79	0	289
31–16				---	---	12	4	2	148	32	0	198
31–11	206	do	do	---	---	3	8	12	118	74	0	215
31–12				---	---	9	10	50	146	5	0	220
31–5	202	Normal Washington limb.	Washington	---	2	11	43	129	206	264	33	688
31–6				---	3	17	58	144	221	300	129	872

The four progeny trees—31–15, 31–16, 31–11, and 31–12—make up two progenies representative of the third group of the Unproductive strains of the Washington Navel which bear coarse fruits, but in somewhat larger quantity than that produced by the trees of the two other groups. In this set, the trees of the Unproductive strain have produced totals of 289, 198, 215, and 220 oranges, respectively, for the 6-year performance record period during which these trees have been in fruiting, whereas the comparative progeny trees of the normal strain have produced totals of 688 and 872, respectively, for the same period. The normal-strain trees bore a few oranges one year earlier than trees of the Unproductive strain and have been consistently more productive each season. This record is an illustration of the common experience in the citrus-propagation work in these investigations, which shows that the prolific trees usually begin production earlier than the Unproductive ones. The total production of each of the progeny trees recorded in Table 6 is shown graphically in Figure 10.

The fruits of these progeny trees of the Unproductive strain have had a texture of rind somewhat coarser than those of the normal-strain trees but otherwise have been very similar to them. The differences in the quantities of fruit produced by these Unproductive trees as compared with those of the normal strain have not been so marked as was the case with those shown in Table 5 or those recorded for the first two comparable progenies in Table 6. This condition

is typical of other comparative progeny-performance records in this progeny planting in that the different degrees of variations, productivity, or other characteristics of the parent-limb variations of individual-parent trees have been consistently transmitted to their progenies through bud propagation.

In the instances recorded in Tables 5 and 6 it is evident that quantity production has been transmitted through bud propagation, thus demonstrating the possibility of such inheritance. Variations in production are also sometimes due to soil or stock influences and to differences in cultural practices, but such variations are of an entirely different nature from those described and are not transmitted in propagations.

AUSTRALIAN STRAINS

The name Australian as applied to strains of the Washington Navel orange seems to have been commonly adopted by growers on account

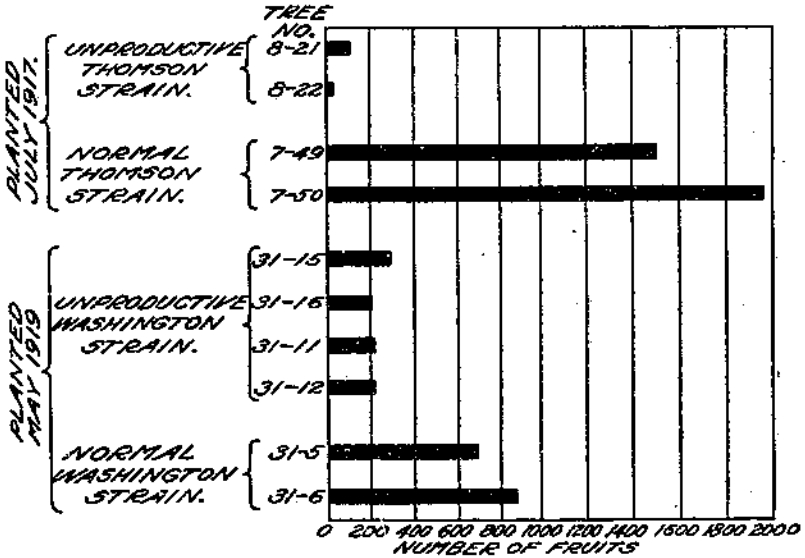

FIGURE 10.—Diagram showing the total number of fruits produced by the individual trees of the Unproductive and normal strains of the Washington Navel orange which are recorded in Table 6

of the resemblance of the trees of these strains to those grown in California at one time to a very limited extent from an early importation from Australia. It has gradually become generally used to indicate rank-growing, unproductive trees bearing coarse, inferior fruits.

The trees of the Australian strains are vigorous and have a characteristic upright habit of growth, as shown in Figure 11. If not kept down by severe pruning, these trees stand out in striking contrast to the trees of other strains of the Washington Navel orange and can be easily identified by reason of their greater height and larger size. They produce a large volume of vigorous vegetative nonfruiting growth, formerly highly prized as bud wood for propagation. They bear light crops of fruits of poor quality. Thus far, pruning and other treatments have failed to improve their fruiting characteristics, and their presence in any considerable numbers in established

orchards is the cause of serious economic losses to the growers. Fortunately, it has been found that these trees can be successfully topworked by using carefully selected buds from desirable trees of the Washington strain, and many thousands of trees of the Australian strain in California orchards have been made profitable during recent years in this manner.

The Australian strains are quite variable and may be classified by their fruit characters as: (1) Small Australian, resembling Washington strain fruit except in size, as shown in Figure 12; (2) Coarse Australian, of large size, globular shape, light color, and very coarse texture of rind, abundant rag, and with small quantities of juice of poor quality (fig. 13); and (3) Wrinkled Australian, of small size, flattened shape, and peculiarly wrinkled around the stem ends, as shown in Figure 14. The fruits are seedless and frequently develop large protruding navels

FIGURE 11.—Progeny trees of the Australian (right) and Washington strains of the Washington Navel orange. These are trees 7-10 and 7-11 as recorded in Table 7. University of California Citrus Experiment Station, Riverside, Calif., November, 1924

which detract from their appearance and market value. The fruits of these three classes sometimes occur on the same tree, but more commonly those of one class tend to predominate, to the exclusion of those of the other classes. For this reason in these progeny propagations the trees have been classified according to the dominant kind of fruit produced by the parent variations and their progenies.

In Table 7 the performance records of 11 progeny trees of the Australian strains are presented in comparison with those of 2 progeny trees of the Thomson strain and 1 of the Washington strain.

The total average production of the 11 progeny trees of the Australian strain for the 8-year performance-record period has been 637 oranges, whereas the total average for the trees of the Thomson and Washington strains has been 1,757 oranges. Figure 15 presents a diagram showing the average number of fruits produced each season by these Australian trees and by the normal Thomson and Wash-

TABLE 7.—*Records of annual production of progeny trees propagated from tree and limb variations of the Australian strain of the Washington Navel orange compared with records of trees propagated from a normal limb of one of the same trees and from a near-by normal tree*

[These progeny trees were all planted in July, 1917, and have produced only fruit typical of that borne by the parent tree or limb]

Progeny tree No.	Source of buds: Parent tree No.	Source of buds: Tree or limb	Number of fruits produced by progeny trees: 1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28	Total[1]
7–9	3	Australian tree, small fruited	0	13	30	70	0	135	318	0	572
7–10	3	Australian tree, small fruited	2	51	37	63	0	233	128	0	514
7–13	5	do	16	0	6	51	0	28	159	0	260
7–14	5	do	9	13	53	165	0	111	128	0	410
7–15	6	Australian tree, coarse fruited	1	59	46	28	0	101	168	0	403
7–16	6	Australian tree, coarse fruited	1	23	48	63	1	210	83	0	429
8–31	40	Australian limb, wrinkle fruited in Thomson tree	9	64	31	165	45	146	315	100	875
8–32	40	Australian limb, wrinkle fruited in Thomson tree	24	75	87	258	102	107	209	55	917
8–39	52	Australian tree, wrinkle fruited	10	89	31	60	37	158	320	240	945
8–40	52	Australian tree, wrinkle fruited	18	81	23	67	5	144	293	204	835
8–53	62	Australian limb, wrinkle fruited in Thomson tree	13	46	75	138	130	82	168	196	848
8–49	62	Normal Thomson limb	30	168	112	374	277	255	505	233	1,984
8–50	62	Normal Thomson limb	23	177	44	184	198	172	345	215	1,358
7–11	4	Normal Washington tree	30	125	127	505	148	300	522	171	1,928

[1] The average total production of 11 Australian trees was 637 fruits, and that of 3 normal trees was 1,757.

FIGURE 12.—Fruits of the small-fruited Australian (left) and normal Washington strains of the Washington Navel orange which were produced on different limbs of the same tree. Riverside, Calif., February, 1912

ington trees. These data, together with those giving the annual yields of these trees, show that the progeny trees of the Australian strains have produced an average of less than one-half the quantity of the Thomson and Washington strains. The small quantity of fruit borne by the Australian progeny trees is correlated with inferior commercial quality, much of which is unfit for marketing and undesirable for consumption.

Particular attention is directed in Table 7 to the performance records of progeny trees 8–53, 8–49, and 8–50. Tree 8–53 was propagated from an Australian limb variation bearing wrinkled fruits in the same parent Thomson tree from which progeny trees 8–49 and 8–50

were propagated. In this instance the Australian progeny tree has produced a total of only 848 oranges, whereas the comparable Thomson strain trees from the same parent have produced totals of 1,984 and 1,358 oranges. The fruits borne by the Australian progeny trees

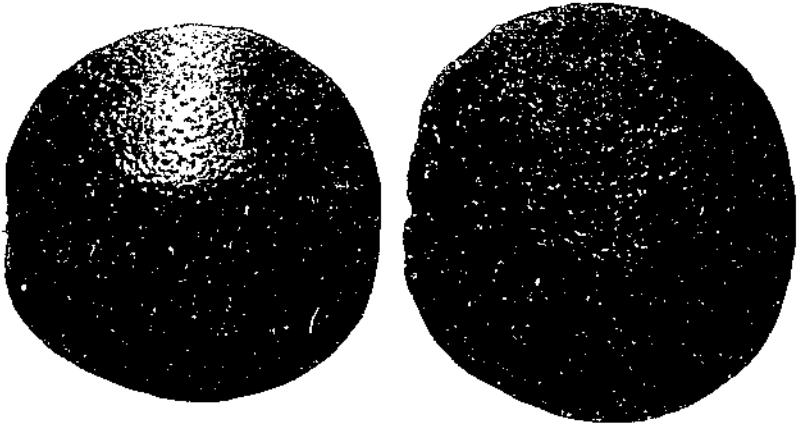

FIGURE 13.—Fruits of the coarse-fruited Australian (right) and normal Washington strains of the Washington Navel orange which were produced on a limb variation and on the normal portion of a single tree. Riverside, Calif., February, 1914

have been consistently very inferior in quality to those borne by trees of the Thomson strain and largely worthless for marketing.

The performance records of the Australian progeny trees show clearly that the habits of tall growth and quantity and commercial

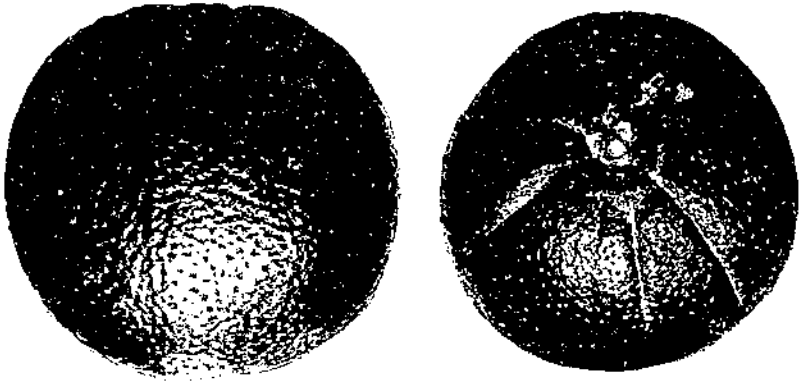

FIGURE 14.—Fruits of the wrinkled-fruited Australian strain of the Washington Navel orange which were borne on the parent-limb variation from which tree 8–53 in Table 7 was propagated. Riverside, Calif., February, 1915

quality of fruit produced by limb or tree variations have been perpetuated through bud propagation. These facts are of fundamental importance in the economic production of Washington Navel orange crops, as has been repeatedly demonstrated both experimentally and commercially in the course of these investigations.

WILLOW-LEAF STRAIN

The name Willow-Leaf was used to designate this strain of the Washington Navel orange because the narrow and acutely pointed leaves, as shown in Figure 16, resemble those of the common willow tree.

TABLE 8.—*Records of annual production of progeny trees propagated from a tree of the Willow-Leaf strain of the Washington Navel orange compared with records of trees propagated from a normal Washington tree*

[These progeny trees were planted in July, 1917]

Progeny tree No.	Source of buds		Fruits produced by progeny trees									
	Parent tree No.	Limb	Character	Number								
				1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28	Total[1]
8–45	56	Willow Leaf	Willow Leaf	2	30	22	212	22	34	197	0	519
8–46		Washington tree		7	52	41	86	5	31	145	2	369
8–48				2	5	12	60	4	43	131	7	264
9–21	78	Normal Washington tree.	Washington	12	54	116	457	169	324	653	190	1,975
9–22				28	76	141	490	207	387	531	199	2,059

[1] The average total production of 3 Willow-Leaf trees was 384 fruits and that of 2 normal Washington trees was 2,017.

The trees of the Willow-Leaf strain are unproductive as compared with those of the normal strain. They might be considered as one of the unproductive strains, but have been listed separately on account of their characteristic appearance. They make a vigorous, healthy growth and have an abundance of foliage. The leaves are lanceolate in shape and are sharply pointed as compared with the oval shape and more obtuse ends of normal leaves.

The fruits are of smaller size and somewhat coarser texture than those of the normal Washington strain.

Table 8 presents the performance records of three progeny trees which were propagated from a typical parent tree of the Willow-Leaf strain and the comparative performance records of two progeny trees of the normal Washington strain. The average total yield of the trees of the Willow-Leaf strain has been 384 oranges, whereas that of the comparable trees of the Washington strain has

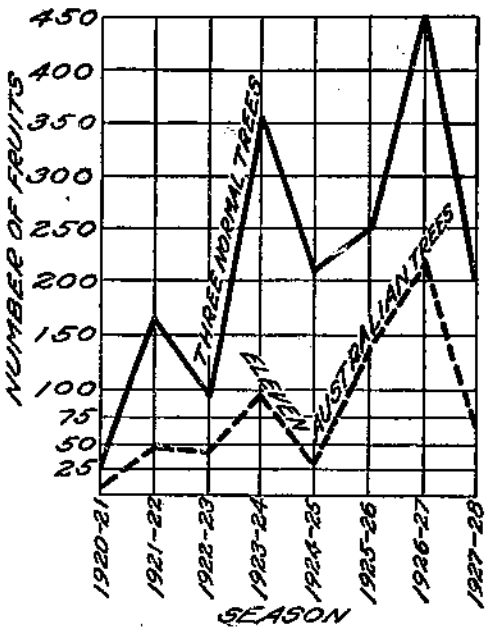

FIGURE 15.—Diagram showing the average number of fruits produced per tree each season by the progeny trees of the Australian strains and the normal Thomson and Washington strains which are recorded in Table 7

been 2,017 oranges for the 8-year performance-record period. Figure 17 shows these production differences graphically. Not only has the production of the Willow-Leaf trees been much less than that of the Washington trees, but the commercial quality of the fruits has also been very inferior.

In this progeny test the Willow-Leaf strain characteristics of the parent-tree variation, including shape of leaves and quantity and quality of fruit, have been transmitted through bud propagation.

