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THE RELATION OF TREE TYPE TO PRODUCTIVITY IN THE APPLE

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BULLETIN 305

THE RELATION OF TREE TYPE TO PRODUCTIVITY IN THE APPLE.[1]

Karl Sax and John W. Gowen.

SUMMARY

A study of 881 trees in Ben Davis Orchard No. 1 at Highmoor Farm, shows that trees of the same age and even under apparently identical environmental conditions may vary enormously in productivity.

Productive and unproductive trees are closely associated with a definite type of habit of growth. The productive or Type 1 trees are large, open and spreading with short laterals and bear many spurs. The unproductive or Type 3 trees are small and upright with slender branches and few spurs. Between these two extreme types are a number of intermediate types.

An analysis of cost of production for 1914 shows that in our Ben Davis orchard a tree must produce approximately 108 lbs. of fruit to return a profit. On this basis 29% of the 881 trees were kept at a loss. Most of the unprofitable trees were of Types 3 and 3-2. Type 3 trees were kept at an average loss of 90 cents while Type 1 trees were kept at an average profit of $2.30.

The primary causes of differences in productivity of fruit trees may be attributed to soil, root stocks, or differences in scions. Soil was found to play an important part in causing differences in yield as indicated by the natural grouping together of unproductive trees. Of the 257 unprofitable unproductive trees about 65% are apparently due to soil conditions. Unproductive trees surrounded by only productive trees are unproductive due primarily to unfavorable root stocks, inherent differences in scions of the clonal variety or factors other than soil. The percent-

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[1]Papers from the Biological Laboratory, Maine Agricultural Experiment Station, No. 151.

A more technical presentation of the same subject may be found in the Journal of Heredity, v. xii, no. 7.

age of such trees is about 35% of all unprofitable trees. There is no critical evidence that there are inherent differences in yields of apple trees of a clonal variety due to bud mutation. In all cases when scions have been selected from productive and unproductive apple trees there has been no increased yields of the scions from productive trees. There is evidence that variable root stocks may cause differences in yield of fruit trees and that unproductive trees may often be attributed to unfavorable root stocks.

If apple trees are unproductive due to soil conditions it is possible that they can be made more productive by application of commercial fertilizer. We have, however, found no influence of even heavy applications of a complete fertilizer on our Ben Davis orchard during a 6 year period. The addition of fertilizer to other varieties or the addition of other forms of fertilizer may cause inceased yields, but increased yields may not mean more profitable trees under such conditions.

A digest of the evidence shows that inherent differences in productivity are rarely or never present in clonal varieties of apple trees. Such being the case little justification exists for top working unproductive trees with scions from productive trees.

Unfavorable root stocks probably cannot be remedied in a mature orchard but they can be avoided to a considerable extent in a new orchard by selecting only large, vigorous, rapid growing nursery stock, as the evidence shows that small nursery trees usually result in small trees in the orchard. The best grade of one year old trees are recommended because their large size is due to ability to make good growth and not due to age. The establishment of clonal varieties of unusually favorable root stocks would undoubtedly result in more uniform and in general more productive trees.

INTRODUCTION

In animal husbandry work it has long been recognized that within the flock or herd there are individuals which return a large profit, individuals which return a small profit, and individuals which are kept at a loss. By a study of the external characters making up the conformation of these profitable and unprofitable groups of animals it has been possible to show that certain of these characters bear a relationship to the productivity of the animal. By the use of these external characteristics it is possible to choose the animals whose production is high from those whose production is low. Little attention has been given to the differences in productivity of fruit trees. Unproductive trees are not easily discovered because the absence of fruit in any given year may be attributed to the "off-year" for the tree. Only annual records of the yields of individual trees or a method of classifying productive and unproductive trees by a study of tree type will enable the unprofitable trees to be detected. By the use of these annual records and by a careful study of the conformation of the apple trees in our Ben Davis orchard, it has been possible to show that there is a high association between certain tree types and the yield of fruit which they bear. In this paper data will be presented to show this relation between type of tree and yield, the probable cause of the various types, the loss sustained by the grower in keeping certain inferior types. The available methods by which these unprofitable trees may be eliminated will also be discussed.

MATERIALS AND METHODS.

The data for the present study were obtained from Ben Davis Orchard No. 1 at Highmoor Farm, Monmouth, Maine. The orchard contains 1235 trees but on discarding injured or reset trees there are left 881 trees for analysis. These trees are set 25 x 25 feet. They are about 28 years old. During the time the records were taken the trees were well cared for and were relatively free from disease. The trees were given row and tree numbers which were printed on metal tags and attached to the tree.

The soil in the orchard is not uniform. There are wet areas along the south side and in the northwest quarter, while the southwest quarter of the orchard is high and sandy. Fertilizer and cultivation experiments have been conducted on various parts of the orchard, but we have been unable to detect any results of such treatment.