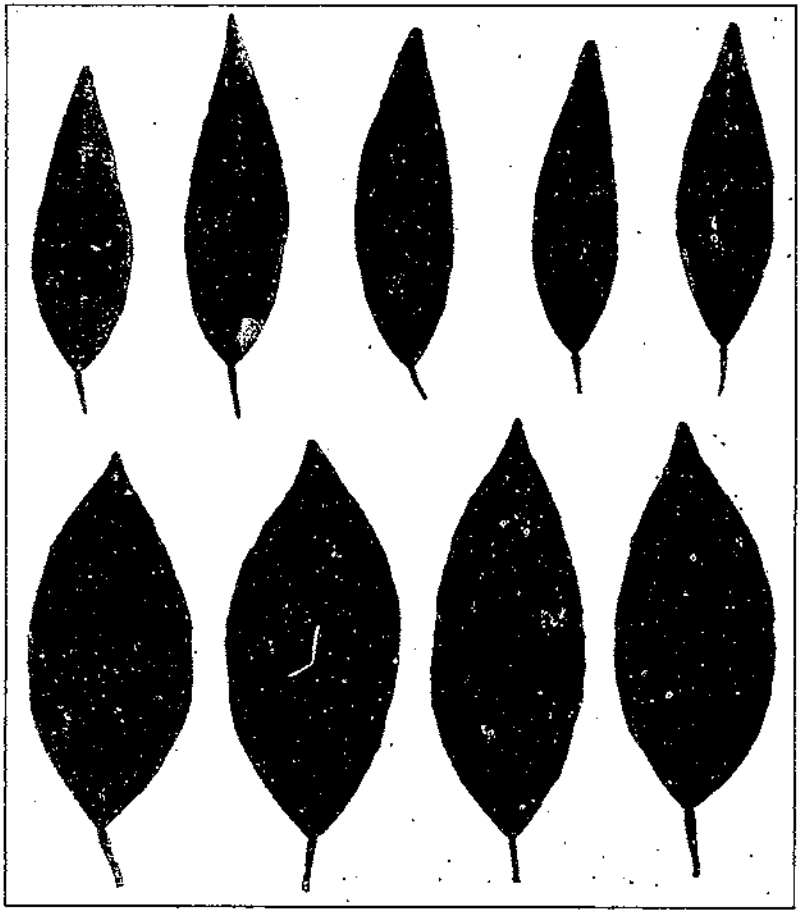

FIGURE 16.—Typical leaves of the Willow-Leaf (top) and Thomson strains of the Washington Navel orange. University of California Citrus Experiment Station, Riverside, Calif., April, 1928

DRY STRAINS

The Dry strains of the Washington Navel orange were so called on account of the fact that the trees of these strains produce fruits having little or no juice. Different conditions of dryness of the fruits have led to the classification of these forms as Dry-Solid, where the fruit pulp is composed of a large number of dry cells compacted into a mass of coarse tissue with a complete or almost entire absence of juice, and Dry-Hollow, where the fruit segments are nearly empty

and lined with a partial layer of small globular pulp vesicles which are usually dry. There is frequently considerable variation in the quantity of juice in different fruits of the Dry-Solid strain, but an examination of hundreds of Dry-Hollow fruits has revealed little juice in any of them, most of them being so nearly dry that it has been impracticable to obtain a complete chemical analysis of the juice. In foliage characteristics the Dry-Solid and Dry-Hollow trees are very similar, their main differences being in the characteristics of the fruits. Typical specimens of the Dry-Solid and Dry-Hollow fruits are shown in Figures 18 and 19.

The trees of the Dry strains have a finely branched arrangement and an upright habit of growth somewhat resembling these characteristics of the Unproductive strain. The foliage is dense, and the leaves are somewhat lanceolate and acutely pointed.

The fruits are globular or oblong in shape, of medium to small size, and the rinds are very thick, coarse or pebbled in texture, and yellowish orange in color, seedless, and have small or rudimentary navels with the navel opening very small or entirely closed. The rag is very abundant and coarse in fruits of the Dry-Solid strain and nearly lacking in those of the Dry-Hollow strain. The fruits are very light in weight, on account of the absence of juice and the thickness of the rinds, and they are unusually uniform in size so far as observed.

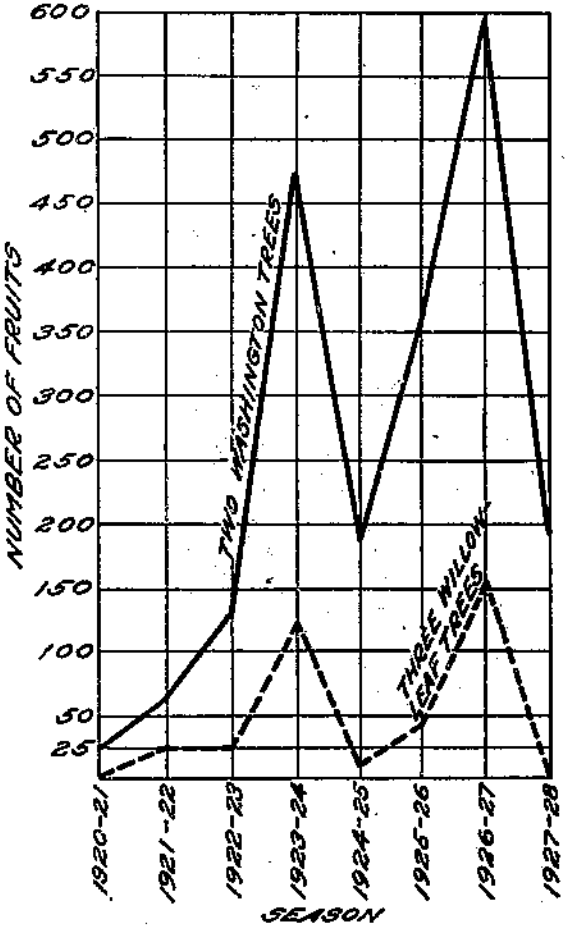

FIGURE 17.—Diagram showing the average number of fruits produced per tree each season by the progeny trees of the Willow-Leaf strain and comparable trees of the normal Washington strain which are recorded in Table 8

The performance record of a Dry-Solid progeny tree which was propagated from a limb variation in an otherwise normal tree of the Washington strain planted in 1917 is shown in Table 9 together with the record of a tree propagated later from another similar limb

variation. For comparison with these yield data, the performance records of two progeny trees of the Washington strain are also included.

TABLE 9.—*Records of annual production of progeny trees propagated from limb variations of the Dry-Solid strain of the Washington Navel orange compared with the records of trees propagated from a normal limb in one of the same parent trees*

[Trees 8–47, 9–21, and 9–22 were planted in 1917, and tree 8–20 was planted in 1923]

Progeny tree No.	Source of buds		Fruits produced by progeny trees								
	Parent tree No.	Limb	Character	Number							
				1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28	Total
8–47	57	Dry-Solid limb variation in Washington Navel tree.	Dry-Solid	13	65	95	185	29	82	297	92	862
9–21	78	Normal Washington tree	Washington normal	2	54	116	457	169	324	653	190	1,965
9–22				28	76	141	490	207	387	531	199	2,059
8–20	506	Dry-Solid limb variation	Dry-Solid							3	0	3

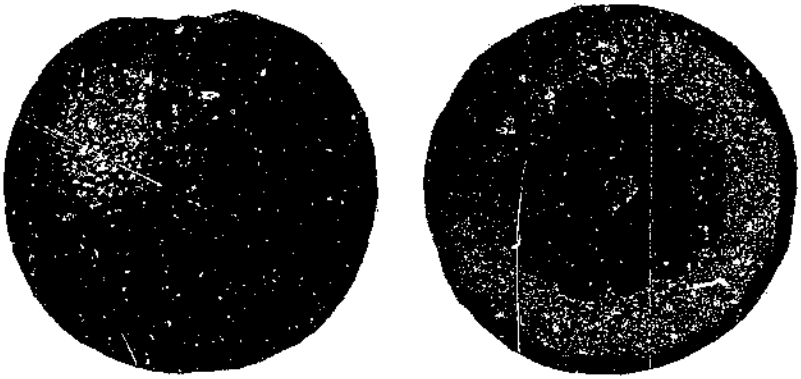

FIGURE 18.—Fruits of the Dry-Solid strain of the Washington Navel orange produced by the progeny tree listed in Table 9 which was propagated from a similar limb variation. Riverside, Calif., January, 1928

The Dry-Solid progeny tree 8–47 has produced a total of 862 oranges for the 8-year performance-record period, and the younger tree of the same strain has just begun to bear, producing 3 fruits in the season of 1927–28. The comparable progeny trees of the Washington strain have produced totals of 1,965 and 2,059 oranges, respectively, showing more than double the yield of the Dry-Solid tree.

Yield records were not obtained from the two progeny trees of the Dry-Hollow strain, but close observation has shown that they have usually produced somewhat more than those of the Dry-Solid strain, but less than the Washington trees. As a whole it can be said that the Dry strain trees have been less productive than Washington strain trees, but somewhat more productive than those of the Unproductive strain.

The outstanding characteristics of the fruits of the Dry strains are their usual small content or entire absence of juice and the abnormal

thickness of their rinds. These conditions were found in the fruits of the parent-limb variations and have been transmitted to the progeny trees through bud propagation in a very striking manner. These tests indicate that the quantity of juice in the Washington Navel orange is a heritable character which can be perpetuated through budding.

Table 10 presents analyses of representative samples of fruit from the Dry-Solid, Dry-Hollow, and Washington strain progeny trees. It is apparent that the hollow nature of the Dry-Hollow strain fruits is responsible for their relatively low specific gravity. The thickness of the rinds of the Dry-strain fruits, and particularly those of the Dry-Hollow strain, is clearly shown in the data giving the percentage of rinds. From this table it can be seen that in addition to the very thick rinds, abundant rag, less oil, and very much less insoluble

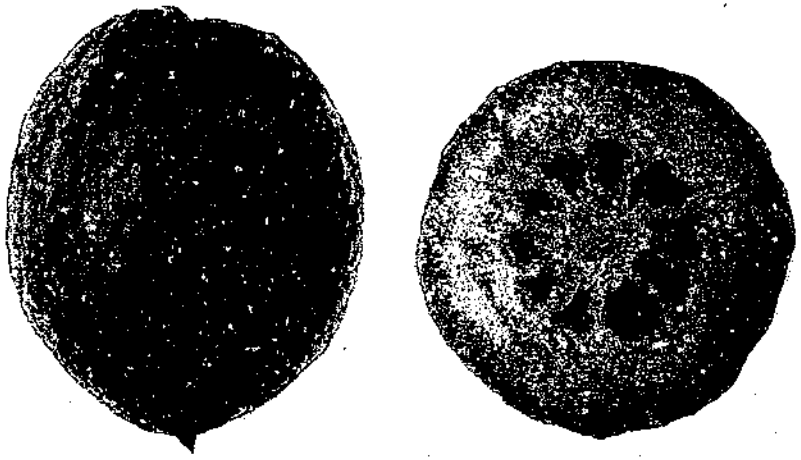

FIGURE 19.—Fruits of the Dry-Hollow strain of the Washington Navel orange produced by a progeny tree from a limb variation. Riverside, Calif., January, 1928

solids in the pulp, the juice of the fruits of the Dry strains have less acid and are correspondingly insipid to the taste.

TABLE 10.—*Composition of fruits from progeny trees of the Dry and Washington strains of the Washington Navel orange*

[Analyses made by the laboratory of fruit and vegetable chemistry of the Bureau of Chemistry and Soils, United States Department of Agriculture, at Los Angeles, Calif., December 1, 1924]

Strain	Tree No.	Specific gravity of fruit	Constituents (per cent)						
			Rind	Pulp	Oil	Insoluble solids in pulp	Total sugar in juice	Acid in juice	Soluble solids in juice
Dry-Solid	1	0.825	48.4	51.4	0.592	5.83	7.77	0.88	10.58
Dry-Hollow	2	.654	73.2	26.5	.338	9.70	8.40	.25	Too dry.
Do	3	.640	72.6	27.1	.338	9.75	8.40	.21	Too dry.
Washington	4	.899	32.1	67.4	.677	2.72	8.46	1.22	12.30
Do	5	.912	30.4	69.5	.508	2.80	8.29	1.26	12.29

On account of the almost complete absence of juice, if for no other reason, the fruits of the Dry strains are absolutely unfit for marketing.

The accidental inclusion of such fruits in the regular market packs must have a detrimental effect upon the reputation of the crop as a whole. It is very important that the further propagation of trees of these strains should be avoided through careful bud-selection practices. In established orchards Dry-strain limb variations in otherwise normal trees can be removed by pruning, and entire trees can be replaced by top-working or replanting.

BROWN-SPOTTED STRAIN

The name Brown-Spotted has been given to a strain of the Washington Navel orange the fruits of which develop irregular brownish and slightly sunken spots when near maturity. When these fruits were first found it was thought that the spots were due to a disease, to insect injuries, or to fumigation burns, but subsequent studies proved the tissues of the rinds of the fruits to be inherently

FIGURE 20.—Progeny trees of the Brown-Spotted (right) and Thomson strains of the Washington Navel orange which are listed as 7–47 and 7–48 in Table 11. University of California Citrus Experiment Station, Riverside, Calif., January, 1928

weak and that the spots are caused by the breaking down of groups of cells in the rind. The brownish color of the spots apparently results from the action of the released citrus oil on the surface areas of the peel, and the spots have a similar appearance to those which develop in handling operations with citrus fruits where the oil cells become broken and the free oil spreads over adjacent areas of the rind.

The foliage characteristics of the trees of the Brown-Spotted strain differ from those of the Washington strain in that the leaves are smaller, more lanceolate, and acutely pointed. The trees are small, with very small twig diameters, and the growth is more finely branched than is ordinarily the case with the Washington strain. Figure 20 shows a Brown-Spotted tree and a normal Thomson tree which was propagated from the same parent tree.

The fruits are of small size, distinctly flattened, pale yellow in color, and frequently have one or more reddish orange stripes and

small sunken brown spots of irregular shape. The fruits are seedless, and the navels are usually small in size, sometimes rudimentary, and frequently with no navel opening. The rinds of the fruits are thick, and the flesh is coarse and tough. The quantity of juice is small, and it usually lacks flavor, being deficient in both acid and sugar. The fruits ripen early, and most of them drop from the trees during November and December, two or more months before comparative normal fruits reach full maturity. A few brown spots usually develop on the fruits before they drop, and after the fruits

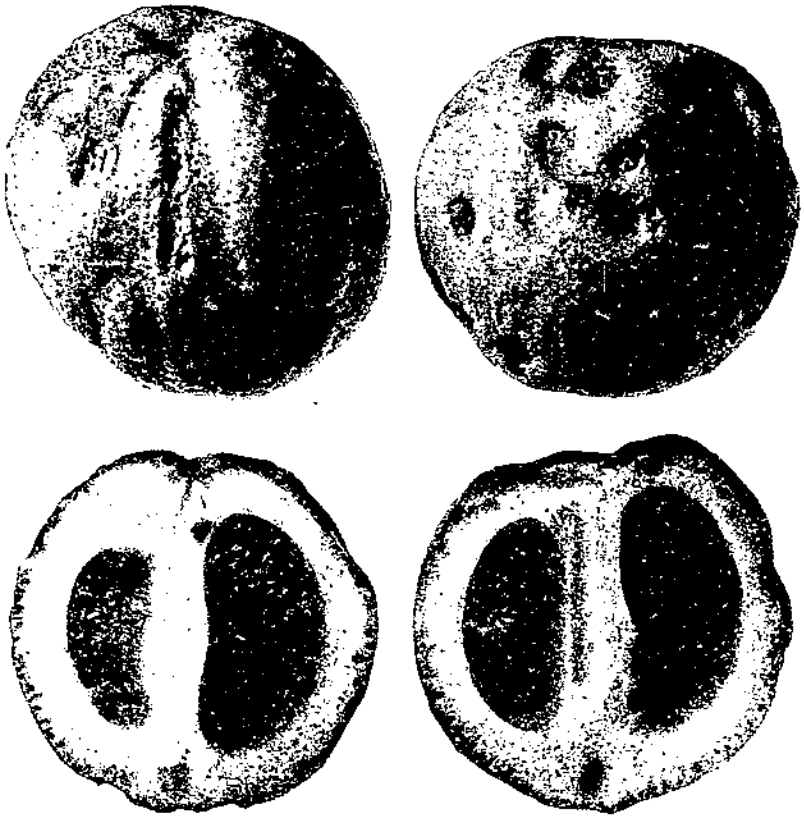

FIGURE 21.—Fruits of the Brown-Spotted strain of the Washington Navel orange produced by progeny tree 9–1, as listed in Table II, which was propagated from a similar limb variation. Both the exterior views show spots that have been limited in their extension by adjacent sections of normal Washington rind. Riverside, Calif., January, 1923

drop, the brown spots increase rapidly in number and size. Typical fruits of this strain are shown in Figure 21.

At the time the limb-variation propagations were being made in 1915, small Brown-Spotted limbs were found in two trees in orchards about 3 miles apart, one of them being in a tree of the Thomson strain and the other in a tree that was otherwise typical of the Washington strain. Both of these trees were of normal size for their age and were in a vigorous growing condition.

The performance records of progeny trees which were propagated from these two Brown-Spotted limb variations are shown in Table

11, two of the trees having been budded from the variation in the Thomson tree and two from the one in the Washington tree. For comparison, there are also included the performance records of two normal Thomson trees propagated from the parent Thomson tree which produced the Brown-Spotted limb variation and two progeny trees of the Washington strain.

TABLE 11.—*Records of annual production of progeny trees propagated from limb variations of the Brown-Spotted strain of the Washington Navel orange compared with the records of trees propagated from a normal branch in one of the same parent trees and from a normal tree of the Washington strain*

[All these progeny trees were planted in 1917]

Progeny tree No.	Source of buds		Fruits produced by progeny trees									
	Parent tree No.	Limb	Character	Number								
				1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28	Total
7–47	25	Brown-Spotted limb variation in Thomson tree (all fruits spotted).	Brown-Spotted	12	24	59	155	22	22	94	122	510
7–48				25	49	92	382	21	46	162	206	883
7–49		Normal Thomson limb in same parent tree.	Normal Thomson	10	95	92	248	223	209	369	247	1,493
7–50				7	107	96	499	288	268	455	225	1,948
9–1	53	Brown-Spotted limb variation in Washington tree (bears both spotted and normal fruits).	Brown-Spotted	11	7	45	134	54	62	148	64	525
			Brown-Spotted with Washington sections	0	4	1	20	20	4	24	111	184
			Normal Washington	5	7	4	25	19	14	60	36	170
			Ribbed Washington	1	2	2	11	7	1	3	1	28
			Total	17	20	52	190	100	81	235	212	907
9–2	53	do	Brown-Spotted	44	17	50	268	16	53	169	43	660
			Brown-Spotted with Washington sections	0	17	6	20	52	13	42	45	195
			Normal Washington	0	2	7	2	1	0	4	0	16
			Ribbed Washington	0	0	0	1	0	0	0	0	1
			Total	44	36	63	291	69	66	215	88	872
7–27	12	Normal Washington tree	Normal Washington	13	96	27	532	249	316	630	163	2,028
7–28				1	91	78	355	131	154	416	143	1,369

The two Brown-Spotted progeny trees from the limb variation in a Thomson tree have borne Brown-Spotted fruits exclusively during this performance-record period, indicating an inherent stability in this respect which has been transmitted through bud propagation.

The yields of the progeny trees of the Thomson strain which were propagated from a normal branch of the parent tree having the Brown-Spotted limb variation have been much heavier than those of the comparative Brown-Spotted strain, being 1,493 and 1,948 oranges, respectively, whereas the Brown-Spotted trees have borne only 510 and 883 fruits, respectively, during the 8-year performance-record period.

In the performance records of the two progeny trees of the Brown-Spotted strain grown from the limb variation in a Washington strain tree the yields have been classified according to fruit characteristics and include those which were typically brown spotted, those brown spotted with sections resembling typical Washington fruits, normal Washington fruits, and Washington fruits having a distinctly ribbed

appearance. No instance has been found where a brown spot has developed on the normal-appearing sections of these fruits. Even when a spot appears very close to a section of normal rind it does not spread into it. Fruits showing this condition are included in Figure 21. The brown-spotted fruits make up the bulk of the crops from these trees, and the other classes have been produced by branch variations, those bearing the Washington-strain oranges being apparent reversions to the type of the parent tree. The total production of the two Brown-Spotted progeny trees for the 8-year performance-record period has been 907 and 872 oranges, respectively, whereas that of the comparative progeny trees of the Washington strain has been 2,028 and 1,369 fruits, respectively. The parent limb from which these two Brown-Spotted progeny trees were propagated has given quite variable production, similar to that of the progeny tree, which condition indicates an inherent instability that has been perpetuated through bud propagation.

The relatively low yields of the four progeny trees of the Brown-Spotted strain as compared with the heavier production of the progeny trees of the Normal Washington and Thomson strains indicate that the trees of the Brown-Spotted strain are inherently less productive than normal, comparable trees. The fruit characteristics—including size, shape, color, spotting, and early maturity—have been perpetuated, except that in the Brown-Spotted progeny trees from the limb variation in the parent tree of the Washington strain apparent reversions showing as part or entire fruits have been found, which have been produced by particular branches or limbs in these Brown-Spotted trees. The foliage characteristics of the progeny trees of the Brown-Spotted strain have been similar to those of the parent-limb variations from which they were propagated.

YELLOW STRAINS

The term "Yellow" has been applied to certain strains of the Washington Navel orange on account of the light-yellow color of their fruits, as compared with the reddish yellow or orange color of the normal fruits. They have been found as limb variations in trees of both the Washington and Thomson strains and occur as single-fruit, limb, and entire-tree variations in established orchards of those strains.

The trees of the Yellow strains have a somewhat erect habit of growth, and the foliage is rather sparse. The leaves are smaller, more pointed, and lighter green than those of Washington or Thomson trees.

The fruits of these strains differ in appearance from those of the Washington or Thomson strains mainly in color. They have a light-yellow color with occasional characteristic small red stripes or spots. The fruits tend to mature somewhat earlier, the juice is slightly less acid, and the flesh is of lighter color than that of the comparative Washington and Thomson fruits. In Yellow Thomson fruits the rag is usually more abundant than in the normal Thomson fruits. No illustration of the Yellow strain is presented, because it is impossible to show the color variation.

The performance records of a number of Yellow strain trees which were propagated from limb and tree variations and of comparable Washington and Thomson progeny trees are shown in Table 12.

TABLE 12.—*Records of annual production of progeny trees propagated from limb and tree variations of the Yellow Thomson strains of the Washington Navel orange compared with records of trees propagated from normal Thomson and Washington limbs*

[The first 17 progeny trees were planted in July, 1917, and the last 9 in May, 1919]

Progeny tree No.	Source of buds		Fruits produced by progeny trees									
	Parent tree No.	Limb	Character	Number								
				1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28	Total[1]
7–37	20	Yellow limb variation in Thomson tree.	Yellow Thomson.	6	88	70	258	183	257	296	319	1,477
7–38				40	116	53	183	108	142	171	155	968
7–41	20	Normal Thomson limb in same tree as above.	Thomson	22	39	74	453	325	268	405	230	1,816
8–23	40	Yellow limb variation in Thomson tree.	Yellow Thomson.	18	52	34	82	32	50	152	55	475
8–24				6	47	25	148	75	133	230	179	843
8–35	50	do	do	45	151	62	263	140	232	396	170	1,459
8–36				21	50	26	110	33	98	163	53	554
8–37	50	Normal Thomson limb in same tree as above.	Thomson	33	136	63	191	208	190	341	231	1,393
8–38				15	28	55	177	45	[2] 103	306	182	913
8–51	60	Yellow limb variation in Thomson tree.	Yellow Thomson.	30	75	36	97	35	92	151	57	573
8–52				28	72	43	126	26	122	104	154	765
8–49	60	Normal Thomson limb in same tree as above.	Thomson	30	198	112	374	277	255	505	233	1,984
8–59				23	177	44	184	[3] 198	172	345	215	1,358
9–23	81	Yellow limb variation in Thomson tree.	Yellow Thomson.	18	48	67	354	127	278	594	280	1,766
9–24				10	61	[3] 43	168	41	51	249	191	814
9–25	81	Normal Thomson limb in same tree as above.	Thomson	1	47	105	[4] 258	80	[5] 238	569	198	1,526
9–26				17	103	121	249	117	147	306	159	1,219
31–1	209	Yellow Washington strain tree.	Yellow Washington.			25	75	82	225	201	85	693
31–2						53	67	80	192	203	55	650
31–3						14	43	105	250	269	90	771
31–9	211	do	do			77	52	120	188	279	87	743
31–10						23	51	148	123	255	63	666
31–29	206	Yellow Washington strain tree.	do			20	67	165	102	210	99	609
31–30						25	80	158	108	186	61	618
31–17	202	Normal Washington strain tree.	Washington			29	64	148	228	306	125	900
31–28	204	do	do			11	80	198	189	283	139	810

[1] The average 8-year production of 10 yellow strain Thomson trees was 969 fruits and that of 7 normal Thomson trees was 1,458 fruits. The average 6-year production of 7 yellow strain Washington trees was 679 fruits, while that of 2 normal Washington trees was 855 fruits.

[2] Includes 1 fruit with yellow section.

[3] Includes 1 fruit of the Washington strain.

[4] Includes 4 fruits with yellow sections.

[5] Includes 1 fruit of the Yellow Thomson strain and 3 with yellow sections.

The 10 trees of the Yellow Thomson strain have produced an average of 969 fruits, while the 7 comparative Thomson trees have borne an average of 1,458 oranges for the 8-year period. The 7 progeny trees of the Yellow Washington strain were planted in 1919, two years after the Thomson trees, and they have produced an average of 679 fruits per tree for the 6-year period since they came into bearing. The two comparable trees of the Washington strain have produced an average of 855 fruits during this same 6-year period.

These results, indicating that the trees of the Yellow strain are not as productive as those of the normal Thomson or Washington strains, are in accord with commercial orchard experience. Some of the pioneer Washington Navel orange growers in southern California propagated Yellow-strain limb variations and planted small orchards to this strain on account of the early ripening of the fruits and their characteristic color. Individual-tree performance records in some of these plantings revealed the relative unproductiveness of the trees, and because market experience proved the light-yellow color to be detrimental rather than advantageous, the Yellow-strain trees have been largely top-worked to the normal Washington strain during recent years.

The performance records of the progeny trees of the Yellow strain show that these trees have produced with one exception only typical Yellow-strain fruits, similar to those borne by the parent-limb variations, and that the Thomson and Washington strains have produced normal fruits with only 10 variations. The fruit and foliage characteristics of the parent-limb variations have been strongly transmitted through bud propagation, and these records suggest the origin of the Yellow strains from limb variations.

GOLDEN BUCKEYE STRAIN

In the early study of the variations of the Washington Navel orange, the Golden Nugget and Golden Buckeye fruits were considered to be identical. The subsequent studies of the fruits of the progeny trees which were propagated from these bud variations have shown that the Golden Buckeye oranges are distinguished from the Golden Nugget fruits by characteristic reddish-orange streaks, ridges, and other markings, so that these variations are now classified as separate strains.

The name Golden Buckeye was given to this strain by one of the pioneer citrus nurserymen of southern California. It was grown commercially to a very limited extent several years ago, but its propagation was soon abandoned, and orchard trees of this strain were subsequently top-worked.

The trees of the Golden Buckeye strain resemble those of the Thomson strain, but are likely to be somewhat smaller in size and more dense in habit of growth. They are very similar to the trees of the Golden Nugget strain. The fruits are usually somewhat elliptical in shape, medium to large in size, and tend to early maturity. The rinds are of medium thickness, yellowish orange in color, and have occasionally irregular ridges of varying size which are usually reddish orange in color. The rag is coarse and very abundant, the juice is deficient in quantity and lacking in distinctive flavor. The fruits are seedless and normally have small or rudimentary navels with the navel openings nearly or entirely closed. The Golden Buckeye oranges have a peculiar appearance, due to the relatively few oil cells in the rinds, their light yellowish orange color, and the prominent reddish color of the ridges, raised sections, or knoblike projections on the rinds. The fruits are likely to be variable in shape, size, and other characteristics on different trees or on the individual branches of the same tree. Figure 22 shows typical fruits of this strain.

Table 13 shows the performance records of two progeny trees which were propagated from a limb variation of the Golden Buckeye strain in a Thomson strain parent tree. The parent tree was quite variable, having in addition to the Golden Buckeye limb a Washington strain limb and a limb bearing corrugated fruits. In this table, performance records are included for a Thomson strain progeny tree which was propagated from a normal limb of the parent tree and of two Washington strain progeny trees which were propagated from the Washington strain limb variation in the same parent tree. The performance records of the progeny trees from the Corrugated strain limb variation in this same parent tree are shown in Table 16.

TABLE 13.—*Records of annual production of progeny trees propagated from a limb variation of the Golden Buckeye strain in a tree of the Thomson strain of the Washington Navel orange compared with records of trees propagated from a normal Thomson limb and from a typical Washington Navel limb in the same parent tree*

[All these progeny trees were planted in July, 1917]

Progeny tree No.	Source of buds in Thomson tree No. 16 [1]	Fruits produced by progeny trees								
		Character	Number							
			1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28	Total
7–33	Golden Buckeye limb variation in Thomson tree.	Golden Buckeye.	20	114	60	216	151	177	241	182	1,161
		Washington	0	0	0	0	3	4	10	5	22
		Thomson	0	0	0	0	4	5	4	0	13
		Golden Buckeye and Washington sections.[2]	0	0	0	0	0	10	0	0	10
		Total	20	114	60	216	158	196	255	187	1,206
7–34	do	Golden Buckeye.	25	101	59	259	209	203	309	237	1,402
		Washington	0	0	0	0	6	4	3	[3] 10	23
		Thomson	0	0	0	0	2	2	0	0	4
		Golden Buckeye and Washington sections.[2]	0	0	0	0	3	13	1	3	20
		Total	25	101	59	259	220	222	313	250	1,449
7–35	Normal Thomson limb	Thomson	18	76	73	247	216	235	338	201	1,403
7–31	Washington limb variation.	Washington	15	95	98	277	179	249	539	252	1,704
7–32			25	140	104	253	243	278	552	192	1,787

[1] This tree also had a limb bearing corrugated fruits, and records of progeny trees propagated from it are included in Table 16.
[2] Golden Buckeye and Washington sections on the same fruits.
[3] Including two fruits of the Yellow Washington strain.

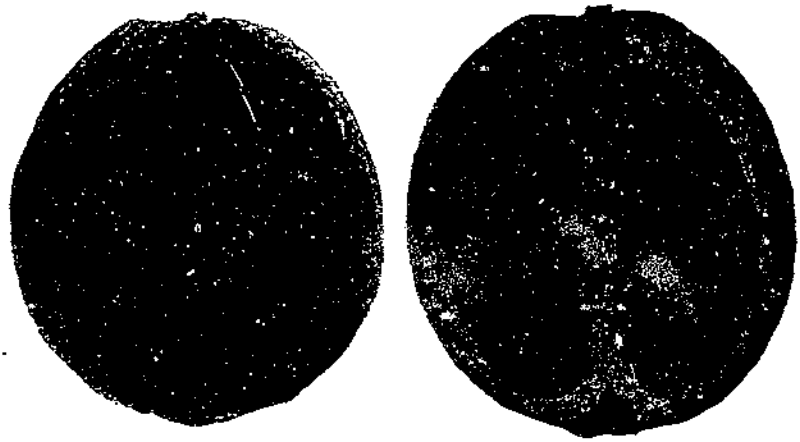

FIGURE 22.—Fruits of the Golden Buckeye strain of the Washington Navel orange produced by progeny tree 7–33, as listed in Table 13, which was propagated from a similar limb variation. Riverside, Calif., January, 1923

It will be seen in Table 13 that while the progeny trees of the Golden Buckeye strain produced mainly fruits of this strain, during the latter part of the performance-record period they have also borne

a few Washington and Thomson strain fruits, together with Golden Buckeye oranges having typical Washington sections in the same fruits. The progeny trees of the Thomson and Washington strains have produced only fruits typical of these strains during the performance-record period.

These performance records indicate a condition of inherent instability in the trees of the Golden Buckeye strain. The yield data also indicate the relative productiveness of comparable trees of the strain, as shown through their performance records, which are corroborated by commercial orchard experience, the trees of the Golden Buckeye strain producing the least and those of the Washington strain the most fruit. The market value of the fruits of these strains is greatest for those of the Washington strain, with the Thomson fruits somewhat less valuable, and those of the Golden Buckeye of little or no value from the economic standpoint.