Records of yield and growth of each tree have been kept since 1913. The fruit from each tree was weighed each year and measurements of the trunks in circumference were made each fall after the apples were picked. The weighing apparatus used in this work is shown in Figure 1. With this device one man can weigh and record the fruit picked by a crew of 10 to 15 men. Since one man can weigh the fruit and at the same time supervise the picking crew the cost of obtaining the tree yields is not excessive. The data were recorded in a permanent book and later punched on cards for analysis.

The recording of the data until 1918 was done under the direction of Dr. Frank M. Surface. Much credit is due Doctor Surface for the initiation of the work and for the careful manner in which the records were kept. The presence of various types of trees and the general relation of tree type and yield was first noticed by Mr. Walter Curtis, former scientific aid at Highmoor Farm. The trees were classified into the various types by Walter Curtis and the late Doctor Jacob Zinn, associate biologist of this station.

TYPES OF BEN DAVIS TREES.

A study of variation in the habit and amount of growth of Ben Davis trees reveals two principle contrasting types, type 1 and type 3, and certain intermediate types intergrading between the two main types.

Type 1 is a strong vigorous tree with a large head. The form of the head is open and spreading The general appearance of this type suggests great productivity and vigor. The main branches are very large, ramifying profusely, especially in the upper regions where they form numerous short, stout laterals and twigs bearing many spurs. The branches especially in the lower region of the tree, are drooping thus increasing the volume of the head. The twigs are rather short, stout and slightly crooked. The characteristic feature of this type is the differentiation of the large branches into many laterals bearing an abundance of spurs. The type is well shown by tree 13, row 21. (Fig. 2.) This tree bore 922.3 lbs. of fruit in the period 1914-20.

Type 3 is a medium sized tree with a rather small head. The form of the head is upright but not spreading. The branches are of medium size near the trunk but are very slender at the top. The ramification of the branches is sparse and limited to regions at the base. The characteristic feature of this type is the upright slender branches. The twigs are willowly, very slender, long and upright with few spurs. Type 3 is illustrated by tree 13, row 2.

(Fig. 3.) This tree bore only 81.8 lbs. of fruit in the 7 years, 1914-20.

Between type 1 and 3 are a number of integrading types whose position in the series is determined by the resemblance to the types described above. Type 2 may be regarded the center around which are grouped the other types in the series. Type No. 2 is characterized by a vigorous growth, spreading head, stout numerous and drooping branches. It differs from Type 1 in that it has longer laterals and fewer spurs. Type 2 grades off to type 1 through types 2-1 and 1-2, the latter approaching type 1. Similarly, the distance between type 2 and 3 is bridged by type 2-3 and 3-2 the former approaching type 2 ,the latter type 3. Type 2 is shown in Fig. 4.

RELATION BETWEEN TREE TYPE AND YIELD.

In general trees of type 1 are the most productive and the average productivity decreases for the intermediate types as they approach Type 3. Type 3 is very unproductive, and even in the most favorable year the trees of this type bore an average of little more than one bushel of fruit per tree. The 1914 distribution of the yields of the various types together with the means and degrees of variability are shown in Table 1.

The average yield of the 121 trees of type 1 was 283.7 lbs. or more than 2 bbls. per tree while the average yield of the 136 trees of type 3 was only 40.1 lbs. or less than a third of a barrel per tree. The 233 trees of type 2 averaged 190.3 lbs. or nearly a barrel and a half per tree in 1914. Of the total number (881) of trees more than one-third produced less than one barrel per tree due largely to the presence of unproductive types of trees.

The same relative relation between tree type and yield is shown in the years 1915-18 as was found in 1914 although the total yields are in no case as high as in 1914. The average yield for type 1 trees varied from 117.6 lbs. per tree in 1917 to 220.6 lbs. per tree in 1915. Type 3 trees produced an average of 27.1 lbs. of fruit in 1917 and 47.8 lbs. of fruit in 1915. For the five year period 1914-18 the type 1 trees averaged nearly 1.5 bbls. of fruit per tree annually while the type 3 trees bore an average of less than 0.3 bbls. per tree.

In the tables given above it is evident that the trees of type 1 are the most productive and that the productivity decreases as the

TABLE 1.

Yields of the Various Types of Apple Trees.

Yield 1914.

Type	Yield in Pounds of Fruit																							N	Mean	Standard Deviation	Coefficient of Variation
	0-20	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400	420	440	460-480				
1							3	4	3	6	5	6	19	11	14	16	6	13	7	1	2	3	2		121	283.72±4.31	70.32±3.05	24.79±1.14
1-2						1	1	6	5	5	11	6	14	6	8	6	5	1		1	1				77	243.25±4.67	60.78±3.30	24.99±1.45
2-1				1	3	4	4	9	18	9	12	17	11	11	10	8	7	4	2					1	131	228.01±4.17	70.80±2.95	31.05±1.41
2	1	2	9	5	10	10	18	24	24	14	33	24	25	13	9	3	7	1		1					233	190.34±3.13	70.85±2.21	37.22±1.31
2-3	3	5	7	9	8	7	9	11	14	10	7	3	2	3	2	1									101	139.70±4.65	69.32±3.29	49.62±2.88
3-2	9	10	14	9	12	4	6	5	7	1	1	2		2											82	89.76±4.67	62.66±3.30	69.81±5.17
3	51	33	27	11	7	2		1	2			1		1											136	40.15±2.35	40.58±1.66	101.09±7.21
Total	64	50	57	35	40	28	41	60	73	45	69	59	71	47	43	34	25	19	9	3	3	3	2	1	881	175.20±2.32	102.32±1.64	58.40±1.22

intermediate types approach type 3. Tree type is closely associated with yield and also with size of tree. As a rule the unproductive trees are small and of type 3, while the productive trees are large and of type 1. In general the trunk girth of a tree is a fairly reliable index of its productivity.

THE CAUSE OF VARIOUS TREE TYPES.

Consistantly unproductive trees have often been attributed to inherent differences resulting from bud mutation. In other words certain varieties are thought to contain high and low yielding strains of trees. There are, however, a number of factors which may cause consistent differences in the productivity of trees in the same orchard. Soil heterogeneity, including such permanent differences as soil moisture, depth of soil, elevation, and physical and chemical properties of the soil, may cause certain trees to yield more than others from year to year. Root stocks are grown from seed. These seeds are of widely different origin, are undoubtedly crossed fertilized and consequently considered from the genetic standpoint are highly heterozygous, each tree making up the whole number of stocks being far from comparable with its neighbor. Under such conditions it is to be expected that such stocks vary widely in their ability to produce vigorous, high yielding trees, when budded or grafted to scions from a given clonal variety. The influence, favorable or unfavorable, of root stock constitute the second variable affecting the productivity of the mature tree. No such heterozygosity exists in the bud or scion. These buds or scions are selected from a clonal variety asexually reproduced. It has, however, been frequently asserted, on the basis of what the authors believe to be uncritical evidence, that bud variations affecting yield frequently occur within a clonal variety. The evidence for or against this supposition is reviewed and makes the third possible variable which might conceivably influence yield. No consideration is given to differences in yield due to injury by disease or insects, because in this Ben Davis orchard at least during the period covered by this record these factors are of minor importance. The various known factors which may cause consistent and significant differences in productivity of trees of a clonal variety will be considered in the following order,—1. Soil heterogeneity. 2. Root stocks, and 3. Bud mutation.

VARIABILITY IN PRODUCTIVITY, DUE TO SOIL HETEROGENEITY.

If differences in productivity are due to variable root stocks or variable scions we would expect a random distribution of high and low yielding trees throughout the orchard. If soil variability is the cause of differences in performance we would expect to find the high and low yielding trees in rather definite groups. It is hardly possible that soil differences can be so local in extent as to affect the productivity of but a single tree. Frequently an unproductive tree will be found entirely surrounded by comparatively productive ones. We have dug up several of these trees and in every case the root system of the unproductive tree was so interwoven with the root systems of the productive trees that they had to a great extent a common feeding ground. In no case was the isolated, unproductive tree in apparently poorer soil than the productive trees. We can expect then that high and low yielding trees will be grouped if tree variability is due to soil.

TABLE 2.

Distribution of types of trees in Ben Davis Orchard. Showing in each block the total number of trees, number and percentage of Type 1, and number and percentage of Type 3. Further explanation in text.

N. (left) — S. (right)

	1–8	9–16	17–24	25–32	33–37
33-	28 — 4–14	12 0— 2–17	8 — —	1 — —	0 — 0—
25–32	62 4–6 5–8	59 6–10 —	49 2–4 2–4	43 5–12 1–2	25 3–12 2–8
17–24	64 8–12 4–6	60 4–7 2–3	56 9–16 4–7	36 15–42 1–3	31 5–16 4–13
9–16	63 20–32 3–5	63 16–25 2–3	51 5–10 2–4	41 18–44 4–10	33 2–6 3–9
Trees 1–8	51 3–6 15–29	57 8–14 15–26	56 1–2 26–46	49 2–4 27–53	33 1–3 17–52

Rows

Ben Davis orchard No. 1 contains 37 rows with 29 to 37 trees per row. The orchard was divided into 25 blocks as shown in Table 4. The number of trees per block varies considerably due to missing or replanted trees, or to variations in rows or trees per row included in certain blocks. The distribution of the extreme types of trees is readily observed in Table 2.

The total number of trees, the number and percentage of type 1 trees, and the number and percentage of type 3 trees for each block are shown. Thus in the block of trees including rows 1-8 and trees 1-8 we find a total of 51 trees. Of these 51 trees, 3 or 6% are of type 1, while 15 or 29% are of type 3. A study of the distribution of the two extreme types, 1 and 3, shows that they are in rather definite areas of the orchard. Most of the type 3 or unproductive trees are located along the west side of the orchard and especially towards the south end of this area. The location of the unproductive trees coincides very closely with the high sandy portion of the orchard. Clearly the grouping of the unproductive trees is due to unfavorable soil conditions or exposure. The type 1 or productive trees are grouped largely in the west-central part of the orchard, especially in the blocks including rows 1-16, trees 9-16, and the blocks including rows 25-32, trees 9-24. In these four blocks the percentage of type 1 trees varies from 25% to 44%. The grouping of productive trees in definite areas can only be attributed to unusually favorable soil conditions in these areas.[2]

VARIABILITY IN PRODUCTIVITY DUE TO ROOT STOCKS.