The performance records shown in Table 13 and additional observations of the foliage characters of the trees show that the characteristics

FIGURE 23.—Fruits of the Golden Nugget strain of the Washington Navel orange produced by progeny tree 9-38, listed in Table 14, which was propagated from a similar limb variation. Riverside, Calif., January, 1925

of the limb variations as well as the normal have been perpetuated through bud propagation. They also indicate the origin of the Golden Buckeye strain from limb variations in Thomson strain trees.

GOLDEN NUGGET STRAIN

In these studies a few Washington and many Thomson strain trees which bear individual oranges of the Golden Nugget strain have been found, and occasional limbs in such trees which have typical leaves and fruits of the same strain have been discovered. In the early days of the development of the Washington Navel orange industry in the Southwest Golden Nugget limb variations were propagated commercially to a limited extent, but the resulting trees have largely been top-worked during recent years with buds obtained from Washington strain trees.

Trees of the Golden Nugget strain have a characteristic appearance, the branches having a peculiar drooping habit of growth and the rather dense foliage being of a light olive-green color. They grow less vigorously than trees of the Washington or Thomson strain, so

that under comparable conditions the Golden Nugget trees appear to be somewhat dwarfed.

The fruits of the Golden Nugget strain are usually of medium to large size and elliptical or pyriform in shape. They are light yellow in color, have few oil cells, and the texture of the rind is exceptionally smooth. The rag is coarse and tough, as in the Thomson oranges, and the juice is abundant and of a distinctive flavor. The fruits are seedless and have very small or rudimentary navels as a rule, with navel openings that are oftentimes nearly or entirely closed. Figure 23 shows typical fruits of this strain.

The performance records of trees of the Golden Nugget strain which were propagated from typical variations in otherwise normal Thomson trees are shown in Table 14, together with the records of Thomson trees which were propagated from normal branches of the same parent trees and the record of a Golden Nugget progeny tree which was propagated from a Golden Nugget tree found in a Thomson orchard.

TABLE 14.—*Records of annual production of progeny trees from limb and tree variations of the Golden Nugget strain of the Washington Navel orange compared with records of trees propagated from normal limbs of two of the same parent trees*

[The first four progeny trees listed below were planted in July, 1917, and the others in May, 1919]

Progeny tree No.	Source of buds		Fruits produced by progeny trees									
	Parent tree No.	Limb	Character	Number								
				1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28	Total
9–37	99	Golden Nugget limb variation in Thomson tree.	Golden Nugget	20	68	45	147	75	92	217	61	723
9–38				15	24	44	202	96	122	160	34	697
9–39	99	Normal Thomson limb in same tree as above.	Thomson	9	38	47	227	103	153	231	109	917
9–41	101	Golden Nugget tree	Golden Nugget	22	14	35	279	168	207	319	160	1,204
31–13	200	Golden Nugget limb variation in Thomson tree.	do	---	0	5	65	169	112	137	49	535
31–14				---	0	4	30	158	133	175	81	581
31–31	200	Second Golden Nugget limb in same tree as above.	do	---	1	3	50	123	78	239	30	522
31–32				---	0	7	48	126	55	159	44	439
31–25	200	Normal Thomson limb in same tree as above.	Thomson	---	2	12	68	163	121	215	203	789
31–26				---	3	13	34	149	153	312	145	809
31–27				---	8	24	151	193	208	342	65	991

The progeny trees of the Golden Nugget limb variations have produced typical Golden Nugget fruits throughout the performance-record period, and the Thomson trees propagated from the same parent trees have consistently borne typical Thomson fruits. The Golden Nugget trees have not produced as much fruit as the comparable Thomson trees, but the progeny tree of the productive Golden Nugget parent tree has borne more oranges than the three other comparable progeny trees which were planted at the same time.

On account of their light color and the abundance of rag in the fruits, the Golden Nugget strain is not a desirable one for commercial propagation in the established citrus districts of the Southwest, and the presence of occasional trees of this strain in existing navel-orange orchards reduces the value of the crops produced by those orchards.

However, the striking characteristics of the fruits and foliage of this strain make it an important one in the study of the origin and development of strains from bud variations.

DUAL STRAIN

The foliage characteristics of the Dual strain trees are so similar to those of the Washington strain trees that it has not been possible to distinguish them so far as these studies have gone. The habits of growth of the trees and the size, shape, and color of the leaves and the blossoms of the Dual strain trees are almost if not entirely identical with those of the trees of the Washington strain.

The fruits borne by the Dual strain trees present a peculiar appearance in that the rinds of some of the oranges are smooth and thin

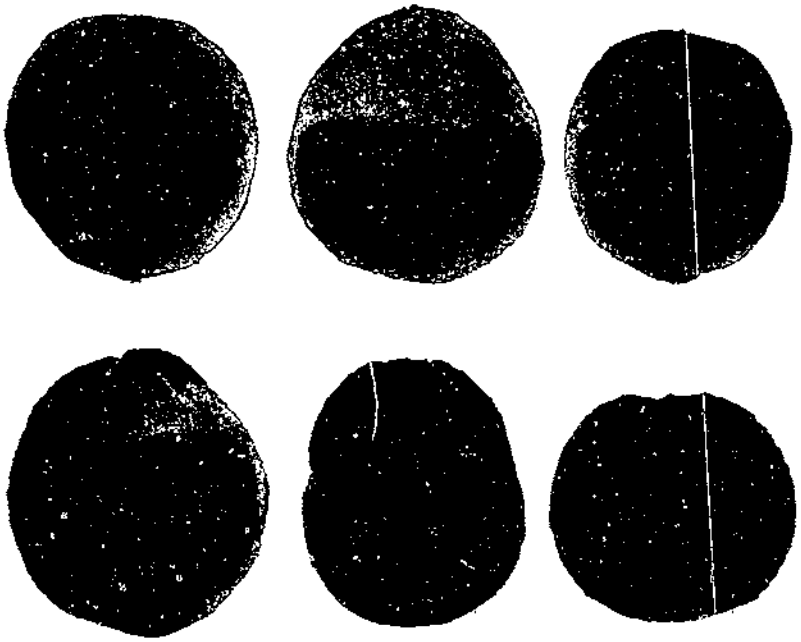

FIGURE 24.—Fruits of the Dual strain of the Washington Navel orange produced by the limb variation from which the trees listed in Table 15 were propagated. Corona, Calif., January, 1923

at the blossom ends and rougher and thicker at the stem ends, whereas in others this arrangement is reversed. On other fruits a smooth area forms a band around the middle zone of the oranges, the remainder of the surface being rougher, while in still other instances smooth areas occur as irregular patches at various points on the surface, often near the stem end of the fruits. In some instances the rinds are entirely smooth; in others they are wholly rough. The smooth areas resemble the rinds of the Thomson fruits, whereas the rougher areas have the appearance of Washington fruits. This condition has led to the belief that the Dual strain oranges may be a type of periclinal chimera. Fruits of this strain are shown in Figure 24.

Dual strain limb variations in a Washington strain tree were found by the senior writer in the spring of 1910 in a 7-year-old Washington Navel orchard near Corona, Calif., while the remaining branches bore

largely Washington strain fruits together with a few typical Thomson strain oranges. The Dual strain limb variations have borne fruits of this strain and those typical of the Washington and Thomson strains each year since they have been under observation, but there has been no segregation of these fruits on the different branches of the limbs so far as observed.

The performance records of three progeny trees of the Dual limb variation and the comparative records of two progeny trees of the Washington strain are shown in Table 15.

TABLE 15.—*Records of annual production of progeny trees propagated from limb variations of the Dual strain found in a Washington Navel orange tree compared with records of trees propagated from a normal Washington Navel tree*

Progeny tree No.	Source of buds	Fruits produced by progeny trees								
		Character	Number							
			1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28	Total
9–15	Dual limb variations in Washington Navel tree No. 75.	Dual	6	11	14	27	1	3	46	5	113
		Washington	0	26	32	110	31	115	223	40	577
		Thomson	0	0	29	22	2	18	14	3	88
		Total	6	37	75	159	34	136	283	48	778
9–16	do	Dual	3	14	18	62	0	60	84	14	255
		Washington	2	6	14	26	0	58	216	37	359
		Thomson	6	3	0	22	0	11	17	0	59
		Total	11	23	32	110	0	129	317	51	673
9–17	do	Dual	1	5	23	119	12	25	87	16	288
		Washington	1	5	11	14	8	26	82	17	164
		Thomson	0	0	0	0	1	8	11	2	22
		Total	2	10	34	133	21	59	180	35	474
9–21	Normal Washington Navel tree No. 78.	Washington	12	54	116	457	169	324	653	190	1,975
9–22			28	76	141	490	207	387	531	199	2,059

The progeny trees of the Dual strain have produced total yields of 778, 673, and 474 oranges, respectively, whereas the comparable Washington strain trees have borne total crops of 1,975 and 2,059 oranges for the 8-year performance-record period, indicating that the Dual strain trees are much less productive than those of the Washington strain.

The fruits borne by the Dual strain progeny trees have been classified as Dual, Washington, and Thomson strain oranges, and the proportion of crop of these strains has varied in the individual trees. These data indicate that the variable or unstable condition of the parent-limb variation has been transmitted to the progeny trees in varying degrees, possibly as a result of the particular character of the bud used in the propagation of each tree. From the commercial point of view the comparatively low yields and the variable nature of the crops produced by the Dual strain trees render them undesirable for propagation under existing orchard conditions, and their accidental propagation through lack of careful bud selection is detrimental to profitable orange culture.

CORRUGATED STRAIN

The trees of the Corrugated strain observed in these investigations resemble closely those of the Thomson strain in quantity of production, habit of growth, and foliage characteristics.

The fruits are very different in appearance from those of the other Washington Navel strains, being prominently ridged or corrugated, as indicated by the name of the strain. The rind is of medium thickness and the color a deep orange. The rag is tender and small in quantity, and the juice is abundant and of fair quality. The fruits are seedless, and the navels are small to medium in size, as shown in Figure 25.

Trees, limb variations, and individual fruits of the Corrugated strain are of rather frequent occurrence in some navel-orange orchards

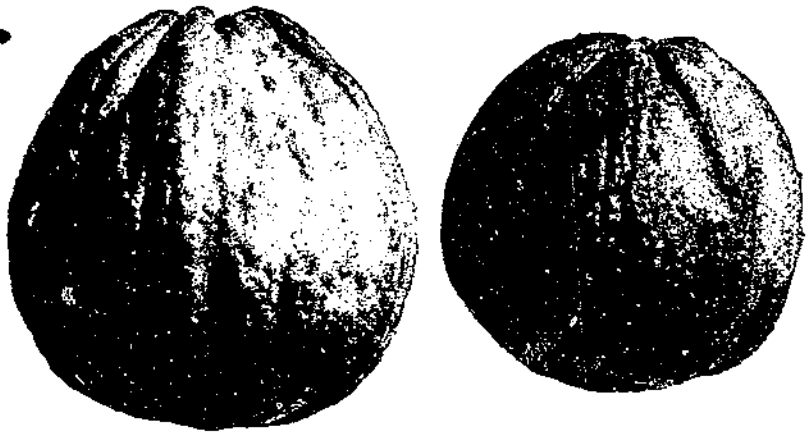

FIGURE 25.—Fruits of the Corrugated strain of the Washington Navel orange produced by progeny tree 29–43, listed in Table 16, which was propagated from a similar limb variation. Riverside, Calif., April, 1927

of the Southwest. Because the peculiar and prominent markings of the fruits make them easily identified, the strain has been an interesting one in the study of the origin and development of strains from bud variations.

The performance records of progeny trees from Corrugated limb variations in two Thomson trees with those of progeny trees which were propagated from normal branches of the same parent trees are shown in Table 16.

The parent Corrugated limb variations produced both Corrugated and normal Thomson fruits in both parent trees. This characteristic has been perpetuated in all of the progeny trees, but one of the progeny trees of the Corrugated strain has produced a much larger proportion of Corrugated fruits in its crops than the other one. This condition indicates that the two buds used for the propagation of these two trees varied in their inherent tendencies with respect to the corrugated character of the fruits. The second set of two progeny trees of the Corrugated strain which were propagated from another Thomson parent tree and planted one year later than the first set have produced a larger proportion of normal Thomson fruits than the first set, indicating that the inherent tendency for the production of normal fruits by these trees is relatively stronger than in the case of the first set.

TABLE 16.—*Records of annual production of progeny trees propagated from limb variations of the Corrugated strain in trees of the Thomson strain of the Washington Navel orange compared with records of trees propagated from the normal portion of the same parent trees*

[Trees Nos. 7–29 and 7–35 were planted in 1917, trees 29–42 and 29–43 were planted in 1918, and trees 31–35 and 31–36 were planted in 1921]

Progeny tree No.	Source of buds		Fruits produced by progeny trees									
	Parent tree No.	Limb	Character	Number								
				1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28	Total
7–29	16	Corrugated limb variation in Thomson tree.	Corrugated	1	11	83	133	[1] 38	24	76	8	374
			Thomson	2	14	16	87	38	22	41	11	231
			Total	3	25	99	220	[1] 76	46	117	19	605
7–30	16	do	Corrugated	1	21	117	345	[1] 230	154	260	39	[1] 1,167
			Thomson	0	0	2	61	5	9	6	9	77
			Total	1	21	119	406	[1] 235	154	260	48	1,244
7–35	16	Normal Thomson limb.	Normal Thomson	18	76	73	247	215	235	338	201	1,403
29–42	244	Corrugated limb variation in Thomson tree.	Corrugated	----	1	1	9	2	4	24	2	43
			Thomson	----	3	17	25	17	72	125	40	299
			Total	----	4	18	34	19	76	149	42	342
29–43	244	do	Corrugated	----	8	7	19	23	45	92	51	235
			Thomson	----	0	4	15	16	31	133	85	284
			Total	----	8	11	27	39	76	225	136	522
31–35	244	Normal Thomson limb.	Thomson	----	----	----	----	1	4	35	4	44
31–36				----	----	----	----	2	28	56	15	101

[1] Includes one fruit that was part Corrugated and part normal.

The Corrugated strain fruits are almost wholly worthless for commercial purposes, and the unintentional propagation of trees of it has been the cause of loss to the Washington Navel growers in the Southwest in the past. Not a single tree of this strain has been found in the large number of orchards studied which have been propagated from carefully selected parent trees during recent years. This experience furnishes additional proof of the importance of the use of systematic bud-selection practices in order to avoid the unintentional propagation of undesirable strains.

RIBBED STRAIN

The name Ribbed was applied to this strain of the Washington Navel orange on account of the peculiarly ribbed or deeply creased appearance of the fruits borne by the trees of this strain. Trees, limb variations, and individual fruits of this strain have been observed in nearly all of the Washington Navel orchards studied in the Southwest.

The trees of the Ribbed strain have an appearance similar to those of the Washington strain except that they usually have a somewhat more open, drooping, and finely branched habit of growth. The foliage of the Ribbed strain trees is normally less dense than that of the Washington strain trees, and the leaves, as a rule, are more sharply pointed.

The fruits of the Ribbed strain, as shown in Figure 26, are usually somewhat pyriform, with a tendency to flattened stem and blossom ends, and medium to small in size. The rind has a dull-orange color and is of medium thickness, has a strikingly ribbed appearance, and is normally of smooth texture. The rag is tender and small in quantity, and the juice is fairly abundant but of poor flavor. The fruits are seedless, and the navels and navel openings are usually small.

The performance records of seven Ribbed progeny trees which were propagated from limb variations in four otherwise normal trees of the Thomson strain are shown in Table 17. The records of progeny trees which were propagated from normal branches of two of the same parent trees are also included for comparison.