It is clear that the various types of trees, productive and unproductive, are due to a considerable extent to soil heterogeneity. It is also evident that an unproductive type of tree when surrounded by productive type, all having a more or less common feeding ground, cannot be attributed to unfavorable soil. The behavior of such trees indicates that the various types of trees may be caused to some extent at least by one or both of the other factors mentioned, i. e., root stocks or bud variation. We will consider next the influence of the root stock on type and yield.

It is well known that seedlings grown for root stocks are extremely variable both in regard to morphological characters and

[2]The soil in our Ben Davis orchard was also found to be heterogeneous when measured by the test for soil heterogeneity proposed by Harris (4). For the average soil heterogeneity based on the yields of the 881 trees for 1914-18, r=.40. The individual tree was used as the ultimate unit and trees were grouped in a four by four fold manner for the combination plots.

growth. In our seedling orchard 586 trees which were planted in 1911 vary in circumference from 2 to 18 c.m. and the coefficient of variability was found to be $32.07 \pm .69$. Such great variability would be expected in the growth of seedling apple trees since all apple trees are more or less heterozygous and are usually cross pollinated.

So-called "standard stocks" may vary greatly in growth. Hatton (5) found about 14% of a block of "free stock" seedlings to be distinctly dwarfed and weak. About the same range of variability in root stocks was found in "free stocks," crab stocks, and paradise stocks. The latter stocks are generally considered dwarfing stocks, but both the "free" and "paradise" stocks were found to contain dwarfing and free growing stocks. "Paradise" stocks are apparently from different sources and the variety is not a true clonal variety.

In our "stock and scion" orchard we have over 400 trees of ten varieties. These trees were worked in "French Crab" and Tolman Sweet roots in 1913. An analysis of the data on this orchard shows that in circumference of trunk in 1921 the trees worked on "French Crab" stock are more variable than trees on Tolman Sweet roots. This is to be expected since "French Crab" seedlings are from numerous varieties and types of trees. The Tolman stocks are from a clonal variety and are less variable than French Crab stocks.

When the trees for the "stock and scion" orchard were taken from the nursery they varied considerably in size. If these differences in size were due to difference in the soil of the nursery we would not expect these differences to be permanent when the trees were transplanted in the orchard. The random planting of large and small trees should smooth out differences in growth if soil is the only factor involved. If, however, the variation in size of nursery trees is due to the effect of root stocks or scions then differences in size will persist in the trees when set in the orchard. The buds of each variety were selected from a single tree in each case, thus largely eliminating any possible difference in growth of scion due to bud mutation. The growth of different varieties on different stocks was not found to be the primary cause of correlation between size of nursery tree and the same tree in the orchard. We have found that the trees which are small when set in the orchard are also the small trees in succeeding years. The correla-

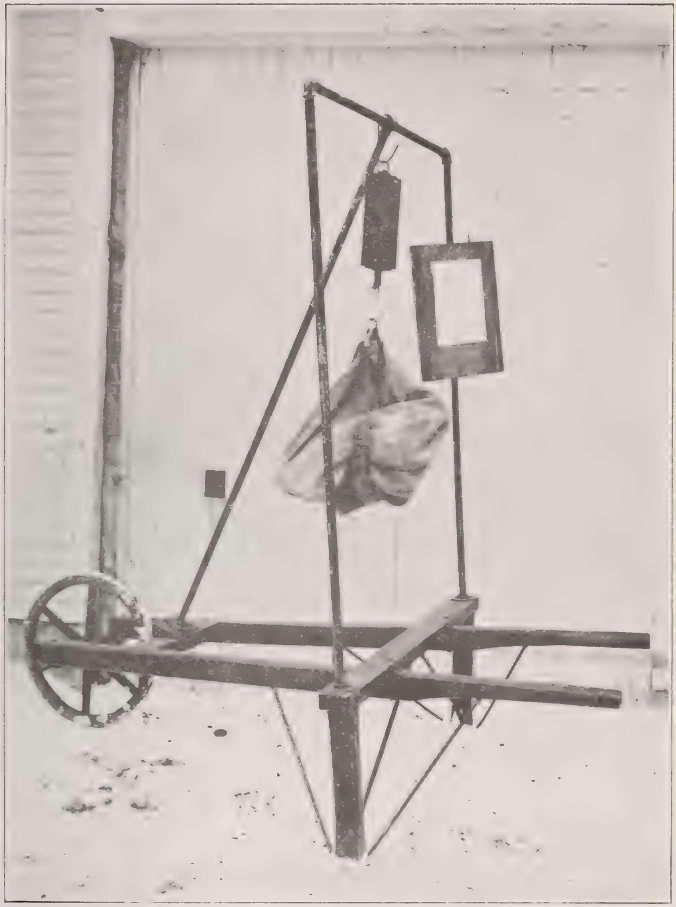

Fig. 1. Apparatus used for weighing fruit.