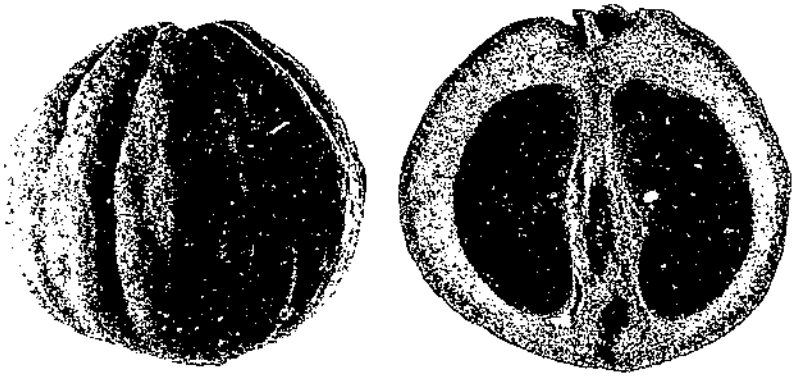

FIGURE 26.—Fruits of the Ribbed strain of the Washington Navel orange produced by progeny tree 9-27, listed in Table 17, which was propagated from a similar limb variation. Riverside, Calif., January, 1923

TABLE 17.—*Records of annual production of progeny trees propagated from limb variations of the Ribbed strain found in trees of the Thomson strain of the Washington Navel orange compared with records of trees propagated from normal limbs of two of the same parent trees*

[The first eight trees were planted in July, 1917, and the other three in May, 1919]

Progeny tree No.	Parent tree No.	Source of buds: Limb	Source of buds: Character	Fruits produced by progeny trees: Number 1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28	Total
9-27	82	Ribbed limb variation	Ribbed	2	0	75	115	1	27	247	7	474
9-29				4	21	69	229	7	107	294	31	762
9-33	85	do	do	27	85	141	273	226	319	427	264	1,762
9-34				36	143	100	168	126	267	430	221	1,501
9-47	105	do	do	35	101	37	94	120	148	253	94	882
9-48				45	147	96	119	174	189	384	80	1,234
9-49	105	Normal Thomson limb	Thomson	30	157	93	233	238	315	484	381	1,931
9-50				14	62	56	95	72	116	253	264	932
31-4	196	Ribbed limb variation	Ribbed	...	0	19	24	28	183	415	49	718
31-7	196	Normal Thomson limb	Thomson	...	1	41	106	188	227	326	119	1,008
31-8				...	6	25	120	210	218	408	134	1,121

The oranges produced by the Ribbed progeny trees have been particularly uniform, and no marked variations have been found in any of the crops, which indicates a condition of inherent stability of

these limb variations as shown by the consistent perpetuation of their characteristics through bud propagation.

The quantity of fruit produced by the Ribbed progeny trees has been somewhat smaller than that borne by the comparable Thomson progeny trees. From these and other tests with top-worked trees it seems probable that the trees of the Ribbed strain are slightly less productive than those of the Thomson or Washington strains, and the fruits are of no commercial value, on account of their peculiar appearance and inferior quality.

SEAMED STRAIN

The name Seamed has been applied to this strain of the Washington Navel orange from the peculiar longitudinal sunken lines in the rinds

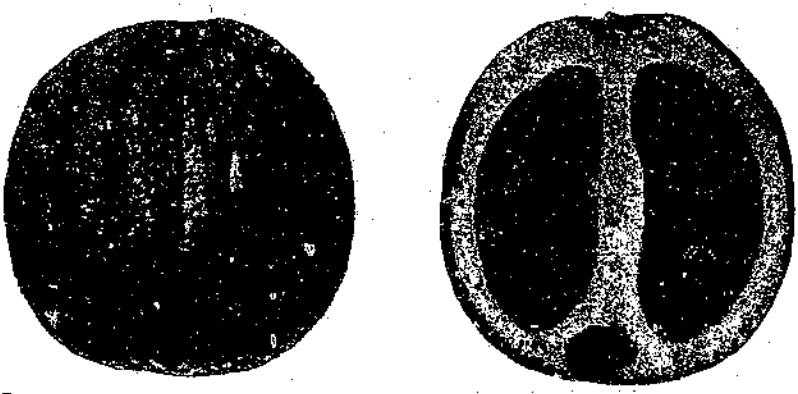

FIGURE 27.—Fruits of the Seamed strain of the Washington Navel orange produced by progeny tree 7-26, listed in Table 18, which was propagated from a similar limb variation. Riverside, Calif., January, 1928

of the fruits somewhat resembling the creases made by seams in cloth.

The habit of growth and foliage characteristics of the trees of the Seamed strain are similar to those of the Washington strain.

The fruits of the Seamed strain, as shown in Figure 27, are oftentimes oblong, the texture of the rind is rather rough, and the navels are usually of large size. The color of the fruits is light yellowish orange, the rinds are of medium thickness, the rag is coarse and somewhat tough, and the juice is fairly abundant but of inferior quality.

The performance record of two progeny trees propagated from a Seamed limb variation of a Washington tree and of two comparable progeny trees which were propagated from a normal branch of the same parent tree are shown in Table 18. This Seamed limb bore both Seamed and normal Washington fruits, but usually there were more Seamed than Washington-strain oranges. This inherent condition has been perpetuated in the two progeny trees, as is shown by the classification of the yearly production of the trees. The two progeny trees which were propagated from a normal limb of the same parent tree have produced only normal Washington fruits. The average quantity of fruit produced by the trees of the Seamed strain has been somewhat less than that of the comparable trees of the Washington strain.

TABLE 18.—*Records of annual production of progeny trees propagated from a limb variation of the Seamed strain of the Washington Navel orange compared with records of trees propagated from the normal part of the same parent Washington Navel tree*

[All progeny trees were planted in July, 1917]

Progeny tree No.	Source of buds		Fruits produced by progeny trees									
	Parent tree No.	Limb	Character	Number								
				1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28	Total
7–25	12	Seamed limb variation in Washington tree.	Seamed	40	90	111	192	100	89	367	71	1,066
			Washington	5	38	0	170	12	152	52	49	478
			Total	45	134	111	362	112	241	419	120	1,544
7–26	12	do	Seamed	30	85	47	166	116	105	282	76	907
			Washington	5	67	0	186	6	142	57	75	538
			Total	35	152	47	352	122	247	339	151	1,445
7–27	12	Normal Washington limb in same parent tree.	Washington	13	98	27	532	249	316	630	163	2,028
7–28				1	91	78	355	131	154	416	143	1,369

The rough and uneven texture of the fruits of the Seamed strain, as well as their pale color, oblong shape, and tendency to large and

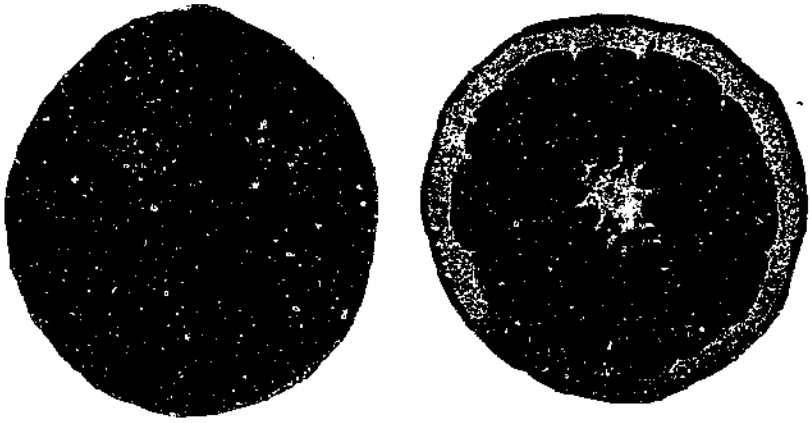

FIGURE 28.—Fruits of the Fluted strain of the Washington Navel orange borne on progeny tree 9–4, listed in Table 19, which was propagated from a similar limb variation. Riverside, Calif., January, 1928

protruding navels, render these fruits less valuable for commercial purposes than those of the Washington strain.

FLUTED STRAIN

The name Fluted was given this strain on account of the resemblance of the surface of the fruits to that of fluted columns having regular and wave-like longitudinal depressions.

The trees resemble very closely those of the Thomson strain, except that their leaves are usually slightly pointed.

The fruits are pyriform, as is shown in Figure 28, medium to small in size, and yellowish orange in color; the rinds have a rather rough texture and are of medium thickness. The rag is small in quantity

and tender, the juice is fairly abundant but of rather poor quality, and the fruits are seedless. The navels are of small size, oftentimes rudimentary, and the navel openings are small or entirely closed.

The performance records of the progeny trees from two Fluted limb variations of Thomson and of two typical Thomson trees are shown in Table 19. The first two Fluted progeny trees were propagated from a limb variation bearing Fluted strain oranges exclusively, whereas the second two Fluted trees were propagated from a limb that bore several normal Thomson fruits in addition to those of the Fluted strain. The two progeny trees of the Thomson strain were propagated from a normal limb on the same parent tree from which the second two Fluted trees were propagated.

TABLE 19.—*Records of annual production of progeny trees propagated from limb variations of the Fluted strain of the Washington Navel orange compared with records of trees propagated from a normal Thomson limb of one of the same parent trees*

[These progeny trees were planted in July, 1917]

Progeny tree No.	Source of buds		Fruits produced by progeny trees									
	Parent tree No.	Limb	Character	Number								
				1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28	Total
9–3	63	Fluted limb variation in Thomson tree (all fruits Fluted).	Fluted	6	86	60	294	134	364	633	189	1,766
9–4				12	102	25	99	30	190	361	222	1,041
8–33	50	Fluted limb variation in Thomson tree (bears both Fluted and Thomson fruits).	Fluted	24	62	34	14	33	74	169	19	420
			Thomson	0	24	7	75	18	13	69	78	284
			Total	24	86	41	89	51	87	238	97	713
8–34	50	do	Fluted	47	181	128	455	217	306	502	188	2,034
			Thomson	3	2	11	16	2	22	14	30	106
			Total	50	183	139	481	219	328	516	224	2,140
8–37	50	Normal Thomson limb in same parent tree.	Thomson	33	136	63	191	208	190	341	231	1,393
8–38				15	28	55	177	45	103	308	182	913

The first two Fluted trees have borne only Fluted fruits during the period of these performance records. The second lot of Fluted progeny trees have produced mainly Fluted fruits, but have also borne some normal Thomson oranges, as did the parent-limb variation. The progeny trees of the Thomson strain have produced only Thomson fruits thus far.

The performance records show that the characteristics of the parent Fluted limb variations have been perpetuated through bud propagation. The production of some of the progeny trees of the Fluted strain has been greater than that of the Thomson progeny trees, indicating that the trees of this strain are inherently productive. The rough texture of the rinds, their peculiar fluted appearance, and the inferior quality of the juice makes them less desirable for commercial culture than trees of the Washington or Thomson strains in the established citrus districts of the Southwest.

FLATTENED STRAIN

The name Flattened has been given to a strain of the Washington Navel orange on account of the characteristic oblate or flattened shape of the fruits borne by the trees of this strain. This strain

has been found occurring as limb variations and as individual fruits in trees of both the Washington and Thomson strains and as entire trees in orchards of these two strains.

The trees of the Flattened strain are similar in habit of growth and foliage characteristics to those of the parent trees from which the strain originates.

The fruits, as is shown in Figure 29, are distinctly flattened at both the stem and blossom ends. They are of medium size, and the rind is similar in color, thickness, and texture to those characteristics of the parent strain. The rag is tender and of medium quality, and the juice is abundant and of good quality. The fruits

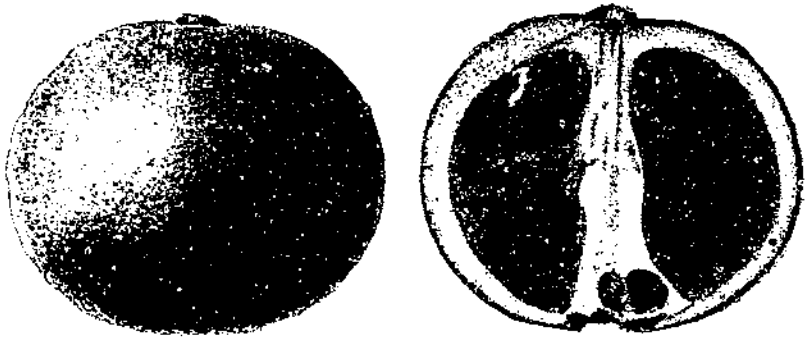

FIGURE 29.—Fruits of the Flattened strain of the Washington Navel orange produced by progeny tree S-28, listed in Table 20, which was propagated from a similar limb variation. Riverside, Calif., January, 1928

are seedless and have navels and navel openings of medium to small size.

The performance records of two progeny trees which were propagated from a Flattened strain limb variation in a Thomson strain tree and comparable records of two progeny trees of the Thomson strain are shown in Table 20.

TABLE 20.—*Records of annual production of progeny trees propagated from a limb variation of the Flattened strain found in a tree of the Thomson strain of the Washington Navel orange compared with records of trees propagated from a normal Thomson limb of a near-by tree*

[All progeny trees were planted in July, 1917]

Progeny tree No.	Source of buds			Fruits produced by progeny trees								
	Parent tree No.	Limb	Character	Number								
				1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28	Total
S-27	43	Flattened limb variation in Thomson tree.	Flattened	9	56	23	125	121	139	174	280	927
			Thomson	2	42	34	92	36	35	178	0	419
			Total	11	98	57	217	157	174	352	280	1,346
S-28	43	do	Flattened	8	48	11	90	170	181	183	323	1,020
			Thomson	4	23	19	60	21	11	197	0	335
			Total	12	71	30	156	191	192	380	323	1,355
S-37	50	Normal limb in Thomson tree	Thomson	33	136	63	191	208	100	341	231	1,303
S-38				15	28	55	177	45	103	308	182	913

The fruits borne by the progeny trees of the Flattened strain have been classified as typical Flattened strain fruits and those which more nearly resemble Thomson oranges. Most of the fruits produced by the Flattened strain trees have had the characteristic shape of the fruits of this strain, while a part of the production has been similar to that of Thomson trees. This condition has varied somewhat from year to year, indicating that the proportion of markedly flattened fruits in the crops is influenced to some extent by growth conditions.

The fruits produced by the progeny trees of the Thomson strain have all been normal or typical of this strain. The yields of these trees have been about the same as those of the Flattened strain.

These progeny tests indicate that the tendency for the development of the flattened shape of fruit characteristic of the parent-limb variation has been perpetuated through bud propagation. The flattened shape of the fruits is a disadvantage in handling and packing operations. It is difficult under existing conditions to size them

FIGURE 30.—Fruits of the Pear-Shape strain of the Washington Navel orange produced by progeny tree 9-36, listed in Table 21, which was propagated from a similar limb variation. Riverside, Calif., January, 1923

accurately, and they can not be packed in the customary manner so as to make an attractive package. For these reasons the fruits of this strain are not considered as desirable commercially as those of the Thomson and Washington strains.

PEAR-SHAPE STRAIN

The Pear-Shape strain was so named on account of the pearlike shape of the fruits produced by the trees of this strain. It has been found rather frequently as individual-fruit, limb, and entire-tree variations of the Washington, Thomson, and other strains of the Washington Navel orange in orchards where these investigations have been conducted.

The trees of the Pear-Shape strain have a somewhat upright habit of growth and rather sparse foliage. The leaves tend to be sharply pointed and are usually smaller than those of the Washington or Thomson trees.

The fruits, as is shown in Figure 30, are distinctly pyriform, and they oftentimes have a collarlike development at the stem ends. They

are medium to small in size, and the rind is usually rather rough, of medium thickness, and yellowish orange in color. The rag is fairly abundant and frequently coarse in texture, the juice is medium to small in quantity and of inferior quality. The fruits are seedless, the navels are of small size, sometimes rudimentary, and the navel openings are very small, frequently entirely closed. The fruits are of inferior commercial value on account of their small size, abnormal shape, and poor quality. This shape is also a characteristic of the fruits of some other strains of the Washington Navel variety.

Table 21 shows the performance records of two progeny trees which were propagated from a Pear-Shape limb variation in a Washington tree and six progeny trees of Pear-Shape limb variations in three Thomson trees, together with those of two progeny trees from a normal limb in a Thomson tree.

TABLE 21.—*Records of annual production of progeny trees propagated from limb variations of the Pear-Shape strain found in trees of the Washington and Thomson strains of the Washington Navel orange, compared with records of trees propagated from a normal limb in one of the same parent trees*

[All progeny trees were planted in 1917]

Progeny tree No.	Source of buds		Fruits produced by progeny trees									
	Parent tree No.	Limb	Character	Number								
				1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28	Total[1]
9–11	67	Pear-Shape limb variation in Washington Navel tree.	Pear-Shape	0	20	68	218	69	208	25	8	616
			Washington	8	25	2	17	13	0	367	116	548
			Total	8	45	70	235	82	208	392	124	1,164
9–12	67	do	Pear-Shape	2	7	42	168	51	215	40	26	551
			Washington	3	13	42	69	25	0	444	127	723
			Total	5	20	84	237	76	215	484	153	1,274
8–3	24	Pear-Shape limb variation in Thomson tree.	Pear-Shape	3	19	48	4	102	293	288	98	855
			Thomson	1	2	69	27	19	0	14	108	240
			Total	4	21	117	31	121	293	302	206	1,095
8–4	24	do	Pear-Shape	2	9	7	29	59	221	414	29	770
			Thomson	0	3	9	222	33	0	25	56	348
			Total	2	12	16	251	92	221	439	85	1,118
8–25	42	do	Pear-Shape	20	10	15	178	168	177	261	183	1,018
			Thomson	0	0	9	24	20	0	0	0	53
			Total	20	10	24	202	188	177	261	183	1,071
8–26	42	do	Pear-Shape	5	5	29	216	258	315	464	275	1,567
			Thomson	1	0	15	88	32	0	0	0	136
			Total	6	5	44	304	290	315	464	275	1,703
9–35	95	Pear-Shape variation in Thomson tree.	Pear-Shape	40	245	92	348	201	275	408	116	1,725
			Thomson	0	5	5	0	15	4	41	66	136
			Total	40	250	97	348	216	279	449	182	1,861
9–36	95	do	Pear-Shape	45	112	62	126	90	242	325	151	1,153
			Thomson	0	0	0	0	7	10	15	79	111
			Total	45	112	62	126	97	252	340	230	1,264
8–37	50	Normal limb in Thomson tree.	Thomson	33	136	63	191	208	190	341	231	1,393
8–38				15	28	55	177	45	103	306	182	913

[1] The average total production of 8 Pear-Shape trees was 1,319 fruits.

The fruits of the Pear-Shape progeny trees have been classified as those typically Pear-Shape and those resembling the normal Washington or Thomson strain fruits. All of these trees have borne both classes of fruit, the proportion varying with the progeny and from year to year. The progeny trees of the Thomson strain have produced only fruits normal for this strain.

These records show that the habit of the parent-limb variation to produce Pear-Shape fruits has been perpetuated by bud propagation. The foliage as well as the fruit characteristics of the parent-limb variation have been shown to be heritable characters in these tests.

The Pear-Shape trees have been fully as productive as the Thomson trees, but on account of the less desirable character of the fruits, the Pear-Shape strain is not a valuable one for commercial propagation.

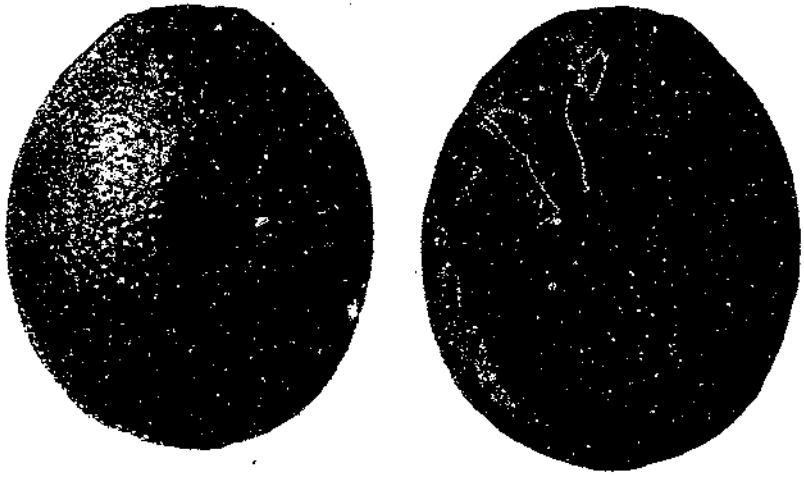

FIGURE 31.—Fruits of the Elliptical strain of the Washington Navel orange produced by progeny tree S-30, listed in Table 22, which was propagated from a similar limb variation. Riverside, Calif., January, 1928

ELLIPTICAL STRAIN

The Elliptical strain of the Washington Navel Orange has been so named on account of the characteristic shape of the fruits produced by the trees of this strain.

The trees of the Elliptical strain are similar to those of the Thomson strain.

The fruits, shown in Figure 31, differ from Thomson strain fruits mainly in shape, having an oblong longitudinal midsection with tapering stem and blossom ends. The rind, rag, and juice characteristics of the Elliptical strain fruits in these studies have been very much like those of Thomson oranges.

The performance records of four progeny trees which were propagated from Elliptical strain limbs in Thomson strain parent trees, together with those of two comparable progeny trees of the Thomson strain, are presented in Table 22.

TABLE 22.—*Records of annual production of progeny trees propagated from limb variations of the Elliptical strain of the Washington Navel orange compared with records of trees propagated from a normal Thomson limb*

[These progeny trees were planted in July, 1917]

Progeny tree No.	Source of buds: Parent tree No.	Source of buds: Limb	Fruits produced by progeny trees: Character	Number: 1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28	Total [1]
8–1	23	Elliptical limb variation in Thomson tree.	Elliptical	0	0	4	55	4	159	340	29	591
			Pear-Shape	0	0	0	20	1	0	5	0	26
			Thomson	0	0	0	18	4	0	0	47	69
			Total	0	0	4	93	9	159	345	76	686
8–2	23	do	Elliptical	0	0	4	131	68	172	359	30	764
			Pear-Shape	0	0	0	22	15	0	6	1	44
			Thomson	0	0	2	61	28	2	0	50	143
			Total	0	0	6	214	111	174	365	81	951
8–29	45	Elliptical limb variation in Thomson tree which also has a Pear-Shape limb.	Elliptical	27	148	51	230	222	197	402	87	1,364
			Pear-Shape	0	8	5	0	0	13	0	0	26
			Thomson	3	0	13	0	0	0	0	39	55
			Total	30	156	69	230	222	210	402	126	1,445
8–30	45	do	Elliptical	28	173	81	321	245	270	512	130	1,760
			Pear-Shape	3	7	10	0	0	5	0	0	25
			Thomson	4	0	7	0	0	0	0	42	53
			Total	35	180	98	321	245	275	512	172	1,838
8–37	50	Normal limb in Thomson tree containing two limb variations.	Thomson	33	135	63	191	208	190	341	231	1,393
8–38				15	28	55	177	45	103	308	182	913

[1] The average total crop of 4 Elliptical strain trees was 1,230 fruits.

The crops of the Elliptical strain trees have been classified according to the shape of the fruits. While these trees have borne largely Elliptical fruits, they have also produced a few oranges that have been classed as of the Pear-Shape strain and others of the normal Thomson strain. One of the parent trees in addition to the Elliptical limb variation also had a Pear-Shape limb sport, while the other parent tree has developed an occasional Pear-Shape fruit on the Elliptical limb variation.

These records show that the elliptical shape of fruits of the parent limb variations has been transmitted to progeny trees, and they constitute additional evidence that fruit shape is a characteristic of limb variations which can be perpetuated through bud propagation. The Elliptical strain progeny trees have been as productive as those of the Thomson strain, but by reason of their unusual shape the fruits of this strain are less desirable commercially than those of the Thomson strain.

SHEEPNOSE STRAIN

The name Sheepnose has been adopted for a strain of the Washington Navel orange on account of the similarity in the shape of its fruits to those of the so-called Sheepnose apples.

The trees of this strain are more finely branched and the leaves are smaller, narrower, and more sharply pointed than is the case with Washington trees. They are prolific bearers and tend to produce a larger number of oranges than the normal trees of the parent strain under comparative cultural conditions. However, the weight of the fruits produced by Sheepnose trees is usually less than that of the crops produced by comparable normal-strain trees, on account of their small size.

The fruits of the Sheepnose strain, shown in Figure 32, are of very small size, yellowish orange color, ovate in shape, with peculiar and characteristic protrusions of the distal ends, due to the development of abnormally large inclosed navels at the tips of the fruits. The texture of the rind is coarse, and many of the fruits are wrinkled or ridged, especially at the stem end. The rinds are thick, the rag abundant and coarse, and the juice is small in quantity and of poor flavor. On account of the peculiar shape of the fruits, their very small

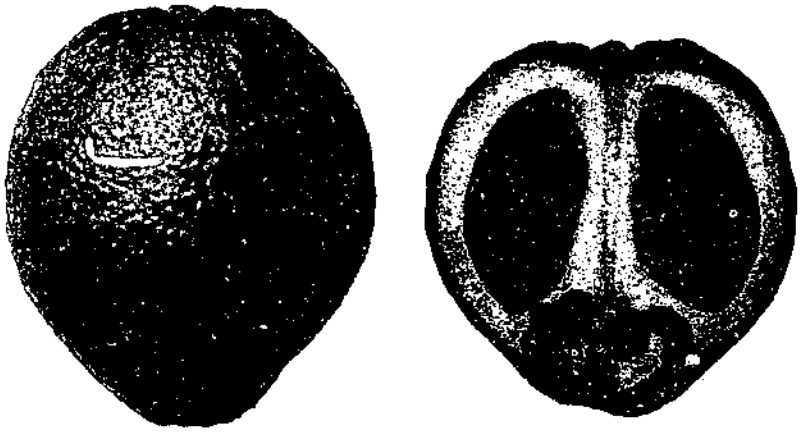

FIGURE 32.—Fruits of the Sheepnose strain of the Washington Navel orange produced by progeny tree 9–30, listed in Table 23, which was propagated from a similar limb variation. Riverside, Calif., January, 1925

size, coarse texture of the rinds, and inferior quality of the juice, the Sheepnose strain is a very undesirable one for commercial cultivation.

The performance records of two progeny trees of the Sheepnose strain which were propagated from a limb variation in a Thomson tree and those of two comparable progeny trees of the Thomson strain which were propagated from a normal limb of the same parent tree are shown in Table 23. These records show that all the oranges produced by the Sheepnose strain progeny trees have been typical Sheepnose fruits, whereas those borne by the Thomson strain progeny trees have all been normal Thomson oranges. The small size of the fruits produced by the trees of the Sheepnose strain is shown by the fact that during the last three years they averaged only 3.01 ounces each in weight, whereas those borne by the normal Thomson trees averaged 5.35 ounces. The shape, color, texture of rind, quality of juice, and other characteristics of the fruit produced by the parent-limb variation have also been transmitted to the progeny trees. This

is a striking illustration of the origin of strains through the propagation of limb variations.

TABLE 23.—*Records of annual production of progeny trees propagated from a limb variation of the Sheepnose strain found in a tree of the Thomson strain of the Washington Navel orange, compared with records of trees propagated from a normal limb of the same parent tree*

[All these progeny trees were planted in 1917 except 9–32 which was replanted in 1919.]

Progeny tree No.	Source of buds		Fruits produced by progeny trees									
	Parent tree No.	Limb	Character	Number								
				1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28	Total
9–29	84	Sheepnose limb variation in Thomson tree.	Sheepnose	60	157	259	214	104	269	543	353	1,959
9–30				75	251	451	285	400	706	1,160	633	3,976
9–31	84	Normal Thomson limb	Normal	18	84	103	176	129	220	426	219	1,380
9–32				4	49	26	96	85	149	343	172	904

ROLLED-LEAF STRAIN

The Rolled-Leaf strain of the Washington Navel orange was so named because the leaves develop in a characteristically rolled manner instead of being flat or nearly flat like normal leaves.

This strain was first seen in an orchard in which there were several entire trees of this character and other trees containing similar large and small limbs. The owner was rather concerned about these trees because they appeared to be in a wilted condition, though ample irrigation water had been used. The leaves were peculiarly rolled upward about the midribs, so that the upper sides of the leaves were largely concealed, and the area exposed to view was almost entirely that of the under surface.

In the spring of 1921, in order to determine whether the rolled-leaf condition was due to environmental influences or to inherent causes, buds were obtained from some of the limbs having rolled leaves in otherwise apparently normal trees and were inserted in sour-orange seedlings in a citrus nursery at Altadena, Calif. Of about 100 nursery trees resulting from these propagations, all produced typically rolled leaves similar to the parent limbs. These nursery trees were transplanted in 1923 to several experimental progeny plantings, including two trees at Riverside in progeny orchards of the Citrus Experiment Station of the University of California. The Rolled-Leaf progeny trees have continued to produce typically rolled leaves, as is shown in Figure 33, and their condition has shown that this character is an inherent one.

Some of the trees in the parent orchard were found to bear fruits typical of the Washington strain, whereas others produced Thomson strain oranges. The progeny trees have just begun to bear, and those that have been observed have produced typical Washington Navel fruits.

This progeny test is of particular interest in showing that striking and peculiar leaf characteristics occurring as limb variations have been transmitted through bud propagation.

STRAINS OF MINOR ECONOMIC IMPORTANCE

Many other bud and tree variations of the Washington Navel orange have been found in these investigations, but on account of their less striking appearance or less frequent occurrence they have been

considered to be of rather economic importance. The performance [illegible] progeny trees which were propagated from five such [illegible] otherwise normal trees are presented in Table 24, [illegible] performance records of two progeny trees of the [illegible] which were propagated from a normal branch of one [illegible]

TABLE 24.—*Records of annual production of progeny trees propagated from limb variations of various forms compared with records of trees propagated from the normal Thomson portion of one of the same parent trees*

[Nearly every season some normal fruits were produced on the abnormal progeny trees or some that showed only part of the typical abnormal characters and these have been listed in a miscellaneous class. These progeny trees were planted in July, 1917]

Progeny tree No.	Source of buds		Fruits produced by progeny trees									
	Parent tree No.	Limb	Character	Number								
				1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28	Total
8–5	31	Yellow, wrinkled, pebbled, red streaked—limb variation in Thomson tree.	Typical	6	32	7	150	114	242	[1] 231	106	888
			Miscellaneous	0	4	2	4	0	5	58	2	75
			Total	6	36	9	154	114	247	289	108	963
8–6	31	do	Typical	14	29	14	70	108	129	[1] 128	106	607
			Miscellaneous	1	5	2	3	0	0	27	3	41
			Total	15	34	16	82	108	129	155	109	648
8–7	31	Yellow, ridged, protruding oil cells—limb in Thomson tree.	Typical	18	0	0	80	52	84	[1] 151	35	420
			Miscellaneous	0	0	0	2	0	0	11	3	16
			Total	18	0	0	82	52	84	162	38	436
8–8	31	do	Typical	5	3	0	93	18	110	[1] 250	55	534
			Miscellaneous	0	0	0	0	0	0	13	0	13
			Total	5	3	0	93	18	110	263	55	547
8–9	31	Normal part of same Thomson tree.	Thomson	5	0	0	91	27	105	204	31	463
8–10			do	16	4	[2] 14	124	[3] 26	171	321	106	792
9–5	64	Yellow and Washington fruit sections—limb variation in Washington tree.	Sections	24	38	21	21	120	74	110	74	482
			Washington	0	5	14	43	27	16	55	0	160
			Yellow Thomson	0	76	42	225	41	108	253	27	832
			Thomson	0	10	0	0	0	32	0	22	64
			Total	24	129	77	289	188	290	418	123	1,538
9–6	64	do	Sections	17	89	8	15	36	41	23	76	305
			Washington	0	0	3	8	10	5	5	0	31
			Yellow Thomson	0	0	19	80	46	148	203	40	542
			Thomson	0	8	0	0	0	4	8	2	22
			Total	17	97	30	103	92	198	239	124	900
9–7	64	Thomson and Washington fruit sections—limb variation in Washington tree.	Sections	0	0	1	9	5	11	0	0	26
			Thomson	21	44	93	249	149	205	175	1	937
			Total	21	44	94	258	154	216	175	1	903
9–8	64	do	Sections	1	1	3	11	10	5	0	2	33
			Thomson	9	28	74	302	72	170	315	28	998
			Washington	0	2	3	5	0	0	1	0	11
			Total	10	31	80	318	82	175	316	30	1,042
9–9	64	Intermediate between Thomson and yellow Thomson, limb variation in Washington tree.	Typical	19	18	60	200	3	10	170	4	484
			Miscellaneous	0	2	4	6	1	1	0	1	15
			Total	19	20	64	206	4	11	170	5	499
9–10	64	do	Typical	1	1	12	150	0	16	227	8	415
			Miscellaneous	0	0	0	11	0	16	25	1	53
			Total	1	1	12	161	0	32	252	9	468

[1] None of these fruits were pebbled or showed protruding oil cells, but a few fruits with those characters are included in the miscellaneous class for this season.
[2] Includes 1 yellow Thomson fruit.
[3] Includes 2 ridged Thomson fruits.