Fig. 2.

Ben Davis tree 13 Row 21. A productive "Type 1" tree.

Fig. 3.

Ben Davis tree 13 Row 2. An unproductive "Type 3" tree.

Fig. 4.

Ben Davis tree 27 Row 5. Medium productive "Type 2" tree.

tion between circumference in 1916, two years after the trees were set, and the circumference in 1921, was found to be very high. (r=.68) We may conclude then that small trees in the nursery, in general result in small trees in the orchard, due to a considerable extent to the effect of the root stock.

In citrus trees Webber (12) has found great variability of root stocks both in size and morphological characters. The variable root stocks are considered one of the primary causes of variability in nursery trees budded on such stock. Webber has shown that large, medium and small nursery trees of Washington naval and Valencia oranges and Marsh grapefruit retain, to a considerable extent, their relative sizes when grown in the orchard for several years. The growth of the different sizes of nursery trees are not given in detail and it may be questioned if the differences in size of orchard trees are significant. Webber attributes many of the irregularities in size and fruitfulness of orchard trees to the use of the seedling root-stocks for citrus trees.

Since root stocks grown from seeds are extremely variable and may often be weak and dwarfed it is not surprising that clonal varieties grafted on such stock vary greatly in growth and productivity. The presence of many unproductive trees in our Ben Davis orchard may be attributed, in part at least, to the effect of weak or incompatible root stocks.

VARIABILITY IN TREE TYPE AND PRODUCTIVITY DUE TO BUD VARIATION.

In recent years much of the variability in performance of fruit trees within a clonal variety has been attributed to bud mutation. This belief has been strengthened by the work of Shamel and his colleagues (8-11) with citrus fruit in California. As a result of Shamel's work there has been a general acceptance of the idea that bud mutation may cause increased or decreased yields not only in citrus varieties, but in other fruits as well.

In a paper, the publication of which has been somewhat delayed, we have analyzed in considerable detail the data pertaining to bud variation in citrus and apple varieties. We will therefore limit the present discussion of bud variation to the more important phases of the work with apples.

Experiments on bud variation in apples have been conducted by Whitten in Missouri, Macoun and Davis in Canada, and Cummings in Vermont. Whitten (13) selected scions from an exceptionally poor Ben Davis tree and others from the best Ben Davis tree in the orchard. There was no significant difference in the performance of the progeny of the two extreme types.

Macoun (6) selected scions from a heavy bearing, a regular bearing, and a very unproductive tree in a row of 18 Wealthy trees. A comparison of four years' yield of trees obtained by grafting with scions of the above tree types showed no significant difference in the performance of the progeny of the parental types. In actual amount of fruit, the trees resulting from the most productive parent produced slightly less fruit than either the progeny of the regular bearing or unproductive trees. The differences were in no case statistically significant.

More recently Davis (1A) has reported the performance of the above Wealthy trees covering a nine year period—1912-1920. The progeny of the productive regular bearing and unproductive trees perpetuated these characters to a great degree and the differences are statistically significant. The productive progeny were large and thrifty while the trees from the unproductive parent were small and weak and many had died during the course of the experiment. It may well be questioned whether the differences in productivity of these Wealthy trees are due to inherent genetic differences or to a transmitted disease or perhaps due to the relative vigor of the parents.

Recently Cummings (1) has reported the results of a rather extensive bud selection experiment in Vermont. Scions were selected from productive and unproductive trees of seven varieties. Two hundred and forty-eight scions were used, 120 scions from productive trees and 128 from unproductive ones. At the end of ten years 86 of the "productive" and 82 of the "unproductive" scions had borne fruit. In many cases the two classes of scions were grafted into the same variety or even the same tree. In general the scions from the productive trees were no more productive, in fact they were somewhat less productive, than scions from the unproductive trees. The difference in favor of the "unproductive" scions are probably not significant, but at least there is no indication that scions from productive trees are superior to scions from unproductive trees of a clonal variety.

In other words the difference in performance of trees of a clonal variety of apples, in the above case at least, are apparently not inherent but are the result of environmental factors—probably soil and root stocks.

THE COST OF KEEPING UNPRODUCTIVE TYPES OF TREES.

The cost of bringing an orchard to a bearing age and the cost of keeping a mature orchard in good condition is so great that the presence of many unproductive trees prevents profitable operations. We have shown that a considrable number of the trees in our Ben Davis orchard are very unproductive, due primarily to the effect of soil and unfavorable root stocks. It is possible to determine the approximate cost of growing, cultivating, and spraying a mature apple tree. With this knowledge we can determine the number of unprofitable trees in the Ben Davis orchard.

Since the Ben Davis orchard at Highmoor Farm is used for experimental purposes the cost of producing fruit is not comparable to commercial operations. We have therefore used Gardner's (2) figures on the cost of growing apples in Maine in 1914. From an analysis of 9 orchards Gardner found the cost per tree for growing, picking and hauling the apples was $1.94. A more extensive analysis of 218 New York orchards by Miller (7) shows the cost per tree to be $3.39. The New York orchards were much older and the trees bore considerable more than the Maine trees recorded. We have selected the first three orchards reported by Gardner for an estimation of orchard costs as these orchards are similar to our Ben Davis orchard.

The cost of raising the apples but not picking, packing or hauling was found to be $1.41, per tree. The average price of apples in Maine for 1900-14 was $2.03 per bbl. or 1.55 cents per pound. Deducting the cost of picking, packing and hauling the cost of production was found to be 1.3 cents per pound on the tree. The cost of fruit production per tree, 141 cents, divided by the price per pound on the tree, 1.30 cents, gives us 108.5, the number of pounds of fruit a tree must have produced to pay expenses. Trees in our Ben Davis orchard which produced less than 108 lbs. of fruit in 1914 were kept at a loss while those producing more than 108 lbs. of fruit returned a profit. This figure is of course only approximate, but it is believed to be conservative and suitable for purposes of illustration.

An examination of Table 1 shows that a large proportion of the trees in our Ben Davis orchard did not yield enough to pay expenses. Most of the unprofitable trees were of Type 3 or Type 3-2. The following table shows the number and percentage of unprofitable trees in the entire orchard and for each tree type.

TABLE 3.

Unprofitable trees in Ben Davis Orchard No. 1.

Trees	Number	Percentage
Entire orchard	257	29%
Type 3	130	96%
Type 3-2	56	68%
Type 2-3	35	35%
Type 2	31	13%
Type 2-1	6	5%
Type 1-2	0	0%
Type 1	0	0%

The relation between tree type and number of unprofitable trees is shown graphically in Figures 6 and 7. The yields of Type 1 trees are shown in Figure 5.

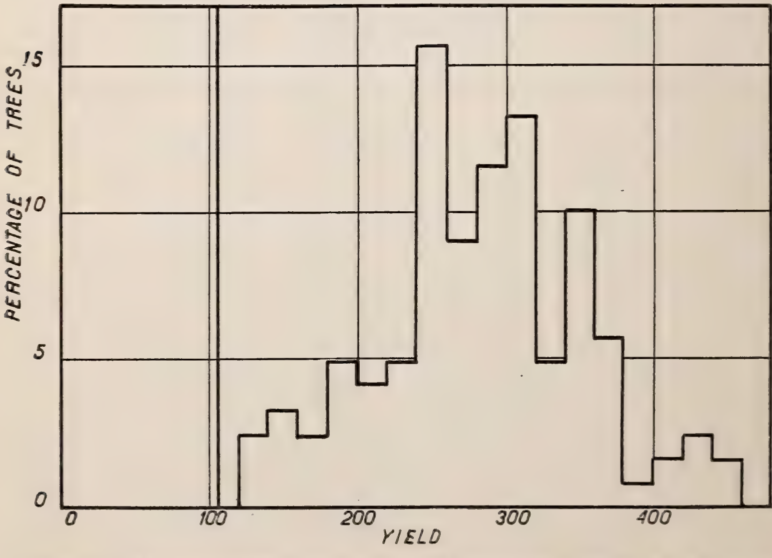

FIG. 5. Distribution of yield of Type 1 trees for 1914. All of these trees yielded more than 108 lbs. of fruit and were kept at a profit.

The yields are grouped in 20 lb. classes and the percentage of trees in each class is graphically represented. All of the Type 1 trees yielded more than 108 lbs. of fruit per tree and were kept at a profit. The average yield of the Type 1 trees for 1914 was 284 lbs. or 176 lbs. more than necessary to pay for cost of pro duction. The average net profit of Type 1 trees was then approximately $2.30 per tree.

Figure 6 shows the yields of Type 2 trees in 1914. Only 31, or 13%, of these trees failed to pay expenses.

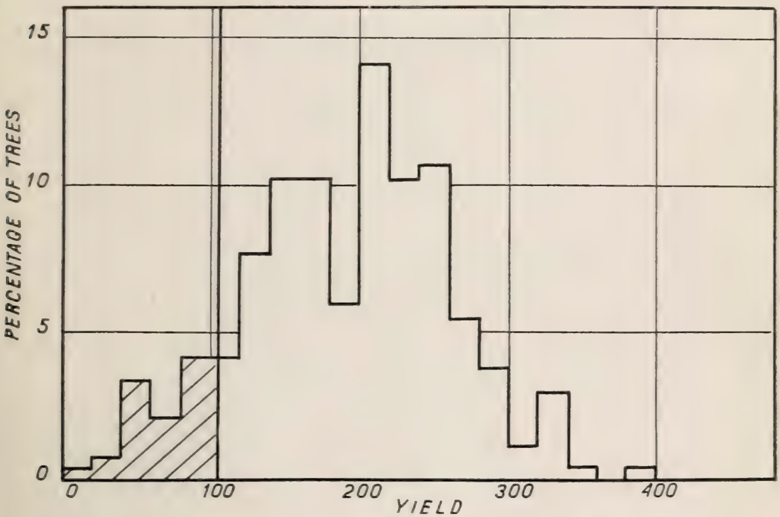

FIG. 6. Distribution of yield of Type 2 trees for 1914. The shaded area shows the number of trees which were kept at a loss. The other trees were kept at a profit.