The trees of these strains which were propagated from the limb variations are very similar in appearance to those of the parent limb. The fruits differ from the normal ones in color, texture, and to some extent in shape, as indicated in the table, and they are all of inferior commercial quality as compared to those of the Washington strain. Fruits showing Washington and Yellow Thomson sections as produced by tree 9–5 listed in Table 24 are shown in Figure 34.

The most interesting point brought out in these performance records is the relatively unstable character of the production of the progeny trees. Some of the progenies have been more inherently stable than others, but as a whole the tendency has been for the progeny trees to

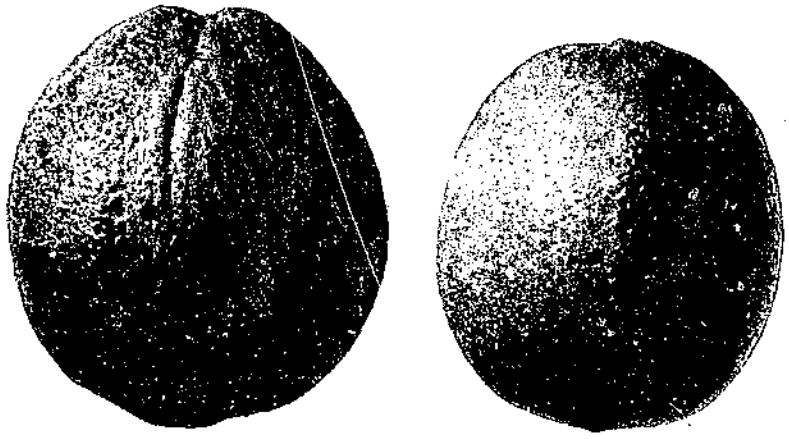

FIGURE 34.—Fruits showing sections of rind that resemble those of both the Yellow Thomson and Washington strains. These were produced by progeny tree 9–5, listed in Table 24, which was propagated from a limb variation. The tree containing this limb also had several other variable limbs and many individual-fruit variations. Riverside, Calif., January, 1928

produce a large proportion of fruits typical of those borne by the parent-limb variations.

OTHER STRIKING LIMB VARIATIONS

In addition to the striking limb variations of Washington Navel orange trees described in the foregoing pages, many others have been found from time to time which are of more than ordinary interest. These variations have been discovered for the most part in trees growing in orchards other than those where the original Washington Navel individual-tree performance-record work was carried on, and many of them have been found in the course of subsequent tree-estimate studies with full-bearing trees in established orchards. Progeny propagations have been made of most of these limb variations during recent years, but the performance records are not complete enough as yet for their presentation. Enough evidence has been obtained in some instances, however, to warrant a brief presentation of the results of these tests, together with descriptions of the outstanding characteristics of the limb variations and their progenies.

Variegated-Leaf limb variations have been found in two otherwise normal trees of the Washington strain. The outer edges of the leaves of these variations have been of a creamy color, while the central por-

tions have been apparently normal, showing one or more shades of light green with a dark-green central area. (Fig. 35.) The growth of the Variegated-Leaf variations has been less vigorous than that of normal branches. The fruits of the Variegated-Leaf limb variations have been apparently normal in appearance, but their number has been somewhat less than that of comparative normal limbs. These variations of the Washington Navel variety are similar in appearance to those found in Valencia orange and Eureka lemon trees. They have no apparent economic value except possibly for ornamental plantings, as the production of the progeny trees is less than that of progeny trees from normal branches of the same tree.

An Everbearing limb variation found in an orchard in the Highgrove district of Riverside, Calif., has proved to be of great interest.

FIGURE 35.—Foliage from a progeny tree propagated from a Variegated-Leaf limb variation in an otherwise normal Washington Navel tree. Riverside, Calif., March, 1928

In this instance a single limb in an otherwise normal Washington Navel tree has produced clusters of oranges of different sizes and stages of maturity. (Fig. 36.) On account of the tendency of this limb, and the progeny trees propagated from it, to flower and develop fruits at different seasons of the year, the term Everbearing has been given to this variation.

The parent-limb variation was discovered on account of the development of large clusters of fruit produced by some of the branches. On some of the small branches fruits developed from buds in the axils of nearly every leaf, and in a few instances thorns were found bearing oranges similar to the fruits in the clusters.

Buds cut from the Everbearing limb variation were first inserted in sour-orange seedling stocks in 1922, and subsequent propagations

have been made from both the parent limb and the progeny trees. The progeny tests of the Everbearing limb variations have not gone far enough to warrant final conclusions, but enough evidence has been obtained to show that some of the peculiarities of the parent limb have been transmitted to the progeny trees. The extraordinarily prolific characteristic of the parent limb is shown in the progeny trees, some of them bearing from 25 to 53 oranges at 2 years of age

FIGURE 36.—Cluster of fruit on the Everbearing limb variation in an otherwise normal Washington Navel tree. Highgrove, Calif., January, 1927

while standing in nursery rows. On some of the nursery trees flowers have grown on thorns and have developed into fruits in a manner similar to that of the parent-limb variation. At different seasons the progeny trees have tended, to an unusual extent, to produce flowers, some of which develop fruits but many of which drop either just after flowering or when the young fruits are from one-quarter to one-half inch in diameter. A tree bearing 58 oranges one and one-half years after being planted is shown in Figure 37.

The progeny trees of the Everbearing limb have habits and vigor of growth and size and shape of leaves similar to trees of the Washington strain, although frequently a long semitrailing branch is produced which blooms freely and usually sets a few fruits. The fruits vary in appearance, particularly in the texture of the rind, some of them being very smooth and others having a somewhat rough texture with few oil cells. The thickness of the rind, the quantity of rag and

FIGURE 37.—Progeny tree of the Everbearing strain of the Washington Navel orange that was propagated from the limb variation [illegible] n in Figure 36. This tree was planted in the fall of 1926 and photographed February 8, 1928, when it was bearing 58 fruits. Corona, Calif.

juice, and the flavor of the juice are very similar to those characteristics of fruits of the Washington strain.

In another outstanding instance a limb variation was found in an otherwise normal tree of the Washington strain which bears seedless oranges closely resembling those of the Washington strain except that they do not have navels (fig. 38) and they remain on the tree in good condition for two or three months longer than normal fruits. A progeny propagation of this limb variation has shown the same characteristics of the parent-limb variation. The indications are that this strain may be a commercially valuable one on account of its fruiting characteristics, and a commercial test is now being made of it.

A series of teratological variations have been found from time to time in all of the Washington Navel orange orchards where these investigations have been carried on. These variations have usually occurred as individual fruits, although in some instances several have

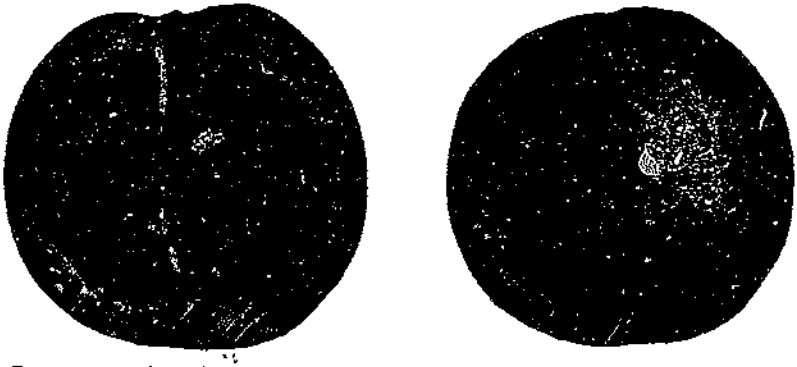

FIGURE 38.—Fruits produced on a tree that was top-worked from a limb variation in a Washington Navel tree. The parent limb bore seedless fruits without navels that remained on the tree several weeks longer than the normal fruits on the other limbs, and the fruits on the top-worked tree appear to have the same characters. Redlands, Calif., March, 1928

been found on a single limb, indicating a tendency toward the production of these abnormal fruits.

One of the most common of these fruit variations is the occurrence of extraordinarily large protruding navels, as shown in Figure 39. In these cases the secondary orange or navel sometimes develops to

FIGURE 39.—Fruits with large protruding navels from a Washington Navel orange tree which produced similar abnormal fruits several seasons during the performance-record period. Riverside, Calif., February, 1917

one-quarter or one-half the size of the primary orange, with a structure somewhat similar to that of the fruits to which they are attached.

In a number of individual trees and limbs under investigation the large protruding navel condition seems to vary during different sea-

sons, so that, although many such protrusions are found during certain seasons, the fruits on these trees are apparently normal in this respect the following season. In two progeny propagations of limbs having fruit with protruding navels in otherwise normal trees there has not been any conclusive evidence thus far that this condition has been transmitted except that more such abnormal fruits have occurred on these progeny trees during occasional seasons than on comparable trees of the Washington strain. The protruding navels are very objectionable from the commercial standpoint, on account of their appearance and because of the susceptibility to injury and diseases which lead to decay of the oranges having these abnormal growths. All such fruits are sorted out in the packing houses and are thrown into the cull bin.

A growth somewhat similar to a large protruding navel has been found on the side of some fruits. (Fig. 40.) Commercially, this

FIGURE 40.—Views of an abnormal Washington Navel orange having a secondary growth near the stem end, like a large protruding navel. Riverside, Calif., February, 1917

condition is even more undesirable than that of the ordinary protruding navel, but it is of some interest from the bud-variation point of view.

Double navel oranges have been found occasionally in trees of several strains of the Washington Navel, but more often in those of the Australian strain. This tendency for trees of certain strains to produce more of such teratological forms than do those of other strains has been observed in these studies, but examples of abnormal fruits have been found in one or more trees of all of the strains under observation.

The structure of the double oranges indicates that these fruits have developed from individual flowers having double ovaries. (Fig. 41.) In some instances both ovaries grow at about the same rate, whereas

in others one ovary develops more rapidly and reaches a greater size than the other. In other instances several ovaries are produced in a flower or one ovary becomes cut or broken and develops with resulting

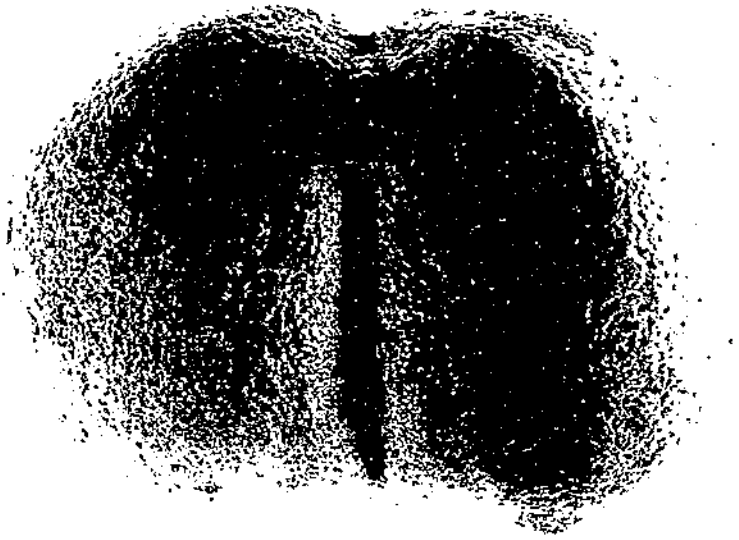

Fig. [illegible] Navel oranges borne on a single stem. This fruit [illegible] Riverside, Calif., March, 1923.

small fingerlike fruits attached to a single stem. So far as observed there has been no evidence of an inherent tendency to produce these fruits, nor have any of them appeared to be of commercial value.

Witches'-broomlike growths have been found in several trees of the different strains of the Washington Navel orange during these investigations. (Fig. 42.) These abnormal vegetative growths somewhat resemble those called witches'-brooms, which are thought to be of a pathological nature in certain other plants. However, careful studies

FIGURE 42.—An abnormal development of a Washington Navel branch like a witches'-broom. Several similar growths have been observed in citrus trees, but no pathological condition has been found in any of them. Riverside, Calif., spring of 1920

of these structures in Washington Navel trees have failed to reveal any diseased condition. Progeny propagations of some of these forms have resulted in trees having very abnormal foliage and fruits.

The witches'-brooms observed in Washington Navel trees apparently originate from adventitious buds. The growth is made up of

rapidly growing straight branches which have an angular shape, large size, and soft tissues. Peculiar burlike growths bearing many buds occur at many or all of the leaf axils, and the leaves are oftentimes abnormally large, acutely pointed, and of light-green color. The fruits, usually very few in number, are smaller than the normal and have thick rinds of coarse texture and but little juice of an inferior quality.

Many other abnormal foliage and fruit forms have been observed in the course of these studies, some of which have been propagated in order to determine their heritability. One of these appears as fruits which split open as they approach maturity. Progeny propagations from these trees and others of more than ordinary interest are under way but have not gone far enough as yet to permit the presentation of final conclusions regarding their performance.

LESSONS FROM THE PROGENY TESTS

The progeny tests of limb variations in otherwise normal Washington Navel orange trees which have been described in the foregoing pages show the inheritance of the different characters which were noted as limb variations and indicate clearly the importance of bud selection in the propagation of this variety in order to avoid the perpetuation of undesirable variations in orchard plantings. These tests, together with related orchard experience during the past 18 years, prove that limb variations are of great importance from the fact that in obtaining bud wood for nursery propagation buds taken unintentionally from such limbs have probably given rise to many if not to all of the trees of the diverse strains which have been observed during these investigations.

These progeny tests have shown that where the fruit and foliage characters were uniform in the parent-limb variations these characters are uniformly transmitted to the progeny trees. When the parent limb produced normal as well as abnormal fruits, or where the limb developed more than one kind of fruit or foliage variation from the normal, the progeny trees of such limbs perpetuated the unstable characteristics of the parent variations and in about the same relative proportion. The perpetuation of the undesirable limb variations, whether of the stable or the unstable class, is a matter of fundamental importance to commercial orchardists where profitable cultivation depends upon the production of uniformly desirable crops.

The trees of some of the strains grow much more vigorously than those of other strains. Some of them produce an abnormal proportion of rank-growing, nonfruiting branches, which are commonly called suckers. The tendency to produce this type of growth has been found to be perpetuated through bud propagation. As a result of these investigations the commercial propagation of trees of these undesirable strains has been discontinued.

These progeny tests have shown that certain low-producing limb variations in otherwise normal trees have transmitted this characteristic to their progenies, thus indicating that quantity of fruit is an inherent character which is perpetuated through bud propagation.

The distinction between inherent variations in quantity of production and those which are not transmitted through bud propagation is not always clearly realized. In these studies only those variations in

quantity of production which are perpetuated through budding have been considered as a strain characteristic. Differences in quantity of fruit due to environmental conditions which are not inherited are commonly called fluctuations. The progeny test as described in this bulletin is a reliable method for determining whether variations in quantity of production are inherent or are merely fluctuations in yield due to environmental factors.

Inasmuch as quantity production is of primary importance to the profitable growing of orange crops, the value of bud selection in avoiding the unintentional propagation of unproductive variations has been forcibly demonstrated.