In Figure 7 is shown the distribution of the yields of Type 3 trees. Practically all of these trees were kept at a loss. Since the Type 3 trees produced an average of only 40 lbs. of fruit in 1914 they were kept at an average loss of approximately $.90 per tree. It is evident that Type 3-2 and especially Type 3 trees were unprofitable.

ELIMINATION OF UNPRODUCTIVE TREES.

The unproductive apple trees in our Ben Davis orchard have been shown to be associated with a certain type of growth. Although no detailed records have been made casual observation indicates that tree type or habit of growth is also associated with yield in other apple varieties . The trunk girth is also a very accurate measure of an apple tree's productivity and for practical purposes may be a better index of productivity than tree type since the problem of personal judgment is eliminated. The trunk girth is also a good index of a tree's value at a very early age so that it could be used to advantage in culling nursery stock or culling undesirable trees from a young orchard not yet in bearing. If a tree makes a very poor growth for several years after it has been set in the orchard it will probably never be a desirable and profitable tree. Such trees could be replaced while the orchard

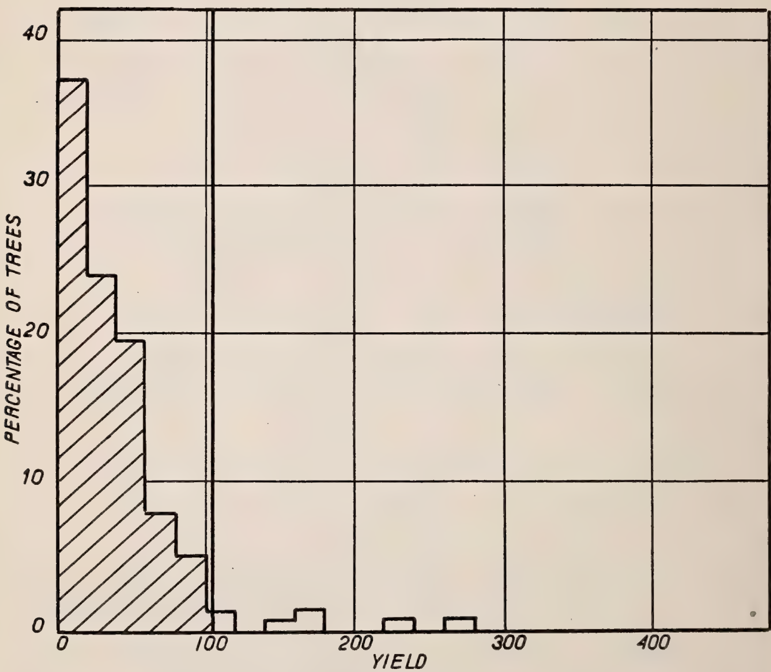

FIG. 7. Distribution of yields of Type 3 trees in 1914. Most of the trees of this type yielded less than 108 lbs. of fruit and were kept at a loss.

was young but in an older orchard the shading of adjacent trees and competition of food makes the replacing of a mature tree a difficult problem.

We have shown that the unproductive types of apple trees are due, to a considerable extent, to unfavorable nutritional conditions caused by poor soil, or by unfavorable root stocks. There is little evidence that unprrductive types of trees within a clonal variety are due to inherent differences caused by bud variation.

It is possible to determine approximately the number of unproductive trees due to the effects of soil and the number of unproductive trees caused by unfavorable root stocks or factors other than soil. Where unproductive types of trees are found in groups in the orchard it is evident that soil conditions are the primary cause of these unproductive trees. Where isolated, unproductive trees are found surrounded by and sharing a common feeding ground with productive trees it is probable that root stocks are an important cause of unproductiveness. A study of the location of the unprofitable trees of inferior types shows that about 90 trees or 35% are not due to soil differences and that about 170 trees or 65% are grouped in such a manner to indicate that soil is the primary cause of unproductiveness. We have assumed that the proportion of trees found on good soil due to unfavorable root stocks or other factors also obtains on poor soil where a large percentage of inferior trees are clearly due to poor soil.

Where trees are unproductive due to poor soil the problem of bringing these trees into profitable bearing becomes one of nutrition. Fertilizer experiments on our Ben Davis orchard extending over a period of six years do not indicate that the addition of complete commercial fertilizer, even in large quantities, will influence productiveness to any great extent. So far there has been no appreciable benefit from adding a complete commercial fertilizer to our Ben Davis trees. The addition of certain nitrogenous fertilizers to Ben Davis trees or the use of fertilizer with other varieties may be of value, but if the soil is decidedly poor the necessary treatment to make it productive may not be a profitable operation. The problem becomes one of soil treatment which cannot be considered in detail in the present paper.

In a mature orchard the presence of unproductive trees due to factors other than soil presents a difficult problem. In California unproductive or otherwise undesirable citrus trees have been extensively topworked with buds from productive trees bearing fruit of a desirable type. However, what little critical evidence there is supports the belief that the top working of unprofitable apple trees is unlikely to produce returns. The severe cutting back of excessive vegetative growth of an unproductive tree for budding or grafting might possibly of itself cause it to bear heavily. Severe pruning is known to throw large, vigorous, but unproductive trees into bearing.[3] Most of our unproductive Type 3 apple trees are small and severe cutting back would probably be of no value in inducing fruitfulness.

If an unproductive tree cannot be made profitable by soil treatment or by topworking with buds or scions from productive trees the only remaining known factor of primary importance is the root stock. The unfavorable relation of the root stock cannot be easily remedied, if at all, in a mature orchard.

Unfavorable root stocks can be avoided to a considerable extent when the root stocks are budded or when the trees are set in the orchard. In citrus fruits Webber (12) has shown that small trees in the nursery are in general also small trees when grown in the orchard several years. He suggests that only large vigorous nursery trees be set in the orchard as the small nursery trees will not as a rule develop into large trees in the orchard. We have found that the small apple trees in the nursery are also small trees in the orchard in most cases. Samuel Fraser of Geneseo, N. Y. has concluded, from his extensive experience with apple trees, that small trees in the nursery result in general in small trees in the orchard. The consistent relation in size of nursery trees and the same trees in the orchard indicates that root stocks play an important part in tree growth. It is advisable then, as Webber has suggested, to select only large vigorous seedlings for budding, and to select only nursery trees which make a rapid and vigorous growth. Small stunted nursery trees should never be planted in the orchard. Such trees are not likely to be profitable at any time.

Since seedling root stocks are so variable and in some cases probably have an unfavorable influence on tree growth and productivity, it would be desirable to establish clonal varieties of root stocks. In our stock and scion orchard the trees on Tolman Sweet root stocks are more uniform in size than the trees worked on French crab stocks. These clonal varieties of Tolman Sweet

[3]According to Shamel (8) severe pruning of the Australian "strain" of Washington Navel orange, which is said to be less productive but larger than the Washington strain, does not result in greater production. Only two trees of the Australian "Strain" are recorded and their production is not significantly less than those of the Washington "strain."

root stocks were obtained by budding Tolman Sweet on French Crab and setting the scion deep enough to root. The Tolman Sweet on its own roots was then budded with the same varieties as were used on French Crab seedlings. Clonal varieties of root stocks could also be obtained by root cuttings. The use of clonal varieties of root stocks would result in more uniform and probably more productive trees.

LITERATURE CITED.

1. Cummings, M. B.
1921. Apple scion selection from high and low yeilding parent trees. *In* Vt. Agr. Exp. Sta. Bull. No. 221, p. 36-38.

1A. Davis, M. B.
1921. *In* Scientific Agriculture 2, No. 2.

2. Gardner, A. K.
1915. The cost of producing apples in Maine in 1914. Bull. of Maine Dept. of Agr. v. 14, no. 3. p. 1-22.

3. Gardner, V. R.
1920. Bud selection with special reference to the apple and strawberry, Mo. Agr. Exp. Sta. Res. Bull. No. 39, p. 3-30.

4. Harris, J. A.
1913. On the calculation of intra-class and inter-class coefficients of correlation from class moments when the number of possible combinations is large. *In* Biometrika, v. 9, p. 446-472.

5. Hatton, R. G.
1920. Suggestions for the right selection of apple stocks. *In* Jour. Roy. Hort. Soc. v. 45, p. 257-268.

6. Macoun, W. T.
1916. The apple in Canada, its cultivation and improvement. *In* Dominion Exp. Farms Bull. no. 86, p. 27-31.

7. Miller, G. H.
1920. Cost of producing apples in five counties in western New York, 1910-1915. U. S. Dept. Agr. Bull. No. 851, p. 1-47.

8. Shamel, A. D., Scott, L. B., and Pomeroy, C. S.
1918. Citrus-fruit improvement. A study of bud variation in the Washington Naval orange. U. S. Dept. Agr. Bull. 623, p. 1-146.

9. ——————
1918. Citrus-fruit improvement: A study of bud variation in the Valencia orange. U. S. Dept. Agr. Bull. 624, p. 1-120.

10. —————— and Dyer, C. L.
1920. Citrus-fruit improvement: A study of bud variation in the Lisbon lemon. U. S. Dept. Agr. Bull. 815, p. 1-70.

11. ———————
1920. Citrus-fruit improvement: A study of bud variation in the Eureka lemon. U. S. Dept. Agr. Bull. 813, p. 1-88.

12. Webber, H. J.
1920. Selection of stocks in citrus propagation. Calif. Agr. Exp. Sta. Bull. 317, p. 269-301.

13. Whitten, J. C.
1915. Bud selection for increasing yields. *In* Mo. Agr. Exp. Sta. Bull. 131, p. 479-480.