The quality of oranges from the commercial viewpoint depends largely upon their size, shape, color, nature and extent of blemishes, texture and thickness of rind, quantity and kind of rag, and quantity and flavor of juice. These progeny tests have included the records of trees propagated from limb variations which differ markedly in one or more of these characteristics from the normal fruits borne by other branches of the same parent trees. The very small and the abnormally large sizes of oranges borne by the parent-limb variations have been perpetuated in their progenies. The pyriform, oblong, flattened, and other abnormal shapes of the fruits produced by limb variations have been transmitted to the progeny trees. The brown-spotted, corrugated, ridged, granular, knobbed, and creased oranges of the limb variations have been largely or entirely reproduced in the progeny trees. The thickness of the rind and quantity and quality of the juice of the fruits produced by limb variations have been transmitted to the progeny trees. On the whole these progeny tests have shown that all types of variations in those characteristics that make up commercial quality of the fruits have been produced by different limbs and have been transmitted to their progenies through bud propagation.

In addition to quantity and quality of fruits, the season of their maturity is an important economic factor in commercial orcharding. It is particularly important that the market package include only uniformly mature fruits. The fruits of some strains of the Washington Navel orange mature at different periods from the normal. For example, the fruits of the Australian strain do not reach a satisfactory stage of maturity for a considerable time, often three months, after the normal oranges have ripened. With a mixture of trees of the Australian strain in orchards of the Washington strain, the late, maturing fruits are either picked with the general crop or are left for later picking. The assorting of the Australian oranges in the packing houses is a difficult and expensive matter, and usually some of them are accidentally included with the regular pack, thus lowering the grade for the pack as a whole. If the scattered trees are picked separately this method involves a heavy extra expense which is usually not justified on account of the inferior value of the fruits. Other progenies in which the trees produce mature fruit out of the normal season and similar to that of the parent-limb variations indicate that the season of maturity is another characteristic of certain limb variations which can be perpetuated through bud propagation.

Seasonal fluctuations in the fruiting or foliage characteristics of Washington Navel trees due to abnormal environmental influences are not perpetuated through budding. However, it has been found

that the trees of some strains tend to resist certain unfavorable climatic or cultural influences more strongly, or that they respond more readily to favorable conditions than those of other strains of this variety. The progeny test is a satisfactory method for showing whether or not observed variations are inherent and for determining their relative values.

VALUE OF BUD SELECTION TO THE WASHINGTON NAVEL ORANGE INDUSTRY

As a result of these investigations it has been shown that bud variations in trees of the Washington Navel variety are of frequent occurrence and of fundamental importance in this variety. The presence of some of the inferior trees found in established orchards has been proved to be due to the unintentional propagation of undesirable bud variations when the trees in these orchards were propagated. These studies have shown the possibility of maintaining the variety from so-called "running out" and improving its efficiency for valuable fruit production by avoiding the further propagation of the unproductive and undesirable strains because their occurrence was not suspected. This knowledge has given orange growers renewed confidence in the Washington Navel variety, which has resulted in increased plantings in recent years. As a result of the bud-selection investigations the new plantings have been composed almost entirely of trees grown from carefully selected bud wood.

In striking contrast to the numbers of trees of inferior strains which were found in established orchards at the time these bud-variation and selection studies were begun is a recent tree-estimate study of more than 100 young Washington Navel orchards in which the trees were propagated from selected superior parent trees. These orchards have failed to reveal a single markedly off-strain tree. The production of these young groves has been more uniformly satisfactory both as to quantity and quality of fruit than have groves otherwise comparable in which the trees were propagated from bud wood not systematically selected.

In established orchards the abnormal-strain trees have largely been eliminated by top-working or replanting, and the undesirable limb sports have been pruned from the trees. This removal of undesirable bud variations has resulted in an improved production both as to the quantity and the commercial quality of the crops.

The most serious loss arising from the presence of poor fruit is that to the reputation of the crop as a whole. While it is possible to sort out many of the undesirable fruits, it is impracticable to eliminate all of them in the sorting processes in the packing house. Some off-type strains, such as the Ridged or Sheepnose fruits, are easily distinguished from the normal by their appearance. Others are apparently normal in outward appearance but when cut open are found to have thick peel, coarse rag, juice of poor flavor, or other detrimental qualities.

It costs as much to care for the trees bearing the undesirable variations as for those with the most desirable fruits. In assorting the crop preliminary to packing there is an added expense in eliminating the undesirable oranges, most of which go into the cull grade. These unmarketable fruits are usually a total loss to the growers, and the

expense of disposing of them must be added to the cost of handling the crop.

The Washington Navel variety is the most important possession of the industry by reason of its proved production of profitable crops which have obtained an invaluable market reputation. The necessity for maintaining and improving the productiveness of the variety must therefore be apparent to every thinking person.

In May, 1917, the California Fruit Growers' Exchange, a cooperative marketing organization having a membership of more than 11,000 citrus growers, established a bud department in its Fruit Growers' Supply Co., a subsidiary which furnishes supplies to its members. From 1917 to 1928, inclusive, the bud department as a public service furnished to nurserymen and growers, nonmembers as well as members of the organization, a total of 1,065,253 Washington Navel orange buds selected from superior fruiting parent trees of the Washington strain. In addition, other organizations and individual nurserymen in the Southwest have used more than 300,000 Washington Navel buds obtained from similarly selected parent trees. Many growers have used buds obtained from superior trees from their own orchards for top-working undesirable strain trees in the same orchards. The commercial results of this work have been a heavier and a more uniformly valuable quality of production than was the case before the use of carefully selected buds became almost universal in the Washington Navel orange industry.

ISOLATION AND PROPAGATION OF SUPERIOR STRAINS

Some of the limb variations studied have been found to produce more or better fruits, or both, than the normal branches of the same parent trees. Such limb variations are less easily distinguished than those which bear markedly inferior fruits or those which are decidedly different from the normal. Progeny propagations of the apparently superior limb variations in comparison with those of normal branches of the same parent trees must be carried on for a considerable period of time in order to determine the relative value of these variations.

The progeny tests of apparently superior limb variations which have been made in commercial orchards indicate that superior strains have been isolated from superior limb variations in otherwise normal trees.

In full-bearing Washington Navel orchards, where cooperative commercial tree-performance record work with growers has been carried on, individual trees have been found which have produced consistently, for a period of four or more years, a larger quantity and a better quality of fruit than the other trees in the orchards. In many instances buds cut for commercial propagation from these trees have been budded in the nurseries as individual tree progenies, so that the nursery trees can be traced back to the parent trees. The nursery progeny trees have been transplanted to commercial orchards where the arrangement of planting is such that each progeny can be identified, so that its performance records may be compared with those of other progenies and of the parent trees.

The performance records of a number of these commercial progeny plantings indicate that in some of the progenies the characteristics of the parent trees have been perpetuated more uniformly than is

the case in other progenies. The individual trees which have consistently borne the heaviest crops of desirable fruits in the most uniformly superior progenies have been selected for further propagation, and the individual-tree performance records in several orchards of this second bud selection indicate that further improved production has been obtained in this way.

The individual-tree performance record is the basis for the selection of apparently superior parent trees as sources of budwood for the development of superior strains. Methods for obtaining such records have been described in Farmers' Bulletin 794 (*13*).

In several commercial Washington Navel progeny plantings in California where commercial individual-tree performance records have been obtained, about 50 per cent of the total number of trees on the average have been considered satisfactory sources of buds for further propagation, whereas in the orchards where the parent trees were located less than 1 per cent of the trees were selected for propagation. In some particularly desirable progenies more than 75 per cent of the trees have been used as sources of selected bud wood.

The general application of the results of these investigations has led to greatly improved yields and more profit from the culture of the Washington Navel orange. This variety has been stabilized through the isolation and propagation of the best strain and the elimination of the undesirable ones. The performance records which are being obtained in commercial orchards of this variety which were propagated from superior parent trees and limb variations indicate that better yielding strains have been obtained than any heretofore in cultivation.

Progeny tests of a number of striking and apparently valuable limb variations in otherwise normal Washington Navel orange trees are now being conducted at several locations in the Southwest. In most instances the fruits of the parent-limb variations and the progeny trees propagated from them have one or more characteristics which are considered to be improvements upon the normal Washington strain fruits for commercial production. So far as these tests have gone, the results indicate that improved strains have been isolated which will be of commercial value at least in certain districts, and they show the importance of a study of all apparently valuable limb variations by means of the progeny-test method and commercial orchard experience.

REPLACING TREES OF UNDESIRABLE STRAINS

The trees of undesirable strains in bearing Washington Navel orange orchards can be replaced by either one of two proved methods, viz, by top-working or by replanting. Each of these methods has been used successfully, both experimentally and commercially, in the course of these investigations.

The identification of the inferior-strain trees for top-working or replacement in the orchard should be based upon their performance records. Where it is not practicable to obtain individual-tree records of actual production it has been found that estimate records of the individual-tree yields before they have been picked are satisfactory for the purpose of locating the undesirable-strain trees. Methods of obtaining such records are described in Farmers' Bulletin 794 (*13*).

Detailed directions for top-working the inferior trees are given in Farmers' Bulletin 1447 (*17*). It is important that all new growth of the top-worked trees be carefully removed from time to time excepting that from the inserted buds. Many thousands of trees of undesirable strains have been successfully top-worked in the Washington Navel orchards of California during the period covered by these investigations, and the production of these orchards, both as to quantity and quality of fruit, has been materially improved as a result of this work.

In some of the old orchards which have trees of undesirable strains, replanting with desirable young Washington strain trees has been found to be preferable to the top-working method of replacement, especially where the inferior-strain trees have been injured by disease or in other ways. The treatment and care of the replanted trees are described in Farmers' Bulletin 1447 (*17*). In a few instances under recent observation desirable trees of the Washington strain up to 12 years of age have been used for replacing inferior-strain trees in old orchards, and the results of the practice of replanting with older trees thus far indicate that it has been successful under the conditions where it has been used.

SUMMARY

The Washington Navel orange variety was introduced into the United States from Bahia, Brazil, in 1870, by the United States Department of Agriculture, and two trees propagated from this introduction were sent to Mrs. Eliza Tibbets, at Riverside, Calif., in 1873. From this beginning the Washington Navel orange industry of the Southwest has developed, largely within the last 35 years, until the variety is now one of the most important and extensively grown citrus fruits in the United States.

The individual-tree performance-record studies of bearing trees of the Washington Navel orange which have been made in several orchards in southern California since 1909 have shown that these groves consist of at least 20 strains of commercial importance with 5 or more others of less economic consequence. The trees of each of these strains have fruit or vegetative characteristics, or both, which serve to distinguish them from all other trees of the variety.

About 25 per cent of the total number of trees studied in the original orchards in which these investigations have been conducted were found to be of undesirable strains having consistently low yields, or bearing fruits of poor quality, or both, such as those of the Australian, Unproductive, Corrugated, Pear-Shape, Sheepnose, Flattened, Dry, and other inferior strains. The presence of these trees reduced the quantity and quality of the crops of these orchards about in proportion to their number, and added to the expense of preparing the crop for the market by reason of the cost of assorting and grading the fruits in the packing houses. When accidentally included in the packed boxes the fruits of the trees of the undesirable strains had a detrimental effect upon the market reputation of the variety as a whole.

Limb variations in which the fruit and foliage characteristics were strikingly different from those of the normal limbs of the same trees were found in certain Washington Navel trees during these investigations, and when once identified they were easily recognized during subsequent studies.

The similarity of the fruits and foliage of the limb variations to those of entire-tree variations in established orchards suggested the probability that the tree variations were the result of the unintentional propagation in commercial nursery practice of limb variations occurring in trees otherwise normal. In order to obtain definite evidence on this subject, propagations of a number of limb variations and of normal limbs in the same parent trees were made in 1915, and the resulting progeny trees were planted at Riverside in the orchard of the Citrus Experiment Station of the University of California in 1917. The results of these progeny tests as shown by the performance records of the trees for the fruiting period 1920–21 to 1927–28, inclusive, are presented in this bulletin, together with notations and observations on the development of the progeny trees during their entire growth.

In the study of the limb variations of the Washington Navel trees two conditions of development have been found: (1) Stable ones or those in which the fruit and foliage characteristics are uniform for the entire limb, and (2) unstable ones in which normal fruit or foliage occurs as well as that typical of the variation.

The vegetative growth and the fruits of the progeny trees which were propagated from the stable limb variations have been relatively uniform throughout, whereas the foliage and fruits of the progeny trees which were propagated from the unstable limb variations have been variable and typical of the fruit and foliage characteristics of the parent limbs. The stable and unstable conditions of growth and fruiting of the parent limbs have been perpetuated in their progenies through bud propagation, indicating that these conditions are inherent ones.

The performance records of the low-yielding progenies which were propagated from the unproductive limb variations indicate that quantity of fruit is an inherent characteristic which may occur as limb variations and which can be perpetuated through bud propagation. The unintentional propagation of such limb variations in commercial nursery practice where systematic bud selection has not been used in the selection of superior parent trees probably explains the origin of the consistently unproductive trees studied in these investigations and those observed in other orchards of this variety.

The progeny trees that were propagated from limb variations having fruit and foliage strikingly different in one or more characteristics from those of the normal limbs of the same parent trees have developed fruits and foliage similar to those of the parent-limb variations. These fruit variations include differences in shape, size, texture, and thickness of the rinds, color, blemishes, proportion and nature of the rag, quantity and flavor of the juice, size of the navel and the navel opening, and other characteristics which are important as regards the commercial quality and value of the fruit.

The vegetative variations include those which have an excessive growth, an abnormal number of large nonfruiting branches, those with small and sharply pointed leaves, variegated leaves and twigs, and rolled leaves.

During recent years tree-estimate studies in commercial Washington Navel orchards, in which the trees were propagated from superior parent trees selected as sources of buds on the basis of their consistent production of uniformly good fruits, show an almost entire absence of trees of undesirable strains, whereas in a few comparable orchards

where the trees were not propagated from systematically selected buds an economically important percentage of trees of inferior strains have been found. These studies indicate the value of the systematic selection of productive and uniformly good-fruiting normal parent trees as sources of buds for propagation and the perpetuation of the desirable characteristics of superior producing trees through bud propagation. They also indicate that the mixed stock in many Washington Navel orchards has been due to the unintentional cutting of bud wood from limb variations.

Other striking bud variations and progeny trees propagated from them in addition to those described in detail in this bulletin have been studied, but on account of their infrequent occurrence or apparent minor importance have been only briefly mentioned. The performance records of these variations in every instance show that the characteristics of the parent limbs have been perpetuated in the progeny trees through budding.

The performance records of progeny plantings of Washington Navel trees propagated from parent trees selected on the basis of their consistent production of heavy crops of uniformly good fruits indicate the probability that superior yielding strains of this variety have been isolated through systematic bud selection.

The progeny propagations of several valuable limb variations of Washington Navel trees which produce fruits having one or more improved quality characteristics as compared with the normal Washington strain fruits show the possibility of isolating strains from limb variations in which the trees produce a superior quality of fruit.

Replacing trees of undesirable strains in established orchards through top-working and replanting has been successfully accomplished in many instances. Such trees have been given special attention and cultural care for several years in order to provide the proper conditions for their growth and development in competition with near-by larger trees. The results have been an improvement in the quality and value of the crops through the elimination of the established trees of undesirable strains.

The value of the application of the results of these investigations to the Washington Navel orange industry includes: (1) Maintaining the efficiency of this proved variety through the propagation of uniform progeny trees of the valuable Washington strain from superior parent trees selected as sources of bud wood on the basis of their performance records, and avoiding the unintentional propagation of undesirable limb or entire-tree variations; (2) improving the quality and quantity of production of established orchards through replacing the undesirable strain trees with desirable ones by top-working or replanting them; (3) the isolation through progeny tests of improved strains from valuable limb or entire-tree variations which have an inherent tendency to produce more fruits of superior quality for commercial purposes than the normal; (4) the use of the progeny-test method for determining the relative value of bud variations and strains arising from them for local orchard conditions.

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